Addis Ababa University

College of Business and Economics

Department of Project Management

ASSESSING THE FACTORS THAT CONTRIBUTE FOR THE PERFORMANCE OF CFM56 ENGINE IN THE CASE OF ETHIOPIAN AIRLINES

By

Derib Teketay Sebsibe

Advisor

Temesgen Belayneh (PhD)

A Project work submitted to the School of Graduate studies at Addis Ababa University College of Business and Economics in Partial Fulfillment of the Requirements for the Degree of Master of Arts in Project Management.

June, 2017

Addis Ababa, Ethiopia

Statements of certification

I hereby declare that the study which is being presented in this project work entitled as "**Assessing the factors that contribute for the performance of CFM56 engine in the case of Ethiopian airlines"** was conducted by Derib Teketay for partial fulfillment of the requirements for the award of Master of Art Degree in Project Management; is to the best of my knowledge an original work conducted by him, had not been presented for a partial fulfillment for any educational qualification at this university or any other.

Temesgen Belayneh (PhD) Date

Advisor

Statements of Declaration I, the undersigned, declare that the study which is being presented in this project work entitled as "**Assessing the factors that contribute for the performance of CFM56 engine in the case of Ethiopian airlines"** my original work had not been presented for a partial fulfillment for any educational qualification at this university or any other, all the sources used are also duly acknowledged.

_____ _____

Derib Teketay (GSE/0667/07) Date

Researcher

Addis Ababa University
College of Business and Economics
Department of Project Management

MA Project Work
By
Derib Teketay Sebsibe
Approved By Board of Examiners

Temesgen Belayneh (PhD) Advisor	_____ Signature	_____ Date
_____ Examiner	_____ Signature	_____ Date
_____ Examiner	_____ Signature	_____ Date

Acknowledgements

Prior thanks and gratitude of my heart is goes towards the almighty lord who gives me strength and wisdom at every angle of my life as well as during the whole research period. His guidance and abundance love towards my every day move like when the dessert receives a blessing of the rain in the midst of the day. What I have in my heart to express all is just the word -thank you God!!

I gratefully acknowledge the staff and management of Ethiopian engine maintenance for their immense contribution. Also, I am thankful towards all engine maintenance planners' as well as technical sales and marketing staffs who help me in providing all the necessary documents.

I would like to acknowledge, my advisor, Dr. Temesgen Belayneh (PHD) for his assistance. An acknowledgment of this kind would not be complete without an expression of profound gratitude towards my work colleagues, friends, parents and my whole family for every kind of support they provided me.

Derib Teketay

ABBREVIATIONS/ACRONYMS

Ethiopian: Ethiopian Airlines

Ethiopian MRO: Ethiopian Airlines Maintenance, Repair & Overhaul

MRO: Maintenance Repair and Overhaul

FAA: Federal Aviation Administration

EASA: European Aviation Safety Agency

TC: Transport Canada

CMM: Coordinate Measuring Machine

FAR: Federal Aviation Regulation

FR: Foreign Repair

TAT: Turnaround Time

OEM: Original Equipment Manufacturer

ECAA: Ethiopian Civil Aviation Authority

CAGR: Cumulative Average Growth Rate

SFC: Specific Fuel Consumption

HPC: High Pressure Compressor

HPT: High Pressure Turbine

QEC: Quick Engine Component

ACE: Achieving Competitive Excellence

VSM: Value Stream Mapping

OAU: Organization of African Unity

CEO: Chief Operating Officer

JIT: Just In Time

TPS: Toyota Production System

WIP: Work In Process

TWA: Trans Western Airlines

Abstract

Following the CFM56 overhaul capability development Ethiopian airlines aspires to boost revenue from customer engine maintenance. However, there are questions to be raised from different stakeholders.The purpose of this research is to assess the current performance of CFM56 Engine maintenance in different parameters, to look the past, current and future industry practice regarding MRO business in comparison with vision 2025 road map and give recommendation. Publications from several sources have been discovered to bring relevant resolution method for the stated problem of study. To avoid bias, different sources have been used from all concerned bodies such as customer opinion from market perspective, international aviation MRO publications, historical performance data and also primary sources from employees from different departments and positions. Descriptive research design is implemented during the analysis of results and findings of a research work. Viable instruments were used in the methodology section to secure the required data to properly answer the research question. The collected data was analyzed and the major findings isolated. Based on findings and the literature survey, a two-section solution is forwarded. One is a generic model that can be adapted to the other processes of the airline. The second is an alternative way to form a joint venture with the selected OEM to cope up the worldwide market fierce competition in this sector. The specific result of the case study can be adapted to the other organizations in Ethiopia. In addition what should be done to recover CFM56-3 engine of-design performance problem discussed and recommendation forwarded. Finally the results of a research work are summarized, concluded and recommendations are given to bring a solution for performance improvement in the area of study

***Key Words**: performance, Joint venture, Lean, value adding process, non-value adding process.*

Table contents

CHAPTER ONE

INTRODUCTION

1.1 Background of the study

Ethiopian Airlines (Ethiopian) (ET) is a government owned company found in the capital city of Ethiopia, Addis Ababa, with its head office located at Bole International Airport. The airline, which was established on 21 Dec 1945, is one of the world's and Africa's oldest airlines, with 72 years of existence in the aviation industry.

Up to the mid 1950s, Ethiopian Airlines sent its aircraft and engines maintenance was conducted by external maintenance provider abroad for routine maintenance and overhaul. The Pratt & Whitney engines of the Skytrain, for example, were overhauled in Cairo. The Suez Canal crisis in 1956 highlighted the perils of that policy. The water way was blocked shortly after the ship that was carrying Ethiopian Airlines' overhauled engine passed though the Canal. The canal effectively remained blocked for five months stranding 49 ships. Had the ship with the engine been one of those stranded, the airline would have faced difficulty in maintaining its domestic and cargo services (Ethiopian airlines, 2014).

These events prompted the airline to establish its own engineering facility at Addis Ababa. Through years this facility has expanded into a well-equipped center of maintenance, overhaul and modification work on aircraft, engine and component parts including avionics systems. The facility also undertakes work for many other operators in the region. The airlines' maintenance facility has evolved considerable investment over the years.

As the Ethiopian fleet grew, so did the need for in-house maintenance and repair facilities. Ethiopian Engine maintenance shop becomes one of the known Jet Engine maintenance providers in the world in late 70 for Pratt and Whitney JT3D and JT8D Engines. Currently Engine maintenance shop has a modular maintenance capacity on PW 2000, PW 4000 and full overhaul capability on CFM56-3/7, and APU331-200. Beside there are overhaul capability development for PW150 that power Q400 Aircraft and APU 131-9B that used for B737 NG series Aircraft under facility construction, besides quick engine components (QEC) build up and modular level maintenance on GE 90, GEnx engines and modular capability for GEnx engine signed and development under evaluation (Ethiopian airlines, 2016).

Airlines and lessors often rely on third-party aircraft maintenance providers to perform a variety of maintenance tasks. The MRO market contains four distinct segments: heavy airframe, engine,

component, line maintenance and modifications. The 2012 civil market is estimated at over $65 billion for engine overhaul which is the largest segment at $26.1 billion followed by component at $16.8 billion. (Michaels, 2016; Wyman's, 2016)

The global MRO market is expected to reach US$100 billion by 2025 growing at a CAGR of 4.1% during 2015-2025. The growth will be largely driven by growth in the engine overhaul and component segment (Cooper, 2015).

CFM56 engines are the most abundant engines in the world,

- Today, nearly 21,000 CFM engines (35% of commercial fleet powering engines) are in service with more than 450 customers around the world.
- The CFM56-3 powers approximately 2,000 Boeing 737 classic aircraft's and 4,500 engines are in service.

In total, nearly 9,500 CFM56-7B engines are in service on 737 aircraft, making it the most popular engine/aircraft combination in commercial aviation

- CFM56 -7B has the largest share (18%).
- By 2019 though, CFM56-7B will have greatly increased fleet size by almost 3,500
- CFMI's fleet will continue to dominate the marketplace with over 40% share by 2024
- By 2024, CFM56-7B could begin to see a decline in fleet size as the 737NG fleet recedes and MAX takes hold (Cooper, 2015).

Current CFM56 Engines is more dependable and stay on the wing for long time has minimal shop visit history. Since the world fleet increases in very fast pace the demand for maintenance increases as same rate. On the other hand those original manufacturers (hereafter OEM) want to control even after sale maintenance service due to this OEM and Maintenance, Repair and Overhaul providers (hereafter MRO) are making stiff competition for receiving orders in the field of engine maintenance of commercial airlines, aiming at expanding their shares (Franklin, 2013).

In the middle of those competition and problems Ethiopian Airlines decides to invest huge sum of money to expand and upgrade the existing engine maintenance facility aiming that to support its own fleets and to generate revenue from third party engine maintenance work in the region especially in Africa and the Middle East. After all the necessary investments positioned in to place the performance of the project and expected maintenance order from customers are not satisfactory and promising. The increasing need for Maintenance Repair Overhaul organizations

(MROs) to meet customers' demands in quality and reduced lead times is crucial to its survival within the Aviation industry. Furthermore, with the unpredictability in the global market and difficulties with forecasting characteristic of the MRO industry there is an increased need for the re-evaluation of the operation models of organizations within this sector.

The management of Ethiopian Airlines tries to find out the problem related to engine maintenance performance by organizing a group of experts to assess the industry practice by taking the group to the best MRO providers in the industry to observe their facility layout and experience sharing with expertise and to forward their recommendation to re-engineer Ethiopian Airlines Engine maintenance process. The management also hires consultants companies to re-arrange the lay out and forward their recommendations. Even all those efforts were taken by the management the problem is still prevalent.

This paper tries to identify and analyze the contributing factors that affect engine maintenance performance, assess the industry outlook regarding third party engine maintenance work and give possible solutions and recommendations for performance improvement to align with the company strategy formulated on its vision 2025.

In summary, the performance study on engine maintenance is very useful for the company. Because the company needs to improve the efficiency of its production system and at the same time it needs to increase the type of engines and the scope of the work to be performed. Thus the researcher took this as a gap and conducted further discussions in the Literature review section where all dimensions of global aviation MRO outlook are incorporated.

1.2 Statement of the problem:

Success in Engine Maintenance indeed in survival and gear shifting advantage for Ethiopian airlines, it always demands continuous development and improvement on the way for which the system follows. Industrial competition is truly global; customers always expect the best quality product, with best price and immediate availability within the agreed time. Meeting customer demands requires a high degree of flexibility as well as abilities to reconfigure operations for new demands. As a result, the performance of how the products developed within the production system will be a strategic weapon for competition in a turbulent and changing business environment. The performance of the production system is largely dependent on the ability to be flexible as well as being able to reconfigure operations for new demands.

- ❖ The overall environment of MRO in which Ethiopian Engine maintenance engaged in;
- ❖ The current status of the Ethiopian Engine maintenance based on SWOT analysis.
- ❖ The immediate concern areas where the shop should address immediately.
- ❖ The emerging trends of MRO business ….. (Michaels, 2016; Cooper, 2015)

Furthermore, the service quality spectrum of various industries in general and that of the Aviation MRO industry in particular has been assessed.

For the MRO business, among the service quality items, on-time performance plays a central role. In the aviation MRO, studies show that among the service quality elements, on-time performance is the most important determinant of customer satisfaction.

Traditionally, an MRO service industry competes on price, quality, TAT, diversity, after service warranty, etc. Now, these conditions are the basic requirements in all over the world. Few businesses exist today without offering this requirement, and the key competitive factor has become speed. Major businesses have been trying to accept new business initiatives in order to exist/survive in the new competitive market place. It is known that the aviation industry is a highly competitive and volatile industry.

With this in mind that Ethiopian MRO develops the strategy to Provide third party maintenance work for customers around the globe especially on CFM56-3 and CFM56-7B engines to generate revenue 414 Million USD from maintenance of 153 customer engines per annum by 2025. (Ethiopian airlines vision 2025 road map, 2009)

When we compare the 2013/2014 year plan with the actual, the company performance is 72% below the vision in that means only 28% is attained (Company annual performance report data 2013/14). The main determining factor/reason for low customer orders was low customer order and poor Turn Around Time (TAT) of engines stay at the shop before get certified (Ethiopian airlines, 2014).

1.3 Basic Research Question:

The major research questions which will be raised in the research could be generalized in the following points:

- What are the basic contributing factors that affect Ethiopian Engine maintenance performance?
- What are the most frequent problems in the current maintenance system?

- What are the current industry outlook and the way forward in MRO business?
- What kind of maintenance system is required in improving engine maintenance performance?

1.4 Objective of the study:

The core objective of this research is to assess the current performance of Engine maintenance in different parameters, to look the past, current and future industry practice regarding MRO business and give recommendation.

The objective of the study incorporates both the general as well as the specific one.

1.4.1 General Objective:

The main objective was to evaluate the causal factors that contribute for low performance of engine maintenance in comparison with vision 2025.

1.4.2 Specific Objective:

- To indentify the contributing factors that directly or indirectly affect Engine maintenance performance.
- To assess and provide a comprehensive review of problem sources that affect engine maintenance performance.
- To identify problem areas and suggest suitable recommendations to improve the productivity and product quality.

1.5 Definition of terms:

Customer Engine: An Engine belonging to other operators but sent to Ethiopian Airlines premises for maintenance purpose (at cost)

Core processes: Those central processes that directly deliver results against targets. See also *Key business processes, Strategic processes and Support processes.*

Critical success factors: Those key external or internal elements that a business needs to focus on for success, such as market growth or employee involvement.

Current state map: A visual method of succinctly recording the key aspects of the current structure and processes in the whole or any part of a supply chain. See *Big picture mapping.*

Flow: All activities being undertaken within the *Lean enterprise* at an even rate without delays, interruptions or other batching.

Future state map: A vision of a lean system which is used as the guide for the change process.

Key business process: Patterns of interconnected value-adding relationships designed to meet business goals and objectives, or the main cross-functional activities required in a business for success. See also *Strategic processes*, *Core processes* and *Support processes.*

Lean: A consumer focused approach to the provision of effective solutions involving the consumption of a minimum of resources.

Lean enterprise: The extended supply chain responsible for effectively satisfying consumer requirements using a minimum of resources.

Lean thinking: The process by which individuals can understand the need for, create and implement a *Lean enterprise.*

Mapping: The use of an appropriate tools and technique to analyze the current situation in any process.

Muda :(The Japanese term for Waste), Any activity which consumes resources but adds no value.

Necessary non value adding: Non value adding activities which are necessary under the present operating system or equipment. They are likely to be difficult to remove in the short term but may be possible to eliminate in the medium term by changing equipment or processes.

Non value adding: Those activities within a company or supply chain that do not directly contribute to satisfying end consumers' requirements. Useful to think of these as activities which consumers would not be happy to pay for.

Turnaround Time: is the elapsed time (usually an average, expressed in days) between the induction of a component, engine or aircraft into the repair shop process and the time at which the repair/overhaul is completed and the unit certified and released for service from the repair shop facility.

From an airline's perspective, TAT is defined as: the elapsed time between the removal of the component from the aircraft and its return to the operator's premises as serviceable. With this approach, the operator needs to provision, not only for the time the part is in the repair shop, but also for transportation, customs clearances and other times consumed before the part reaches the

repair shop or after it leaves the shop in transit to the airline. Considering shop TAT instead of total TAT is a common pitfall.

1.6 Significance of the research:

The significance of conducting this research is it can act as a spring board for other researchers to investigate on performance measurement and analysis. At the same time this study provides information for Ethiopian management team to make informed decision how to maximize MRO performance and the significance obtained by forming joint venture for the company in particular and for the country in general.

From this specific research Ethiopian MRO Engine Shop Department could get a significant advantage through the suggestions provided on how to improve the existing maintenance system, finally a lot of cost saving will be expected which in return brings more profit to the company by implementing lean philosophy in value streaming production management system on their Aircraft Engines maintenance sector. .

Therefore the study could be significant in identifying and understanding the level of maintenance industries with respect to flexibility, productivity and profitability in the maintenance system.

The performance study on engine maintenance is very useful for the company, because the company needs to improve the efficiency of its production system and at the same time it needs to increase the type of engines and the scope of the work to be performed. Improving the performance helps the company to achieve its mission and vision.

This paper discusses the general aviation MRO business and suggests proper means that consider the current business model for Ethiopian airlines.

The discussion in this paper is focused on the production time (turnaround time) to perform engine maintenance that indicates the performance of the production system.

Generally this research study could benefit all Ethiopian maintenance sections especially Engine maintenance that follow cascaded processes one after another such as Assembly, repair, Overhaul, Inspection, scheduling and production by far.

1.7 THEORETICAL FRAMEWORK:

The researcher develops a frame work based on the previous studies to precisely explain about the validity and reliability of the study. This framework will also extensively clarify the cause-effect relationship as well as the interrelatedness of variables in performance management from the perspective of Turn Around Time (TAT), Price, Quality and Scope. The change in scope affect the final acceptable performance parameters of the repaired engine, it also affect all other variables. The price also dependent of the task included in the work packages in which it affect the TAT, Quality and the final delivered performance parameters which the engine certified to operate. In general the performance of maintained engine is measured how it meet planned TAT, offered price to the customer during initial work scope definition, minimum acceptable quality and with the minimum scope crip.

The next model is developed by the researcher to explain the conceptual framework of the study.

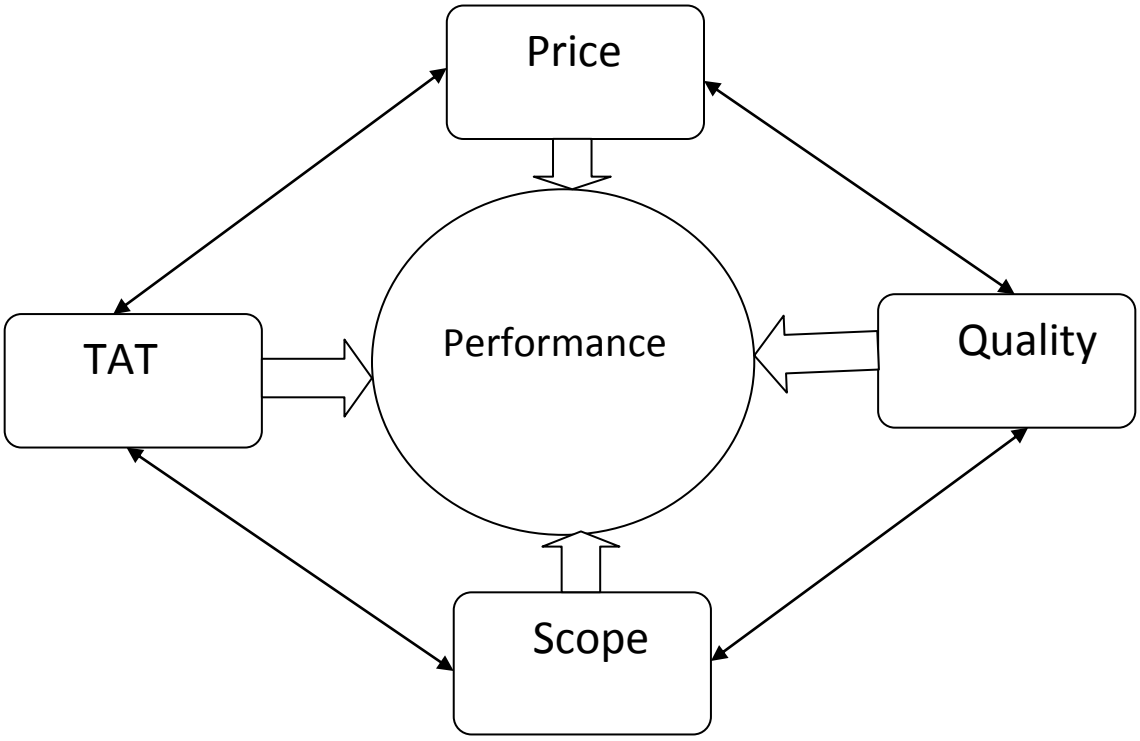


Fig. 1 Frame work developed by the researcher

1.8 Scope of the study:

Delimitation or scope of the study refers the factors that delimit the boundary of the proposed study. This study covers Ethiopian engine maintenance shop performance analysis specifically

CFM56-7B and CFM56-3 engine series only for the period of 2013 to 2016. The basic reason restricting the study to these engine series is the company main focus to generate additional revenue from third party work is primarily focused on these engines. The period restricted to past three years since the company completed capability build up and certified in the fourth quarter of 2011.

1.9 Limitation:

In the aviation industry information is very limited specially the data that have comparative advantage over others and they are not available for general public to make comparison. This research lacks other MRO provider data to have clear picture where is the position of Ethiopian engine maintenance concerning on time performance, hence the researcher tries to make data comparison of Ethiopian engines maintained at other MRO providers even though it lack reliability due to the reason for the delay factor is not know.

1.10 Structures of the Thesis

The thesis is subdivided in to five chapters. Each chapter of the thesis illustrates different aspects of the research work. These are described as follows:

Chapter one: Problems and its approach it introduces background of the study, statement of the problem, objectives of the research, scope of the research, significant and beneficiaries of the study. Chapter two: review of related literatures: This chapter Comprises of literature review, and quotes the various related works done in this area of study and the Overall Environment of global Air Transport Industry will be addressed the current situations and emerging trends of aviation MRO in detail Chapter three: Research methodology: In this chapter will describe the type and design for the proposed research that is adapted from the previous studies, the subject/participant of the study, the sources of the data, the data collection instruments to be employed, the procedures of data collection and the method of data analysis. Chapter four: Data analysis and finding: This chapter contains the analysis of the information gathered from secondary data as well as primary data will be the discussed and analyzed in detail. Chapter five: conclusions and recommendations: This chapter forwards conclusions and recommendations of the research.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

2.1. Historical Background of Ethiopian Engine Maintenance:

As other African nations began setting up airlines, Ethiopian provided technical and human resource development assistance. In 1968, Ethiopian was at the forefront of the African Airlines Association, a platform for establishing best practices. Since then Ethiopian airlines starts maintenance activity on its Aircrafts and Engines. Ethiopian Engine maintenance shop becomes one of the known Jet Engine maintenance providers in the world in late 70 for Pratt and Whitney JT3D and JT8D Engines. Engine maintenance shop has a modular maintenance capacity on PW 2000, PW 4000 and full overhaul capability on CFM56-3/7B, and APU331-200. Currently overhaul capability under development for PW150 that power Q400 Aircraft and APU 131-9B that used for B737 NG series Aircraft under facility construction, besides QEC build up and modular level maintenance on GE 90, GEnx engines and modular capability for GEnx engine signed (Ethiopian fact sheet 2016).

2.2 Success Factor of Ethiopian Airlines:

2.2.1 Operational Autonomy:

"A capitalist success in Marxist Ethiopia," is how the US newspaper *Christian Science Monitor* described the company in 1988. Under the dictator Mengistu Haile Mariam, the Provisional Military Government of Socialist Ethiopia (popularly known as the Derg) confirmed the company's commercial status and prohibited all intervention by its sole shareholder, the state – which nonetheless gave it the benefit of certain fiscal exemptions. Ethiopian airlines were the only company set apart to work with US companies even though the country strategy was socialist.

2.2.2 A Cutting-edge Aviation Academy:

The Ethiopian Airlines Aviation Academy, inaugurated in 1964, is the company's pride and joy. More than 1,300 students of 49 different nationalities were trained there in 2015, and student numbers are set to triple by 2020.

2.2.3 State-of-the-art fleet:

Having been the first African airline to operate jet aircraft, and then a Boeing 767, Ethiopian Airlines is now adding Boeing 787s and A350 to its fleet. Since 2010, the company has invested several billion dollars to acquire new aircrafts. It aims to have a fleet of 150 aircraft by 2025. (Ethiopian airlines Vision 2025 road map, 2009)

2.2.4 A Captive Market:

"Ethiopian Airlines has been given more protection by the Ethiopian government than any other airline on the continent," states an aviation industry expert. In skies that were for many years closed to all competitors, and benefiting from the many expatriates from other African Union countries working in Addis Ababa, the airline enjoyed optimum conditions for take-off, subsequently opening its own market to some extent in order to pave the way for accessing other markets, too.

2.2.5 A Long-standing Alliance:

Emperor Haile Selassie I visited the United States in 1941 in order to realize his dream of founding an airline company. A few years later an agreement was signed with representatives of Transcontinental and Western Airlines (TWA) for the creation of Ethiopian Airlines. Apart from a few US government surplus aircraft acquired at the outset, the airline purchases exclusively Boeing aircraft.

2.2.6 Maintenance and Engineering Support Services:

Up to the mid 1950s, Ethiopian Airlines sent its aircraft and engines maintenance was conducted by external maintenance provider abroad for routine maintenance and overhaul. The Pratt & Whitney engines of the Skytrain, for example, were overhauled in Cairo. The Suez Canal crisis in 1956 highlighted the perils of that policy. The water way was blocked shortly after the ship that was carrying Ethiopian Airlines' overhauled engines passed though the Canal. The canal effectively remained blocked for five months stranding 49 ships. Had the ship with the engine been one of those stranded, the airline would have faced difficulty in maintaining its domestic and cargo services. (Ethiopian fact sheet 2014)

These events prompted the airline to establish its own engineering facility at Addis Ababa. Through years this facility has expanded into a well-equipped center of maintenance, overhaul and modification work on aircraft, engine and component parts including avionics systems. The facility also undertakes work for many other operators in the region. The airlines' maintenance facility has evolved considerable investment over the years.

In 1995 a new jet engine test facility, allowing engines of up to 45,000 kgs (100,000 lbs) thrust to be ground run, was built at a cost of 15 to 16 million US dollars. There was not any aircraft engine in service that can develop so much power, except those under development stage at that time.

From July 1998 to June 1999 alone, the airline had income from third party work worth a total of US dollars 7.93 million from aircraft maintenance, engine maintenance, component maintenance and other technical handling for customers.

2.2.7 Ethiopian MRO:

Ethiopian has advanced maintenance base that is capable of carrying out the following maintenance activities with efficiency and quality:

A. Airframe maintenance packages for aircraft models of Airbus 350, Boeing (B737, B757, B767, B777, B787), and Bombardier Q400.

B. Engine Maintenance (covers 8000 square meter) for different model engines: Complete repair, modification, overhaul and testing.

   Modular maintenance

   Engine performance test

   Special process shops; Machining, Electro-chemical Plating, Welding, Plasma Spraying and Vacuum Furnace Heat Treatment.

C. Aircraft component overhaul/testing (equipped with state-of-the-art Automatic Test Equipment – ATEC 5000)

D. Aircraft interior reconditioning

E. Aircraft stripping and painting

The maintenance base is approved by Ethiopian Civil Aviation Authority, USA Federal Aviation Administration, European Aviation Safety Agency (EASA), United Arab Emirates General Civil Aviation Authority, Egyptian Civil Aviation Authority, Kenya Civil Aviation Authority, Angola

Civil Aviation Authority, Jordan Civil Aviation Authority, Nigeria Civil Aviation Authority, Gabon Civil Aviation Authority, Afghanistan Civil Aviation Authority, Kingdom of Saudi Arabia General Authority of Civil Aviation and Sudan Civil Aviation Authority.

Per Ethiopian vision 2025 road map, Ethiopian Maintenance Repair and Overhaul Services aspires to become the most competitive and leading provider of commercial aircraft Maintenance, Repair and Overhaul (MRO) services in Africa by 2025. (Vision 2025 road map)

_ECAA approval secured since----------1946

_ US FAA approval Secured ---------- 1968

_EASA approval secured----------2012

_ 3rd Party Maintenance Repair & Overhaul (MRO) Services Started -------- 1975

_ Maintenance Capabilities & Activities:

- Airframe Maintenance
- Engine Maintenance
- Component Overhaul Capabilities
  - _Hydraulic
  - _ Pneumatic
  - _ Fuel/Oil
  - _ Electrical
  - _ Radio
  - _ Wheels & Brakes

2.3 Overall Environment of the Aviation MRO Industry:

Before we deal in to Ethiopian Airlines MRO current problem let's try to look in to international aviation MRO environment highlights to understand the situation and to reach in to the comprehensive solution. Since Ethiopian MRO do businesses internationally, understanding and scanning the international business environment helps to visualize available opportunities as well as the treats pertaining the aviation MRO industry.

2.3.1 Emerging Trends in the MRO Business Environment:

New technology will have a profound influence on the MRO industry. Construction of the latest generation aircraft involves the use of carbon fiber composites, hybrid alloys and coatings that impact maintenance frequency and methodologies. Modern aircraft are also self-monitoring, with the capability to report on the condition of hundreds of systems and components, creating gigabytes of data from each flight. Properly harnessed, this data will provides the operator and the MRO information on the health of the aircraft, as well as provide prognostications of impending issues, thus reducing maintenance costs while improving operational performance.

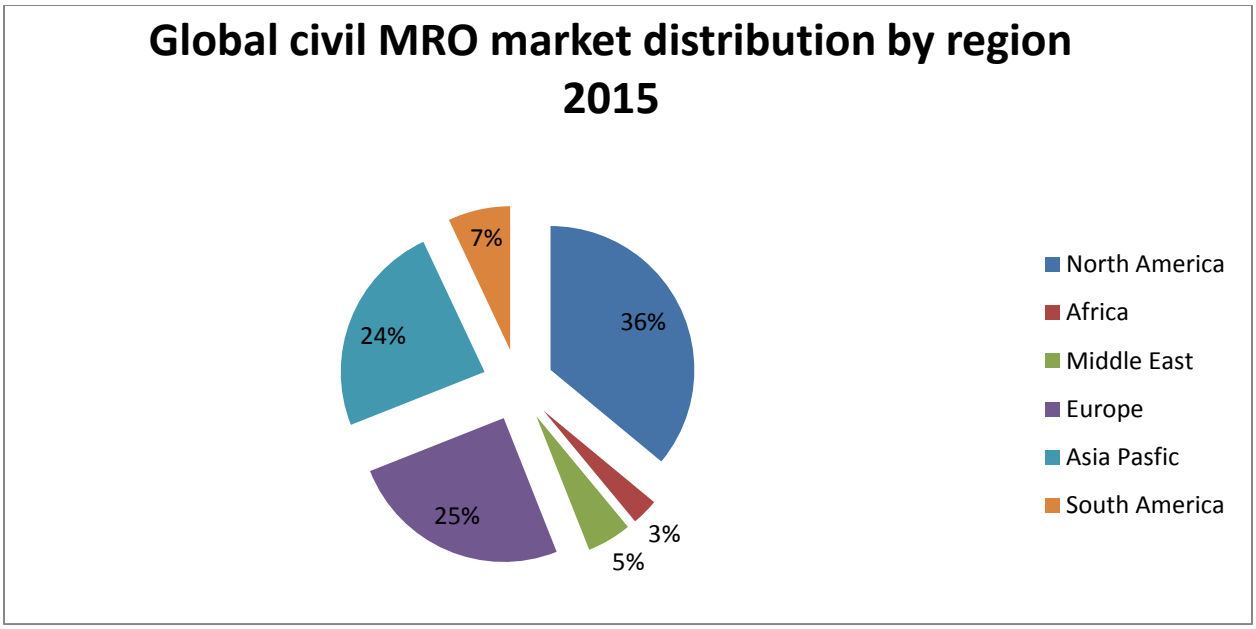
2.3.2 The Aviation MRO Segments and Market Share of Engine Maintenance:

The aviation MRO market contains four distinct segments: heavy airframe, engine, component, line maintenance and modifications. The market study conducted in 2015 the civil market is estimated at over $67.1 billion, among the sectors engine overhaul is the largest segment at $27.9 billion which is expected to reach 46.8 billion by 2025. (Global Engine Fleet and Market Forecast 2015-2025 by Tom Cooper, 2015). As the study indicates OEM have the major share for after sale maintenance service and as can be seen from the below forecast it will continue to dominate the market. And North America has the line share (36%) followed by Europe (25%) and Asia pacific (24%) respectively.

2015-2025 Global MRO Market Forecast and their share by main MRO providers

OEM	2015	2020	2025	2015-2025
GE aviation	$8.2	$10.2	$11.5	3.5%
CFM INT'l	$5.3	$7.8	$14	10.3%
Rolls Royce	$5.2	$7.3	$8.9	5.6%
IAE	$4.8	$7.4	$6.1	2.5%
Pratt & Whitney	$4.3	$3.4	$5.0	1.4%
GE-P&W Alliance	$0.2	$1	$1.2	20.9%
Honeywell	$0.1	$0.0	$0.0	-26.9%
Grand Total	**$27.9**	**$37.1**	**$46.8**	**5.3%**

Source: Cooper, 2015



Engine MRO Market share by regions by Wyman, 2015

The global MRO market is expected to reach US$100 billion by 2025 growing at a CAGR of 4.1% during 2015-2025. The growth will be largely driven by growth in the engine overhaul and component segment. (Cooper, 2015; ICF International, 2016).

The Asia-Pacific MRO market is likely to outpace the global MRO demand driven by new aircraft deliveries and passenger growth in the region.

During 2015-2025, the fleet size is expected to grow at a CAGR of 6.6% that will account for more than 6,500 new aircraft deliveries in the region. (Global fleet forecast and economic assessment study by (Cooper, 2015).

CFM56 engines are the most abundant engines in the world. (ICF International, 2016).

- Today, nearly 21,000 CFM engines (35% of commercial fleet powering engines) are in service with more than 450 customers around the world.
- The CFM56-3 powers approximately 2,000 Boeing 737 aircraft's and 4,500 engines are in service.

In total, nearly 9,500 CFM56-7B and CFM56-3 engines are in service on 737 aircraft, making it the most popular engine/aircraft combination in commercial aviation

- CFM56 -7B has the largest share (18%). (Cooper, 2015).
- By 2019 though, CFM56-7B will have greatly increased fleet size by almost 3,500
- CFMI's fleet will continue to dominate the marketplace with over 40% share by 2025

- By 2025, CFM56-7B could begin to see a decline in fleet size as the 737NG fleet recedes and MAX takes hold (Cooper, 2015).

2.3.3 Engine Maintenance Providers:

Engine maintenance providers can be classified into five categories.

Airline: Commercial air transport operators that perform maintenance utilizing in-house engine maintenance capabilities. Generally, this is limited to operators that have a large enough fleet and experience to merit conducting engine maintenance for themselves.

Airline Third Party: Maintenance subsidiaries of airlines, often operating with varying degrees of autonomy and performing maintenance for other operators and possibly their own parent. These organizations leverage maintenance capabilities at scale to offer competitive pricing to the marketplace.

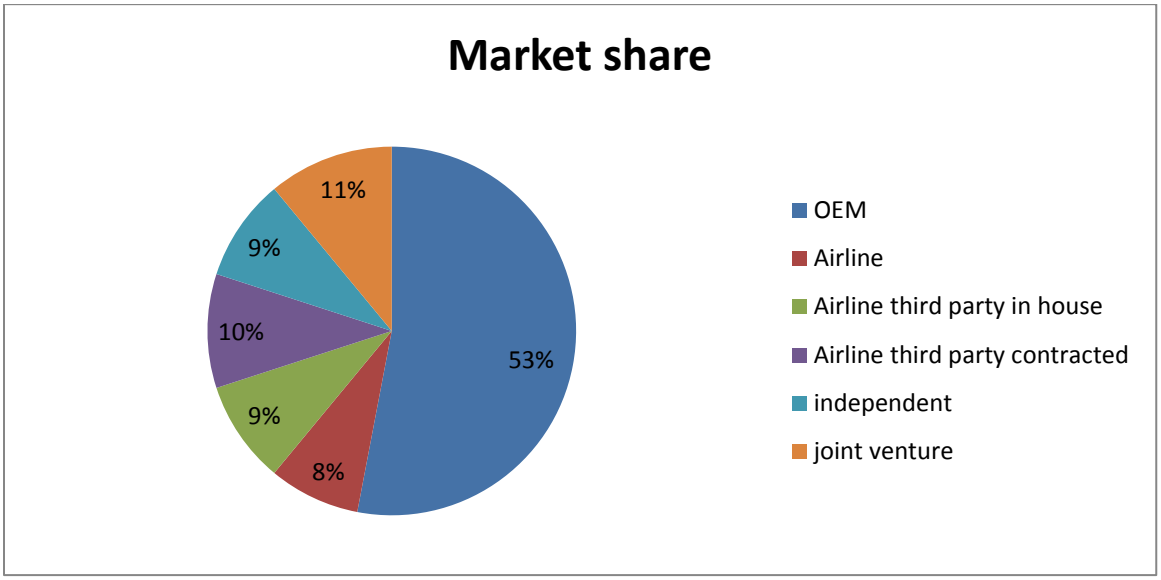
Independent: Dedicated maintenance providers with no relation to either airlines or OEMs (i.e. not part of an authorized service center network). From large to small, these maintenance providers often have lowest labor costs.

Joint Venture: Airframe maintenance providers that are formed (typically) by joining the resources of OEMs and in-country capabilities to build indigenous capacity (e.g., TAESL, HAESL, AMECO Beijing, Turkish Engine Center, etc.).

OEM: Some original equipment manufacturers or OEMs provide aftermarket product support as a value added service throughout the product life cycle for the engines, systems or components they manufacture and supply. This characteristic is more prevalent in the engine and component product support markets than in the airframe manufacturing sector. OEMs that provide MRO services include Engine manufacturers, such as GE, CFM, Rolls Royce, Pratt & Whitney, SNECMA, IAE, etc., offering maintenance capabilities for their respective engine types utilizing company owned facilities.

Based on known MRO contract information, it is possible to estimate the market share that each category enjoys. In the air transport segment, OEMs are by far the dominant player in the engine MRO space, controlling more than half of the market capacity. Airlines perform just under 20% of the engine MRO spend themselves (when combining airline work and the in sourced work of airline third party providers). Airline third party providers servicing other airlines' engines take

on another 10%. Independent providers capture just 9% of the market spend, though it will be interesting to see how their collective effort to obtain more and better repair information from OEMs improves their market position. JVs, which benefit from their OEM connections, control 11% of the market. For the foreseeable future, it seems that OEMs are sure to maintain a strong hold on this market. (Global aviation MRO market study)



Source: ICF international

2.3.4 Technology:

Modern aircraft engines are among the most reliable systems installed on aircraft. Typically they are kept operating on the aircraft up to a specified hour limit, as long as they are operating within predefined operating parameters or conditions such as vibration levels, fuel flows, oil consumption and temperatures etc. Advances in engine trend monitoring, means that these parameters are monitored continuously throughout the flight to ensure the engine's safe operation and to predict when maintenance is required in advance of any problems or failures occurring. Besides visual inspections, technicians monitor the internal condition using boroscope and oil sample spectrographs. This helps keep costs down and minimises unnecessary maintenance particularly when engine MRO is the most expensive of all the MRO activities. Besides engine overhaul facility should be equipped with the cutting edge technology like

robotic measuring and grinding equipment which is capable to measuring accuracy in hundredth thousands of an inch.

2.3.5 Regulatory Issue:

To carry out MRO work on aircraft parts, requires what is called 'Part 145 Approval' or its equivalent that is provided by the national aviation authority in which an aircraft is registered. Engine maintenance shop should have approval certificate from local as well as foreign regulatory agencies like the European Aviation Safety Agency (EASA) and Federal Aviation Administration (FAA). Part 145 approved maintenance organizations have the necessary certificate to carry out MRO work on A/Cs, engines and components. These Part 145 approved maintenance organizations are classified according to their capabilities or specialties according to their approval Class and Rating.

2.2.6 Mergers & Acquisitions:

Merger and acquisition activity in the Maintenance, Repair & Overhaul industry continues to boom with 86 transactions completed during 2015. Utilities are turning to smart meters in an effort to monitor energy consumption and convert to smart grids, which in turn allows utilities to cut costs and improve customer service. (Capstone David et al 2015)

Merger and acquisitions activity in the aviation industry is expected to persist as companies with a national foot print expand their scope of services to provide holistic solutions to customers. M&A markets continue to be driven by the strong winds of consolidation and expected that to continue.

Currently merger and acquisitions in aviation MRO business becomes the way of doing business in the most effective and efficient system. Most OEM need to expand their market share all over the world and that creates endowment factor for airlines to develop their MRO in a very fast pace even to transform from maintenance base to manufacturing sector.

2.3.7 Best Case Scenario of Joint Venture:

The global aeronautics industry is comprised of a worldwide network of manufacturers, vendors and suppliers, which are organized under a supply chain structure. To point out some of the best examples in joint venture in the African continent as well as in the world aviation industry:

SNECMA Morocco Engine Services:

SNECMA Morocco Engine Services (SMES) is founded in 1999 as a subsidiary owned 51% by SNECMA and 49% by Royal Air MAROC. SMES is specialized in the maintenance and repair of commercial aircraft engines (CFM 56 engines powering the Boeing 737). SMES inherited the maintenance of engines from RAM. Morocco is now ready to transform itself into a fast growing supply and manufacturing base for the world's major OEMs. In 2001, only 10 companies were active in the Moroccan Aeronautics nascent cluster. Ten years later, there are more than 100 SMEs employing more than 10,000 people (from 300 workers in 2001) with total sales of over USD 1 billion (CAGR of 20%) (Moroccan Agency of Investment of Development (AMDI), 2013).

AMECO Beijing:

One of the largest MROs of china is aircraft maintenance and engineering corporation (AMECO Beijing), a joint venture between air china limited and Lufthansa German airlines, was established on august 1, 1989, with air China limited holding 60 per cent and Lufthansa 40 per cent stake. Besides Airframes, engine makers such as GE, Pratt & Whitney, Rolls-Royce, Hamilton Sundstrand, SNECMA and Volvo, are also involved with Chinese MRO companies. AMECO Beijing is becomes one of the best known MRO provider in the world that can attract MRO market all over the world and most US operators receive maintenance service at their facility and Ethiopian is one of their customer for engine service.

XEOS Joint Venture with GE Aviation Engine Services:

Lufthansa Technik and GE have chosen Poland as the location for their Joint Venture XEOS and will build a state-of-the-art aircraft engine service center focused on GEnx-2B engines. The capability of servicing the new GE9X model, which is currently in development, will be established by 2021. The establishment of the XEOS engine shop with Lufthansa Technik and GE is a major milestone in Lufthansa Technik's growth strategy. The facility will create hundreds of technical and high level jobs in Poland for a further evolving aviation industry. The facility is designed to be a world-class aircraft engine service center focused on the maintenance, repair and overhaul of GE's technologically advanced next generation engines.

These are some examples of joint venture activities and currently control the major share of MRO business world.

2.4 Lean Process Philosophy:

Shigeo Shingo, co-developer of the Toyota Production System (TPS) with Taiichi Ohno, constantly stressed the difference between process and operation. A process is the transformation of raw materials into finished goods (what is now referred to as the internal value stream); an operation is the interaction of operator, machine and materials.

Starting in the early 1900's Henry Ford "married consistently interchangeable parts with standard work and moved conveyance to create what he called flow production." Not soon after WWI the Toyota Production System, TPS, introduced lean manufacturing concepts into the manufacturing industry (Ansari, 2007).

With manufacturing becoming a more and more competitive market, companies globally strive to increase their efficiency. Increasing labor costs in many industrialized countries, as well as reducing and controlling operating costs, are just a few reasons companies choose to move or outsource their operations. Typically a majority of companies outsource to countries where wages are low and production costs are lower. To reduce cost and remain competitive with manufacturers abroad, companies use a variety of different methods. One of the main methods is called "lean manufacturing." The main principle of lean manufacturing is to reduce waste in an operation, such as long lead times, defects and material waste. In order to visually display where waste occurs in the process, a value stream map (VSM) is drawn. VSMs are often used to assess current manufacturing processes as well as create ideal, future state processes.

With the manufacturing field escalating and spreading more widely across the globe, it is important for companies to adapt to the increasing and evolving business strategies.

2.4.1 Background:

"Lean" is a proven and comprehensive approach to operational transformation that—by focusing on the customer and eliminating waste—enables companies to simultaneously decrease cycle times, increase labor productivity, and improve quality and reliability. (Mercer Management Consulting definition. 2005,)

2.4.2 What is 'Lean'?

"Lean" is a business philosophy pioneered by Toyota after World War II. It harnesses a set of standard tools and techniques to design, organize, and manage operations, support functions,

suppliers, and customers. Compared with the traditional system of mass production, Lean meets or exceeds customer requirements while using less human effort, space, capital, and time to make a wider variety of products. Lean techniques cut costs by eliminating waste—those items and process steps the customer doesn't value. These reductions paradoxically increase quality as production problems become more visible and root causes more easily identified and remedied in simplified work processes.

The approach increases throughput dramatically by a focus on single-piece continuous flow and a flexible structure of cellular product-family work teams. Since flow starts with the pull of actual customer demand, overproduction is essentially eliminated. Inventory levels are reduced and turns increased through the combination of just-in-time (JIT) and kanban-controlled production. As a result, Lean significantly reduces working capital requirements.

Fixed assets are managed more efficiently through the application of Total Productive Maintenance and revamped accounting systems that seek to measure value in the eyes of the customer. In addition, a by-product of Lean is more available floor space, freeing additional capacity to support a more aggressive sales effort.

To achieve the ambitious goal of continuous improvement and to create flow and pull, there are four key elements to consider: production system design, organizational system design, training, and culture (Wolfgang et al 2007).

2.4.3 Can **Lean work in MRO?**

Compared with traditional manufacturing, MRO provides unique challenges. By its nature, it is more complex in both work scope and variability of demand. "Lean" addresses the variability inherent in job shops with mixed modeling, a tool that offers great flexibility. MRO job shops can be analyzed to identify product family patterns; reorganized into these natural groups; redesigned in a cellular fashion to increase flexibility and adaptability; and managed with kanban to achieve tasks, flow, and pull (Wolfgang et al 2007).

Another technique to manage the variability and variation of an MRO environment is the integration of Lean with Achieving Competitive Excellence (ACE). This approach supports continuous improvement through the use of 5S+1 and visual control/Kanban (Sort, Straighten, Shine, Standardize, Sustain, and Safety), RCCA (Root Cause Corrective Action), MFA (Market

Feedback Analysis), QCPC (Quality Clinic Process Chart), and related tools such as VSM (Value Stream Mapping) process analysis, and standardization.

2.4.4 A Successful Approach to Lean Transformation:

Lean implementation benefits from a holistic approach that addresses all elements from strategy to the shop floor. Some of these steps, such as objective-setting, need to be performed annually to ensure constant recalibration. Others are iterative processes that drive waste out of the system and deliver continuous improvement. Still others nurture the Lean culture. Faithful adherence to this cycle leads the way to Lean excellence.

The increased global competition during past decades, where quality and short time to market has been the key to survival, has forced companies to streamline their processes (Liker, 1997). Since the discovery of Toyota's superiority in quality and lead time in the nineties, many companies have turned to the lean philosophy as a potential solution to their needs (Womack et al., 2003). From having had initial focus on manufacturing, the lean movement has more recently spread to other functions like product development. However, in the trials with continuous improvement teams in product development it became obvious that it is difficult to handle more complex or extensive areas of improvements. The improvement area often becomes too large and it is difficult to break it down into manageable pieces. An alternative way to start improvement activities is to follow a flow and identify sub-parts where the focus of improvements should be. One lean method, value stream mapping, has successfully been used to revamp production processes. By visualizing the production flow, value stream mapping helps to identify wasteful activities and processes and serve as an input for continuous improvement (Rother & Shook, 2003).

Lean Manufacturing has increasingly been applied by leading manufacturing companies throughout the world. It has proven to have many positive outcomes which include such concepts as reduced cycle time, decreased cost, reduction of defects and waste. Lean manufacturing aims to achieve the same output with less input; such as less time, less space, less human effort, less machinery, less material and less cost. To better understand lean manufacturing, one first needs to understand the basic principles that guide it. Some major lean manufacturing principles include: recognizing wastes, having standard processes, having a continuous flow, pull-production, quality at the source and maintaining continuous improvement.

According to the TPS, there are seven original wastes known as "muda," which means "waste" in Japanese. In order to create a lean working environment, these wastes need to be identified and depleted. The first muda is over production, which is producing more than necessary, or more than is needed by the costumer. The second muda is the presence of defects. Defects in products lead to more costs and waste of production time, as well as the effort involved in inspecting and fixing defects. The third waste is inventory. Inventory could lead to added storage costs as well as higher defect rates. Even if there is no "inventory fee," large inventories cost company money because it increases their operating costs. The fourth muda is transportation, which could be transporting goods from one factory to another. Transportation, strictly seen, is a non-value added activity, so companies strive to lower transportation distances. The fifth muda, waiting, is very important to lean manufacturing because this is one of the main wastes that production companies want to minimize. Waiting causes waste of time and money. The sixth waste is over processing. Over processing is unintentionally doing more processing work than the customer requires, which can lead to higher costs by using more resources than needed. The final waste is unnecessary motion. Walking from operation to operation or around the factory floor when not necessary slows down the workers and overall slows down the flow of production (Mekong, 2004). Detecting and diminishing these wastes within the production process will overall help to create a lean working environment within a company.

2.4.5 Value Stream Mapping:

VSMs are used to map work processes, material flow, and information flow. They have a multitude of uses and are generally easy to create and understand. Value stream mapping, a lean manufacturing tool, which originated from the TPS, is known as "material and information flow mapping." This mapping tool uses the techniques of lean manufacturing to analyze and evaluate certain work processes in a manufacturing operation. This tool is used primarily to identify, demonstrate and decrease waste, as well as create flow in the manufacturing process. VSMs can be created merely using paper and pencil; however more advanced maps are created using Microsoft Visio as well as Microsoft Excel. The creation of a VSM is divided into five basic steps: 1) Identify the product. 2) Create a current VSM. 3) Evaluate the current map, identify problem areas. 4) Create a future state VSM. 5) Implement the final plan.

The first step, identifying the product, consists of choosing which specific product the VSM will focus on. After the product used has been chosen, an initial VSM of the current process is created. Following the completion of the current map, the team evaluates the process and the steps involved. All this information is then compiled on a map and analysis is performed. On a typical VSM every step of the process is included. For each step, parameters could include cycle time, TAKT time (the rate at which a finished product needs to be completed in order to meet customer demand), work in progress (WIP), set up time, down time, number of workers, and scrap rate. A VSM identifies where value is added in the manufacturing process. It will also show all other steps where there is non-added value. After analyzing and evaluating the current process of the product, the problem areas can be identified. Once you have changed the current process to minimize problem areas completely, you can create a final state VSM. The last step of the value stream mapping process is to implement the new ideas, which will in turn create a more efficient lean manufacturing process (Hines, 2004).

2.4.6 'Lean' results:

Lean manufacturing represents an opportunity to protect future revenues through true competitiveness. Different researcher suggests that with Lean, MRO shops can achieve extraordinary performance improvements. Over a three- to five-year period, it is not uncommon to realize.

During initial period lean implementations things often get worse before they get better due to different reasons. Lean will uncover problems long hidden amid the waste. The benefits, however, clearly justify the journey.

Moreover, this level of performance improvement will be essential to the medium-to-long term viability of MRO providers. With a good strategy and support, substantial Lean benefits can be achieved in as little as six months with exponential benefits thereafter.

CHAPTER THREE: RESEARCH METHODOLOGY:

3.1 Research Design:

Research design is a master plan specifying the methods and procedures for collecting and analyzing the needed Information J.Adams et al. (2007). According to Parahoo (2006) the design selected for research should be the one most suited so as to achieve an answer to the proposed research question. Owing to the descriptive and quantitative nature of this research, data collection and analysis involves an empirical investigation of a particular contemporary phenomenon within its real life context using multiple sources of evidence'.

The study mainly used descriptive research method which is an extension of exploratory research or, more often, a piece of explanatory research. Since I have a clear picture of the phenomena on which I wish to investigate prior to the collection of the data.

The following methodologies are used on this research to identify and define problems, to analyze the alternatives, to reach at reasonable conclusion and recommendations:

To accomplish the objective of the thesis, the researcher has used the following methodologies. Complete literature reviews have been conducted regarding the current Aviation industry emerging trends and philosophy's of operating environment and the current industry outlook. Ethiopian engine maintenance performance data thoroughly accessed and interpreted. Following literature survey /reviews/, in order to assess the contribution of each participating departments on TAT in engine maintenance performance, data collection has been carried out; both primary and secondary data were collected using observation, interviews with the selected management staff, project report document analysis, and review of previous research works.

3.2 Sampling and Sampling Technique:

The engine maintenance performance specifically CFM56 engine is the primary focus for this research that includes directly involving departments' for the problem in the study. This includes: engine maintenance planning section, technical sales department, engine part purchase, power plant inspection section, technical support and part marshalling, and finally the production departments in general were studied. In this study three years performance data were analyzed in

detail. Primary data collected with observation and interviews since the researcher have know the detail process flow, the need for conducting written questioner is not considered as important.

3.3 Data Source and Collection Techniques:

In this study the paper followed a descriptive research method. The study covers Ethiopian Airlines Engine maintenance performance from the year 2012/13-2014/15G.C. since the company financial year ends at Sene 30, data collected from the Ethiopian Airlines Engine shop Departments. For this specific study secondary data were the primary source of information. Primary data collected in the form of interview and discussion from some selected individuals that are valuable for this study and detail observation on the process flow were conducted at shop level to understand the nature of the problem in detail and their view and recommendation are incorporated accordingly.

Secondary data collection relates more so to publications, company portal page, records in personnel department & collective agreements. Manuals and policies the company currently using were checked in detail. Tables, Graphs, Charts and Dialogue formats were used to analysis the data collected.

CHAPTER FOUR

DATA PRESENTATION AND ANALYSIS

4.1 INTRODUCTION

Ethiopian develops engine maintenance capability for CFM56 engine series since 2012 to generate revenue from third part work as well as to repair owned engines. After all the necessary investments positioned in to place the expected maintenance order from customers are not satisfactory and promising. The increasing need for Maintenance Repair Overhaul organizations (MROs) to meet customers' demands in quality and reduced lead times is keen to survive within the Aviation industry. Furthermore, with the unpredictability in the global market and difficulties with forecasting characteristic of the MRO industry there is an increased need for the re-evaluation of the operation models of organizations within this sector**.**

There is a fierce competition among the industry stake holders. Simultaneously, with a rising trend toward globalization, these manufacturing environments must be designed to fulfil new challenges to survive and grow in the marketplace. At the same time the aviation industry is a highly regulated business by national and international regulatory agencies like Ethiopian Civil Aviation Authority (ECAA), Federal Aviation Administration (FAA), European Aviation Safety Agency (EASA), Transport Canada (TC), etc. Quality is always expected, and there is no compromise.

Currently Ethiopian Engine MRO primarily focuses on GE engines particularly on CFM 56-3 and & 7B series to generate revenue from third party work. Now in the whole world nearly 21,000 CFM engines (35% of commercial fleet powering engines) are in service with more than 450 customers around the world. The CFM56-3 powers approximately 2,000 Boeing 737 Classic Aircrafts and 4,500 engines are in service. In total, nearly 9,500 CFM56-7B engines are in service on 737 New Generation aircraft, making it the most popular engine/aircraft combination in commercial aviation. CFM56 -7B will have the largest share (18%). By 2019 though, this engine will increase the fleet size by almost 3,500. CFMI's fleet will continue to dominate the marketplace with over 40% shares by 2025(Tom cooper.2015).

Over the years, the aviation industry has made huge investments in the production system and benefited from this. The industry fierce completion makes all the stake holders to look a way to be in the business environment. So far a number manufacturing philosophies is applied; hence it

requires an integrated maintenance system for accommodating the complex, dynamic and interactive nature of environment.

The Ethiopian Airlines Maintenance Repair and Overhaul (Ethiopian MRO) has a lot of departments under its umbrella; among them it has Engine shop department which is fully committed on maintenance different Aircraft Engine models.

4.1.1 Ethiopian MRO Services Strategy:

To become the leading MRO organization in Africa by providing airframe, engine and component maintenance, repair and overhaul and procurement and material services whose quality and price "value proposition" is always better than its competitors

To be organized as separate profit centre choice to its customers, employer of choice to employees and an investment of choice for the group.

To support the fast growth strategy of the passenger and cargo profit centers of the group and to contribute the share Ethiopian to the development of MRO services in Africa.

4.1.2 Strategic Objectives:

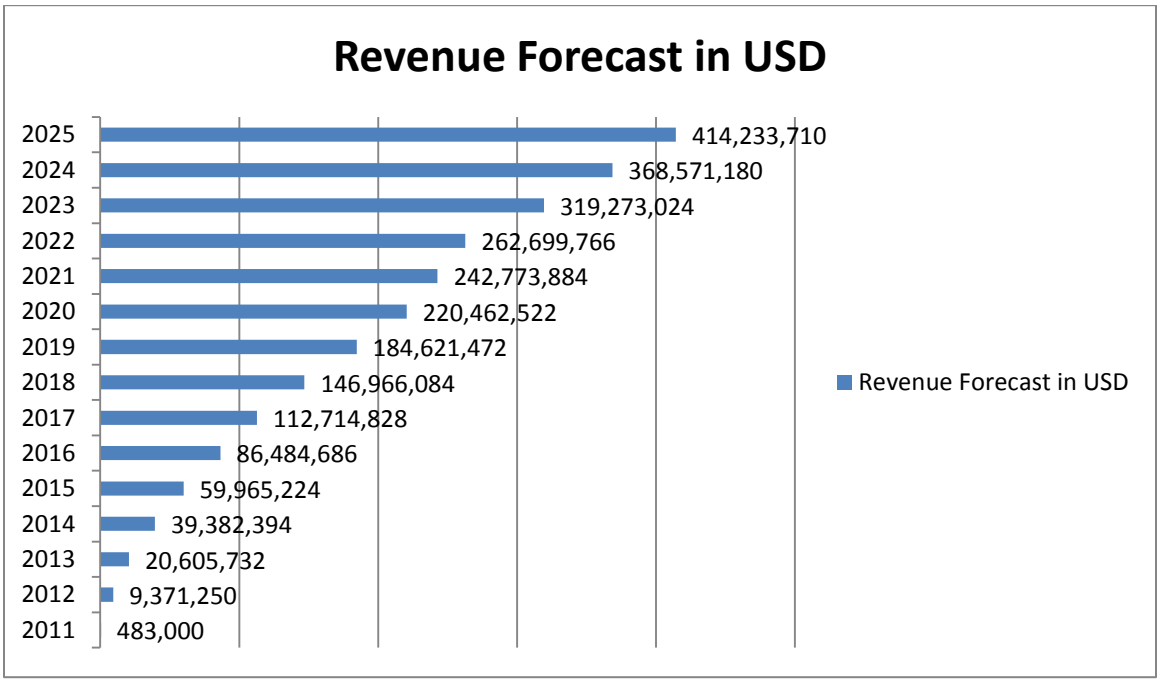
- Provide full airframe MRO services to all aircraft models operated by ETHIOPIAN on terms (price, TAT and quality) each better than the competition
- Provide MRO services to the majority of engines and components installed on ETHIOPIAN fleet at the lowest cost compared to alternate service providers.
- Generate annual revenue of USD 520 Million (and a profit of 100 Million) from third party MRO work by 2025.

. USD 87 Million from maintenance of 79 Airframes Per annum

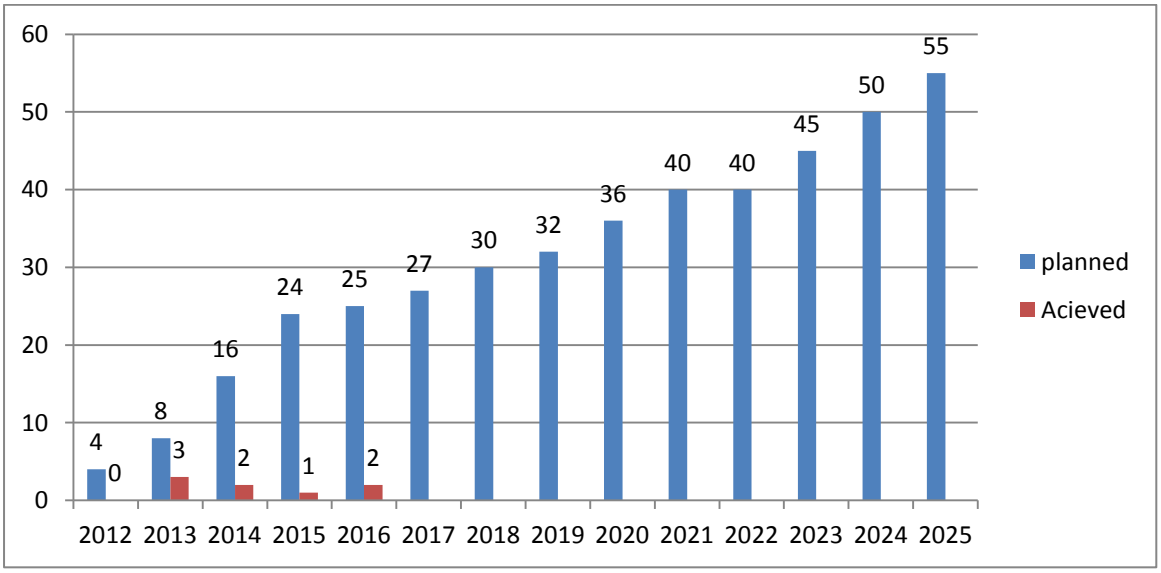
. USD 414 Million from maintenance of 153 Engines per annum

. USD 19 Million from Component Maintenance per annum

The below forecast extracted from vision 2025 road map



Source: Ethiopian Vision 2025 Road Map



Expected Customer Order per Achieved (Source Company Performance Report)

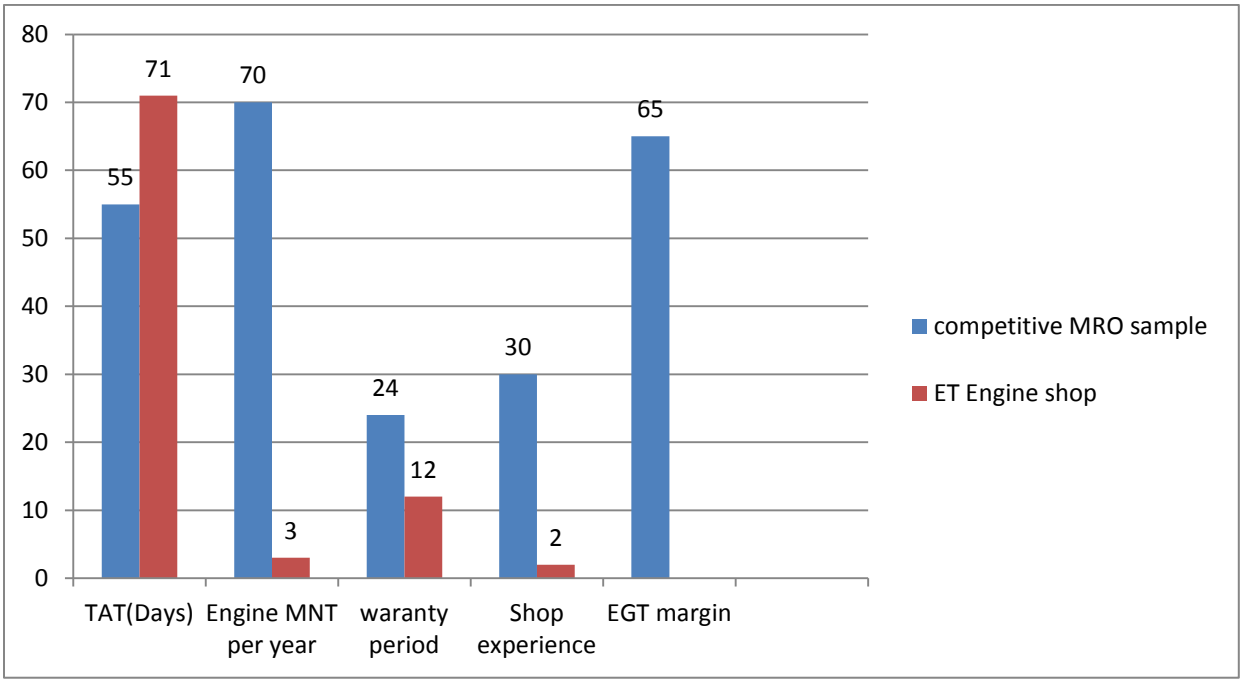
4.2 The basic contributing factors that affect Ethiopian Engine maintenance performance:

The above data which shows the planned Vs actually achieved customer engine maintained at Ethiopian facility shows 37.5% accomplishment for the year 2012, 12.5% for the year 2013, 4% for the year 2014 and 8% for the year 2015. The focused group discussion as well as historical recorded data point out some of the below contributing factors that customer focused to be improved and the Ethiopian engine maintenance have to work hard on those issues that delivered to customers.

4.2.1 Poor TAT record:

The end product of MRO business is maintaining the received customer maintenance order within the shortest possible time and acceptable quality standard to its customers. And the main performance indicator of MRO business is TAT, quality (EGT margin), cost and warranty period. In this regard Ethiopian experienced huge differences from competitive market see below historical record data for Engine maintenance.

Sample bid comparison



Source Ethiopian engine performance report 2014/15

4.2.2 Poor performance record on CFM56-3C engines:

By Quality is meant all the performance parameters should be mate per manufacturer limitations. Performance retention is a key part of jet engine engineering. Over the decades there has been massive improvement jet engine performance retention on wing for the long period of time that has had an effect of reducing the average level of engine maintenance cost per operating hour. At the same time the number of engines has grown significantly as the aircraft fleet has increased. To get customer satisfaction the maintained engine performance should able to serve the maximum on wing life and the main determinant factor is exhaust gas temperature margin to the maximum operating limit when the margin is wide the engine on wing life will increase that longer hot section part deterioration. In this regard except CFM56-7B engine almost all CFM56-3 engines maintained at Ethiopian don't meet performance parameters due to different reason that will discuss in later sections.

4.2.3 Piece part repair capability limitations:

Engine overhaul work is of a highly technical nature and large elements of it call for highly specialized equipment and tooling. Since materials make up of large element of the total cost, and because there is considerable effort put into the restoration of items through sophisticated technical processes such as plasma spray, it gives a natural advantage for the engine manufacturers to carry out the work. Sending parts to foreign repair contribute the highest TAT and decrease profit margin. Currently Ethiopian engine maintenance doesn't have piece part capability for most CFM engine parts. Per the result collected from focused group discussion even though there is some robotic machine which installed to repair hot section parts like combustion chamber proprietary issue from OEM isn't solved until now to repair those parts in house.

4.2.4 Employee Dissatisfaction:

Another grave situation existing in the Ethiopian Airlines operation is the fact that there is heavy employee dissatisfaction system wide. The root causes of the problem could be many; management, poor salary & benefit packages, job satisfaction problem, job security, loss of ownership, overall situation in the country and huge pull force from other MRO providers etc.

4.2.5 Huge Inefficiency:

Related to the above-explained facts, there is huge inefficiency existing in the system. This issue will be dealt with in detail in succeeding sections. For the airline to improve its productivity and sustain its profitability, it has to address this issue.

4.2.6 Interdepartmental Friction (Loss of teamwork):

There are also interdepartmental friction and lose of teamwork. There is a tendency to look the internal customer not as a customer. And in most cases departmental objectives come before company objective. This problem will clearly be seen, especially, for a work that needs cross departmental activities.

4.2.7 Capacity Constraints:

Current shop capability could not able to conduct engine maintenance more than three engines at a time; this creates bottle neck to accept more customer order due to shortage of dollies and fixtures that contributes to the low performance of the shop. Field visit reviles there are four engines at a time in the shop the one which needs repair remains in the transportation dolly due to shortage of Assy/Dis Assy dolly.

4.2.8 High turnover of skilled/licensed professionals:

Aviation by its nature needs highly skilled man power, the degree to which employees are complaining is great concern and one of the weakest points of the airline management, even the management do its best to retain and motivate its employees it does not give the impression that the problem has been given the level of attention it deserves. The sole existence of organization is for people by people if any companies miss its purpose for meeting financial target for sake of profitability and growth is meaningless unless it maintains balance between employees and customers/financial gains. The focused group discussion reviles within the 2015/16 fiscal year alone the shop losses six experienced technicians to Middle Eastern MRO providers.

4.2.9 Low productivity:

There are different reasons that contribute for the low productivity of employees. Employees' moral and commitment greatly affected by the industry environment. The aviation industry is highly volatile and there is a huge pull force around the globe especially from Middle Eastern carriers that capable to give huge sum of tax free salary with different compensation packages and this creates employees to lose moral and concentration.

4.2.10 Deterioration of work culture:

Ethiopian airlines well known by its strong work culture that differ from other Ethiopian companies, but currently the speed of its growth forced the company for mass recruitment and this mass employment creates to deteriorate the existing work culture accordingly. Most employees at engine maintenance are less than five years experience and engine maintenance by its nature needs more experience and relatively low turnover, hence the company should address this issue again.

4.2.11 Policies, Procedures, Systems & Facilities isn't up to date & fine-tuned to the operation

Basic infrastructure required for an efficient product delivery is in place at Ethiopian Airlines. However it is not fine-tuned for the best and efficient delivery of the final product. This is seen the fact that they are not periodically updated to reflect any change in the system. In fact, there are cases where they become a hindrance to the efficient operation of the system just because they are not updated and in tune with the dynamic nature of the aviation business. In 2015/16 fiscal year alone USA FAA suspends Ethiopian MRO license and the company was unable to certify components and engines within this period until its renewal.

The following are the regulatory requirements (the policies the airline is governed by) and the working procedures utilized by the airline:

4.2.11.1 Regulatory Agencies:

- Ethiopian Civil Aviation Authority (FAA): Certifies the maintenance base for proper accomplishment of maintenance task on aircrafts, engines, components and checks Airworthiness of each and every flying airplanes owned by Ethiopian Airlines
- USA Federal Aviation Authority (FAA): Certifies the maintenance base of Ethiopian Airlines and determines whether Ethiopian Airlines can fly to the USA as well as capable to maintain US registered aircrafts. This certifies Ethiopian maintenance can do maintenance with the same standard that American companies do.
- European aviation safety agency (EASA)**:** certifies the maintenance base of Ethiopian airlines and determines whether the airlines can fly to Europe as well as capable to maintain EU registered aircrafts per European standard. This certifies Ethiopian maintenance can do maintenance with the same standard that European companies do.

4.2.11.2 Working Documents:

- Management Policy & Procedure Manual (MP & PM): All policy and working procedure related issues are governed by this manual.
- Organizational Manual (OM): This manual shows the organizational structure and the duties and responsibilities of every management member.
- Standard Operating Procedures (SOP): These are detail operating procedures developed by the user departments for every process that are undertaken in that particular department.
- Maintenance Policy Manual (MPM): This is a manual used in the maintenance division for maintenance related issues only that is approved by Ethiopian civil aviation authority.
- Maintenance Organization Exposition (MOE): This is a manual used in the maintenance division for maintenance related issues only that is approved by European Aviation Safety Agency (EASA).
- Repair Station Manual & Quality Control Manual (RSM QCM): This is a manual used in the maintenance division for maintenance related issues only that is approved by USA Federal Aviation Administration.
- Miscellaneous procedure manuals for the different division such as Marketing, Finance, Information Systems, etc.

Certifying bodies and the availability of the procedure manuals can be seen in two ways:

1. On the positive side, the fact that Ethiopian Airlines is certified by ECAA, EASA & FAA signifies that it is satisfying the minimum requirements set by these regulatory agencies. The day-to-day operations of the airline are also guided by the above-described policy and procedure manuals. These manuals act as a quality control mechanism that ensures consistent and produce uniform end result. In this regard one can say that the airline has approval level equivalent to ISO 9000.

4.3 The basic reason ET get difficulty to attract potential customers to secure maintenance order

2. On the negative side, even if the manuals are in place they have draw backs:

_Most employees could not know and understand their duties and responsibility due to different reason even they could not locate the location on company portal page.

4.2.12 Decision making in some key areas not to level demanded by the aviation industry:

The aviation industry is an industry where there is big dynamics. Situations change very fast. Opportunities come and go. Unexpected situation that can affect the business can develop overnight.

To survive in such an environment, fast decision-making and some level of calculated risk taking is an essential business imperative. In this regard, the management of Ethiopian Airlines seems to lack this scarce resource. This is seen in some areas that need immediate decision-making and fast action. This management inefficiency creates push factor for employees and aggravates skilled man power drainage.

4.2.13 Information System not developed to fully exploit its potential:

The power of information system is in its ability to enable businesses to harness the potentials and capabilities that it can give for the benefit of improving operation and end product delivery.

At Ethiopian Airlines, there are encouraging trend towards incorporating and using information technology to harness the benefits explained above. However, there remains a lot to be done.

4.3 The basic reason ET get difficulty to attract potential customers to secure maintenance order

4.3.1 Market limitations:

By market limitation is meant lack of securing contracts from operator's since most operators have maintenance support agreement from other MRO providers and the remaining ones are bush operators. This could be due to lack of information and strategic decision to think differently for merger with OEM that have market access as well as financial power, lack of vision, or pure avoidance of decision that has an element of risk in it. Market needs some level of aggressiveness, promotional work, persuasion, etc.

African engine MRO market is dominated by big MRO provides. Only 18.182% market can be exploited.

AFRICA CFM56-3/7 ENGINE BUSINESS GE FORECAST FOR FISCAL YEAR OF 2014/15

IN	Engine Model	Operator	Country	MRO shop	2014	2015
1	CFM56-7B	ROYAL AIR MAROC	MOROCCO	SNS	5	5
2	CFM56-7B	COMAIR LTD	SOUTH AFRICA	UNKNOWN	2	2
3	CFM56-7B	AIR ALGERIE	ALGERIA	SNS	6	5
4	CFM56-7B	CAMEROON AIRLINES CORP (	CAMEROON	UNKNOWN	1	1
5	CFM56-7B	MIDWEST AIRLINES (EGYPT)	EGYPT	UNKNOWN	1	1
6	CFM56-3	MAURITANIAN AIRLINES INTE	MAURITIUS	UNKNOWN	1	1
7	CFM56-7B	ARIK AIR LIMITED	NIGERIA	GEES	4	4
8	CFM56-3	RWANDAIR	RWANDA	UNKNOWN	1	1
9	CFM56-3	PRECISION AIR SERVICES	TANZANIA	SNS	1	1
10	CFM56-7B	TAAG-ANGOLA AIRLINES	ANGOLA	SNS	1	1
11	CFM56-3	KENYA AIRWAYS	KENYA	IAI	2	2
12	CFM56-7B	KENYA AIRWAYS	KENYA	IAI	2	3
13	CFM56-3	AIR MADAGASCAR	MADAGASCAR	SNS	1	1
14	CFM56-3	AERO CONTRACTORS NIGER	NIGERIA	LHT	4	2
15	CFM56-3	COMAIR LTD	SOUTH AFRICA	IAI	3	3
16	CFM56-7B	SOUTH AFRICAN AIRWAYS	SOUTH AFRICA	LHT	3	4
17	CFM56-3	TUNIS AIR	TUNISIA	AFI	1	1
18	CFM56-7B	TUNIS AIR	TUNISIA	AFI	4	3
19	CFM56-3	AIR NIGERIA	NIGERIA	GEES	2	1
20	CFM56-3	SAFAIR (PTY) LTD	SOUTH AFRICA	UNKNOWN	1	0
21	CFM56-3	SOUTH AFRICAN AIRWAYS	SOUTH AFRICA	UNKNOWN	1	1
22	CFM56-7B	ASKY AIRLINES	TOGO	UNKNOWN	1	1
				Total Engine	48	44

No data (2014) =18.75% No data (2015) =18.18%

In Middle East GE, SNECMA and Lufthansa together holds 87.88% of the market.

MIDLE EAST CFM56-3/7 ENGINE BUSINESS GE FORECAST FOR FISCAL YEAR OF 2014/15

IN	Engine Model	Operator	Country	MRO shop	2014	2015
1	CFM56-3	JORDAN AVIATION	JORDAN	UNKNOWN	1	0
2	CFM56-7B	ARAMCO SERVICES	SAUDI ARABIA	GEES	1	2
3	CFM56-3	EASTERN SKY JETS	UNITED ARAB EMIRATES	UNKNOWN	1	1
4	CFM56-3	GLOBAL JET DUBAI	UNITED ARAB EMIRATES	UNKNOWN	1	1
5	CFM56-7B	FLY DUBAI	UNITED ARAB EMIRATES	GEES	6	10
6	CFM56-7B	MANGO AIRLINES	OMAN	LHT	2	2
7	CFM56-7B	OMAN AIR	OMAN	SNS	13	14
8	CFM56-7B	MID EAST JET INC	SAUDI ARABIA	GEES	0	1
9	CFM56-7B	IRAQI AIRWAYS	IRAQ	UNKNOWN	1	1
10	CFM56-7B	EL AL ISRAEL AIRLINES LTD	ISRAEL	UNKNOWN	0	1
				Total Engine	**26**	**33**

No data (2014) =15.38% No data (2015) =12.12%

Source *GE forecast for fiscal year of 2014/15*

4.3.2 Resource limitations:

This is directly related to the financial muscle of the company. It is clear that Ethiopian Airline is a fully government owned company and has limited resourced at its disposal. In some cases, its resource limitation hinders it from venturing out to some promising investments.

4.3.3 Empowerment of staff at various levels not fully developed:

Another issue is staff empowerment in some decision-making issues. This is required for the staff to exercise their decision making power for the benefit of the company. However, decisions are highly concentrated at executive levels authority and responsibility for the position should be exercised by each position holder. Responsibility without authority is meaningless and contradicts the basic management principles. Foreign repair invoice took longer time for approval since the line of chain is too long and approval authorization is very limited in middle management positions.

4.4 The current industry outlook and the way forward in MRO business

4.4.1 Very competitive market:

The aviation MRO is exposed to a heavy competition against giant alliance in the international scene, regional alliance in Africa and the Middle East, and strong OEM that form merger and acquisitions in Europe, Middle East and Africa. Unless the airline prepare and develops strategy to counter the upcoming competitive pressure, the consequences could be unmerciful. It should learn from other like royal air morocco that form alliance it's MRO with SNECMA and becomes the world focus for part manufacturers around the globe.

4.4.2 Long engine life:

Modern aircraft engines are among the most reliable systems installed on aircraft. Typically they are kept operating on the aircraft up to a specified hour limit, as long as they are operating within predefined operating parameters or conditions such as vibration levels, fuel flows, oil consumption and temperatures etc. Advances in engine trend monitoring, means that these parameters are monitored continuously throughout the flight to ensure the engine's safe operation and to predict when maintenance is required in advance of any problems or failures occurring. Besides visual inspections, technicians monitor the internal condition using boroscopes and oil sample spectrographs. This helps keep costs down and minimises unnecessary maintenance particularly when engine MRO is the most expensive of all the MRO activities. Besides engine overhaul facility should be equipped with the cutting edge technology like robotic measuring and grinding equipment which is capable to measuring accuracy in hundredth thousands of an inch.

4.3.3 Foreign dominance of African MRO market:

SNECMA Morocco Engine Services (SMES) is founded in 1999 as a subsidiary owned 51% by SNECMA and 49% by Royal Air MAROC. SMES is specialized in the maintenance and repair of commercial aircraft engines (CFM 56 engines powering the Boeing 737). SMES inherited the maintenance of engines from RAM. Morocco is now ready to transform itself into a fast growing supply and manufacturing base for the world's major OEMs. In 2001, only 10 companies were active in the Moroccan Aeronautics nascent cluster. Ten years later, there are more than 100 SMEs employing more than 10,000 people (from 300 workers in 2001) with total sales of over USD 1 billion (CAGR of 20%). Besides most West African countries greatly attached with

France due to colonial reasons that force most government in West Africa doing business with French companies that give SNECMA comparative advantage over others in African aviation (Moroccan Agency of Investment of Development (AMDI), 2013).

Egypt air also investing heavily on its MRO together with Rolls Royce of Britain and it becomes one of the major competitors in the region.

Other mega carriers like Emirates and Etihad based in UAE have developed the maintenance capability to perform engine maintenance activity in the region.

All those including OEM heavily focused in the African market and the operators have ample choice to receive maintenance service from those competitors.

4.4.4 Increasing labor mobility / brain drain:

Currently, one of the major problems of the company is the fact that experienced employees are leaving the company for another company inside or outside of the country. The main reasons being better salary, working environment, and additional benefits package offered by the other company and the push factor from management member. One area where the external pressure expresses itself is in the robbing of experienced manpower. Emerging and new airlines as well as established airlines and MRO organizations in the Middle East, Africa, and the other part of the world are luring the most experienced and senior managers, engineers and technicians using a benefit package that is attractive enough to displace the staff where they worked for the last 20 and above years and amassed a huge amount of experience.

In the aviation business, the current trend is to search a well experience staff and provide him an attractive package than training fresh employee from the ground up. For one thing, these kinds of airlines do not have time for the time taking training process. And also it is much cheaper for them to pay for already trained and readily available staff than to invest on fresh employee. Unless the airline in conjunction with the government device some method to curb the problem, the consequence will be obviously not to be desired.

4.4.5 Alliance among Airlines and its impact on Ethiopian Airlines:

4.4.5 Alliance among Airlines and its impact on Ethiopian Airlines:

Airlines and MRO providers around the worlds are making alliance and this is a threat to Ethiopian Airline's marketing position. Merger and acquisition activity in the Maintenance, Repair & Overhaul industry continues to boom with 86 transactions completed during 2015 in the aviation industry. Utilities are turning to smart meters in an effort to monitor energy consumption and convert to smart grids, which in turn allows utilities to cut costs and improve customer service. (Capstone David et al 2015)

4.5 The most frequent problems in the current engine maintenance:

In the previous, we have seen emerging trends of the global aviation industry environment as well as the current situation of Ethiopian airlines. It is believed that we have got valuable information about the problems and situations of Ethiopian airlines engine maintenance shop. In this section we try to look all available data empirically and analyze to have clear understanding to reach to the solutions. It has been pointed out that every data has a weaknesses and limitations. The best way to overcome this limitation is to collect multiple data types from multiple sources and make the analysis. Analysis of different data from different sources about the same problem will provide an opportunity to assess the problem from several angles. This will help in producing a solution that addresses the problem from all angles. In this chapter, the collected data will be analyzed and the major findings will be isolated

4.5.1. Analysis of On-Time Performance Data

The on time performance data is extensive and several types of relevant analysis can be performed on it. Relevant analysis has been done on the raw data below consecutive graphs shown in the coming sections.

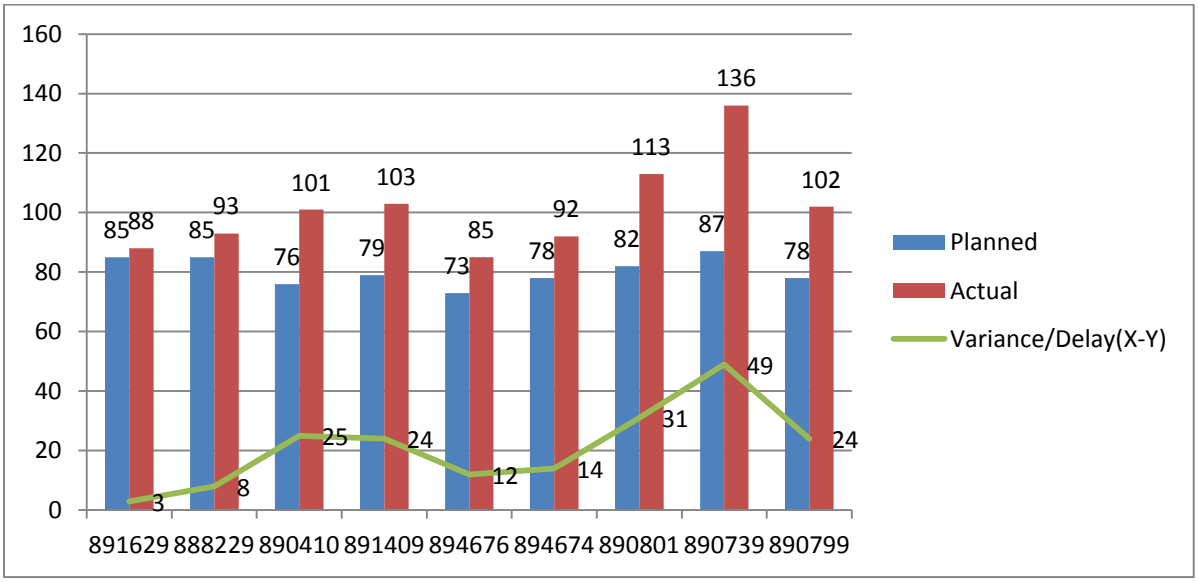
4.5.2 Historical TAT record data presentation, analysis and interpretation:

Since TAT data is confidential it could not be available to general public and basic performance parameter for the aviation industry, getting this data almost impossible. To compare Ethiopian with the other MRO provider performance, the researcher try to compare nine engine historical data available at Ethiopian data base that are maintained at GE Wales TAT record how many days they took to maintain Ethiopian engine at their facility. GE Wales claim that the required

TAT for engine is 55 calendar days but as seen from below graph average TAT for those engines that are maintained at GE Wales's is101.4 calendar days.

From the interview data collected from engine maintenance planning the industry TAT doesn't include time required to procure necessary part, industry TAT only counts the actual time required to perform serious of activities to disassemble, clean, inspect, repair, assemble, test and finally certifying by confirming the performance parameter at test bench. In contrary Ethiopian engine maintenance TAT includes all the time required to procure consumable as well as replaceable part. For comparison Ethiopian average TAT record for different years under consideration shows for three years from 2012/13 up to 2014/15 is 76, 76 and 86 consecutively. Hence, planning section assumption may be logical in this scenario.

GE Wales TAT Performance for the year 2012/2013 (Target vs Actual Turnaround Time).

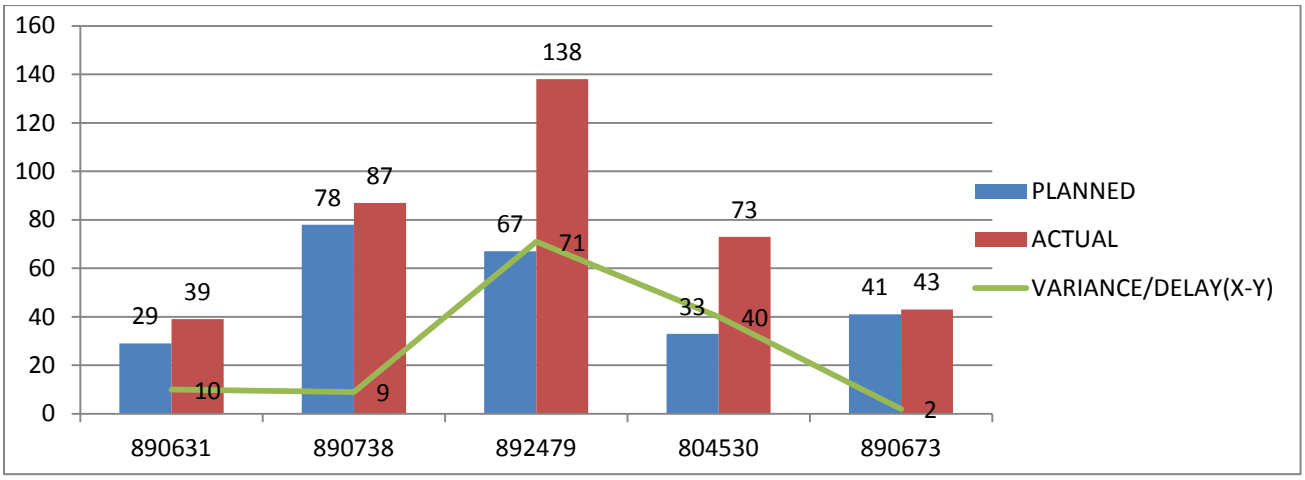


Measurement Parameters	Target Value	Measured Value
Target Achievement in Percentage	100%	0%
Maximum TAT Variation/Delay in days	(X-Y)=0	49 days
❖ Delay reason is not known/Reported ❖ Average TAT is 101.4 Days		

4.5.3 Ethiopian engine shop historical data on CFM56-7B series engine analysis for 2012/13-2015/16:

The below graph shows Ethiopian engine maintenance historical TAT data for CFM56-7B engines maintained at Ethiopian engine maintenance facility in the year 2013/14 as shown on the graph the maximum TAT record is 138 calendar days for engine S/N 892479 and the minimum TAT record is 39 days for E/N 890631 and average TAT for the year 2013/14 is 76 calendar days with major TAT contributor foreign repair station 25.43%, purchasing 16.37% shipment 6.62%, cargo space shortage 7.31% production 2.84% and in house repair accounts for 7.31%. This shows the major TAT contributor is foreign repair station and part procurement. Besides Ethiopian unable to secure a single CFM56-7B customer engine order for the entire year due to different reasons per the information collected through interview from MRO market section the Ethiopian TAT offered for customers is not per the industry standard to win the bid around the globe but when we evaluate in detail historical TAT data that Ethiopian receive maintenance service from different MRO providers like Lufthansa Technic and Delta for its different engines shows the core element for low customer order is not the factor of TAT and Ethiopian should see in detail what is the basic reason for low customer order for engine maintenance.

- **Ethiopian CFM56-7B TAT Performance July2013-Jun2014 (Target vs Actual Turnaround Time)**



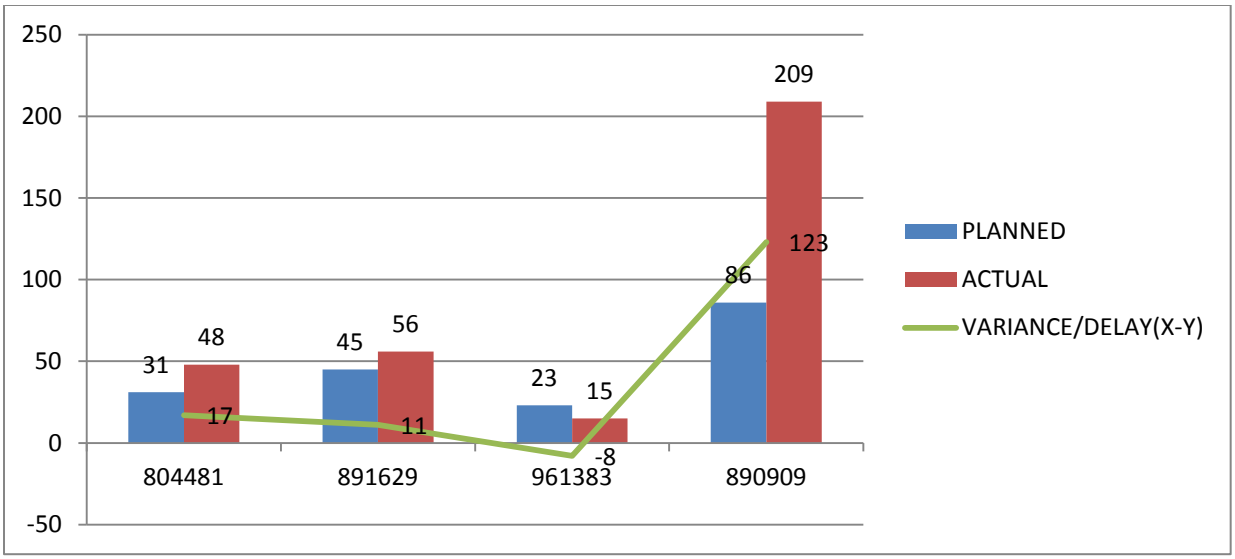
❖ **Ethiopian CFM56-7B TAT Performance July2014-Jun2015 (Target vs Actual Turnaround Time)**

❖ **Ethiopian CFM56-7B TAT Performance July2014-Jun2015 (Target vs Actual Turnaround Time)**

Measurement Criteria	Target Value	Measured Value
Target Achievement in Percentage	100%	0%
Maximum TAT Variation/Delay in days	(X-Y)=0	71 days
*FR REPAIR STATION=== 25.43% *PURCHASING=== 16.37% *SHIPMENT=== 6.62% *CARGO SPACE SHORTAGE=== 7.31% * PRODUCTION===2.84% * INHOUSE REPAIR=== 7.31% *Average TAT========76 Days		

For the year 2014/15 four CFM56-7B engine maintained in the shop out of these S/N 890909 took the lion share of delay for the year due to different reasons that are beyond the control of the shop which is 67 days (54.47%)-due to plasma machine problem for HPT shroud support repair, 50 days (46.65%) - due to Danobat machine problem for HPC stator seals grinding and 6 days (4.87%) - due to purchasing. Delay on other engines totally avoidable with proper planning and proper project management techniques. Engine S/N 961383 which customer maintenance order from Rwandan air completed before the planned delivery date in which it shows there is a possibility and capability to complete before the planned date if all necessary resources are availed in time.

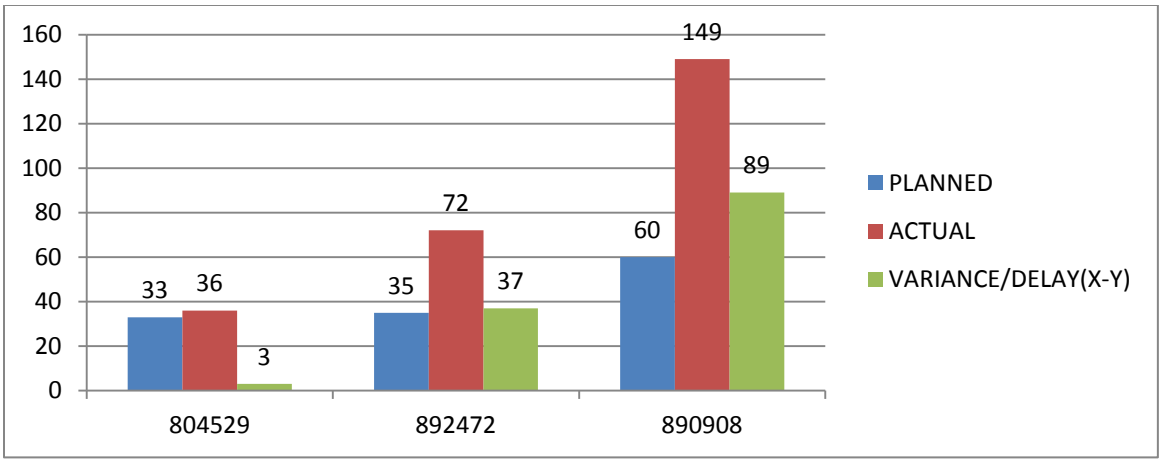
❖ **Ethiopian CFM56-7B TAT Performance July2014-Jun2015 (Target vs Actual Turnaround Time)**



Measurement Parameters	Target Value	Measured Value
Target Achievement in Percentage	100%	25%
Maximum TAT Variation/Delay in days	(X-Y)=0	123 days

Considering the year 2015/16 three CFM56-7B engine maintained in the shop out of ES/N 890908 the most delayed engine due to 70days (78.6%) parts robbing to support fleet since the engine is spare and components that need for testing the engine were taken replacing many robbed parts takes long time, 19days (21.4%) purchasing due to fulfill expendable parts for in-house repair of fan blade platforms since it is on capability development and initial procurement takes long time. For ES/N 892472 delay contributors are 20days (54%)test cell due to test cell screen display failure and due to test cell main server booting problem & therefore, test cell personnel's were tried to communicate with CENCO & IT section. 4days(10.8%)Tech support to compiling data for work scope definition and waiting advise from hangar inspection for justified information that the engine reasoned to be removed with high oil consumption,7days(18.9%)OEM COMM .due to waiting SENECMA'S advise to have a direction to inspect oil leak suspected areas. 2days(5.5%) purchasing to avail missing parts for installation 4days(10.8%)welding shop due to waiting platforms repair process.

- **Ethiopian CFM56-7B TAT Performance July2015-Jun2016 (Target vs Actual Turnaround Time)**



Measurement Parameters	Target Value	Measured Value
Target Achievement in Percentage	100%	0%
Maximum TAT Variation/Delay in days	(X-Y)=0	89 days
*Test troubleshooting=1day (**0.8%**) *Waiting work scope definition/preparation=4days (**3.1%**) *Parts purchase and FR delay=21day (**16.3%**) *Test cell system failure =20day (**15.5%**) *Part robbing for A/C operation=70days (**54.3%**) *Parts in-house repair delay at welding and machine shop=6days (**4.6%**) *Waiting for OEM communication=7days (**5.4%**) *Average TAT ==========85.7 Days		

4.5.4 CFM56-3 shop performance review for the years under consideration:

In the year 2013/14 Ethiopian receives three CFM56-3 customer orders to be maintained at its facility and one engine per year for 2014/15 and 2015/16, but all of them doesn't fulfill TAT target as well as performance parameters due to different reasons and the main TAT contributors are test trouble shooting 43.69%, customer cost approval 26.89%, production 19.32%, purchasing 5.04% and average TAT 75.3 days. Per the performance study conducted for CFM56-3 engines by Daniel et al 2015 the CFM56-3 engine performance problem due to the

engine of wing design behavior specifically two degradations factors in the High Pressure Compressor (HPC) blades: chord length reduction and tip clearance increase:

Per Daniel et al 2015 study the first three stages of HPC blades have the highest contribution of performance deterioration and need chord length and tip clearance restoration to meet required performance in which the second and the third stage have the highest contributor. The increase in tip clearance is a common deterioration for compressor and turbines, the clearance between the blade tip and the annulus wall allows the air to escape between them just like in an aircraft wing tip, creating tip vortexes. Tip clearance influences the overall efficiency of the compressor by increasing the end losses which, consequently, increases the loss factor of the different stages. For the purpose of this study the work scope definition for those engines thoroughly evaluated and none of them consider the above critical tasks to be included and addressed in those shop visits and the study reviles Ethiopian scope definition for those engines should consider after mentioned tasks inclusion in the coming engines for performance recovery purpose. The below highlighted are the major tasks to be considered for CFM56-3 engine work scope definition.

_Changing compressor efficiency will bring modifications to the whole engine. T45 and T5 are measured respectively before and after the high pressure turbine (HPT) and yet they are influenced by changes in the Fan efficiency;

_The high pressure components, HPC and HPT, are the one that influence T45 and T5 the most. Thus, they will also influence EGT the most;

_A 1% efficiency loss in the HPT leads to an incredible loss in EGT margin of almost 12 degrees Celsius;

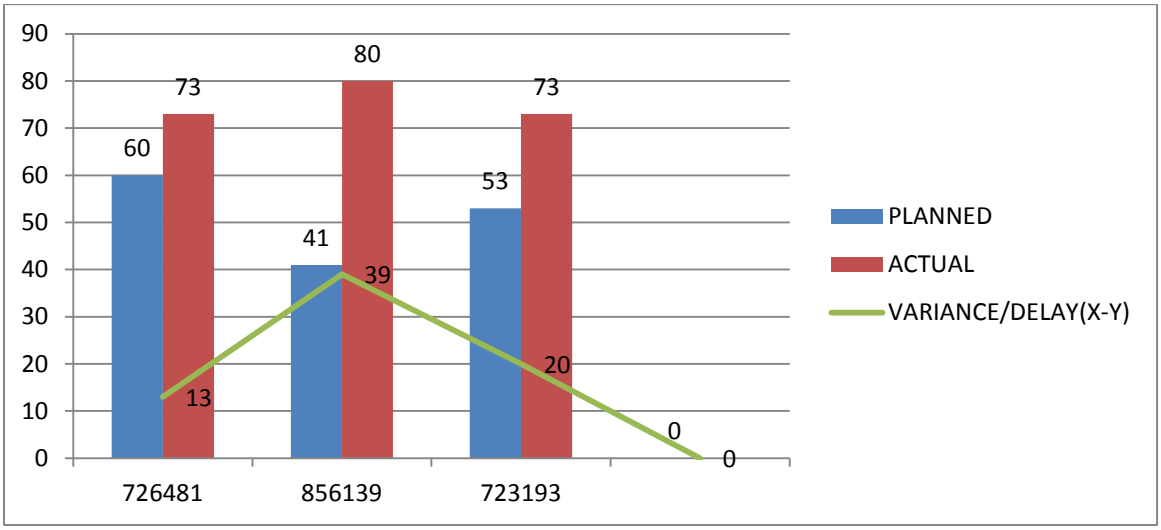
_Net thrust remains practically unchanged when efficiency is changed. This parameter is influenced by changes in flow, especially in the Fan (1% increase in Fan capacity lead to an increase of 2.06kN);

_Changing the components efficiency brings changes to the Fuel Flow, observable by the changes in specific fuel consumption (SFC), which is directly connected to Fuel Flow and Net thrust (which remained almost unchanged).

Since the operator of those engines maintained at Ethiopian are individual investors based in Sudan their primarily focus is profit and have little disposable financial resource to perform performance recovery maintenance that have huge impact on the performance that explained above is not acceptable by the owner due to this meeting the performance target is difficult and

Ethiopian management consider this as the failure of the shop and the reverse is true. Hence to meet performance parameter of CFM56-3 engine planning for tip clearance restoration for fan blades, HPC first three stages and HPT is vital.

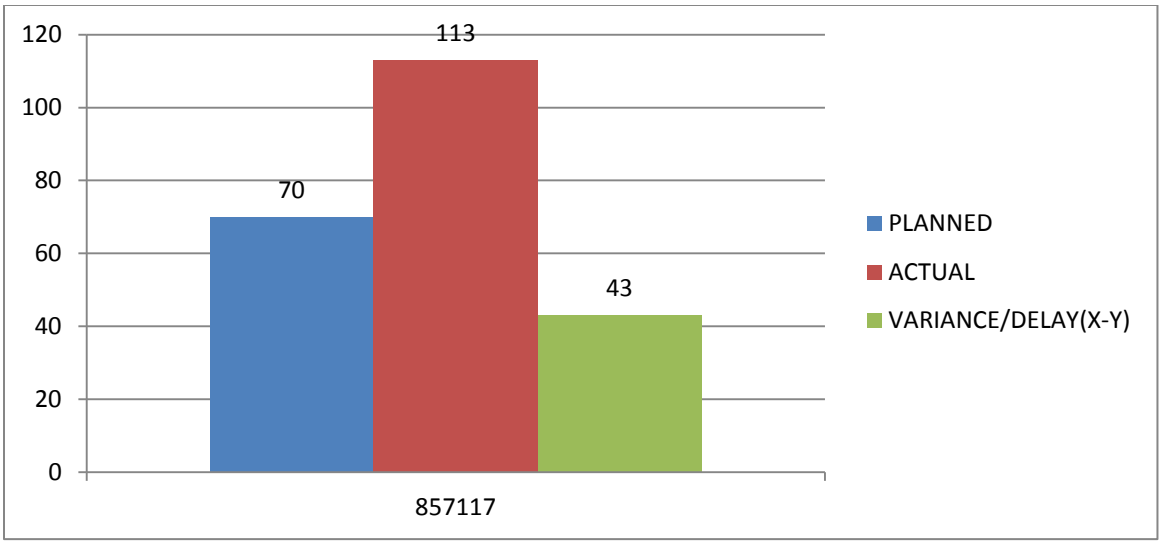
- **Ethiopian CFM56-3C TAT Performance July2013-Jun2014 (Target vs Actual Turnaround Time)**



CFM56-3C

Measurement Parameters	Target Value	Measured Value
Target Achievement in Percentage	100%	0%
Maximum TAT Variation/Delay in days	(X-Y)=0	73 days
*TEST TROUBLE SHOOTING===43.69% *CUSTOMER COST APPROVAL=== 26.89% *PRODUCTION=== 19.32% *PURCHASING=== 5.04% *Average TAT ====75.3 Days		

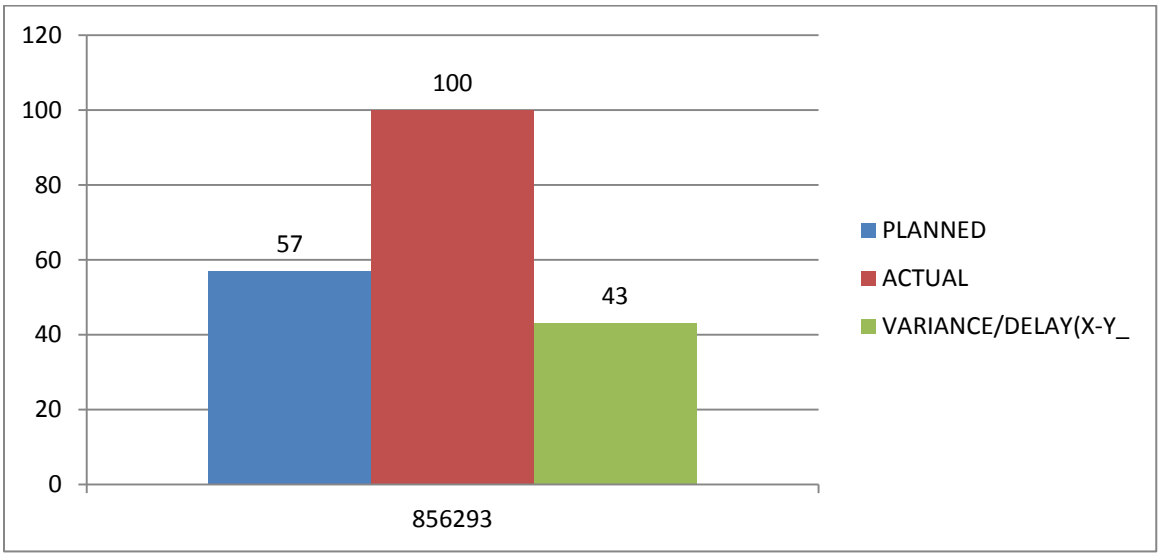
- **Ethiopian CFM56-3C TAT Performance July2014-Jun2015 (Target vs Actual Turnaround Time)**



CFM56-3C

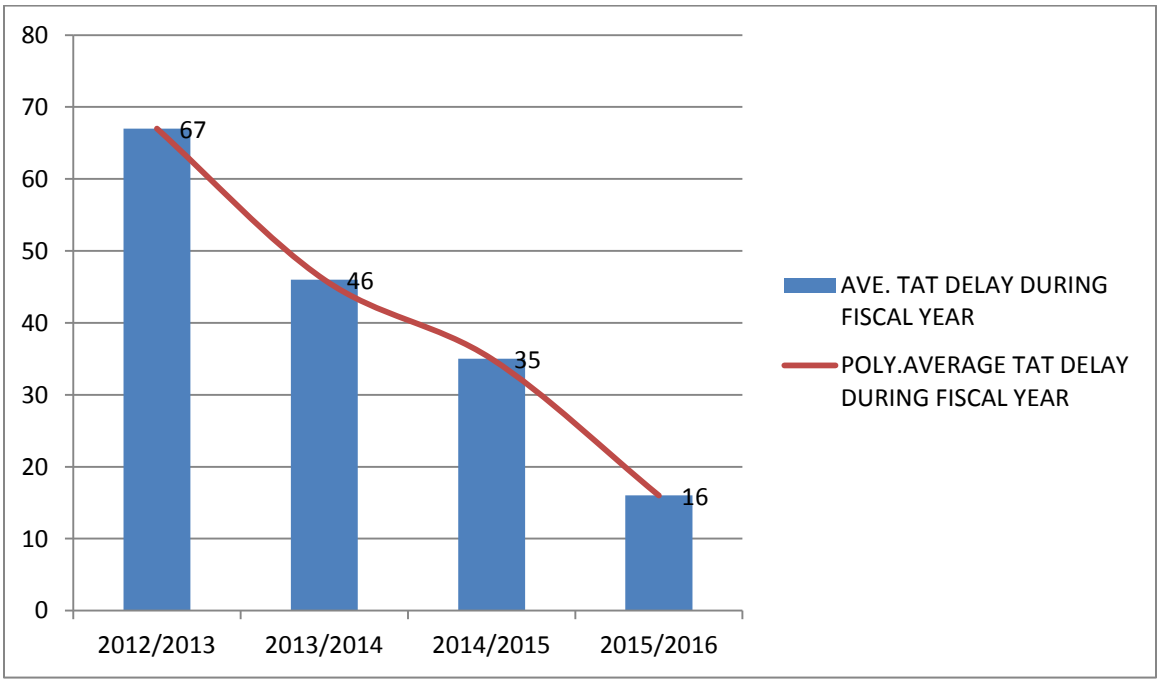
Measurement Parameters	Target Value	Measured Value
Target Achievement in Percentage	100%	0%
Maximum TAT Variation/Delay in days	(X-Y)=0	43 days
48.8%(21days) delay due to late part request by production 39.5%(12days) delay due to wrong parts inclusion in shortage list 11.6%(5days) delay due to test cell problem-UPS inoperative		

❖ **Ethiopian CFM56-3C TAT Performance July2015-Jun2016 (Target vs Actual Turnaround Time)**

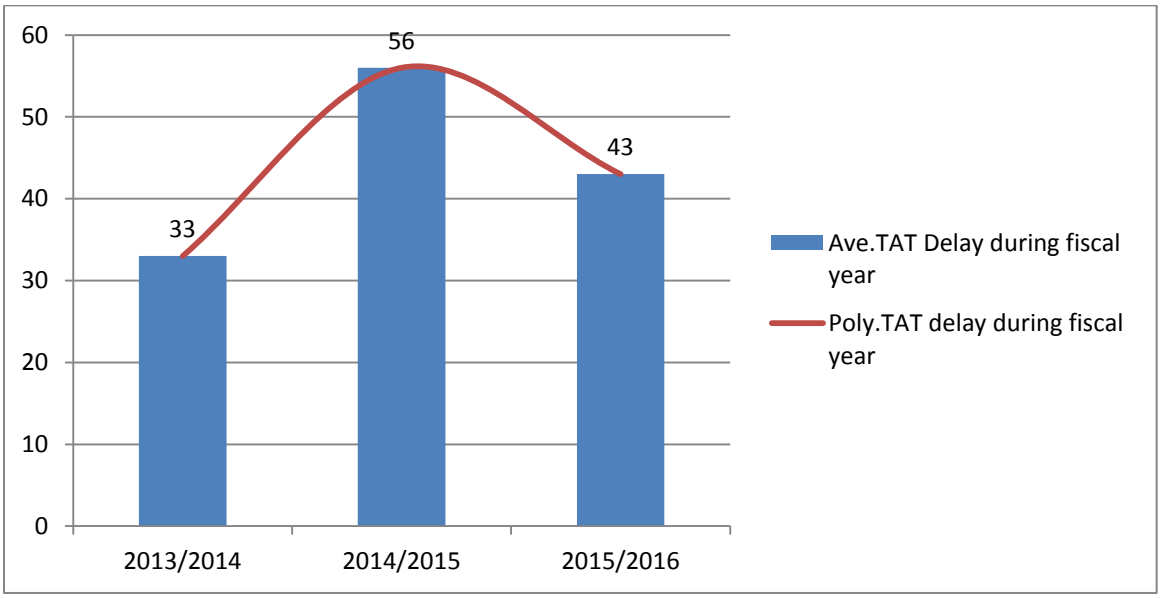


Measurement Parameters	Target Value	Measured Value
Target Achievement in Percentage	100%	0%
Maximum TAT Variation/Delay in days	(X-Y)=0	43 days
*Waiting for task card revision by TES=3days (**7%**) *Parts purchase and FR delay=3day (**7%**) *BI process delay =4day (**9.3%**) *missing of PT49.5 & T54 pick up sensors by Test cell during test preparation=2days (**4.6%**) *Communication with SNECMA and CFMI for fan case abradable repair advice and test troubleshooting=5days (**11.6%**) *Parts NDT delay caused by facility construction=15days (**34.9%**) *Fan case repair delay by structure shop caused by late part request and process delay=6days (**13.9%**) *Part painting delay by painting shop=5days (**11.6%**)		

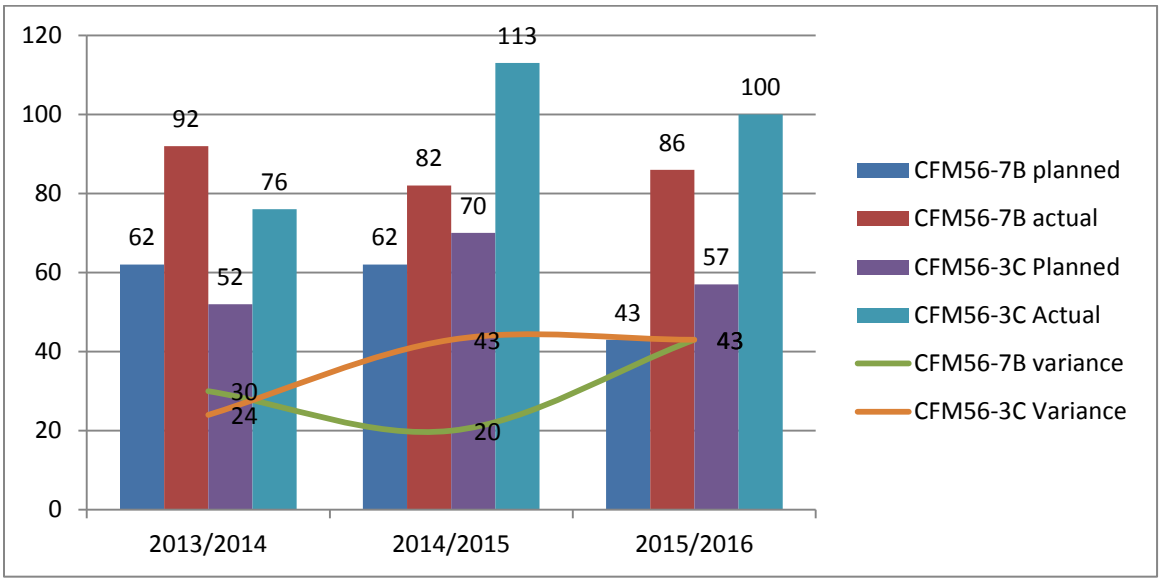
Ethiopian Engine maintenance Delay Trend by Engine model - Over Fiscal years 2012/13, 2013/14, 2014/15 &2015/16



CFM56-7B **TAT Delay Trend over Fiscal Years**



Overall CFM56 Engine TAT Performance Over Fiscal Year (2013/14, 2014/15 & 2015/16)



CFM56-7B ENGINE OVERALL TAT PERFORMANCE AMONG BUDGET YEARS

4.6 Maintenance system that required to improving engine maintenance performance:

As stress in chapter two Lean is basically "Rapid Change, Fast!" approach to business processes. The underlying logic is that with the current pace of change that is taking place in the business environment, no change or a piece meal or slow change process will no suffice. Companies must readjust themselves by changing in a radical way and they have to do it fast, there is no time to waste. A company can reengineer, or it can choose to go out of business. Eventually probably sooner than latter – every business will need to change the way it conducts its operations. The alternative is to be overpowered by the competition. Therefore, the alternative is not whether to change or not, but how to change. Again there is very little choice. Traditional management system such as MBO & cost control by cutting budget does not address a problem that needs a breakthrough level improvement. Introducing quality programs along the lines of ISO 9000, BPR or TQM would not bring about the required result fast enough. The remaining approach is reengineering: analyzing and fundamentally altering the basic work process of the business.

Lean philosophy with Value Stream Mapping (VSM) would be a suitable change process for the on-time performance problem under consideration for the following reason.

_ It is ideally suited for the type of change that needs an order of magnitude change that is beyond the continuous improvement range. This is usually, in the order of 50% and above improvement.

_ It is a proven method that produces fast result for those processes that are in deep problem or that have a problem of crisis proportion.

_ It requires cross-functional teams to work together to bring about change that entails major restructuring which the other management methods do not accommodate that focus on customer deliverable end product.

Ethiopian engine maintenance is the first cell to implement ACE in 2004 and the first cell to reach silver level certification, since then the shop witnessed tremendous improvements. Integrating ACE to VSM level with lean thinking will help to concentrate on the final product delivered to the customer that satisfies in quality, lead time, employee satisfaction, financial performance, employee empowerment and the like.

Lean philosophy position gate keepers that evaluate individual section performance and made accountable the failure and reward the achiever with transparent and objective measuring parameters and the philosophy will help Ethiopian engine shop to improve its bad TAT performance if implemented properly.

Processes and Functions that produce the end product are not investigated in light of the overall business objective of the company. The purpose of functional analysis (some time called process mapping) is to investigate the system to find out the activities that do not add value to the final product or service. Put simply, any activity that is not directed towards the end result is superfluous and unnecessary and the resources tied up with it should be deployed elsewhere.

Functional Analysis achieves its purpose by identifying:

- The purpose of the business as a whole in terms of satisfying the External Customer's needs by the delivered product.
- The purpose of each department in the business in terms of satisfying the Internal & External Customer's needs.

- Whether departments achieve their objective in a cost effective way and if not locating the exact reasons.
- The costs associated with any failure, inefficiency, delay, etc
- Areas of implementing corrective actions.
- This radical approach requires each department to critically examine its role in achieving the overall objective of the business. This includes deciding why it exists and what it contributes to further the aims of the business.
- In this regard the situation at Ethiopian is the following:
- Each department has its own Standard Operating Procedure (SOP).
- However, the SOPs are not investigated for effectiveness and efficiency and measuring parameters is not developed. Lean philosophy encourage departmental integration with service level agreement (SLA) that have measuring capability inter departmental performance.
- The contribution of each department to the overall result is not assessed. Whether that department is superfluous (i.e. can the airline do without it?) or is it really needed is not studied.
- In the case where a process touches cross-department functions, the process is not optimized (there is a huge departmentalization & lack of team work).

CHAPTER FIVE:

SUMMARY CONCLUSION AND RECOMMENDATION

5.1 Summary:

This chapter will comprise three sections, which include conclusions, limitations of the study as well as hint for future research and recommendations.

This part of the research summarizes the overall performance study work conducted in the Ethiopian engine maintenance specifically on CFM56-3 /7B models. The paper discusses the challenges on customer order and means of resolutions. The researcher made an effort to identify Engine MRO related challenges and current practice in the area. The research work conducted is specific in nature as it focuses on the Aviation industry specifically on Engine MRO in which the biggest challenge for Ethiopian airlines.

The formulation of a research problem has been made as it is one of the very crucial steps and process in scientific researches. To formulate the research problem the researcher made a critical document review. Moreover, data triangulation was made in order to make sure the publications from various sources were rigors enough. By doing so the research problem had been organized as a real research problem for the study conducted. Finally the research problem as a sole major problem entitled assessing the factors that contribute for the performance of cfm56 engine in the case of Ethiopian airlines was drafted.

Literature reviews have been made at organizational, continental and international level. Theoretical and empirical studies were thoroughly reviewed from the very start of the project work. As part of the study area these literatures used in the study gives an in depth knowledge about the topic area and purpose of the study. Empirical studies such as studies about international MRO market structure and the past, present and future trend of MRO business, performance problem of CFM56-3 engine has been added in the literature.

During the data analysis, findings of the research work were discussed in detail to give a clear understanding about the problem. Analysis was made by using different methods of analyzing data including tabulation, graphs, and observation check list. Data from observation was analyzed by using the observation checklist. Results of the study are presented and interpretations of findings were made.

5.2 **Conclusion:**

Organizational performance is defined in terms of the value that an organization creates using its productive assets in comparison with the value that the owners of these assets expect to obtain.

Performance measurement can be viewed as the process of quantifying the efficiency and effectiveness of purposeful action and decision-making (Waggoner et al., 1999).

Performance management is a process that helps an organization to formulate, implements, and change its strategy in order to satisfy its stakeholders' needs. In other words, performance management is 'a comprehensive management process framing the continuous improvement journey, by ensuring that everyone understands where the organization is and where it needs to go to meet stakeholder needs' (Andersen, 1998: 3).

With the unpredictability in the global market and difficulties with forecasting characteristic of the MRO industry there is an increased need for the re-evaluation of the operation models of organizations within this sector (Ayeni et al. 2011).

Assessing the factors that contribute for the performance of cfm56 engine in the case of Ethiopian airlines has been the main focus area of this research work. Performance of CFM56 engine needs a great attention as it constitutes great contribution to fulfilling MRO vision 2025 involves the operationalization of the stated milestones during the planning phase of the forecasted years. The challenges in Ethiopian engine maintenance where the market have been in fierce competition in which Ethiopian competes with the OEM as well as giant MRO providers around the world and market limitation becomes a normal scenario. The problems identified throughout the study are very crucial to bring solution so as to increase market share as well as to transform the shop to manufacturing sector.

To conclude on the analysis, the researcher emphasize on the findings of the research work to give a clear picture for audiences on what has been identified as a major challenges and forecasted conceivable means of resolution in the area.

The points that were taken as major findings of the research discussed in chapter four section of the study comprises critical points such as Challenges of meeting turnaround time, Challenges of meeting designed performance for CFM56-3 engine, improving stakeholders involvement, integrating departments in line with product delivered to customer, worldwide competition in the MRO business, Absence of clear articulation of current engine MRO business during planning. The conclusions made over those variables of shop performance regarding CFM56 engine will

enable the concerned body for taking corrective actions in order to successfully manage related projects.

The research design employed while working on the methodology part of the research gives a greater chance for collecting data scientifically. The instruments used were relevant with the research design which quantitative method. As part of the design sampling technique used were targeted in generating sources of the research problem formulated at the very start of the research process.

Analysis made to interpret the data collected in a rigor fashion so as to implicate the desired level of results. Analysis about the observation made by a researcher has a great deal of impact on the findings of the research. Moreover, the interpretations made regarding the performance of the shop in relation to CFM56 engine and means of resolution gives an insight to look on the major objective as well as specific objectives of the study.

5.3 Recommendation:

The overall activities in research work shows an endeavor taken to produce solution for the stated problem of a study. The formulation of the research problem gave the first insight for the move in finding the conceivable means of resolutions. As part of a research work done, the analysis gives a direction on what to do here after for the successful accomplishment of projects in the Ethiopian airlines engine shop.

Aviation MRO especially the engine maintenance sector dominated with major engine manufacturers and Ethiopian engine maintenance face fierce competition with those OEM that target after sale market all over the world to secure maintenance order from operators. Nowadays, there is a growing trend for OEMs to adopt '*servitized*' business models and thus offer an array of support packages directly to the customer. Servitization is traditionally described as the shift by manufacturers from selling the product alone with a few essential services to using services as a basis for competitive strategy. With more value generated with increased interaction with the customer(Wise and Baumgatner,1999), OEM are offering packages that extend beyond the warranty of purchased products to include a complete service package that deals with the maintenance, servicing and spare- part replacement over a fixed time period. These support packages range from bundled asset management program to integrated customer support. An example of such support or services offering includes 'Totalcare' offered

by Rolls Royce and GE aviation, 'Goldcare' offered by Boeing. This kind of move by OEM forced independent MRO providers to form joint venture with those manufacturers. Hence, Ethiopian engine maintenance should prepare to transform itself into a fast growing supply and manufacturing base for the world's major OEMs by forming merger with selected OEM like GE. Joint venture Provide companies with the opportunity to gain new capacity and expertise like:

- Allow companies to enter related businesses or new geographic markets or gain new technological knowledge
- access to greater resources, including specialized staff and technology
- sharing of risks with a venture partner

The other witnessed short coming with Ethiopian engine Maintenance is inadequate in house piece part capability to minimize foreign repair dependence since the major TAT contributors are foreign repairer and the current investment in this area should be accelerated to curve this issue in the near future. Besides the agreements with FR vendors shall be revised to account FR vendors when delays occurred for those parts that are mandatory to be sent for FR repair since the existing agreements accept delays occurred by FR vendors resulted from parts outsource repair delays, OEM and non-OEM parts shortage in the market, test rejection, and FR vendor's repair process delay. As a result, the most delay of 34.17% of total delay in 2015/16 occurred by foreign repairers.

The major investment necessary for engine maintenance put in place by Ethiopian but those sophisticated and robotic machines counting years without proper functioning due to different reasons, the major ones are proprietary issue with the manufacturers. The management of Ethiopian should work aggressively to solve this problem and made functional those machines to overhaul piece parts that are currently sent to foreign repair due to repair license issue.

In the production area capacity shortage witnessed, the shop couldn't able to handle more than three engines at a time due to shortage of fixtures and the shop manager should consider purchasing additional dollies and fixtures to handle more engine at a time.

For the internal process the lean principle will help to steam line the process as literature review reveals that different approaches have been adopted in lean implementation programs within the aviation MRO industry which complements the findings by pettersen. For example, Lufthansa Technik in its implementation journey has adopted a strategy has recorded great success in its formative years. They have initially interpreted the lean concept and developed a three phase

approach to its implementation. Ethiopian have witnessed great achievements by implementing achieving competitive excellence (ACE) since 2004 and integrating lean principle with value streaming methodology will help to improve the witnessed TAT problem in the departments. For the value steaming project management system it will bring improvement on TAT performance for the coming years, effective implementation of the system can bring much more improvement on TAT performance.

The low TAT compliance percentage of production of CFM56 engines were resulted from inefficient performance of Parts purchase, parts/ modules FR, parts in-house repair, assembly and engine testing. Therefore, the responsible department heads and their staffs appointed as process owners shall examine/evaluate their respective processes for improvement and be responsible and accountable for their TAT performances.

The other major problem to fully implement the system is project managers' lack of knowledge and experience on the maintenance production activities task management. However, project manager is expected to coordinate and guide all the complex engine shop activities and challenge the gate keeps towards meeting goal.

Even though, head count of technicians in engine maintenance is excess at the moment, there is no adequate number of seniors. Therefore, management shall devise a system to keep seniors as seniority generally reflects experience and effectiveness.

The other major discovery in this detail investigation of Ethiopian engine maintenance performance disparity reviles that the problem of planning without considering the international MRO business environment and by assuming that the only competitive parameters are quality, TAT, price and the like but the actual scenario reviles that the environment in the aviation MRO dramatically changed towards cooperation and venturing. As can been seen from best scenario discussed in chapter two Ethiopian business model looks like Lufthansa Technik that organizes in seven profit center and Lufthansa Technik aggressively expanding their market share by forming joint venture all around the world with both OEM as well as airlines, Hence, Ethiopian should consider joint venture if the company want to increase the market share from engine maintenance since the assumed low TAT achievement is not the case for low customer order securing.

Ethiopia as a country become one of the best FDI recipient in sub Saharan region due to different reasons and this will give Ethiopian airlines endowment power to attract potential OEM to form a joint venture and this is the best solution to solve the current engine maintenance problem.

For CFM56-3 engine the major problem lays on meeting of-design performance parameters for repaired engine which is the factor of wrong scope definition and customer requirement for pure financial reasons. In this case meeting TAT target is meaningless unless you meet the designed performance parameters (quality of product) for the engine to operate for the specified time period on the installed aircraft.

As one can see from the above graph the disparity with planned vs achieved due to poor planning during project appraisal that have limitations in considering the world MRO environment. Aspiring to become best MRO provider in the region by simply providing best price, quality and TAT is not bearing fruit in the case of Ethiopian airlines engine maintenance not because of poor TAT record, it is due to the market competition that most operators already agreed with OEM or other MRO providers outside the region. Hence the failure of engine maintenance performance is due to wrong planning.

The increased need for maintenance repair and overhaul organizations (MROs) to meet customers' demands and reduced lead time it is key to its survival within the aviation industry. Furthermore, with the unpredictability in the global market difficulties with forecasting characteristics of the MRO industry there is an increased need for the re-evaluation of the operation models of organization in this industry. However, sever economic turmoil and ever increasing global competition introduce the opportunity for the adoption of resilient, tried and tested business operation model such as 'lean'.

In this enquiry the following major findings were observed and appropriate recommendations to solve those problems that Ethiopian engine maintenance should address:

- ✓ The first and main finding worldwide competition in the MRO market that those major OEM participate in the after sale market aggressively that put Ethiopian engine maintenance not to achieve the planned market share since most operators have agreement with those OEM for their maintenance need and Ethiopian should consider joint venture to transform its engine maintenance and to increase its market share.

- ✓ The second and the major finding of this study is that the vast majority of the delay causes are foreign repair of parts that can be eliminated by developing in house capability for those parts that have long lead time and relatively easy to accomplish the task and revise agreements with those maintenance providers concerning TAT improvement.
- ✓ The other major finding of this study is that the on-time performance process of Ethiopian Airlines is fragmented. The component parts of the system are owned by different departments who belong to different departments within the same division. Process owners should not be concentrated in the departmental issues to solve this issue lean process that organizes departments towards the final end product should be implemented.
- ✓ There is a low level of focus on the customer. The major driving force of the individual departments' activity is to complete the assigned task irrespective of the impact on customer satisfaction. As such the focus is to try to avoid being accountable for delay rather than do the job as team and achieve customer satisfaction.
- ✓ There is a very low level of employee empowerment & morale exhibited by the employees in general and front line employees in particular.
- ✓ CFM56-3 maintained at Ethiopian engine maintenance have performance problem due to inappropriate scoping and engine maintenance technical support department should consider to include and perform performance recovery maintenance tasks to meet of design performance parameters.
- ✓ There is high experienced technical personnel shortage due to brain drain to other MRO providers that compete with Ethiopian this creates experience loss in these departments and strengthen those competitors and Ethiopian management should work to address these issues in the whole MRO and engine maintenance in particular.
- ✓ The company claimed that low TAT record is the main factor for low performance in this sector but this research reviles that the company TAT record isn't far from the best MRO providers around the world and the main problem is planning without considering the current engine MRO environment that the market is in fierce competition from OEM as well as other MRO providers, hence assuming we do business as we do before isn't the current business model that the world follow.

Reference

Arthur Andersen LLP, 1998 Institute of Management Accountants

Ansari, 2007, "A Brief History of Lean," 2007.

Adam Guthorn Aero-Engines Americas Market Forecast and Key Trends, February 11-12, 2015 – Dallas, TX

Article on Ethiopian Airlines symbol of pan africannism and African renaissance selamita magazine May-June 2013

Baines, T. S, Lightfoot, H. W *et al.* State-of-the-art in Product-Service Systems. *Engr Manufacture*

Proc. IMeche J. Part B, 2007, Vol. 221, No 10, pp 1543-1552.

CFM international engine finance roundtable managing an engine April 2009

Chrisman H. August 2005, The Changing MRO Market: Implications for Airlines and Suppliers, Air Carriers Purchasing Conference, San Diego, CA.

Chrisman H. 29 March 2006, Global Outlook for the PMA Parts Industry, 8th Annual Gorham PMA Conference, San Diego, CA.

Daniel Alexandre Rodrigues Martins November 2015 "Of-Design Performance Prediction of the CFM56-3 Aircraft Engine"

Daniel Whitney and Guillermo Peschard 1996 Manufacturing Performance in Automotive Engine Plants; Massachusetts Institute of Technology,

Dahlstrom K. and Ekins P. Vol. 51, 2007, 541-560. Combining Economic and Environmental Dimensions: Value Chain Analysis of UK Aluminum Flows, Resources, Conservation & Recycling,

David Hygate. 2013, The engine MRO market

DTI Manufacturing Advisory Service, 2005, "Manufacturing Management, Lean Manufacturing," 2007(07/19) pp. 2.

Ethiopian Airlines Office use website "Portal" page.

Ethiopian airlines, 2016

FAA Air Carriers' Outsource of Aircraft Maintenance, Report Number:AV-2008 090 September 30, 2008

Grant R. M.2005, Contemporary Strategy Analysis, Fifth Edition, Malden, USA, Blackwell Publishing, 2005.

Hines, P., Howle, M., and Rich, N. Learning to Evolve; a review of contemporary Lean thinking. Int. J. Ops & Prod. Mgmt, 2004 24(10).

Hugh L. McManus 2005 " Product Development Value Stream Mapping (PDVSM) Manual 2005"

Institute of Management Accountants & Arthur Andersen LLP (1998) *Tools and techniques for implementing integrated performance measurement systems*: *Statement on Management Accounting 4DD*, Montvale, NJ.).

Jackman F.2005, MRO Unit Costs Down for Third Straight Year, Overhaul & Maintenance, April 2005.

John w. Creswell 2003 Research design qualitative, quantitative, and mixed methods approaches second edition 2003 university of Nebraska, Lincoln

Journal of Aviation Technology and Engineering (2012) 63-73

DOI: 10.5703/1288284314659

Kevin Michaels 2016,Global MRO industry outlook conference April 2016 Montreal Canada

Liker, J. K. (1997). Becoming lean: Inside stories of US manufacturers: Productivity Pr.

Louis Cohen, Lawrence Manion, and Keith Morrison (2007), research methods in education 6th edn. Taylor and Francis group.

Marcontell D. A.2006, Widebody Airframe Outsourcing, 6th Annual Aircraft Maintenance Outsourcing Conference for the Americas, November 2006.

Mcauliffe G. Aftermarket: The Ascendancy of Lean in MRO. Aviation Today, June, 2007.

Mekong Capital, 2004, "Introduction to Lean Manufacturing for Vietnam," .

Michaels K.2005, The Changing MRO Landscape: Implications for Suppliers, 19th Annual Aviation Industry Suppliers Conference, Beverly Hills, CA, March 23, 2005.

Michaels K.2006, MRO Market Outlook, Aviation Week's 2006 MRO Conference & Exhibition, Phoenix, Arizona, April 26, 2006.

Moroccan Agency of Investment of Development (AMDI), 2013

Morris, T. and Wood, S. (1991) 'testing the survey method: continuity and change in British industrial relations'

Olivier Caslin 2016 article, Jeune Afrique, No 2884 17 to 23 April 2016 p21.

Tom Cooper 2015 Global fleet & MRO market economic assessment from 2015-2025 Atlanta, Georgia

P. Ayeni, 2011. Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture, November 2011, vol. 225, no. 11, pp2108-2123

Peter Franklin (2013) Regional engine MRO capabilities & impact of advanced engines 30855 Hannover –G ermany

Porter M. E.1985, Competitive Advantage: Creating and Sustaining Superior Performance. Free press, New York, 1985.

Porter M. E.2001, Strategy and the Internet, Harvard Business Review, March 2001, R0103D, 63-78.

Reinhard German, 2000 Performance Analysis of Communication Systems: Modeling with Non-Markovian Stochastic Petri Nets, Wiley; 1 edition, 2000

Robson, C. (2002) Real World Research (2nd edn). Oxford: Blackwell.

Rother, M., & Shook, J. (2003). Learning to see: value stream mapping to create value and eliminate muda: Productivity Press.

Selamta in flight magazine May-June 2013 Ethiopian Airlines symbol of pan africannism and African renaissance

Stabell C. B. and Fjeldstad. D.1998, Configuring Value for Competitive Advantage: On Chains, Shops, and Networks, Strategic Management Journal, Vol.19, 1998, 413-437.

Stewart D.2005, European MRO Outlook, Berlin, October 2005.

Stewart D.2005, MRO Asia-Ten Year Forecast & Key Trends, Singapore, November 2005.

Stewart D.2006, MRO Facilities Within The Middle East Region , 12th Middle East Airline E&M Conference Dubai, March 2006.

Stewart D.2006, Outlook for Engine Overhaul, 15th Annual International Aero-Engine Conference, London, September 2006.

Stewart D., MRO Market Outlook Forecast & Key Trends, MRO Europe, Amsterdam, September 2006.

Strong, M., "Leaning Toward Lean," (0882).Mercer Management consulting. 2005

"TIME STUDY," 2007.

The Evolving MRO Market - Opportunities for MRO Suppliers, SPEEDNEWS 7th Annual Aviation Industry Supplier's Conference, Toulouse, September, 2006.

Thompson J. D., Organizations in Action. McGraw-Hill, New York.

Tom Cooper (2015) CAVOK_Engine_Sessiosn_MRO_Forecast 2015-2025 Atlanta, Georgia

Waggoner, D.B., Neely, A.D. & Kennerley, M.P. (1999) 'The forces that shape organizational performance measurement systems: An interdisciplinary review', *International Journal of Production Economics*, 60–61: 53–60.

Wolfgang Apel, Jia Yong Li & Vanessa Walton. Implementation major qualifying project the faculty of Worcester polytechnic institute (WPI) and central industrial supply (CIS) August 31, 2007

Womack, J. P., & Jones, D. T. (2003). Lean thinking: banish waste and create wealth in your corporation: Simon and Schuster.

www.ethiopianairlines.com/portal

www.google.com

www.oliverwyman.com

www.mercermc.com

Yin, R.K. (2003) Case Study Research: Design and Method (3rd edn). London: Sage.

Yoshihiko tanaka, shinichi nagai, masanori ushida & tsuyoshi USUI 2003 Mitsubishi Heavy Industries, Ltd. Technical Review Vol.40 No.2 (Apr. 2003)

Appendix A

Addis Ababa University

School of Commerce

Department of Project Management

Derib Teketay (MA Candidate)

Focused Group and Discussion

Dear Participants

I am Derib Teketay student of Addis Ababa University, alumni from department of Project Management. I am doing a Master's Degree thesis for the requirement of the degree in Project Management. For successful accomplishment of the research paper I need your cooperation and am sure that any of the information taken should be kept confidentially.

Here below are some of the demographic data needed for analysis and the discussion questions for your review purpose.

Thank you for all your cooperation!!

Derib Teketay

Focused Group and Discussion Questions

1. What are the major problems related to low customer order in CFM56 engine series and what should be done to solve this problem?
2. How do you see the higher management support to solve the problems happened due to the foreign repair delay and on time settling the payment?
3. How do you see joint venturing with other OEM like GE on these engines to expand the market share?

   Finally what do you think are the issues left being not raised? And if any comment or suggestions you are welcomed.

Addis Ababa University

School of Commerce

Department of Project Management

Derib Teketay (MA Candidate)

Interview and Discussion

Dear Participants

I am Derib Teketay student of Addis Ababa University, alumni from department of Project Management. I am doing a Master's Degree thesis for the requirement of the degree in Project Management. For successful accomplishment of the research paper I need your cooperation and am sure that any of the information taken should be kept confidentially.

Here below are some of the demographic data needed for analysis and the discussion questions for your review purpose.

Thank you for all your cooperation!!

Derib Teketa

deribteketay@gmail.com
Deribt@ethiopianairlines.com
+251911610691
+251115174212

Interview and Discussion Questions (1) for lower management group

1. What is the major problem in the shop to handle more customer engine at a time?
2 What are the basic contributing factors for low TAT that affect Ethiopian Engine maintenance performance?
3 What are the specific challenges with the implementation piece part repair like plasma coating on hot section engine parts?
4 What were some of the problems encountered by the shop related to experience?
5 What do you see the benefit gained by implementing ACE lean philosophy (VSM) to improve departmental relationship towards end product?
6 Finally what do you think are the issues left being not raised? And if any comment or suggestions you are welcomed.

Interview and Discussion Questions (2) for middle level management members

1. What are the major problems related to low customer order in CFM56 engine series?
2. What is the major problem in the shop to handle more customer engine at a time?
3. What are the specific challenges with the implementation piece part repair like plasma coating on hot section engine parts?
4. How do you see the higher management support to solve the problems happened due to the foreign repair delay?
5. How do you see the higher management support to settle payments on time for repair station, who repair modules and parts in their facility?
6. What do you see the market share of Ethiopian in engine MRO in the African as well as other markets?
7. How do you see joint venturing with other OEM like GE on these engines to expand the market share?
8. What do you think about the current Ethiopian strategy regarding CFM56 engine?
9. What do you see the benefit gained by implementing ACE to improve departmental relationship towards end product?
10. Finally what do you think are the issues left being not raised? And if any comment or suggestions you are welcomed.

ENGINE SHOP TAT PERFORMANCE FROM JULY 2013 TO JUNE 2014

MODEL	ESN	WORK ORDER	PLANNED TAT	ACTUAL TAT	VARIANCE/DELAY	INDUCTION DATE	SERVICEABILITY DATE	Mnts TYPE	CUSTOMER	TEST RESULT	Remarks	MAJOR CONTRIBUTOR SECTIONS FOR DELAY
CFM56-7B	890631	TSFN8000MFT1	29	39	10	29-Jul-13	05-Sep-13	minnor repair	ET	1st pass	minnor repair on #3, 4 and 5 brg replacement	** FR REPAIR STATION=== 25.43% ** PURCHASING=== 16.37% ** SHIPMENT=== 6.62% ** CARGO SPACE SHORTAGE=== 7.31% ** PRODUCTION===2.84% ** INHOUSE REPAIR=== 7.31%
	890738	TSFN8000KZKG	78	87	9	18-Jul-13	11-Oct-13	core refurbished	ET	1st pass	repaired at GE wales	
	892479	TSFN80008682	67	138	71	03-Jun-13	31-Oct-13	core refurbished	ET	1st pass	repaired at ETH	
	804530	TSFN8000PAD2	33	73	40	30-Sep-13	04-Jan-14	H-s-i	ET	1st pass	repaired at ETH	
	890801	TSFN8000SEZX	82	113	31	29-Nov-13	21-Mar-14	core refurbished	ET	1st pass	repaired at GE wales	
	890739	TSFN8000RTQ4	87	136	49	10-Nov-13	25-Mar-14	core refurbished	ET	1st pass	repaired at GE wales	
	890799	TSFN8000YE5N	78	102	24	09-Jan-14	30-Apr-14	To Full fill ET-ALU Lease Agrmnt.	ET	1st pass	repaired at GE wales	
	890673	TSFN8000VN86	41	43	2	24-Feb-14	12-May-14	CC Crack	ET	1st pass	repaired at ETH	
CFM56-3	726481	TSFN8000QAFC	60	73	13	16-Oct-13	08-Feb-14	REPAIR	SOUTH SUPREME	1st pass	REPAIRED AT ETH	** TEST REJECTION===43.69% ** CUSTOMER COST APPROVAL=== 26.89% ** PRODUCTION=== 19.32% ** PURCHASING=== 5.04%
	856139	TSFN8000SLWJ	41	80	39	18-Dec-13	06-Apr-14	REPAIR	alfaa air	1st pass-lots of trouble shooting	repaired at ETH	
	723193	TSFN8000ZDE1	53	73	20	04-Mar-14	20-May-14	Repair	Toumai air	1st pass	repaired at ETH	

ENGINE SHOP TAT PERFORMANCE FROM JULY 2014 TO JUNE 2015

MODEL	ESN	WORK ORDER	PLANNED TAT	ACTUAL TAT	VARIANCE/DELAY	INDUCTION DATE	SERVICEABILITY DATE	Mnts TYPE	CUSTOMER	TEST RESULT	Remarks	MAJOR CONTRIBUTOR SECTIONS FOR DELAY
CFM56-7B	804481	TSFN80012GCY	31	48	17	29-Jul-14	14-Aug-14	H-S-I quick turn	ET	1st pass		- 50% production delay - 50% PPI delay
	891629	TSFN800145SX	45	56	11	15-Sep-14	18-Nov-14	H-S-I quick turn	ET	1ST PASS		- 7DAYS(63.63%)-robbing-EEC - 2days(18.18%)-production584 -2days(18.18%)-repair shops
	961383		23	15	-8	18-Feb-15	11-Mar-15	top case repair	Rwanda air	NA	TAT improved by 8days	
	890909	TSFN80014DJM	86	209	123	04-Sep-14	01-Apr-15	core refurbishment	ET	1st pass		'> 67days(54.47%)-due to plasma machine problem for hpt shroud support repair > 50days(46.65%) - due to danobat machine problem for hpc stator seals grinding > 6days(4.87%)- due to purchasing
CFM56-3	857117	TSFN8000UJGD	70	113	43	20-Mar-14	09-Sep-14	'P, LLP replaceme	ALFAA	1st pass	TROUBLE SHOOTING PERFROMED DURING TEST DUE TO FAILED STARTER PREVIOUSLY BRIUGHT WITH THE ENGINE, THE UNIT WAS NR	> 48.8%(21DAYS) DELAY DUE TO LATE PART REQUEST BY PRODUCTION > 39.5%(12DAYS) DELAY DUE TO WRONG PARTS INCLUSION IN SHORTAGE LIST > 11.6%(5DAYS) DELAY DUE TO TEST CELL PROBLEM-UPS inoperative

ENGINE SHOP TAT PERFORMANCE FROM JULY 2015 TO JUNE 2016

MODEL	ESN	WORK ORDER	PLANNED TAT	ACTUAL TAT	VARIANCE/DELAY	INDUCTION DATE	SERVICEABILITY DATE	Mnts TYPE	CUSTOMER	TEST RESULT	Remarks	MAJOR CONTRIBUTOR SECTIONS FOR DELAY
CFM56-7B	804529	TSFN8001MDSQ	33	36	3	26-Aug-15	30-Sep-15	REPAIRE & REPLACEMENT OF CC	ET	1st pass	repaired by ET	>2days (67%)welding shop= due to repaire of oil inlet cover assy and platforms. >1days(33%)production= due to test delay on fan blade vibration out of limit
	892472	TSFN8001RTQX	35	72	37	10-Nov-15	20-Jan-16	MINOR REPAIRE & TO RECTIFY OIL LEAK	ET	1st pass	repaired by ET	>20days(54%)test cell=due to test cell sreen display failure and due to test cell main server booting problem & therefore, test cell pesonels were tried to communicate with CENCO & IT section. >4days(10.8%)Tech support=due to compiling datas for input meeting and waitig advise from hangar inspection for jestified information that the engine reasoned to be removed with high oil consuption. >7days(18.9%)OEM COMM.=due to waiting SENECMA'S advise to have a direction to inspect oil leak suspected areas. >2days(5.5%)purchaising=to avail missing parts for installation >4days(10.8%)welding shop=due to waiting platforms repaire process.
	890908	TSFN8001PFBC	60	149	89	05-Oct-15	01-Mar-16	Repair & replace CC	ET	1st pass	repaired by ET	>70days(78.6%)PARTS ROBBING=delayed due to replacing many robbed parts(transmitter,TBV,ignition lead,12o'clock strut,fuel oil heat exchanger, servo heater,fuel filter cover,EEC, accoustic pannel assy, TAI valve, 17ea platforms) that have been given for A/C demand on operation and also >19days(21.4%)purchaising= due to fulfill expendable parts for in-house repaire of fan blade platforms.
CFM56-3	856293	TSFN8001PFBC	57	100	43	25-Feb-16	02-Jun-16	Repair and replacement of LLP SHAFT, BOOSTER SHAFT & FAN SHAFT.	A/C INSTRUMENT	2nd pass	repaired by ET	>3days(6.9%)TES=due to inspection task cards preparation with the updated revision, >5days(11.6%)OEM communication=3days due to request advise from snecma for the FAN INLET CASE abradable repair; & 2days due to communication with CFMI for troubleshooting of out ranged EGT margine during testing the engine. >4days(9.3%)Inspection=due to bench inspection process delay. >3days(6.9%)Purchaising=delay due to scraped parts purchaising and expendable parts purchaise for the in-house rework process. >15days(35.2%)NDT=due to parts FAN DISC,BOOSTER BLADES waiting FPI test during repair; >6days(13.9%)STR. SHOP=due to delay of requesting sis parts and repair process delay; >5days(11.6)Paint shop=due to repair process delay & missing instruction. >2days(4.6%)Test Cell=due to missing of PT49.5 & T54 pick up sensors during test preparation;

ENGINE SHOP TAT PERFORMANCE FROM JULY 2016 TO JUNE 2017

MODEL	ESN	WORK ORDER	PLANNED TAT	ACTUAL TAT	VARIANCE/DELAY	INDUCTION DATE	SERVICEABILITY DATE	Mnts TYPE	CUSTOMER	TEST RESULT	Remarks	MAJOR CONTRIBUTOR SECTIONS FOR DELAY
CFM56-7B	890631	TSFN800126DX	92	164	72	27-Mar-16	15-Sep-16	Performance Restoration	ET	1st pass		>30days (41.2%) **NDT**= due to NDT facility construction delay and hoist problem (For bigger parts like cases could not be performed at wheel shop facility due to hoist limitation) >4days (5.5%) **PPI**=due to Bench inspection process delay >38days (52.8%) **Purchasing/Mgt**= due to parts purchase delay which are caused by PO approval delay for high cost mtl (e.g ful set HPT blades)by mgt
	876614	TSFN80025HT4	63	85	22	16-Jun-16	08-Sep-16	REPAIR	FORTRESS	1st pass	Repaired at ET	>**7days(31.8%)production 584**=due to three days by assy/dissasy process delay & four days test troubleshooting delay. >**4days(18.18%)Inspection**=due to parts inspection process delay. >**2days(9.22%)NDT**= due to parts waiting for FPI inspection. >**3days(13.6%)Purchaising**:-delay dut to parts cost out preparation for the customer approval. >**3days(13.6%)TES**=delay du to preparation of the cost estimate for the approval. >**3days(13.6%)Customer**=due to Cost estimate approval delay.
	960420	TSFN8002ECU7	8	6	-2	23-Sep-16	28-Sep-16	QT of CC replacemnet	ET	1st pass		> 2days improvement
	804484	TSFN8002A2HM	41	55	14	22-Sep-16	15-Nov-16	Over hou'l (HPTR,HPTS & HPTN)	ET	1st pass	Repaired at ET	>**11days(78.57%)production584**=of which **five days** due to tools shortage for HPT rotor assembly and balancing and six days due to LPT module balancing as well as linipot sensor eccentricity check to installation of HPTR; >**1days(7.14%)EMS inspection**=due to bench inspection process delay; >**1days(7.14%)tech-support**=due to work scope review on HPT & LPT from minimum to heavy mnt. >**1day(7.14%)PP Eng'g**=due to waiting editing for procedure steps & skill to sign EO task card of HPT shroud support modification.
	890977	TSFN8001X98R	65	162	97	09-May-16	24-Nov-16	Overhaul	GE/ LAM Mozambique	2nd pass	Engine test was rejected due to low MOPK	>67days (69.1%) **Customer/GE (Excusable delay)**= 67days total delay caused by customer/GE of which 8days due to workscope change of comp rear stator after discussion with GErep; 18days due to FR delay of parts at various GE (customer) affilates and 41days due to late delivery of LPT case by customer/GE >30days (30.9%) **Production 584**= due to test rejection of engine test due to low MOPK
	804558	TSFN8002JQ42	25	26	1	19-Nov-16	14-Dec-16	Rpair-replacement of CC & full HPT blade	ET	1st pass	work scop performed at ET with a special procedure	>**0.5day(50%)machine shop**=due to DANOBAT machine programming error to pre-grind HPTR; >**0.5days(50%)production**=due to delay of HPT rotor balancing;
	804481	TSFN8002D2M3	41	113	72	06-Sep-16	18-Jan-17		ET	1st pass	Repaired at ET	>**18days(25%)production584**=of which four days due to dissasy process; two days due to LPT module balancing troubleshoot & twelve days due to assembly of piece parts/accessories on robbed LPT shaft; >**12days(16.6%)PPI**=due to of which 6days due to waiting of a bench inspection priority of cfm56-7b s/n: 804484; & 6days due to piece parts inspection process delay; >**13days(18%)ET Mang't**=due to f/r parts PO approval process delay; >**12days(16.6%)EMT purchaising**=of which 6days due to missing certeficate for f/r part(LPT stg-4 nozzle)& 6days due to parts f/r & purchaise processing delay; >**11days(15.2%)Machine Shop**=due to DANOBAT machine programming error for HPT shroud support grinding; >**6days(8.6%)Tech-support**=due to communication with CFMI for removal/installation of LPT with no booster & No.1,2 support;
CFM56-3	856293	TSFN8001PF3B	12	19	7	15-Aug-16	02-Sep-16	REPAIR	ET	1st pass	Repaired at ET	>**7days(100%)production584**=due to two days by dissasy/assy process delay & five days due to waiting tool for AGB crank pad cover modification delay.