Supply Chain Performance Measurement and Framework Development
Case Company: Ethiopian Airlines- Tool Engineering Section

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This is to certify that the thesis prepared by **Melaku Debas**, entitled: **Supply Chain Performance Measurement and Framework Development: The Case of Ethiopian Airlines Tool Engineering Section,** and submitted in the partial fulfillments of the requirements for the degree of Master of Science (Mechanical and Industrial Engineering) complies with the regulations of the university and meets the accepted standards with respect to originality and quality.

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Declaration

I hereby declare that the work which is being presented in this thesis entitled **"Supply Chain Performance Measurement and Framework Development"** is original work of my own, had not been presented for a degree of in any other university, in any Research by any means, and all the resource materials used for this thesis had been accordingly acknowledged.

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Table of Contents

ABSTRACT

The purpose of this paper is to present "*Supply Chain Performance Measurement (SCPM) and Framework Development in case of Ethiopian Airlines -Tool Engineering section using Supply Chain Operation Reference (SCOR) model".* The business environments of the aviation industry maintenance organizations are heavily related to the performance of the supply chain networks and the supply chain performance measurement metrics. Aircraft maintenance stations are competing and measured each other through: on time accomplishment of maintenance tasks, readiness of aircraft for dispatch, customer satisfaction, and secureness of safety and working environment.

Ethiopian Airlines-Maintenance Repair Overhaul (MRO) is one of aircraft maintenance service provider company, but some sections affected with lack of supply chain performance measurement system. From the past half year report and from the secondary collected data - Tool Engineering section is one of the most responsible section for aircraft delay, tasks carryover, customer dissatisfaction, weak inventory management system, material and information distortion are highly occurred from other supporting sections.

Hence; this research focuses on to illustrate impact of supply chain performance measurement metrics and framework development to enhancing profitability of the company and prevent the problems encounters in Ethiopian Airlines- Tool Engineering section. To do this qualitative and quantitative data's had been obtainable from internal and external customers, suppliers and from inter-departments. Based on the research, Supply Chain Operation Reference (SCOR) performance measurement model with pair-wise comparison of Analytical Hierarchy Priority (AHP) methodology has been developed to enhance the section performance and its supply chain measurement system. The developed framework of SCOR with AHP has been proposed, to contribute on tool engineering supply chain performance measurements and metrics enhancement on the company productivity.

The proposed framework is used on tool engineering section supply chain performance measurements. However, the developed measurement and framework also could be consumed in other aviation sub-sections and industries by customizing the SCOR+AHP modules.

Key Words: *Supply chain performance measurement, Supply Chain Operation Reference (SCOR), Analytical Hierarchy Process (AHP), SCOR+AHP performance measurement framework*

LIST OF ABBREVIATION

ABC ………....	Activity Based Costing
AHP …………..	Analytic Hierarchy Process
AHP …………..	Analytic Hierarchy Process
AMM ………....	Aircraft Maintenance Manual
ASE …………...	Aircraft System Engineering
BSC …………...	Balance Score Card
EAL …………...	Ethiopian Airlines
EASA …………	European Air Safety Association
EIS ……………	Entry Into Service
ET-MRO ……...	Ethiopian Maintenance Repair and Overhaul
FAA …………..	Federal Aviation Administration
FLR …………...	Framework For Logistics Research
IATA ………….	International Air Transportation Association
MPD …………..	Maintenance Program Data
MPRC ………...	Maintenance Planning and Record Control
MPTC ………...	Maintenance Program and Task Card
MXi …………...	Maintenix
OEM ………….	Original Equipment Manufacturer
PMS …………..	Performance Management System
SCALE ………..	Supply Chain Advisory Level Evaluation
SCM…………...	Supply Chain Management
SCOR …………	Supply Chain Operation Reference
SCPMS ……….	Supply Chain Performance Management System
SLA …………...	Service Level Agreement
SOP …………...	Standard Operating Procedure
SPM …………..	Strategic Profit Model
TAT …………...	Turn Around Time
TPM …………..	Technical Procedure Manual
WP ………….....	Work Package

LIST OF TABLES

LIST OF FIGURES

CHAPTER ONE

INTRODUCTION

1.1 Background of the study

Aviation industry is the most sensitive operational environment according to various factors which affect the survival of the industry itself. Among the sensitive crucial factors are market competition, fuel cost, and maintenance cost, regulatory body interference in to the operation of the aviation, wars, famine and other direct and indirect factors that has a vibrant role in the market of aviation industry.

(Gunter, 2001) Developed taxonomy of performance measurement system has been completed with a critical evaluation system of the supply chain process; an attempt has been made to take a number of key performance steps and a series of deliberative measures to take into account the logical sequence. And he reviewed the paperwork on the supply chain and the intersection of supply chain performance distribution, providing a broad overview of the technology, process and features of people.

Ethiopian airlines is one of the airline soaring in the sky generating its revenue through passenger transportation, cargo transportations and third party aircraft maintenance, ground handling services, aviation academy and catering. Fuel contributes about 40 to 50 % of the operating cost of the airline. (Ethiopian Airlines, 2013). Most of its peer competitors from the Arabian and gulf regions subsidized from fuel consumptions by the state governments (Zhang Yalin, He Yizheng, 2007). This has created an unfair competition among the airlines in the region and beyond. One of the prominent areas to satisfy customers though delivering aircraft maintenance on time, as well as improving the supply chain system and measure the performance indicator within departments and suppliers through developing a standard framework of supply chain specially for those section that participated on aircraft maintenance using different techniques and models.

Now days, all departments in aviation maintenance environment applied their maximum effort to keep aircraft airworthiness to stay in the dynamic market environment. And Ethiopian Airlines is one of African leader aviation organization that providing safe, market driven and customer focused passenger and cargo transport, aviation training, flight catering, aircraft Maintenance Repair Overhaul (MRO). And Ethiopian MRO provides maintenance service for its own aircraft and customer aircraft; and to do this more than 20 section are participated. Tool engineering is service plays a pivotal role for on time aircraft maintenance and productivity enhancement of the company. Currently there is a substantial gap still exist between other supporting departments and tool engineering when compared with other airlines. As Ethiopian airline-Tool engineering department is newly formed in middle of 2014 to tackle those problems as a gate keeper. This department is not doing well to achieve its intended function. Aircraft maintenance planning and record control, PSCM, Production Engineering, Task Card Engineering, Store, AOG desk and other departments and Boeing, Lufthansa, Airbus, Bombardier, Aircraft Tool Manufacturer and suppliers are the major output and input for Tool Engineering respectively.

1.2 Statement of the problem

To perform a schedule and unscheduled aircraft maintenance task in aircraft maintenance organization, there are defined working procedures, parts, tools, material, manpower's and generated from aircraft and part manufacture Maintenance Program Data (MPD), per regulatory bodies, and per International Air Transportation Association (IATA) policy and procedure. An Ethiopian airline is one of the operators that customized MPD and perform the aircraft maintenance for the past 70 and more years. During these years the company faced and succeeds so many problems and achievements. Currently, Ethiopian Airlines – MRO faced the major challenges while performing the maintenance activities. From the monthly maintenance activity report record and from the researcher observation, the aircraft delays, customer dissatisfaction, incremental of aircraft turnaround time, task carryover reports and other similar reasons are mostly associated with Tool Engineering section. These section responsibilities are evaluating and availing aircraft maintenance tools through purchasing, in-house manufacturing, advice alternate and guide maintenance personnel's how to accomplish the maintenance task - if there is any challenge.

The most noticed problems in this section is the overall supply chain management and inefficiency of supply chain performance measurement system, and the section performance is uncertainty inside the processes and systems; uncertainty in demand, pricing, inventory levels, quality, service provide, support customer and lead time of manufacturing and purchasing aircraft maintenance tools that causes inefficient processes and non-value added activities that are directly affected by erratic human behavior on the quality of the information and material flow between inter-departments. (Simchi-Levi, 2000). Reducing unnecessary movement, process and improve performance measurement of the section; it is difficult due to the complexity of the section supply chain system.

Besides to the above problems the selected case section had the below major problems that reported on monthly maintenance activity report:

- Deficiency of tool quality: per tool engineering report in 2016/2017 - more than 250 maintenance tools had a failure due to their quality. But in my observation the reason for this failure is not a quality issue rather it is supply chain problem as they have no proper supplier selection model.
- High cost incurred: Tool engineering section secure yearly budgets for those scheduled tool purchase and loan for high asset tool. In the past year 2016/2017 the actual tool purchase was much more than the estimated secured budget due to expedite fee, due to the increment of maintenance tool failure and due to loan tool extension fee.
- High customer complaints: From the past 6 month Service Level Agreement (SLA) report that shows service of tool engineering – there were some tool discrepancy and compliance.
- Improper stock item control mechanism: Most of the time stock items are replenished while the aircraft was grounded for maintenance and while requested the tool for the task.
- High number of defective tools: Due to improper selection of suppliers and improper evaluation of tools, tools are become unserviceable and beyond economical repair.
- Inconsistencies in performance measurement: each internal and external customer and supplier performance measurement difference there was no defined and standard measurement indicators.
- Failure to link the strategy objectives and the performance measurement metrics.

To solve and prevent the above and other associate problems, studying of tool engineering supply chain system and measure its performance with various parameters are the output and expectation of this research. To do research tasks, objective and methodologies are clearly specified next.

1.3 Research Questions

This case study research is aiming at understanding complex phenomena of Ethiopian airlines tool engineering supply chain performance and its measurement system. In order to understanding the tool engineering performance measurement, it is essential to study its chain in their genuine context.

Below listed are the research questions:

1. What are the major factors that hinder to change Ethiopia Airlines supply chain system?
2. What are the performance measurement metrics for tool engineering supply chain system?
3. What are the major activities and process of tool engineering on overall aircraft maintenance activates chain?
4. How can measured performance metrics be analyzed and utilized to provide as managerial decision making tools?

1.4 Research Objective

1.4.1 General objective

The main objective of the research is to study the existing supply chain system of Ethiopian Airlines Tool Engineering section; and to measure its supply chain performance through developing Supply Chain Performance model that enhance company profitability and minimizing aircraft maintenance Turn Around Time (TAT).

1.4.2 Specific Objective

To achieve the above general objective, the following specific objectives have been raised and covered. These are:

- To find out problems that encounters from the existing supply chain system of tool engineering.
- To provide supply chain modeling tools, to analyze the processes from holistic point of view and improve it's as-is business process.
- To identify of key factors that affect supply chain processes through literature review and primary and secondary data's.
- To develop of an assessment tool to determine if a company adheres to the best practices.
- To develop appropriate SCPM model for EAL-Tool engineering section

1.5 Significant of the Study

The research attempts to identify the supply chain performance system at EAL-Tool Engineering section, and it is specifically significant for the following major groups:

- **For Ethiopian Airlines**: the researcher definition Supply Chain Operation Reference (SCOR) model has a vital role at EAL-Tool Engineering section supply chain performance measurement techniques, then the company saves remarkable amount of expenses due to proper management of aircraft maintenance tool cost, enhance customer satisfaction, minimize aircraft turnaround time. Besides, after visible out in this section the proposed framework used as an input to implemented on other section and the overall company supply chain network.
- For Aviation Community: used as a reference document to suggest ways hoe to manage the supply chain management system between departments, suppliers and customers, that helps them to perform advance precautionary measures while any company that needs to measure and develop its supply chain system.
- As springboard to initiate further researcher that used as reference for academic and company personnel to study for extra regarding on supply chain performance improvement.

1.6 Scope of the Study

In Ethiopian airlines Maintenance and Repair Overhaul (ET-MRO) there are more than 20 sections are involve together to maintain the aircraft, to do maintenance tasks per the procedure without fail, and to dehangaring the aircraft per the estimated schedule date and time. From those sections this study focuses on Tool Engineering section supply chain performance measurement. This section have a responsibility to avail all maintenance tools before the scheduled aircraft is hangared through tool loan request from other operators, manufacturing tool within in-house manufacturing capability, and purchasing tools from tool suppliers and manufacturer. While this section doing this task high amount of costs are incurred, and observed that insufficient material and information flow between inter-department and with suppliers. Therefore, this study focused mainly to study the existing supply chain performance measurement system that tool engineering section follows. And develop a framework of supply chain performance measurement framework development. Below listed are the major scopes that this research focused on:

- Study supply chain management system and performance measurement metrics of Ethiopian airlines tool engineering section
- Supply chain performance measurement on management process on manufacturing of Tools with in-house capability
- Supply chain performance measurement on aircraft maintenance tools purchasing
- Supply chain performance measurement on aircraft maintenance loan tools

1.7 Limitation of the Study

This research work was mainly focused on the supply chain section of Ethiopian Airlines-Tool Engineering section. The company has several departments; hence the responses obtained from only the supply chain section may not be representative of the entire company. Moreover, the number of responds who are mainly those involved in the day to day supply chain activities may vary from one airlines to another as a result, the research findings can only be used as a guide and can also provide a basis for future research.

This research work accomplished with a lot of time constraints. Achieving the correct balance between work and study was challenging. It’s also important to mention the challenge experienced from the respondents. There are instances when they were reluctant commenting on certain issues for fear of victimization.

CHAPTER TWO

LITERATURE REVIEW

2.1 Definition of Supply Chain

A supply chain is the network of all the individuals, organizations, resources, activities and technology involved in the creation and sale of a product, from the delivery of source materials from the supplier to the manufacturer, though to its eventual delivery to the end user. The supply chain segment involved with getting the finished product from the manufacturer to the consumer as distribution channel (Council, 2010).

Today, many companies are forced to increase their international market share in order to persist and sustain growth their objectives. At the same time, the same organizations must defend their domestic market share from international competitors. The challenge is how to expand the global logistics and distribution networks in order to ship products to customers who demand them in a dynamic and rapidly changing set of channels (Holweg, 2005). Strategic positioning of inventories is essential, so that the products are available when the customer wants them. A supply chain is defined as a set of three or more entities (organizations or individuals) directly involved in the upstream and downstream flows of products, services, finances, and/or information from a source to a customer. The supply chain may include internal divisions of the company as well as external suppliers that provide input to a focal company. A supplier for this company has his own set of suppliers that provide input (also called second tier suppliers). Supply chains are essentially a series of linked suppliers and customers until products reach the ultimate customer (Novinch, 1990).

Supply chain should actually be efficient and effective. In this case, efficient means to minimize resource use to accomplish specific outcomes; and effective, in terms of designing distribution channels. Efficiency is measured by delivery performance, product quality, backorders and inventory level, whereas effectiveness is measured by service quality and the service needs (Christopher, M, 1992).

Long-term competitiveness therefore depends on how well the company meets customer preferences in terms of service, cost, quality, and flexibility, by designing the supply chain, which will be more effective and efficient than the competitor's. Optimization of this equilibrium is a constant challenge for the companies which are part of the supply chain network.

Depending on how complex the supply network is, (Simchi-Levi, 2000) has defined three types of supply chains:

- ✓ **Direct supply chain**, which consists of a company, a supplier, and a customer involved in the upstream and/or downstream flows of products, services, finances, and/or information
- ✓ **Extended supply chain:** is defined the production and sale of a product is guaranteed by the supply of raw materials from the supply chain to the producer, and ultimately and extending up through its eventual delivery to the end use.
- ✓ **Ultimate supply chain**: is a collection of countless companies that include material sourcing, manufacturing, distribution and selling the product.

2.2 Definition of Supply Chain Management

Supply Chain Management can be defined as a collective effort of multiple network members to design, implement, and manage seamless value added processes to meet the real needs of the end customer. The developments and integration of people and technological resources as well as the coordinated management of materials, information, and financial flows underlie successful supply chain management. The supply chain of a firm is often described in terms of upstream and downstream flows (Council, 2010). Besides, (Christopher, M, 1992) defined supply chain and its management as the management of upstream and downstream relationships with suppliers and customers to deliver superior customer value at less cost to the supply chain as a whole, as it used to oversight of materials, information, and finances as they move in a process from supplier to manufacturer to wholesaler to retailer to consumer. The three main flow of the supply chain are the product flow, the information flow, and the financial flow. All definitions state that the supply chain includes upstream suppliers, internal functions, and downstream customers. The first definition mentions the information flow which is connected to the physical material flow, while the second introduces the important economic aspects of cost and price in the management of the flows. In other words, trying to identify a set of supply chain management activities that is not or nothing to do with any known business management activities would futile. The inception of the supply chain management concept did not create a new set of functional activities that has never been carries out before.

Although definitions of Supply chain management may differ, they can be classified in three major groups: a management philosophy, implementation of a management philosophy, and as a set of management processes.

- **Supply Chain Management as a Management Philosophy**

Per (Gunter, 2001) definition SCM is used as a management philosophy takes a system approach to viewing the SC as a single entity. This means that the partnership concept is extended into a multi-firm effort to manage the flow of goods from suppliers to the ultimate customer**.** Each firm in the SC directly or indirectly affects the performance of the other SC members, as well as the overall performance of the supply chain.

- **Supply Chain Management as a set of Activities to Implement a Management Philosophy**

When a company adopts a certain philosophy, a set of management practices must be established to ensure behavior consistent with the philosophy. Below are the key activities that needed for successful implementation of the SCM philosophy. These are: Integrated behavior, mutually sharing information, mutually sharing risks and rewards, cooperation, and integration of process (Norton, 1996).

Therefore, SCM philosophy requires extension of certain behavior to external partners (suppliers, customers) and in this context the philosophy of SCM turns into a set of activities that carries out the philosophy. One of the important aspects of an integrated behavior is also mutual sharing of information among members of the SC. This is particularly valuable for the planning and monitoring processes. Open sharing of information such as inventory levels, forecasts, sales promotion strategies, marketing strategies, reduces uncertainty and increases performance.

- **Supply Chain Management as a Set of Management Process**

SCM is increasingly being recognized as the integration of key business processes across the SC. Implementation is carried through by three primary elements: the SC network structure, the SC processes, and the management components. In terms of SC network structure, it is important to integrate decisions related to purchasing, manufacturing, stocks, warehousing, and distribution, as well as define goals and strategies how to achieve it. On the other hand, it is important to design a set of standard processes, which will assure rational behavior of the individuals, or companies that are part of the SC. Last but not at least, it is necessary to define control mechanisms to be able to audit performance of SC according to the plan, by coordinating activities and processes in order to build links between SC members and making the right decisions.

2.3 Supply Chain Performance Measurement System (SCPMS)

From the business operational perspective, the core purpose of performance measurement system is "a process of quantifying the efficiency and/or effectives of action" (Neely, 2005). Many experts believe performance measurement is a very important component in supply chain planning and control. An appropriate performance measurement and performance management is an asset for enterprise resource management and business mission control. Performance measurement can give feedback on the effectiveness of the plans and their implementation (Gunasekaran A., Williams H.J, 2007).

Studies on supply chain have highlighted the need to measure the efficiency of the integrated supply chain. Per (Neely, 2005) definition, performance measurement is the process of quantifying the effectiveness and efficiency of an action. The efficiency can best be described by customers, and usually retain suppliers who achieve the highest aggregate score on price, quality, and flexibility of production and delivery times. An efficient high quality supply chain is dependent on the achievement of a high-level performance in terms of cost, quality and time-to-market.

(Neely, 2005), defined Performance Measurement System (PMS) is collecting, compiling and analyzing information will be used as a balanced and polite process to stimulate decision-making processes. (Gunasekaran A., Williams H.J, 2007) Defined SCPMS to provide feedback to the producers on the outcome of events, and describe the following description to demonstrate performance and effectiveness, and performance measurement: defined as the process of quantifying the efficiency and effectiveness of action, and defined as a metric used to quantify the efficiency and/or effectiveness of an action.

Effective supply chain management (SCM) has been associated with a variety of benefits including enhanced customer value, profitability, and reduced cycle times, average inventory levels with better product design. The objective of SCPM therefore has to facilitate and enhance the efficiency and effectiveness of SCM. The main goal of SCPM models and frameworks is to assist management helps to measure, analyze and improve business performance and business operational efficiency through better decision-making processes (Tsang AHC, 1998). An effective SCPMS can involve on the one's company performance measurement system as a bridge for company change. SCPM can enable to understand within inter and intra-departments and integration among all supply chain members. It makes a vital influence on decision making process on SCM, mainly on re-designing and reengineering process business objectives and strategies (Lam M.D, Oelsner M. Al-Kaabi H., 2008) .

2.3.1 Supply Chain Performance Measurement Criteria

Performance measurement system (PMS) reveal a set of criteria or principles that serve as guidelines when designing PMS. Restricting this to PMS for supply chain (Gunasekaran A., Williams H.J, 2007) propose a set of criteria and principles for supply chain performance measurement system. Below list is some of the criteria and principles are presented:

- ✓ ***Holistic Approach***: Performance measurement in the supply chain should take a holistic system perspective beyond the organizational boundaries. The performance of supply chains needs to be assessed across the organizations in order to encourage global optimization along the supply chain channels.
- ✓ ***Balanced approach***: The purpose of distribution performance measurement on a set of parameters that is representative for the most part of the business/supply chain. Supply chain performance measurement systems should provide a balance between financial and non-financial measures.
- ✓ ***Process based***: Successful supply chain management requires a change from managing individual's functions to integrated activities within key supply chain business processes. Supply chains metrics should reflect this change and focus on supply chain processes rather than functions.
- ✓ ***A managerial tool***: The performance measurement system is supposed to be a managerial tool, and the system must be able to arrange the transition from measurement to management.

2.3.2 Supply chain performance measurement models

There is a significant corpus summarizing different studies on the performance evaluation models applied in a corporate framework (Bales, 2004) (Wong, 2007) . Identifying performance evaluation systems was a key concerninthe1990s, the aim having mainly been to devise measurement systems whose dimensions would be broadly aligned with the corporate strategy (Neely, 2005). The research trying to check and selected major seven supply chain performance measurement models, these are described high-lightly below:

Activity-Based Costing (ABC): it illuminates costing based activities, and it is a costing methodology that is identifies activities in a company and assigns the cost of each activity with resources to all products and services according to the actual consumption by each supply chain stage. This model cover tactical and operation level of decision level and financial flow type only. Information and physical flow, strategic level, quality factor, human capital and sustainability are not covered on this mode

Framework for Logistics Research (FLR): It has been advanced in the 1990s, and it describes performance demonstrates the degree of dependence between successful levels, logistics and strategy. It can be practical on companywide and strategic level, as its structures logistics function has several dimensions such as: centralization, formalization, integration and areas of control. This strategy covers cover all decision levels strategically, tactical and operation level, and financial flow. But it doesn't cover physical flow, financial flow, and other quality factors and human capital related.

Balanced Score Card (BSC): It has been advanced in the 1990s. It translates an organization's mission and strategy into comprehensive set of performance measures that provides the framework for strategic measurement and management system. This principle proposes four analytical axes: customers, finance, internal processes and innovation-growth and it incorporate a human dimension for the performance measurement (Norton, 1996). This model only covered the strategic level of decision level, information and financial flow, with lack of consideration of physical flow, tactical and operational decision level.

Supply Chain Operation Reference (SCOR): this model has been advanced in 1996 by the Supply Chain Council (SCC). It is management tool that used to cover, enhance, and communicate supply chain management decisions within a company and within suppliers and customers of the company. This model considers all flow types physical, financial, and information flow. Besides its participants supply chain maturities are within organization and intra-organization with having decision level of tactical level and operational level.

World Class Logistics (WCL): this model has been developed by Michigan State University in the 1990s. It evaluates the company's performance in terms of its ability to account for inter organizational relationships through a model comprised of 68 questions. It can be applied at strategic and organizational level. It revolves around four areas of competency: positioning, integration, agility and performance measurement. This model covers strategic and tactical level of decision other than operational level decisions, with contains of information, physical and financial flow.

Efficient Customer Response (ECR): It has been created in 1994 by an ECR Association of manufacturers and retailers. It evaluates good inter organizational practices and uses maturity based evaluation tool: global mapping. It focuses on collaboration between industrialists and distributors in fast moving consumer goods sector. It establishes common language based on joint evaluation of performance by act or sin the chain. It is based on 45 criteria structured into four areas: consumer demand management, supply chain management, technological platforms and integration.

Strategic Profit Model (SPM): It has been created in 2002, derived from the DuPont model. It displays existing interactions between strategic and operational levels by means of financial ratios. It proposes strategic and financial implementation based on cost drivers using returns on asset or returns on net value measurements.

2.3.3 Supply chain performance measurement models analysis

The researcher identified eight level of analysis that are clearly interdependent and enables a company to identify the suitable model. Below are list of models criteria's that used to analysis models:

- ✓ **Types of flows under analysis (physical, informational and financial):** In its commonly accepted definition, logistics distinguishes between physical and information flows. Originally, the optimization of physical flows dominates deficient logistics management efforts, with performance measurement tools being entirely devoted to this one area (C., 1989). Controlling materials via information systems achieved saving sat the level of two traditional performance levers: costs and service levels. Financial flows piloting has also enabled the assessment of value creation with supply chains (Floudas C.A, 2010) (Mohammed Ben-Daya, 2009).
- ✓ **Quality factors:** Quality impacts on organization and performance, the end effect being that companies will start to inject quality management approaches in to their logistics vision. Today's management systems tend to seek total quality based on customer and employee satisfaction principles. This involves the development of a quality mindset shared by then tire staff. Note that companies strive not only to achieve quality, but also to achieve excellence, based on an expanded quality vision including the notion of continuous improvement. Given wide spread interest in this area, it is worth trying to ascertain which supply chain evaluation models in corporate quality and excellence dimensions in their supply chain performance evaluation measurements.
- ✓ **Human capital:** this factor plays a crucial role in supply chain organization and performance, combining the value of knowledge with the kind of competencies that come from the accumulation of experience. Human resource management has become an increasingly important resource for companies, with several models offering very precise descriptions thereof (Friend C.H., 1992). Hence, our decision to use this comparative exercise to present those supply chain evaluation

models that have become today's benchmarks and whose performance evaluation approaches rely heavily on the human factor. The idea here is to evaluate supply chain performance via indicators related to human resource and competency management. One outcome has been the growing significance attributed to the management of staff members, construed as a corporate resource.

- ✓ **Sustainability:** Environmental issues have become a key concern for companies, most of whom integrate a sustainability approach in to their activities and strategies nowadays. The focus here is on protecting the environment and overall economic and social developments. A sustainable supply chain–including any return improve the social, environmental and economic impacts of the raw materials and service flows that link suppliers, manufacturers and end users (NZBCSD, 2001).

Table 1: Analysis of various Supply Chain Performance Models

Models	FLR	WCL	BSC	SPM	ABC	***SCOR***	ECR
Decision Level							
Strategic Level	X	X	X	X	__	__	X
Tactical Level	X	X	__	__	X	***X***	X
Operational Level	X	__	__	__	X	***X***	__
Type of flows							
Physical flow	__	X	__	__	__	***X***	X
Information level	X	X	X	__	__	***X***	X
Financial flow	__	X	X	X	X	***X***	__
SC maturity							
Intra-Organ.	X	X	X	X	X	***X***	__
Inter-organ.	__	X	__	X	X	***X***	X
Quality Factors	__	X	__	__	__	***X***	__
Human Capital	__	X	X	__	__	***X***	__
Sustainability	__	__	X	__	__	***X***	__

2.3.4 Supply Chain Performance Measurement System Approach

Supply Chain Management (SCM) and its performance measurement are an effective business perception and strategy that keep continuous attention from researchers and business entrepreneurs to achieve the business objectives with the customer satisfaction. Performance measurement of supply chain facilitates supply chain to strategically manage and systematically achieve the goal of objectives. Therefore, the performance measurement provides the motivation and driving force for performance improvement in pursuit of supply chain excellence (Gunasekaran, A., Patel, C. & McGaughey, 2004).

SCOR Processes

The Supply Chain Operations Reference (SCOR) model describes the business activities associated with all phases of satisfying a customer's demand. The model itself is organized around the six primary management processes of Plan, Source, Make, Deliver, Return and Enable. Using these process building blocks, the SCOR model can be used to describe supply chains that are very simple or very complex using a common set of definitions across disparate industries. Today public and private organizations and companies around the world use the model as a foundation for global and site-specific supply chain improvement projects (Wong, 2007).

The model is designed and maintained to support supply chains of various complexities and across multiple industries. The model focuses on three process levels and does not attempt to prescribe how a particular organization should conduct its business or tailor its systems or information flow.

SCOR Practices

A practice is a unique way to configure a process or a set of processes. The uniqueness can be related to the automation of the process, a technology applied in the process, special skills applied to the process, a unique sequence for performing the process, or a unique method for distributing and connecting processes between organizations. All practices have links to one or more processes, one or more metrics and, where available, one or more skills.

SCOR Practices are classified to simplify identification of practices by area of interest:

Business Process Analysis/Improvement, Customer Support, Distribution Management, Information Management, Inventory Management, Material Handling and New Product Introduction, Order Engineering (ETO), Order Management, People Management (Training), Planning and Forecasting, Production Execution, Product Lifecycle Management, Purchasing/Procurement, Reverse Logistics, Risk/Security Management, Sustainable Supply Chain Management, Transportation Management, and Warehousing.

Table 2: Definition of assessment criteria elements used-SCOR (Gunasekaran A., Williams H.J, 2007)

Category	Criteria	Definition
SCOR Characteristics	Process	The five management process of SCOR model
	Performance Attributes	A combination of metrics for setting strategic direction of supply chain
	Metric Level	A hierarchical configuration of the SCOR model performance evaluation process
	Process Types	Made-up of Plan, Execution and Enable. They are process categories assigned to planning support to the allocation of resources to expected demand, plus process categories trigged by current or planned demand and process categories that are serve as support to the other process
	Supply chain strategy	It is the decoupling point of a product which can be MTS (Make-to-Stock), MTO (Make-to-Order) or ETO (Engineer-to-Order)
	Practices	Best Practices and leading practices which are conducts that are applied to safeguard supply chain performance
	Return	A process of planning, implementing and controlling the inbound flow of defect or excess products to either recover value or ensure proper of disposal
	Score Version	The different periodical release of the SCOR model

SCOR Performance

The performance or metrics section of SCOR focuses on understanding the outcomes of the supply chain and consists of two types of elements: Performance Attributes and metrics and introduces the concept of Process/Practice Maturities. A performance attribute is a grouping or categorization of metrics used to express a specific strategy. An attribute itself cannot be measured; it is used to set strategic direction. A metric is a standard for measurement of the performance of a supply chain or process. SCOR metrics are diagnostic metrics (compare to how diagnosis is used in a medical office). SCOR recognizes three levels of pre-defined metrics as shown on below Figure 1:

Level-1 metrics are diagnostics for the overall health of the supply chain. These metrics are also known as strategic metrics and key performance indicators (KPI). Benchmarking level-1 metrics helps establishing realistic targets to support strategic directions.

Level-2 metrics serve as diagnostics for the level-1 metrics. The diagnostic relationship helps to identify the root cause or causes of a performance gap for a level-1 metric.

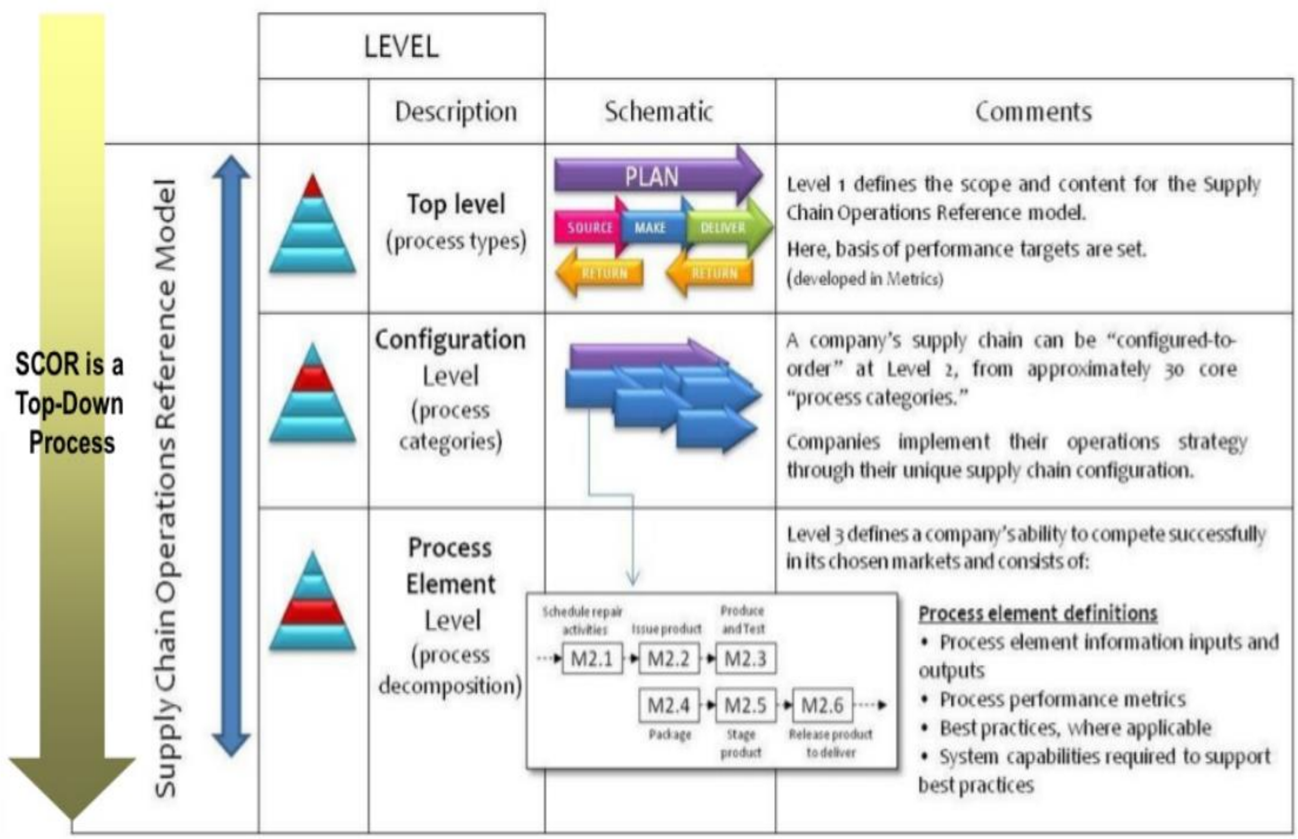
Level-3 metrics serve as diagnostics for level-2 metrics.

The analysis of performance of metrics from level-1 through 3 is referred to as metrics decomposition, performance diagnosis or metrics root cause analysis. Metrics decomposition is a first step in identifying the processes that need further investigation. (Processes are linked to level-1, level-2 and level-3 metrics).

The seven steps and processes of analyzing and decomposing the processes to be measured are as shown in Figure 2 (Chan and Qi 2003a):

1) Identifying the involved processes of internal and external organization.
2) Defining and confining the core processes.
3) Deriving the missions, responsibilities and functions of the core processes.
4) Decomposing and identifying the sub-processes.
5) Deriving the responsibilities and functions of sub-processes.
6) Decomposing and identifying the elementary activities of sub-processes.
7) Structuring hierarchy from processes to elementary activity

Figure 1: SCOR Model Hierarchy (SCOR Model Version 10.0, SCC)



2.4 SCM in Aerospace Industry

The airline industry has shown a continuous increase in sales over the past 3 years, with the growth of new airports, and new markets such as China and Latin America

It is estimated that aircraft production will double or triple in the next years (Friend C.H., 1992). The aircraft manufacturers (OEMs) will need to increase supply speed to accomplish the customer promises/requirements. Considering these aspects, supply chain management has become the key to the major producers of aerospace industry, with the changing structure of the aerospace industry by switching from traditional vertical programs to those with multinational operations distributed in several stages (including production, after sales, maintenance, repairing and reconditioning) come inevitably greater challenges (Knotts R.M.H, 1999). The complexity of this industry is on the design and production of products on the supply chain management. Introduction of the new technologies and growth and the compliance requirements have created difficulties in the management of the supply chain (Mohammed Ben-Daya, 2009) . Also it is essential to have an effective communication in order to clarify the requirements and needs throughout the program stages (Holweg, 2005).

2.5 Aerospace Supply Chain Challenges

The progresses performed in aviation industry in the recent years, have increased the risk level. Supply chains became vulnerable to the disruptions that occurred during the production process (Treuner, 2014). Within the development programs of the new generations of aircrafts (A350XWB and B787 Dreamliner, respectively), the producers had as a main objective to reduce the time of the products release on the market and to share the higher costs for development with suppliers. These new programs involve the development of complex technology projects to increase aircraft operating efficiency by 15 to 20% (Bernardini, 2013). Both Airbus and Boeing outsourced substantial work packages to suppliers that they have selected. Also, the introduction of innovations (composite, low fuel consumption engines, avionics, electrical systems, etc.) and in some cases transformation of the former factories into independent companies has further amplified the complexity of the production chain. Despite the positive effects, this new approach has generated more problems in the production process. The table below highlights some of the challenges that manufacturers and airline have encountered with the introduction of the new aircraft programs.

Table 3: Challenges encountered by the OEMs and Airlines in the new aircraft program

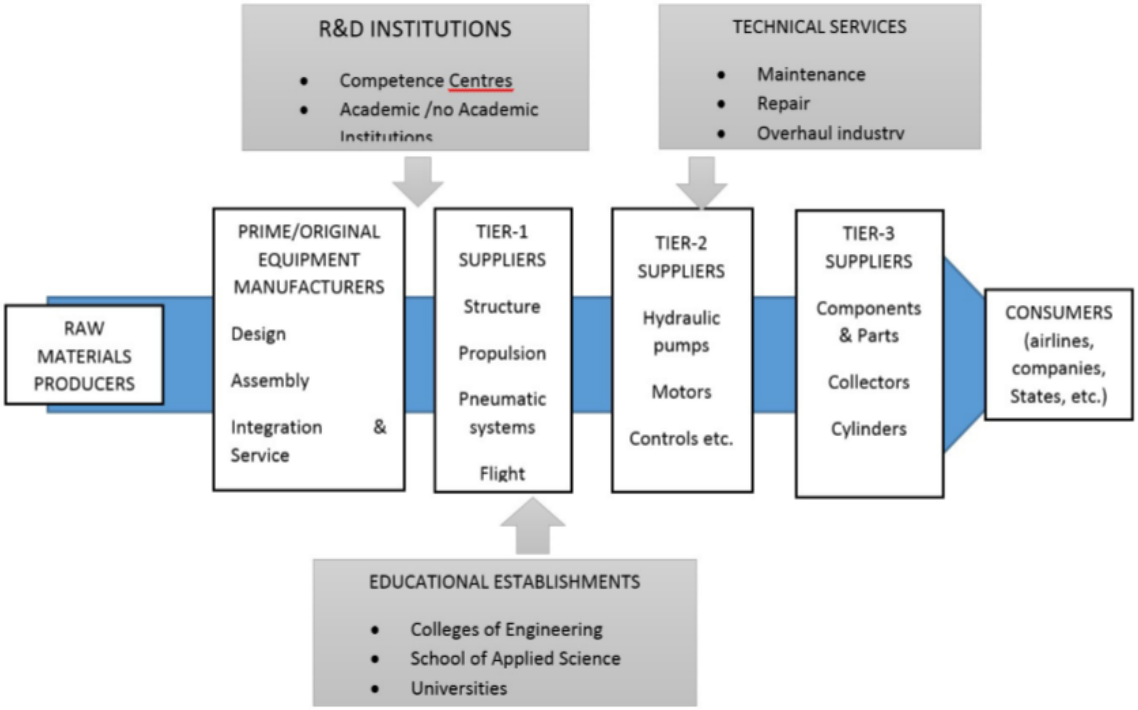
Manufacturers (OEMs)	Airlines (Operators)
** Difficulties in the manufacturing process ** Difficulties due to the need of risk-sharing suppliers ** The limited experience to manage the complex program ** The existence of a fairly long period b/n the planning and actual availability of the new capacities ** Fast and effective training deficit to expand workforce **issues related to production quality and reliability of some of the materials available	** The need to train the pilots to operate this new generation of aircraft ** Using the Obsolete fleets due to delays ** Unplanned and unbudgeted maintenance checks ** Delays due to maintenance, repair and operation ** High financial impact ** Increased competition on the attractive routes

2.6 The Value Chain structure of the Aeronautic Industry

Globally, the airline industry value chains comprise all phases directly or indirectly involved in meeting customer requirements. This network of production usually involves many actors with different functions (manufacturers, suppliers, transporters, warehouses, retailers, etc.).

The aerospace industry has refocused in the recent years towards a new supply chain structure which is based on an extensive process outsourcing. This can be seen in the latest aircraft development programs B787 Dreamliner and A350XWB. In both cases the companies Boeing and Airbus have established a new form of partnership which involves more complex work packages compared to the previous programs but are designed to reduce costs and delivery time component (Responsibility made by Airbus Group, 2013). The new supply chain is based on a number of levels. Both Boeing and Airbus select their suppliers according to their strategies and the fulfillment of the required standards set in the aviation industry. These strategic partners are primarily intended to assemble the different parts and subsystems produced by second-tier suppliers. At the same time work packages launched by the two companies are considering sharing risks with suppliers. The suppliers become responsible for the entire scope of the work packages, including their supply chains. To facilitate the working way under the new programs, the selected suppliers were involved earlier, compared to the previous programs to participate in the definition and development of systems and components for the new aircraft and to agree on a set of details for the package work. This reduced a significant part of the cost of production and their delivery time.

Figure 2: The Aerospace Supply Chain Management



According to (IATA, 2014), process-based approaches are provided with the board of performance metrics containing; cost, time, productivity, resource utilization, capacity, capability, and outcome.

Cost is the financial expense for carrying out one event or activity. It is always one of the indispensable aspects in assessing the performance of the business activities and processes.

- ✓ **Time:** is another indispensable dimension in order to understand the supply chain operation and it is necessary to measure the activity time.
- ✓ **Capacity:** is the ability of one specific activity to complete a task or perform a required function, and this dimension mainly concerns the maximum amount of tasks that a process or activity can complete under the normal conditions.
- ✓ **Capability:** is the aggregate ability by which the activity or process functions, which is identified with four soft measures as effectiveness, reliability, availability and flexibility. These soft measures are intangible, and thus cannot be directly measured, and needs to be transformed to other measurable performance indicators.
- ✓ **Productivity:** is the rate at which one specific event or activity adds value at the cost of resources, which is based on the ratio of the effective or useful output to the total input such as capital, labor, materials and energy.

- ✓ **Utilization**: means the utilizing rate of the resources to carry out one specific activity, which reflects the ability of resource management and the effect of strategies and planning.
- ✓ **Outcome:** is the result or value added of one specific activity or event, which may be a value added to the products and services.

2.7 Maintenance, Repair and Overhaul (MRO) Fundamentals

MRO may be defined as "all actions that have the objective of retaining or restoring an item in or to a state in which it can perform its required function. The actions include the combination of all technical and corresponding administrative, managerial, and supervision actions" (EFNMS, 2013). (Kinnison, 2015) States that maintenance can be described as the process of ensuring that a system continually performs its intended functions at its original level of reliability and safety. And it emphasize the goal of maintenance is not only to reduce repair time but also to improve product reliability, as well as to capture relevant information for analysis. "Maintaining complex systems such as aircraft fleets, rail systems, and production facilities can often exceed the cost of research, development, and production. The aircraft fleet maintenance plays the most important role to guarantee the safety and reliability of the fleet in commercial airlines and military air forces and Maintenance plays an important role in keeping product availability, reliability and quality at an appropriate level. It also addresses the product safety requirements" (Organization, 2014) (Kinnison H., 2012).

The importance of MRO can be judged by the fact that it typically constitutes 12-15 per cent of an airline's operating cost, with annual expenditures estimated to be US $50 billion in 2013 and explain that the record aircraft production following strong sales in 2006 and 2007, given the typical 18,000-cycle or 8–10 years between overhauls, has created an unprecedented demand for landing gear overhauls on both long and short-haul aircraft (Organization, 2014). (McFadden, 2012) State that the worldwide MROs have grown in response to continuous and increasing demand into a viable segment of the aviation industry. Finally, highlights that the profitability of the industry is not from the sale of aircraft, but from maintenance for an anticipated thirty-plus year lifespan.

The MRO in the aerospace market is a complex process that has strict and precise requirements to guarantee the safety of passengers and aircrew and collaborate that maintenance forms an essential part of aircraft airworthiness criteria; its main objective is to ensure a fully serviced, operational and safe aircraft. Proper maintenance is an essential contributor to the high levels of safety experienced today; in contrast, improper maintenance can have tragic effects. (Kinnison, 2015) Explains that to maintain and repair their equipment, airlines take into account the manufacturers' instructions and standards of international organizations to improve the quality and safety of flight. “A number of entrepreneurial operators and support providers have adopted a new group of postproduction support strategies. Although there has been a considerable amount of improvement in the quality and reliability of components and systems, as well as in materials and procedures, over the 100-year life of aviation, they still have not reached total perfection. (Bales, 2004)

MRO emphasize that increasing the level of investigation surrounding aviation incidents is recommended for improved safety and also agree with many of the FAA (Federal Aviation Administration) incident reports which simply state that a particular component failed and more detailed investigations would reveal the root causes of component failures and would, as suspected, identify inadequate maintenance to be an important factor. (EFNMS, 2013)

Regarding in-house airline maintenance capabilities, (Safaei N, 2011) explain that commercial airlines can establish MRO services in their own fleets and operate as profit centers; however, it is not uncommon for airline operators to spin-off these MROs and act as a separate, corporate activity. "Third Party Independents perform similar functions as In-house MROs but are not affiliated to an airline operator. Independents often provide these services at a lower price and analyzing the operation side, (Kinnison, 2015) explains that aircraft maintenance can be divided into scheduled and unscheduled maintenance. Scheduled maintenance is a preventive action to ensure that a product functions properly at pre-set intervals. Unscheduled maintenance is not planned or programmed, but it is required when an item has failed or broken down. (Kinnison, 2015) And authors clarify that scheduled maintenance includes routine and detailed inspections called transit, 48hr, A, B, C and D checks, subdivided in line and base categories.

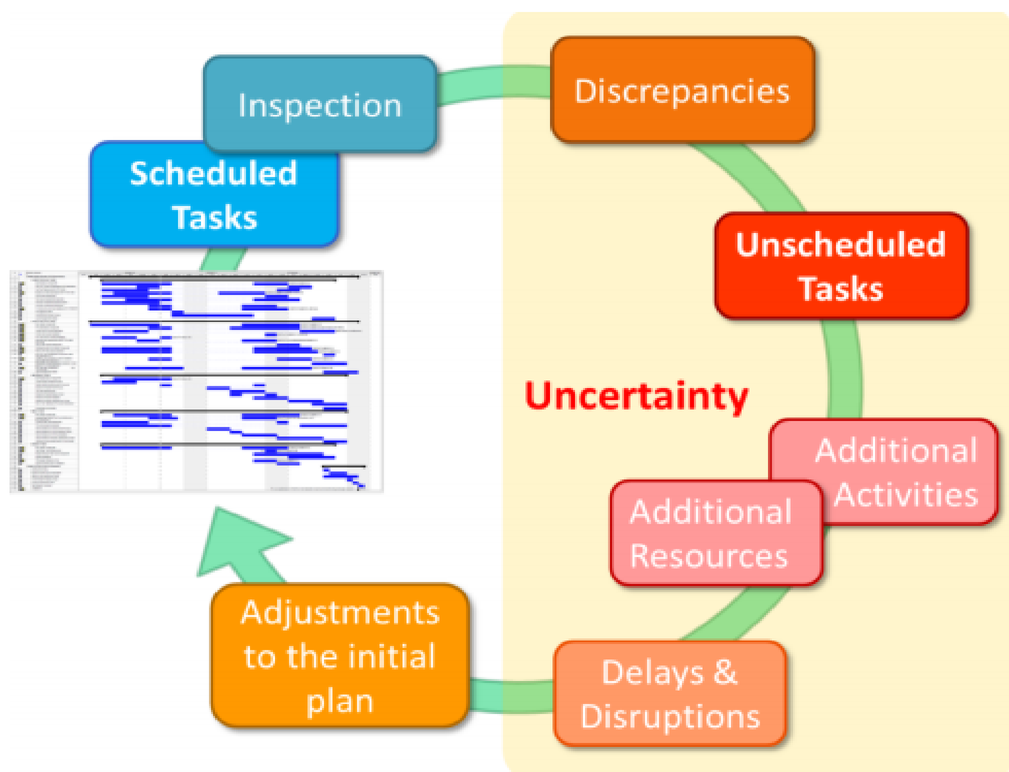
2.8 Key metrics for Tool Engineering SC Performance Measurement in MRO

In this research the, key objective criteria are identified as a performance measurement improvement in a Tool Engineering supply chains. And the case company outsources the most of detail design and engineering works from tool engineering supply chain network. And per (Kinnison, 2015) (Huiskonen J., 2001) recommendation the following metrics are required for maintenance support team.

1) Metrics for order planning performance evaluation: this metric includes service order entry method, service order lead time (total order cycle time), and service order path.

2) Metrics for management performance evaluation: this metric used to achieve qualified service demanded by the customers and considers the evaluation of supply chain performance such as: strategic level, tactical and operational level measurement.
3) Metrics for production performance evaluation: this metric is the serious of activities carried out by the section supply chain and it includes the product/tool of design and engineering, capacity utilization rates, and effective of scheduling techniques
4) Metric for progress and delivery performance evaluation: this metric is used to delivery has met on agreed time frame, and it is a measure of customer service level and includes tool engineering order fill rates, earning rates, on time delivery, and delivery flexibility.
5) Metric for quality service evaluation: this metrics are considered about customer satisfaction and successful strategy of the supply chain includes: flexibility, responsiveness, reliability, agility.

Figure 3: Delays and Disruptions in Tool Engineering working process



As the measures and metrics have a broader perspective, the different dimensions of aggregative assessment for evaluating the supply chain performance has been carried out based on the dimensions and criteria of performance measures classified by (Fitzgerald L, and Johnston R, 1991) F. The results are summarized as shown on below table 4.

Table 4: Summary of SCP evaluation metrics for aviation maintenance organizations -MRO

Measurement Metrics	*Indicators*
Metrics for Managerial Performance Evaluation	✓ Consideration of evaluation of supply chain performance (Strategic Level, Tactical Level, Operational Level)
Metrics for Order Planning Performance Evaluation of Tools	✓ The service order entry method ✓ Service Order lead time ✓ Service Order Path
Metrics for Production performance evaluation	✓ Product range of design and engineering ✓ Capacity utilization rates ✓ Effectiveness of scheduling techniques
Metrics for progress performance evaluation	✓ Order fill rate ✓ Earning rate (Labor to cash cycle)
Metrics of delivery performance evaluation	✓ On-time delivery ✓ Delivery Flexibility
Metrics for Quality service evaluation	✓ Flexibility ✓ Responsiveness (Customer query time) ✓ Reliability

The priority weight of each selected metrics is computed by using pairwise comparison between two criteria at a particular level with the Saaty's nine rating scale as specified below in Table 5.

Table 5: Fundamental AHP judgment scale with integer 1 to 9

Intensity	Definition	Explanation
1	Equal Importance	Two factors contribute equally to the objective
3	Somewhat more important	Experience and judgment slightly favor one over the other
5	Much more important	Experience and judgment strongly favor one over the other
7	Very Much more important	Experience and judgment very strongly favor one over the other. Its importance is demonstrated in practice
9	Absolutely more important	The evidence favoring one over the other is of the highest possible validity.
2,4,6,8	Intermediate values	When compromise is needed

2.9 Ethiopian Airlines Background and Existing System

Ethiopian Airlines formerly Ethiopian Air Lines (EAL) and often referred to as simply Ethiopian, is Ethiopia's flag carrier and is wholly owned by the country's government. EAL was founded on 21 December 1945 and commenced operations on 8 April 1946, expanding to international flights in 1951. The firm became a share company in 1965, and changed its name from Ethiopian Air Lines to Ethiopian Airlines. The airline has been a member of the International Air Transport Association (IATA) since 1959, and African Airlines Association (AFRAA) since 1968. Ethiopian is a Star Alliance member, having joined in December 2011/12. Its hub and headquarters are at Bole International Airport in Addis Ababa, from where it serves a network of 82 passenger destinations -19 of them domestic- and 23 freighter ones. Ethiopian flies to more destinations in Africa than any other carrier. It is one of the fastest-growing companies in the industry, and is among the largest on the African continent. It is also one of the few profitable airlines in the Sub-Saharan region. The airline's cargo division was awarded The African Cargo Airline of the Year in early 2011. Recently, Ethiopian won the Best Regional Airline of the Year award at the 41st Annual Airline Industry Achievement Awards by Air Transport World (ATW), held in Washington, D.C. on 25 February 2015. (Ethiopian Airlines , 2017) .

- **Type of service provide by Ethiopian Airlines**

Ethiopian Airlines provide the following services for its customer

- **Providing safe and reliable passenger transport:** Ethiopian Airlines has a quality and value proposition transport to their customers with 85 passenger destinations. And from these 82 destinations 21 of them are domestic destinations.
- **Cargo air transport:** This Service used for transporting different material which has heavy weights and to transport this loads Ethiopian Airlines uses 6 - Boeing 777-200LRF and 2 - Boeing 757-260F aircraft that sent from Ethiopian or comes from different destinations/Countries.
- **Provide Aviation Training**: Ethiopian Airlines has their own modern aviation academy from Africa and it is one of the best competitors in the word. Ethiopian Aviation academy has different school to trainee Pilots, Technicians, Flight attendant, Aviation Instructors, Flight Operation Engineers, Ticket officers. This aviation academy trainee peoples that comes from different countries additional to Ethiopian Such as: China, Congo, Chine, Malawi, and etc.

Aircraft Maintenance: Ethiopia Airlines perform scheduled and unscheduled aircraft maintenance for its own aircrafts and other customer aircrafts. Such ad: Angola, Nigeria, Togo, Kenya, Sudan and other airlines.

- **Organization structure of Ethiopian Airlines**

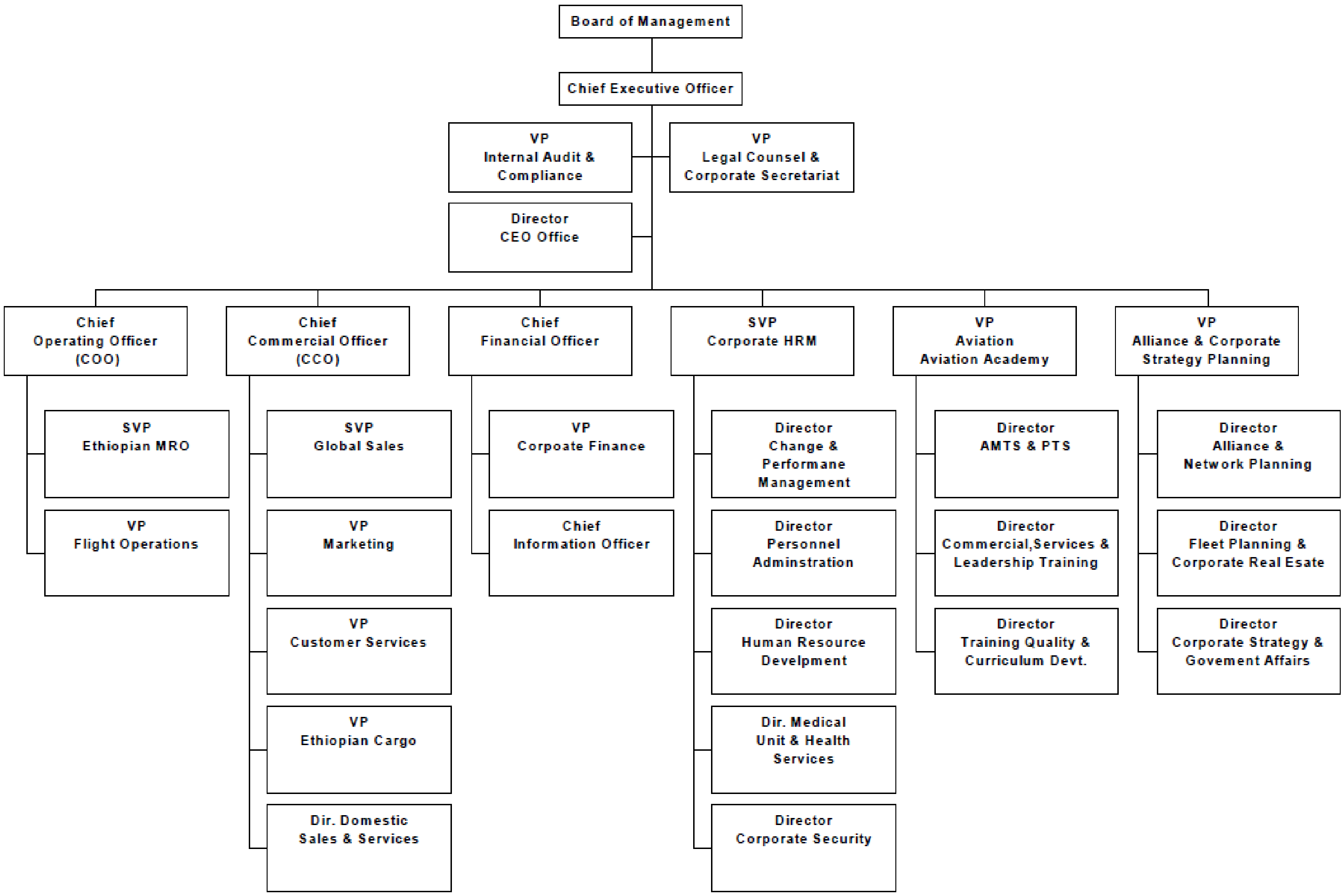
From business point of view, there are different forms of organizational structure. Starting from the simplest form associated with a small business where the owner directly controls and performs managerial tasks, to different types of organizational structures which include unitary organizational form, multidivisional form etc. (Knotts R.M.H, 1999). These different organizational forms have different characteristics of their own and also have merits and demerits as well.

For instance, some airlines adopt a hierarchal unitary (U-form) organizational structure, which incorporates a branching or pyramid management structure organized according to functional specialism. This form has two disadvantages for a large size firms: control loss and cost inefficiency. Whereas, some others use multidivisional (M-form) of organizational structure, which offers distinct advantages for the large and diversified enterprise with economies of scale advantage (Fergusson et.al 1993).

Accordingly, Ethiopian Airlines is one among which uses the multidivisional organizational form which comprises two or more unitary form. It uses such organizational structure with an intention to decentralize decision making and give responsibility for employees. So that, the flexibility of the firms' response to changing market conditions would increase. Thus, based on figure 5 the board management supervises the chief executive officer which he is advised by the two vice presidents of internal audits compliance & legal counsel and corporate secretariat respectively. In addition, the former two vice presidents together with the director of CEO office gives auditing and consultant service for the rest of the management divisions.

On the other hand, the chief executive officer directly supervises the operating, commercial and financial chief officers as well as the vice presidents of the three divisions: corporate human resource management (HRM), Aviation academy and Alliance & Corporate strategy planning respectively. In line with this, the aforementioned chief officer intern supervises vice presidents of their lower department. Likewise, the vice presidents of the above three divisions manage directors of their lower departments. Moreover, these lower divisions in their turn supervise other lower sub division managers and this process proceeds till it reaches to the ordinary staff member of the enterprise.

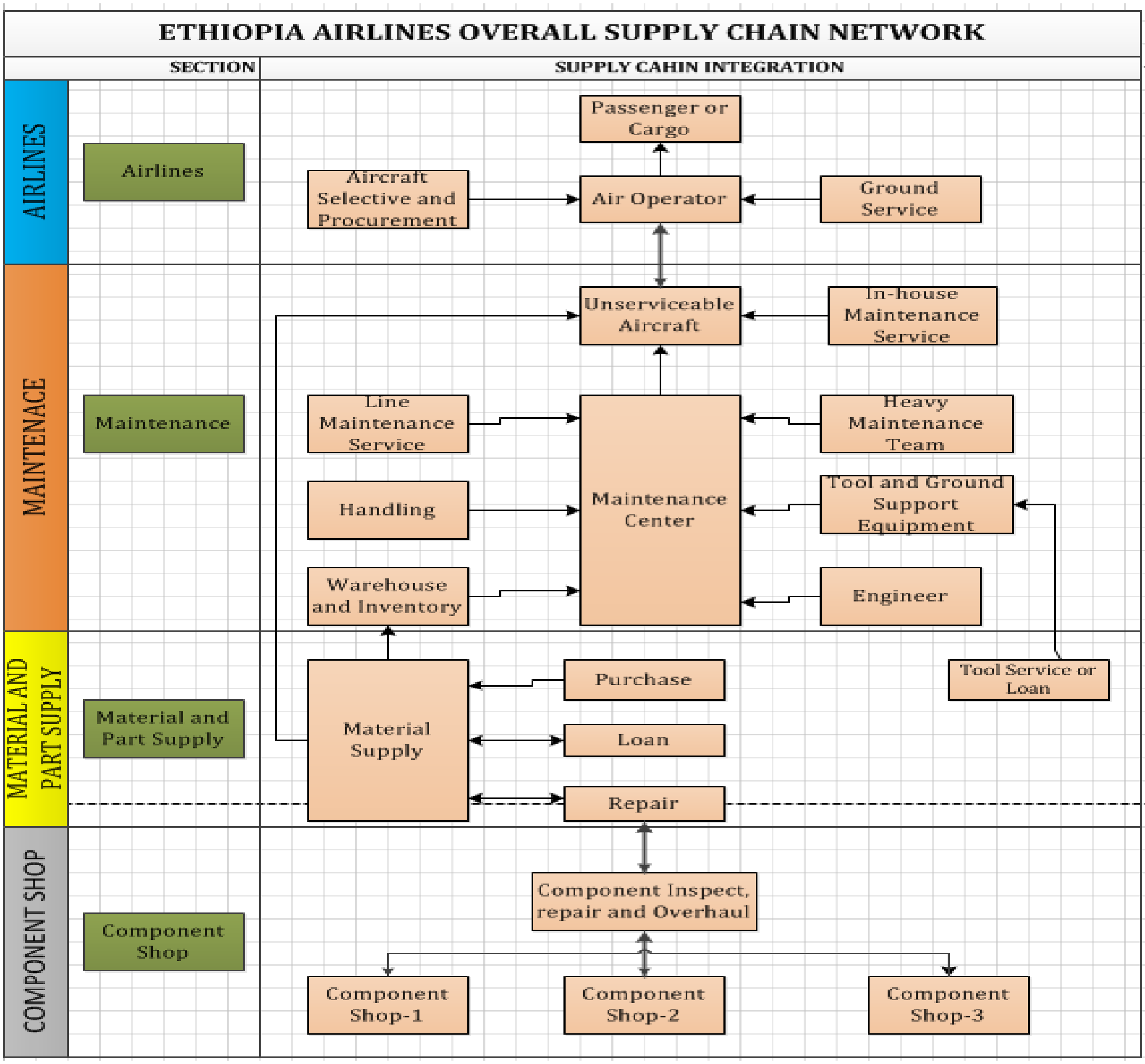
Figure 4: General Overview of Organizational structure of Ethiopian Airlines



❖ Existing Supply Chain System on ET-MRO Tool Engineering

Ethiopian airlines perform maintenance activities for its own aircrafts (Boeing, Airbus, Bombardier, and light aircrafts), and Customer aircrafts (Nigerian, Togo, Equatorial Guiana, Kenya, and etc.). To do these maintenance activities there are different procedures and manuals that must be obeyed such as Aircraft Maintenance Manual (AMM), Component Maintenance Manual (CMM), Structure Repair Manual (SRM), and etc. and all these manuals has detail description of the sequence of the operation, the required parts, tools and material to perform the defined task for all aircrafts that sourced from the original aircraft and part manufacturer on Maintenance Program Data (MPD) which approved by Regulatory bodies; such as: European Air Safety Association (EASA) and Federal Aviation Administration (FAA) (European Federal of National Maintenance Society, 2013) (Federal Aviation Administration (FAA), 2014).

Figure 5: Ethiopian Airlines overall supply chain network



Currently, Ethiopian airlines execute different airlines maintenance activities. And, the trends that Ethiopian airlines perform customers' requests are shown on the bellow:

- ❖ The Boeing, Bombardier and Airbus Company provide the Aircrafts with different types of aircrafts. E.g. B787, B777, B767, B757, B737 from Boeing, Q400 from Bombardier, and A350 a/c from Airbus.

- ❖ Owned aircraft: the company gives scheduled and unscheduled maintenance tasks for its greater than 100 aircraft within defined planning schedule, defined tool, part, man power, material, and other requirements.
- ❖ Customers: - the above mentioned customers provide their Aircrafts to get maintenance support from Ethiopian airlines, and these customers deal with the Ethiopian airlines on their requirements and specifications.
- ❖ ET-MRO (Maintenance Repair and Overhaul): is the responsible maintenance station in Ethiopian to perform any aircraft maintenance issues.
- ❖ MRO has two main categories:-these are Base maintenance and line maintenance. [this research is deals with the maintenance activities on Base maintenance only]
- ❖ Base maintenance area performs any aircraft maintenance that is scheduled and unscheduled tasks mentioned in Boeing, Bombardier maintenance manual to prevent the aircraft from damage and it takes the major maintenance task.
- ❖ Line maintenance area performs maintenance of aircraft that is required while departure and take off tasks like servicing, checking tire pressure etc… Simple maintenance tasks are done.
- ❖ Then the A/c planner plan and write all the tasks step by step in the system to be performed by the Hangar technicians, and then forward his/her required manpower to the respected Hangar managers and also for the part and tool list to the Technical manager. And hangar managers assign a team leader to perform all the scheduled tasks required by the Customers, and he assigns his technicians and follow all the instructions that written to the Aircraft Maintenance Manual (AMM).
- ❖ The technical manager will assign the tasks to the respected production controller to prepare consumable materials like oil, SKYDROL etc. and parts. And for the tool engineering department; it will be also advised to prepare the required tools. And tool engineering will avail the tool by any means.

Figure 6: Ethiopian MRO Organizational Structure

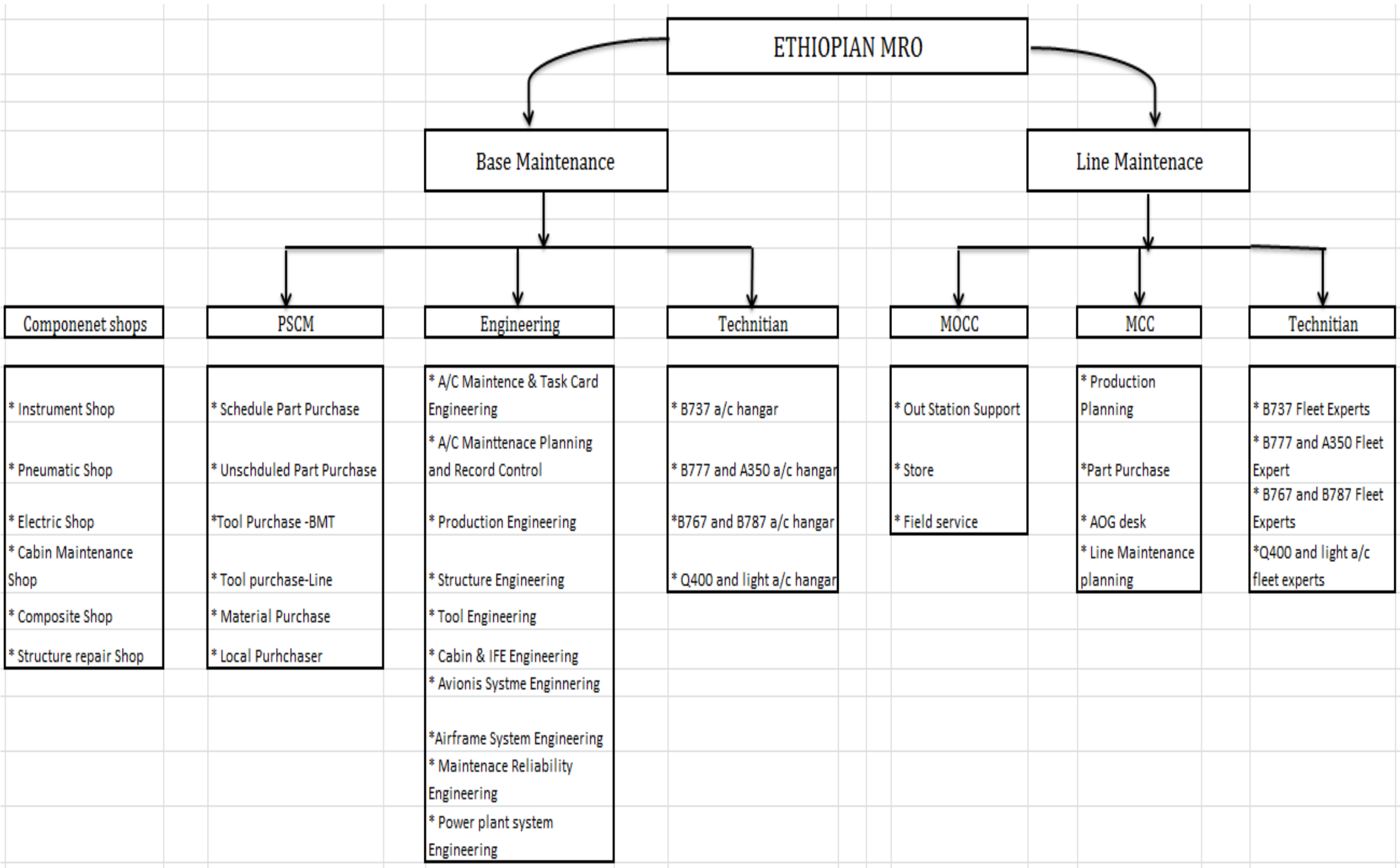
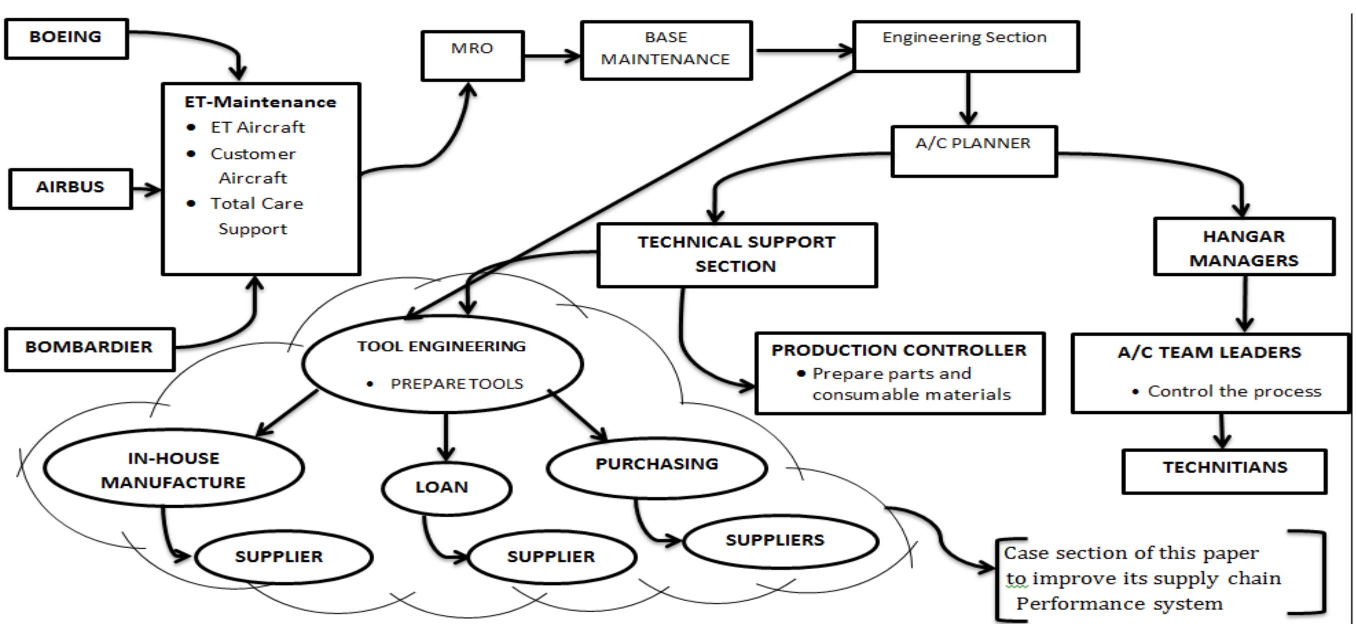


Figure 7: General tool engineering working flow



2.10 Literature Review Summary

From the above reviewed literatures, supply chains performances metrics are classified per the organization perspective. From table 4 of various performance models comparison, for this study the researcher select supply chain measurement model SCOR model. SCOR model contains decision levels (Operational level and Tactical level), physical flow, information flow, and financial flow has supply chain maturity within inter-departments and intra-departments, have multi chains with social, quality factors and human capital and has sustainability behaviors.

Hence, SCOR model describes the business activities associated with all phases of satisfying customers demand. Those five basic performance measurement targets (Plan, Make, Source, Delivery, and Return) was developed to assist business in understanding structuring and evaluating the performance of supply chain system of tool engineering, beside SCOR three levels are also addressed on this study.

After identifying all tools engineering metrics with respect to SCOR principle, AHP (Analytic Hierarchy Priority) are used to settle the priority that should tool engineering should have given.

The performance of tool engineering supply chain is identified as the criteria of productivity, quality, agility and customer satisfaction. Also, the performance is measured and evaluated to fit with the strategic, operational and tactical level. The below three level measures are amended from the literature and from Ethiopian airlines tool engineering section supply chain system. These level measures will give to measure the overall supply chain performance measurement of tool engineering system.

**** Strategic level measures** include productivity, variation against budget, total cash flow time, order lead-time, and delivery performance.

**** Tactical level measures** include accuracy of forecasting technique, supplier cost saving initiative, delivery reliability, order entry method, effectiveness of the master schedule, ability to respond to problems, responsiveness.

**** Operational level measures** include cost per operation unit, supplier rejection rate, capacity utilization, quality of delivery, and delivery reliability.

With the above approaches of defining the measures and metrics dimension for evaluation of Ethiopian Airlines Tool engineering supply chain, and the hierarchical structure is structured for further process of SCOR+AHP performance measurement module creation.

Table 5: Tool Engineering Key performance criteria and performance metrics

Tool Engineering Key Performance Criteria and Performance Metrics	
Tool engineering Key Criteria	***Tool engineering performance metrics***
Tool Engineering Overall Key Performance activities	❖ Strategic activities ❖ Operational activities ❖ Tactical activities
Strategic activities	❖ Productivity of the section ❖ Tool Purchasing/loan Variance against budget ❖ On-time delivery of tools ❖ Delivery flexibility for AOG tasks ❖ Defect free delivery of tools ❖ Tool order lead time
Operational activities	❖ Cost per manufacturing and purchasing time ❖ Capacity utilization ❖ Inventory management ❖ Effective scheduling ❖ Service delivery reliability
Tactical activities	❖ Cost saving initiative on alternative mechanism ❖ Purchase and manufacturing tool delivery reliability ❖ Tool order entry method ❖ Responsiveness on customer query ❖ On-time order fill rate

❖ **Literature Gap:**

The empirical literature review generally showed the overall performance measurement metrics than an aviation industry should have. Especially on aircraft maintenance organization-MRO detail supply chain management system should be carried out and measure their performance system with the integration of each and every section. But most of the documents are focused on the general performance measurement of the organization and some of them are descripted and trying to measure manufacturing industries and none of the documents are described on aircraft maintenance organization engineering maintenance tooling servicing section. It is also knows if the performance of each individual section metrics measures as they are integrated with each other. From this section tool engineering section has a greater interaction from other to have effective and affect performance measurement metrics that used during the aircraft maintenance time.

Most of the studies have focused on the overall supply chain management system majorly on Boeing company and others. It was not possible to get any paper done in Ethiopian airlines or African airlines operating situation and supply chain performance measurement metrics. Therefore, it is believed that this research work will bridge this gap by suggesting ways for appropriate performance measurements metrics and develop a model to maximize the efficiency and effectiveness of tool engineering and to enhance the company productivity through minimize turnaround time, through maximize customer satisfaction and prevent from incurring unnecessary maintenance cost.

After reviewing different articles, journals, the major limitations that are found from the selected case company section that not considerably important so as to develop new performance measurement model system against the problems raised in this paper, most studies have been conducted to develop a performance measurement metrics for maintenance organization based problems at the design stage, Finally the researcher plans to gather information from literatures and develop new supply chain performance measurement metrics and model enhancement using SCOR+AHP model through analyzing tool engineering supply chain management system and its performance measurement metrics.

CHAPTER THREE

RESEARCH DESIGN AND METHODOLOGY

3.1 Research Approach

The business environments of the aerospace companies are heavily related to the performance of the supply chain networks and the supply chain management performance measurement is commonly requested for the aviation industry.

The aim of this section is to highlight the overall methodological considerations of the study. This methodology section is divided into five sub-sections. The first section outlines the general research approach which this paper relies on and the second encompass a discussion of the actual research design applied throughout the thesis. The following third section discusses the data collecting method. The fourth section also elaborates on the sampling method and sample of population used and the justification for it and the sample size determined for the research. Finally, section six and seven respectively constitute the methods and materials used for analyzing the data and the research questions or hypotheses are mentioned in line with the objective set.

This research method helps to gather data about the practical problems of the existing situation and to explain basic concepts regarding aircraft tooling availing through purchasing, loan from other suppliers and develop an alternate. This also helps to explore the practical situation of aircraft maintenance planning and production scheduling and examine to search alternative potential solution for the problem.

The data obtained in this study was mainly from primary data collection from questionnaires, interview and observation, and from secondary source from recorded data of the airline. Nonetheless, supporting arguments or patterns found in monthly aircraft maintenance reports and brochures were involved where necessary.

3.2 Research Design

In order to answer the problem statement and pertaining research objectives carefully, the research design is reflected on and discussed in each step below. In answering the research objectives, this research develop an integrated conceptual framework for measuring tool engineering supply chain performance and derived satisfaction as a point of aircraft maintenance and release on time or before the schedule time.

The Supply Chain Operation Reference (SCOR) framework models using Analytical Hierarchy Process (AHP) analyzes the supply chain gap between expected and perceived chain with respective to tool engineering service attributes using a five point Likert scale in the following manner: much worse than expected, worse than expected, equal to expected, better than expected and much better than expected, and these classifications were assigned with 1, 2, 3, 4, 5 score respectively. For those open ended questionnaires, it designed to gather the general situation for the subject matter.

3.3 Data Collection Methods and Sources

3.3.1 Secondary Data

This research is based on a single case study (Ethiopian Airlines-Tool Engineering Section). According to (William M.K., 2017) (Klenke, 2008), single case studies are preferred approach if the research topics belong to unique or extreme cases such as specific dedicated business organizations. This secondary data are the major data that helps to see how the existing system of maintenance operation is going on and it leads to the actual operation system. And in this case to perform aircraft maintenance activity more than 20 sections are participated starting from the aircraft inducted to hangar to dehangaring. The major section participating in this activity is MRO Engineering section. And the case study section-tool engineering has a greater link from all of others engineering section and other supporting section. Hence, secondary data's questionnaires are distributes and collects for the MRO-Engineering section such as: Aircraft Maintenance and Task Card Engineering, Task Card Engineering, Aircraft Maintenance Planning and record Control, Production Engineering, Structures Engineering, technicians, Forman's, Purchasing and Supply Chain Management sections. In addition tool Engineering support some African airlines as total care support for Rwanda, ASKY, and Congo. This paper distributes questionnaires to those airlines representative to fill out the questionaries' through email. The data collected was analyzed through both qualitative and quantitatively to show the existing system and reach an optimal solution

3.3.2 Questionnaires

Questionnaire to support or validate findings from the secondary data-based analysis was held and enable to show how those data leads to accurate justification. Hence, structured questionnaires conducted to affected section and it is analyzed through Likert scale method. Appropriate data collection instruments were selected to gather relevant information. Of these, **questionnaires** were the most useful to investigate the aircraft maintenance planning and production scheduling related problems and to get deep information for the researcher and the respondents are free from restriction to put out their idea. Hence the questionnaire released to the above selected section among those who participated in this questionnaire from a total population size of 194.

3.3.3 Direct Observation

The other effective instrument used to collect source of data was **direct observation**. It was very helpful to assess the existing supply chain system and performance measurement in aircraft tool engineering practical activities and the interaction with other maintenance affected sections. The researcher was also used this method for collecting the required data and information from the respective industry. In this research direct observation is used as a means to assess the existing tooling service on scheduled and unscheduled request and when tool engineers support the technicians on spot practices in the case company.

3.3.4 Interview

Moreover, to strengthen the validity and reliability of the study, **interview** was conducted with Tool Engineers, Task Card engineers, technicians, tool planners, production engineers and, and aircraft maintenance planning and record control department.

3.4 Sampling Techniques and Sample Population

As described in above to conduct the research internal and external customers and suppliers were selected as a respondent. The population is too large and it is impossible to include every individual/customer and supplier due to their convenient accessibility and proximity to the researcher. Therefore, **Random Sampling Techniques** was used in the study (Kothari, 2004).

Hence sample size is taken from each respondent section, and to determine the total sample size to be taken with the below standard formula:

Size of Sample = $\mathbf{n} = \frac{\boldsymbol{N}}{\mathbf{1}+\boldsymbol{N}(\mathbf{e2})}$

N = size of population
n = size of sample
e = acceptable error (the precision or margin of error)

At 90% confidence level (to have a genuine random sampling relevant population), *e = 1-0.90 =* ***0.1***

Hence sample size can estimated by taking the below table data,

Sample size n = $\frac{\mathbf{194}}{\mathbf{1+194}(0.1^2)}$

n = **66** sample size should be selected.

A total sample of **194** internal and external customers and suppliers who had strong relationship with Tool Engineering will take as a respondent. Out of which **48** customers/suppliers of them are returned a completely filled questionnaire, **18** of the returned a questionnaire with missing data and **9** others are unreturned. Therefore, **66** provide a response that served as data for analysis to present the findings and draw conclusion.

Table 6: Total Sample Size and Sample Size taken

No.	Section	Total Sample Size	Sample Size taken	Justification
1	A/C Maintenance planning	13	8	The total sample size has taken for only **day shift**. Hence it doesn't include the evening and night shift.
2	A/C Task Card Engineering	14	7	
3	Production Planning & control	12	7	
4	A/C Structure Engineering	17	8	
5	Hangar Maintenance	51	20	
6	PSCM	7	3	
7	Rwanda- Maintenance Team	7	4	
8	Togo-Asky Maintenance Team	8	5	
9	Malawi-Maintenance Team	7	4	
Total		**194**	**66**	

3.5 Data Analysis and Interpretation Tools

To analyze and interpret the collected data there are different assisting tools depending on the nature of the data and the expected output in line with the research objective. For the collected questionnaires, the process of tabulation was carried out and percentage was also used as a statically tool to analyze the data. The quantifiable collected data was put in a table form and unquantifiable data got through interview was carefully reviewed and stated as it is and the observed data have been summed up.

There is also several software packages used for the analysis of quantitative data some of which are broader in scope and user friendly. The following ones are some of the software application packages:

- ✓ **Statistical Package for Social Science Software (SPSS)**: is will used to organized and interpret collected data of the study in meaningful information.
- ✓ **Maintenix (Mxi) –** is software specifically applicable for aircraft maintenance data storage and analysis in aviation industries. Besides it has different advantages for the study in order to extract aircraft maintenance history and it has been implemented in Ethiopian Airlines since 2012

- ✓ **Microsoft Excel -** this software will be used for mathematical manipulation of the data collected from the case company and for recording information about the maintenance activities based on the nature of data.
- ✓ **Analytic Hierarchy Process (AHP)**: is a structured technique used to organizing and analyzing complex decisions within the supply chain, based on mathematics and process flow.

Thus, this study is based on quantitative research method as well as qualitative research approach since it involves multi-dimensional characteristics of supply chain performance measurement metrics, and the performance measures are interrelated each other. The **Supply Chain Operation Reference (SCOR)** concept and **Analytic Hierarchy Process (AHP)** with Saaty's nine scale ratings of pair-wise comparison method used to utilize as a locomotive tool to accommodate these complexities, and in order to provide the case company with the managerial decision-making criteria.

Here is the summarized overview of data analysis method:

Table 7: General Overview of Data Analysis Method

** Theoretical Backgrounds	➢ Supply Chain performance measurement and framework development
** Research Paradigm	➢ Empirical analysis with implementation of latest research development
**Research strategy and research approaches	➢ Qualitative and Quantitative research ➢ Data collection from Maintenix (Mxi) , questionnaires, experience, observations, monthly maintenance report, discussion and interviews
** Research Method	➢ SPSS (Statistical Package for Social Science Software) ➢ Supply Chain Operation Reference (SCOR) ➢ Analytic Hierarchy Process (AHP)

CHAPTER FOUR

DATA PRESENTATION, ANALYSIS AND INTERPRETATION

4.1 Overview view of data collection

The questionnaire was structured in four parts with the aim of collecting data on; the background information of the company, data on the supply chain performance measures employed by the company, performance measurement dimensions, as well as the key benefits and challenges derived from effective supply chain performance measurement.

The first part of the questionnaires are contain a total of 9 question with descriptive and choose format on their responsibility at Ethiopian airlines and regarding to their views on various aspects of the service they get from tool engineering with normal/scheduled and critical maintenance issues as they have frequently contact with the section.

The previous chapter described the data collection methodology, and in this chapter the collected data's had been presented in detail with four major subjected such as: part one:- Background information of the collected questionnaire survey, part two: Primary data collection- questionnaire on supply chain integration of tool engineering with other sections, Performance measurement dimensions on tool engineering service, and expectation and challenges of the affected section on tool engineering service, third part presented on data's' that collected from the secondary source; specially from tool engineering recorded data on aircraft tool unavailability handling mechanism, aircraft maintenance tool requires from other operators through loan, and half year aircraft maintenance TAT and delay report, in last part all collected data summary and its results were forward.

4.2 Background information of the collected questionnaire survey

Table 8: Background information of the collected questionnaire survey

Respondent Section	Role of Section for A/C Maintenance	Working Year		Assigned Fleet			Frequency of contact with Tool Engineering			Tool Eng. Response Rate		No of Response	Percentage
		<5yrs	>5yrs	B737/ Q400	B757/ B777/ A350	B767/ B787	Always	3-5 Wks.	Never	<50%	>50&		
A/C Maintenance Planning Eng.	Core	5	3	2	3	3	8	_	_	6	2	8	12%
Task Card Engineering	Core	4	3	2	3	2	2	5	_	4	3	7	11%
Production Eng.	Core	7	0	2	3	2	7	_	_	4	3	7	11%
Structure Eng.	Supportive	6	2	For all structural damage			3	5	_	3	5	8	12%
Technicians/ Forman's	Core	12	8	5	8	7	20	_	_	14	6	20	30%
PSCM	Core	1	2	All Aircraft			2	1	_	2	1	3	5%
Rwanda-Team	Supportive	0	4	All Aircraft			1	3	_	2	2	4	7%
Togo ASKY Team	Supportive	0	5	All Aircraft			2	3	_	1	4	5	7%
Malawi	Supportive	0	4	All Aircraft			2	2	_	1	3	4	7%
Total		**35**	**31**	**11**	**17**	**14**	**47**	**19**		**37**	**29**	**147/66**	
Percentage		**54%**	**46%**	**26%**	**40%**	**37%**	**71%**	**29%**		**56%**	**44%**		100%

4.3 Primary data

To check the validity of the data collected and its result from secondary data, structured questionnaires and interviews are conducted.

4.3.1 Supply chain integration of tool engineering with other sections

1 - Extremely worse than expected, 2 - Worse than expected, 3 - Equal to expected,

4 - Better than expected, 5- Much better than expected

Table 9: Questionnaire Survey on SC Integration b/n Tool Engineering with Other sections

Item	**SC Performance Measurement Dimension**	1	2	3	4	5	**Questionnaire Result Summary**
Q1	Firms in tool engineering supply chain establish more frequent contact with each other	5	11	18	21	11	** 76% of the respondent agreed that there is very strong contact with their section
Q2	Tool engineering supply chain create a compatible communication and information system while giving service	5	19	18	15	7	** 61% of the respondent get swift and clear information and material flow from tool engineering
Q3	Tool Engineering firm extends its supply chain beyond its customers/ suppliers expectation	11	20	18	8	9	** 53% of the respondent agreed that they get strong support in the slack season
Q4	Tool Engineering participates in the critical issues and provide a good maintenance	8	12	21	16	9	** 70% of the respondent a get enough support on critical issues
Q5	Tool Engineering participates in the sourcing decisions of its customers/suppliers and make a close follow up	9	19	15	12	11	** 58 % of the respondent have a positive response on tool engineering open task follow up

4.3.2 Performance measurement dimensions service of tool engineering

1 - Extremely worse than expected, 2 - Worse than expected, 3 - Equal to expected, 4 - Better than expected, 5- Much better than expected

Table 10: Questionnaire Survey on Tool Engineering SCPM Dimension

Item	SC Performance Measurement Dimension	1	2	3	4	5	Questionnaire Result Summary
Q6	Ability to respond to and accommodate demand variations, such as seasonality [un/scheduled, AD, EO]. - Responsiveness (Customer query time)	8	16	20	15	7	** 64% of the respondents has got a good respondent from tool engineering service
Q7	Manufacturing/Loan/Purchasing lead times to avail maintenance tool - effectiveness of scheduling techniques	9	21	15	10	11	** 55% of the respondent agreed with the working environment and effective schedule
Q8	Customer Complaints - Customer Service	8	17	22	12	7	** 62% has a complaint on the customer handling system of tool engineering
Q9	Quality of Purchases'/Manufacturing/ Loan tools –Quality	7	14	20	17	8	** 68% has a compliances on the quality of the available tools
Q10	Response time to user demands on regular time	6	14	21	17	6	** 65% of the respond satisfy with the response time of tool engineering
Q11	Flexibility of the section while changing demands pattern - Agility	10	15	18	17	5	** 61% of the respondent agreed on the flexibility of tool engineering working system/process.
Q12	Days taken to clear imported non stocked items - Inventory Management	8	13	21	17	7	** 68% of the respondent observed and satisfied with the inventory management system of tools
Q13	On time Order fill rates	6	15	17	20	8	** 68% satisfy with the reorder fill rate control system
Q14	Cost associated with held inventory	11	17	15	8	5	** 43% of the respondent observed that failure of tool engineering highly associated with cost

4.3.3 Challenges and expectation of other section on performance measurement of TE

1 - Extremely worse than expected, 2 - Worse than expected, 3 - Equal to expected, 4 - Better than expected, 5- Much better than expected

Part IV: Other Section Challenges on Tool Engineering Service and their Performance Measurement points

Table 11: Questionnaire Survey on other sections' compliance and their performance indicators

Respondent Section	Tool Engineering Challenges	Performance Measurement Indicators	No of respondent
A/C Maint. Planning Engineering	**Lack of control, Standardization, Resistance form Planning Change, Man power shortage, lack of information flow	** Swift Response, Delivery, Lead Time, Quality, Inventory Management, Demand Forecast	8
Task Card Engineering	**Shortage of Order cycle, Lack of commitment, have long process, No trust with inter-department, lack of information and material flow	** Quality, Organizational Structure, Process, Response Time, Agility, Inventory Management	7
Production Engineering	** Lack of on-time delivery, Complex process flow, back and for the communication, No forecasting strategy	** On-time Delivery, Quality, Agility, Customer requirement, Quality, Capacity Utilization	7
Structure Engineering	** Organizational structure failure, Complexity of the required tool, Repeated communication, Specialty of the required item, No planning maintenance schedule,	** Procurement tool Quality, Inventory Management, Lead Time, Customers Requirement, Manufacturing Quality	8
Technicians/ Forman's	** No back-up system, Incomplete material and information flow, No scheduled request, Biased of tools	** Quality of Tools, On-time Delivery, On-spot assistance performance, No defect/Rework	20
PSCM	** Undefined request, lack of standardization, Complex communication, Lack of knowledge Lack of quality,	** Organization Structure, On-time Request, Process Capability, Quality,	3
Rwanda- Team	**Urgent request, No budget, incomplete request, High back and forth communication	**Customer Requirement, Lead Time, Quality, Process Capability, Order Fill Rate	4
Togo ASKY Team	** Urgent Request, Repeated request, Biased tool, Lack of information and material flow, Lack of knowledge on tools	** Quality, Customer Requirement, On-time Delivery, Cost, Demand Forecast	5
Malawi	** Nature of the request, shortage of man power, Incomplete of the item,	** Customer Service, On-time Delivery, Quality Tool, Good Support, Reliability	4

4.4 Secondary Data

4.4.1 Aircraft tool unavailability handling mechanism

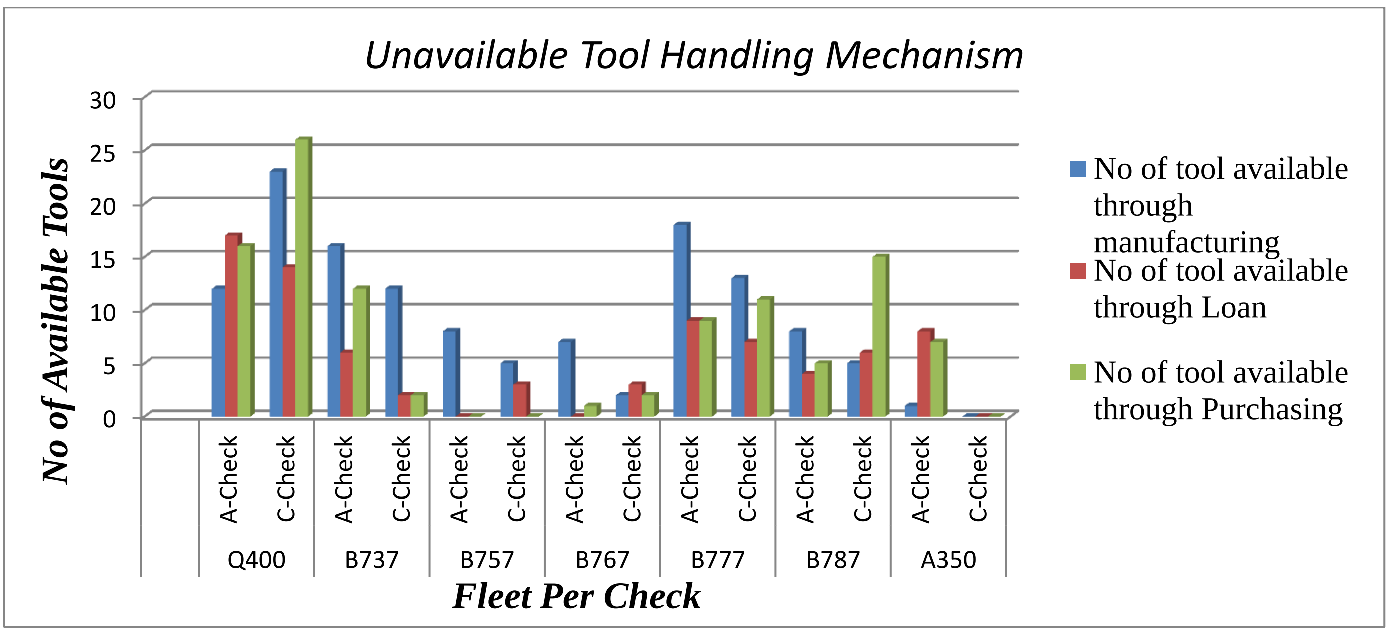
1. Descriptive Statistics of Tool Engineering Unavailability Tool Handling Methods (June – Dec 31, 2017)

Table 12: Unavailability of tool handling for Jun - Dec 2017

Descriptive Statistics

	N	Maximum	Sum	Mean	Std. Deviation	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
Feet Type	14	7	56	4.00	2.075	.000	.597	-1.256	1.154
No of Tasks	14	123	682	48.71	41.742	.579	.597	-1.047	1.154
No of Available Tools through Manufacturing	14	23	130	9.29	6.742	.499	.597	-.337	1.154
No of Available Tools through Loan	14	17	79	5.64	5.138	.975	.597	.548	1.154
No of Available Tools through Purchasing	14	26	106	7.57	7.763	1.045	.597	.797	1.154
Valid N (list wise)	14								

Figure 8: Unavailable tool handing mechanism



From the total of 682 tasks of A-check and C-check for all fleets tools are available with below means:

No tools available through manufacturing a total of 130, required to purchased raw materials

No of tools available through loan a total of 79, some of the tools required and stays extra days

No of tools available through purchasing a total of 106, some of the tool incurred expedite fee

4.4.2 Aircraft maintenance tool loan price calculation

Descriptive Statistics of Tool Engineering – A/C Tool Loan Price Calculation (June – Dec 31, 2017)

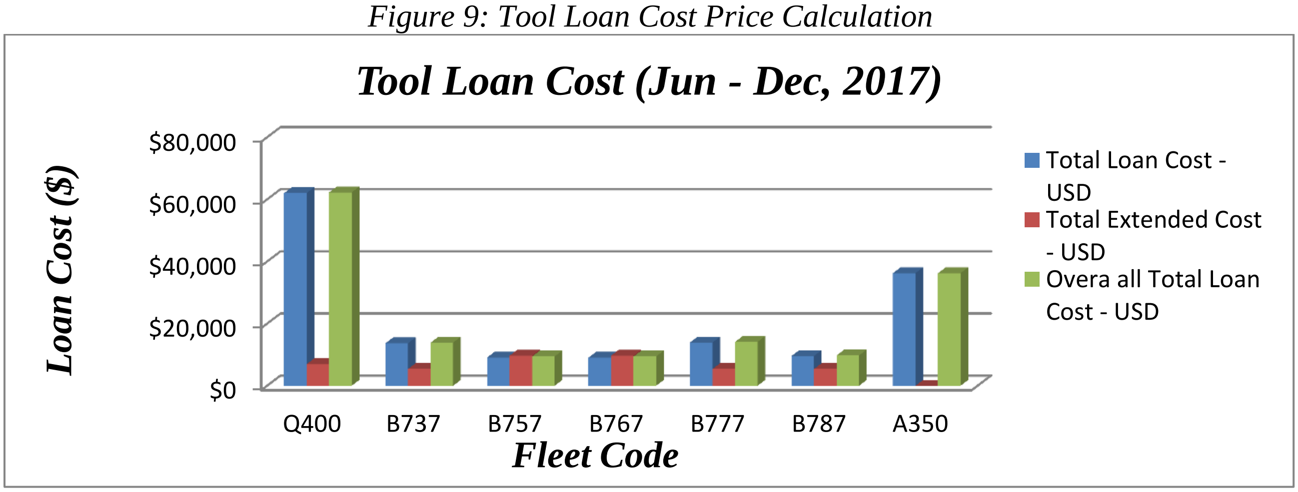
Table 13: Aircraft maintenance tool loan price calculation

	N	Minimum	Maximum	Sum	Mean		SD	Skewness	
	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic	Std. Error
Fleet Type	7	1	7	28	4.00	.816	2.160	.000	.794
No of Unavailable Tool	7	3	31	79	11.29	3.689	9.759	1.646	.794
Average Tool Price Per Day	7	$171	$302	$1,492	$213.13	$17.800	$47.094	1.364	.794
Average No of Day Required	7	5	15	73	10.43	1.744	4.614	-.113	.794
Total Loan Cost	7	$9,065.45	$62,000.00	$153,595.28	$21,942.18	$7,600.85	$20,109.98	1.721	.794
Average Extension Days	7	0	5	24	3.43	.685	1.813	-1.132	.794
Average Extension Charge	7	$42.30	$70.50	$430.07	$61.43	$4.08	$10.81	-1.233	.794
Total Extension Cost	7	$0.00	$352.55	$1,546.17	$220.88	$45.30	$119.87	-.843	.794
Overhaul Total Loan Cost	7	$9,418.00	$62,251.82	$155,140.47	$22,162.92	$7,586.55	$20,072.12	1.734	.794
Valid N (list wise)	7								

Skewness is a measure of symmetry, or more precisely, the lack of symmetry. A distribution, or data set, is symmetric if it looks the same to the left and right of the center point. +ve /-ve value indicate a pile-up of scores on the left/right of the distribution respectively.

Due to the poor supply chain management and performance measurement techniques; tool engineering section is incurring a total cost of **$62,251.82** within the past six months to source loan tools for all aircraft maintenance. Besides due to some reasons some tool were stayed beyond the expected return data and lost an average **$352.55** within six months.

Figure 9: Tool Loan Cost Price Calculation



4.4.3 Aircraft maintenance TAT and delay report

Descriptive Statistics of Ethiopian Airlines –Aircraft Maintenance Delay Reasons (June – Dec 31, 2017).

Figure 10 : Half year Aircraft Delay Report **(Engineers, 2017)**

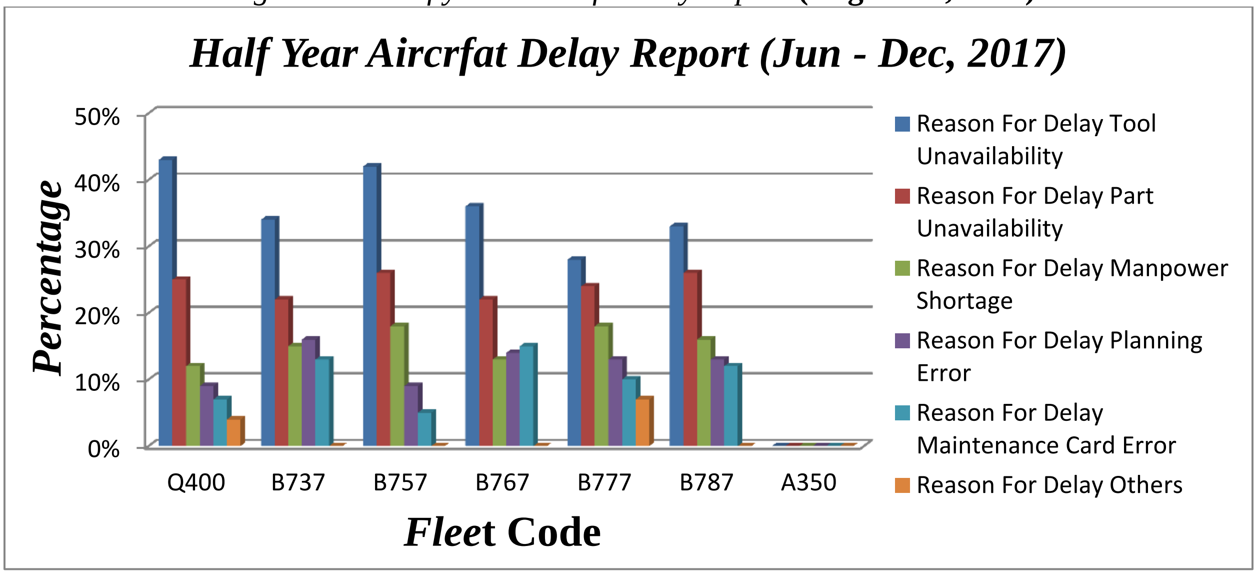
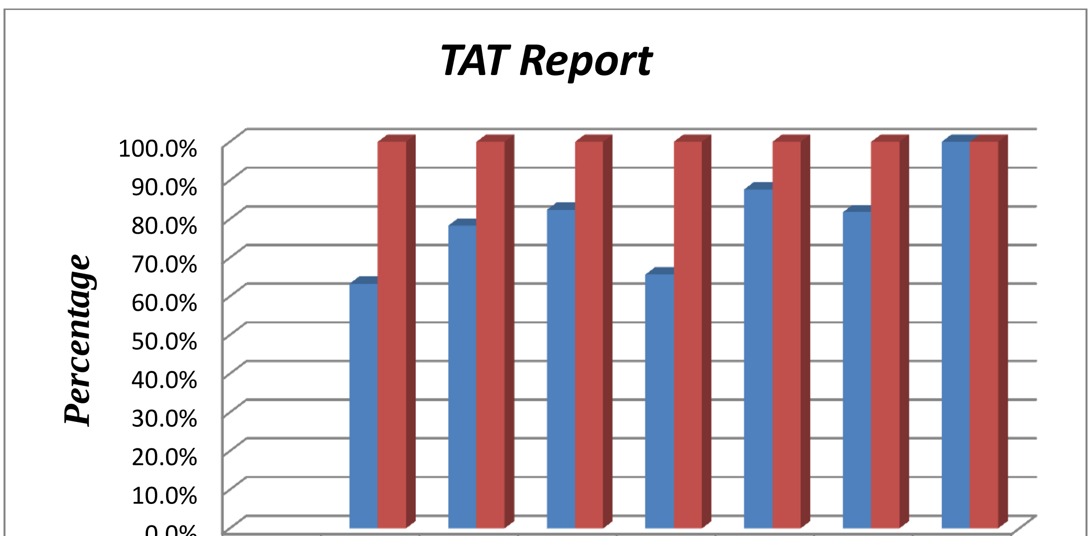


Figure 11: Aircraft Maintenance Delay Reasons with TAT Report **(Engineers, 2017)**



	Q400	B737	B757	B767	B777	B787	A350
Actual TAT	63.3%	78.3%	82.4%	65.7%	87.7%	81.8%	100.0%
Target TAT	100%	100%	100%	100%	100%	100%	100%

For maintenance aircraft delay there are many reasons, but per the past year company report there are five major reason that cause aircraft to delay. Hence it is better to see its correlation one with another and with respect to the number of aircraft delay and the total number of tasks.

Correlations between Aircraft Delay with Engineering Section

Table 14: Correlation between aircraft maintenance with sections

Correlations Between Aircraft Delay with Engineering Section

		No of Tasks	No of Delays	Tool Unavailability (%)	Part Unavailability (%)	Man Power Shortage (%)	Planning Error (%)	Maintenance Card Error (%)	Fleet Type
No of Tasks	Pearson Correlation	1	.864*	.400	.479	.350	.483	.387	-.469
	Sig. (2-tailed)		.012	.374	.277	.442	.272	.391	.289
	N	7	7	7	7	7	7	7	7
No of Delays	Pearson Correlation	.864*	1	.508	.423	.166	.282	.233	-.693
	Sig. (2-tailed)	.012		.244	.345	.722	.540	.615	.084
	N	7	7	7	7	7	7	7	7
Tool Unavailability (%)	Pearson Correlation	.400	.508	1	.940**	.814*	.694	.562	-.768*
	Sig. (2-tailed)	.374	.244		.002	.026	.084	.189	.044
	N	7	7	7	7	7	7	7	7
Part Unavailability (%)	Pearson Correlation	.479	.423	.940**	1	.940**	.797*	.650	-.573
	Sig. (2-tailed)	.277	.345	.002		.002	.032	.114	.178
	N	7	7	7	7	7	7	7	7
Man Power Shortage (%)	Pearson Correlation	.350	.166	.814*	.940**	1	.812*	.622	-.421
	Sig. (2-tailed)	.442	.722	.026	.002		.027	.136	.347
	N	7	7	7	7	7	7	7	7
Planning Error (%)	Pearson Correlation	.483	.282	.694	.797*	.812*	1	.942**	-.421
	Sig. (2-tailed)	.272	.540	.084	.032	.027		.002	.347
	N	7	7	7	7	7	7	7	7
Maintenance Card Error (%)	Pearson Correlation	.387	.233	.562	.650	.622	.942**	1	-.267
	Sig. (2-tailed)	.391	.615	.189	.114	.136	.002		.563
	N	7	7	7	7	7	7	7	7
Fleet Type	Pearson Correlation	-.469	-.693	-.768*	-.573	-.421	-.421	-.267	1
	Sig. (2-tailed)	.289	.084	.044	.178	.347	.347	.563	
	N	7	7	7	7	7	7	7	7

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

SPSS output on the table 18 provides a matrix of the correlation coefficients for the eight variables. Underneath each correlation coefficient both the significance value of the correlation and the sample size (N) on which it is based are displayed. Each variable is perfectly correlated each other as r = 1 along the diagonal of the table (Field, 2009).

From the above correlation table, the below major correlation has been selected as their Significant value is less than 0.05, and the others are ignored as they haven't strong correlation one to another- mean that the relationship between one variable with respect to other variable had a reverse relationship:

- ✓ No of task has a direct relationship with No of delays (when No of tasks increased, No of delays also increased) and the reverse one is also true with significance value 0.012 and person r value 0.864; which implies that they have statistically significant correlation between the two variables, with strong relationship (86.4%).
- ✓ Tool unavailability has a direct correlation with Part unavailability; with significance correlation value 0.002 and Pearson r value 0.940, this implies that they have 94% strong relationship each other [one of the variable increase/decrease the second variables also increase/decrease respectively]. But, from the practical situation enhancement of tool unavailability doesn't have any associate with part unavailability and the reverse one also true. Hence this correlation is rejected.
- ✓ Tool unavailability has a direct correlation with Manpower shortage; with significance correlation value 0.026 and Pearson r value 0.814, this implies that they have 81.4% strong relationship each other [one of the variable increase/decrease the second variables also increase/decrease respectively]. But, from the practical situation and trend enhancement of tool unavailability doesn't have any correlation with man power shortage and the reverse one also true. Hence this correlation is rejected too.
- ✓ Tool unavailability has a direct correlation with Fleet Type; with significance correlation value 0.044 and Pearson r value 0.768, this implies that they have 76.8% strong relationship each other [one of the variable increase/decrease the second variables also increase/decrease respectively]. As there are so many tooling that all fleets used as a common there is becoming a shortage when fleet number is increased.
- ✓ Part unavailability has a direct correlation with Manpower shortage; with significance correlation value 0.02 and Pearson r value 0.940, this implies that they have 94% strong relationship each other [one of the variable increase/decrease the second variables also increase/decrease respectively]. But, from the practical situation and trend enhancement of Part unavailability doesn't have any correlation with man power shortage and the reverse one also true. Hence this correlation is rejected too.

- ✓ Part unavailability has a direct correlation with planning error; with significance correlation value 0.032 and Pearson r value 0.797, this implies that they have 79.7% strong relationship each other [one of the variable increase/decrease the second variables also increase/decrease respectively].
- ✓ Manpower shortage has a direct correlation with planning error; with significance correlation value 0.027 and Pearson r value 0.812, this implies that they have 81.2% strong relationship each other [one of the variable increase/decrease the second variables also increase/decrease respectively]. But, from the practical situation and trend enhancement of planning error don't have that much correlation with planning error and the reverse one also true. Hence this correlation is rejected too.
- ✓ Planning error has a direct correlation with Maintenance card error; with significance correlation value 0.002 and Pearson r value 0.942, this implies that they have 94.2% strong relationship each other [one of the variable increase/decrease the second variables also increase/decrease respectively].

In genera; even if most of the correlation variables have a strong relationship one with another, their significance value is greater than 0.05 which implies that those variables correlation is no statistically significant correlation between variable. Besides, the above discussed variables that have a strong relationship within variables that have significant value less than 0.05; the actual situation is not support the relationship of them and forced to reject their relationship.

Therefore, the research rejects the above overall correlation of variables due to the above reasons and proceeds to the next step.

4.5 Supply chain performance measurement framework development-SCOR

This research pursues to improve the effectiveness of performance measurement system of Ethiopian Airlines-Tool engineering section supply chain performance measurement. The essential information of the literature review of this thesis has been taken into account while structuring of the criteria and metrics for the Analytical framework. This reasoned performance measurement models contains the concept of SCOR methodology in link with the selection of performance measurement metrics and the analysis methodology is compiled on the basis of AHP theory.

The performance metrics of tool engineering supply chain has a complex and multidimensional characteristics. In order to represent these structures of the performance measurement metrics, the idea of SCOR modules has been recognized, and the performance metrics are changed into the SCOR module to assimilate the impacts of each metrics thru AHP methodology. Finally, the developed framework presents the decision-making criteria with SCOR modules for evaluating the performances of tool engineering supply chains continuously and dynamically.

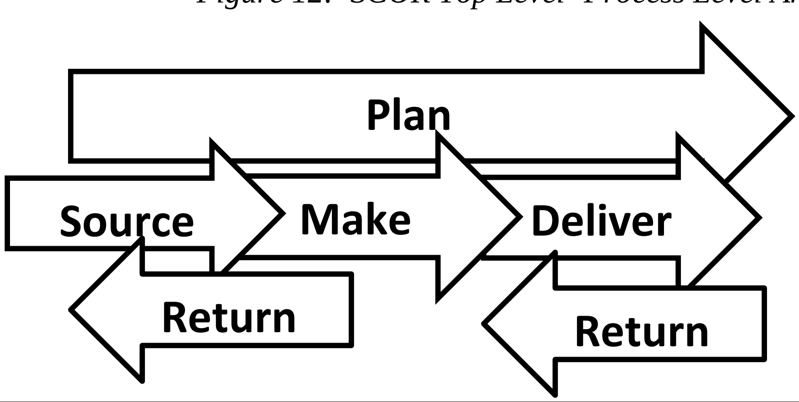
Level Analysis

SCOR analyzes Ethiopian Airlines Tool Engineering section supply chain operation in three levels. The model is based on five different management processes. The processes Source, Make and Deliver of the company, together with those of internal and external customers and suppliers, form a "supply chain" planned as a whole by the different actors in the process Plan. Additionally in all the "contact links" Deliver-Source is included the process Return, for the management of returns.

LEVEL 1: Top level (Process Types)

At this level 1, tool engineering using SCOR establish basic strategic objectives regarding their operations areas. Level 1 defines the scope and content for the Supply Chain Operations Reference-model. Here basis of competition performance targets are set.

Figure 12: SCOR Top Level -Process Level Analysis



PLAN: Processes that balance tool aircrafts maintenance team demand and supply to develop a course of action which best meets the established business rules.

To plan the acquisition of prime matters in Source, to plan adequately the production in Make and to fulfill the clients requirements in the delivery in Deliver, it is necessary to be conscious of the demand's variability along the whole chain to avoid the unwanted effect Bullwhip (Accumulation of high inventory levels in the stages of the supply chain that are farer from the final customer, which face great variability of demand in comparison with the distributors or retailers). For this is necessary to establish narrow relations with suppliers and customer to plan production in agreement to the aircraft maintenance demand of the final maintenance tool. When the tool is perishable, it is necessary to have a constant supply system. The capacity of the productive process must assure a volume adapted to satisfy the internal demand and that of external demand; as for the distribution, the deliveries must be focused to satisfy the delivery times, preserving the quality. Under these considerations arises the need to plan the production according to the different types of demand, for which is indispensable to share information in benefit of all the parts involved.

However, for selected section tool engineering - that purchase maintenance tools and evaluates an alternate for maintenance service and support share companies airlines such as: Togo-Asky, Rwanda, Malawian. Tool inventory planning adapts to control of at least one end of the chain either through tool demanding or tool supply to outstation support. Tool inventory planning of aviation industry is very difficult as there are many tools are required for all fleets and tasks. The industry exactly knows the tool should have properties of quality, reliability and the inventory that balances supply and demand. If not, the section loses its ability to manage the chain optimally. The best it can achieve is sub-optimal performance.

SOURCE: Processes that procure tools and raw materials to meet planned or actual aircraft maintenance demand. The prime matters are an essential part to assure the quality of the final tool. That's why quality standards must be established by the suppliers, to satisfy the final technicians and Forman's. However, the chain must recognize that uncontrollable events such as AOG (Aircraft On-Ground), EO (Engineering Order), SB (Service Bulletin), and TCB (Tool Change Bulletin) will affect the tool and raw material procured. A vendor may have a contract, to clearly identify standards and be a certified supplier, but factors completely outside of the vendor's ability to control, could result in a product delivered that doesn't match established parameters.

The inputs can be divided in scheduled required aircraft maintenance tools (EIS-Entry to Service, A-Check, and C-Check) and unscheduled required aircraft maintenance tools (A/C Structural Damage, SB, AD). For the case of the scheduled maintenance, it is necessary that the supply interval is short to support a minimal inventory, the necessary quantity for the daily maintenance. In this point it is very important to support a good coordination in the supply chain, with the purpose of avoiding tool loan request and from incurring unnecessary cost of tools and assistance from manufacturer.

MAKE: Processes that transform available tools to a finished state (aircraft maintenance) to meet planned or actual aircraft maintenance demand.

In this process it is necessary to take into account all the activities of the transformation process from the raw material to the final tool through manufacturing, tools from purchasing and tools from evaluation of alternatives, as well as the flows of material and information of the productive process. When programming the activities of aircraft maintenance process, it is necessary to have in mind that tools are ready and avail before the aircrafts inducted date and done according to request. Besides, to continuously improve the process, the preferences of the consumer's internal customers: production engineering, structure engineering, PSCM, outstation customers and other operators must be considered. To satisfy these needs and to deliver the maintenance aircraft on-time, methods and quality standards will be proposed in order to support the control of the productive process stepwise.

DELIVER: from the SCOR level-1 principle delivery from tool engineering processes serviceable aircraft maintenance tool and deliver on spot assistance form scheduled and unscheduled maintenance to minimize the aircrafts turnaround time and to meet the aircrafts maintenance demand. Typically these include tool order management, shipping/transportation management and provide service to end user through distribution management.

To deliver the tools, the volume that the technician needs will be assured avoiding excessive deliveries, unnecessary costs of transport, etc. The customer (technicians) portfolio will be defined. In this process it is managed from the questions and requirements of the clients up to the shipments of the product and the selection of logistic companies. To do these in all aircraft maintenance hangar there is a dedicated tool room for each respective fleet.

RETURN: Processes associated with returning or receiving returned tools for any reasons –due to incompleteness, due to budget, due to its obsoleteness, and others. These processes extend into post-delivery customer support.

To do a good returns management and returns of aircraft maintenance tools can be an important source of competitive advantages. It is necessary to assume that, in spite of the good practices to deliver a quality tools, there can always be motives for which manufacturer and supplier purchasing tools, FAK (Fly Away Kit) tools that come together with the aircraft inducted time, will be returned by manufacturer request due to some functional deficiency or return request by Ethiopian airlines tool engineering section due to tool part missing, incorrect product delivery and if there is deficiency of tools. Because of this, it is proposed to offer to the customer an efficient service of management of returns, which allows to answer in time to this type of situations, minimizing a potential worsening in the relation with customers, and also to manage the process of returns with suppliers in case on receiving defective, expired or excessive inputs. There should be networks of communication and chains that properly studied to do this process, in such a way that this situation does not turn into an unexpected complaint, but it works as a good system of feedback in the post-sale, with the objective of minimizing the costs of the return and at the same time, to be in good relations with clients and suppliers, and highly to safe while performing maintenance.

LEVEL 2: Configuration Level (Process Categories)

In this level, tool engineering section configures their supply chain, and its supply chain can be configured-to-order at Level 2 process categories. Their process categories are be defined by the relationship between a SCOR process and a process type. The selected process categories that selected from the SCOR configuration toolkit, in agreement to the type of service that tool engineering provide and from the type of internal and external customers' requirements to the market, to define and develop the supply chain configuration. Each product or product type may have its own supply-chain. Process planning will periodically prepared to align the necessary resources to meet internal and external customer requirements.

The type of tool engineering process planning contains of the scheduled alignment of the necessary resources to meet the requirements of demands. The type execution is released by the existing or planned maintenance demand; here the state of the tool is changed, and implies that the transformation of the task that required the tool. The type enable corresponds to processes that prepares, support or handle information or relations on which depend the processes of planning and developing of tool while executing the maintenance task

LEVEL 3: Process Element Level (Decompose Processes)

In this level, detailed process element information for each process category that described on level 2 is presented. Level 3 defines a tool engineering ability to compete successfully in its chosen markets, and consists of:

- ✓ Process element definitions
- ✓ Process element information inputs, and outputs
- ✓ Process performance metrics
- ✓ Best practices, where applicable
- ✓ System capabilities required to support best practices

It is at this point where a company using SCOR will learn what information inputs are needed for each of the process elements, and what outputs to expect. And the below major consideration should be taken:

SOURCE:

It is recommended to have a differentiated treatment for the inputs and prime matters, according to their priority. Hereby, aircraft maintenance tools are defined from the aircrafts manufacturer its quantity and physical availability is based on operators. And Ethiopian airlines tool engineering section define tool that capable to maintain the aircrafts with their checks. And this section sources tool from manufacturer, suppliers and other operator after making a detail analysis on the tool necessity, if tools are not required frequently and has high price then securing for loan is this section responsibility or else evaluate further for those tools that can be manufactured within in-house capability starting from raw material selection. In this link of the chain, it is of countless usefulness to use tools that allow the analysis of the tool suppliers, in order to identify their qualification standard to establish the interrelationships between the links Source and Deliver in the best possible way. It is recommended the use of tools of strategic analysis of provider companies. Another important matter in this process, is the maintenance of the quality of the inputs and products along the whole chain, since for being used as a maintain aircraft that used to transport passengers safely, an efficient system of monitoring and control is needed.

MAKE

In this level the information of the process elements from levels 1 and 2 is presented in a more detailed way. If there would appear the flows of material of the process (Make), the sources of the income (Source) and the destinies of the products (Deliver), then the phases of the process of production are taken into account that tool is fully serviceability, availability, and completeness.

DELIVER

It can also be taken in account if the management of the orders from different customers' needs a different treatment: for example orders from normal customer or orders from outstation customer. With the last ones, the orders could be bigger, and as the capacity of production is limited and the times of delivery must be short, in that case, these orders should be reported with major fluency and anticipation. Also, it is necessary to know if the cool chain must be kept during the transport or not, to keep the quality of the tool.

4.5.1 Establishment of key metrics for SC Performance Measurement

In this research, key objective measurements are identified as a performance measurement enhancement in Ethiopian airlines tool engineering supply chain system: using SCOR model and AHP analysis. The key objective criteria of performance measurement have been established as the results of the literature review in association with the evaluation of the relevancies to tool engineering supply chain system. From those various supply chain performance measurement models SCOR model is selected. As this model have a great power to make a change on tool engineering section, and this model is recommended model for most organizations specially aviation industry.

To develop and implement this model on the selected section, this paper identified the levels of the process, key performance indicators, attributes and logistics operations that are carried out throughout the chain. The usefulness of the application of the SCOR model is defined by the clear identification of the components that manages the chain, highlighting the strengths and weaknesses of external relations and internal logistics. From this views it is noted that the SCOR model application effectively contributes on the efficient logistics operations back along the chain, marking the need for investigation of SCOR applications in service processes and more on supporting the aircraft maintenance. This research identified components of the supply chain of Ethiopian Airlines Tool Engineering section process that structured through the following links from threads.

Figure 13: Major Structure for aircraft maintenance – SCOR

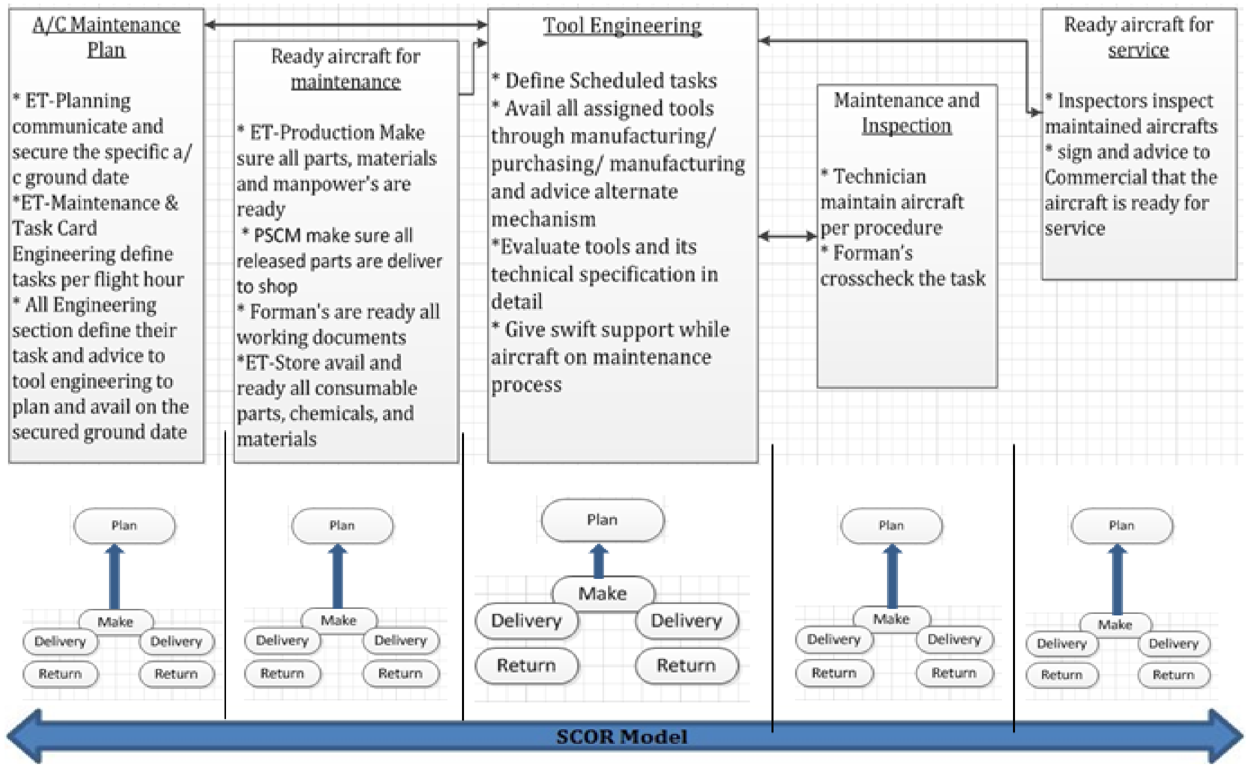


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Figure 14: Overall TE SC performance developed model

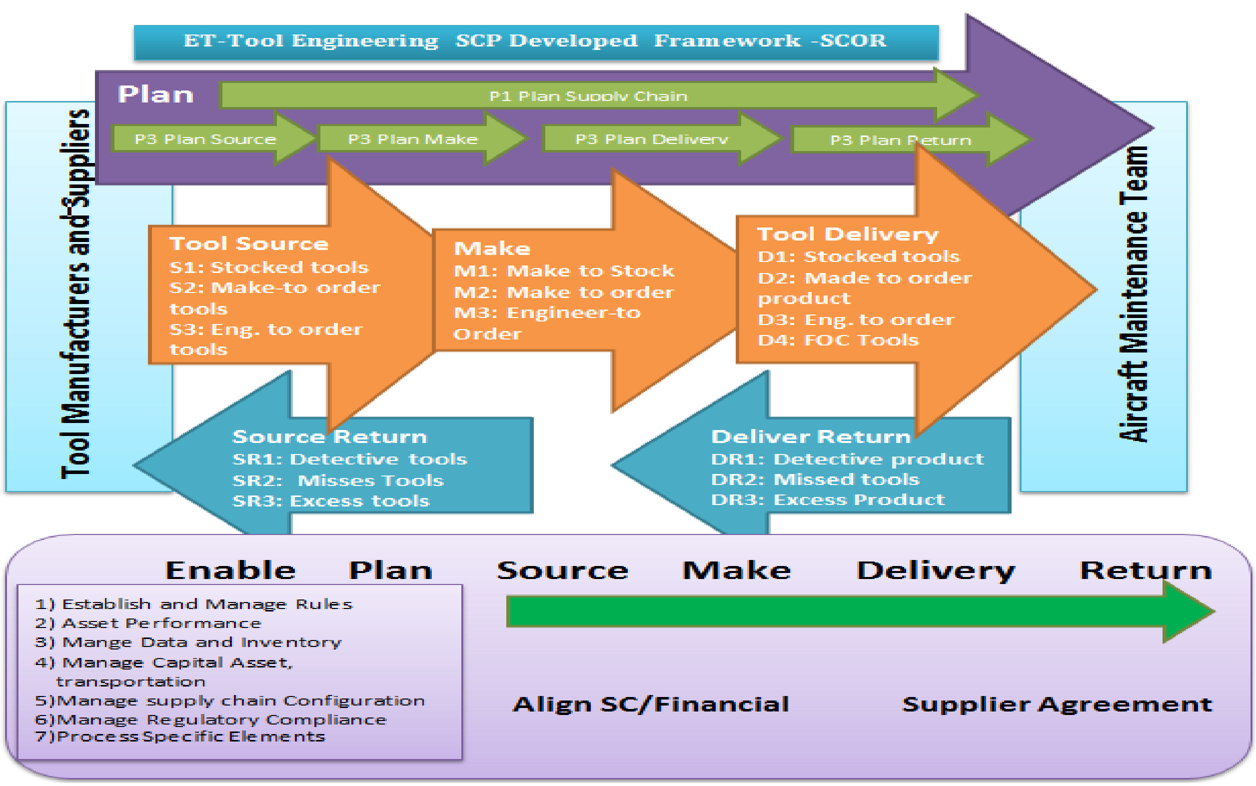
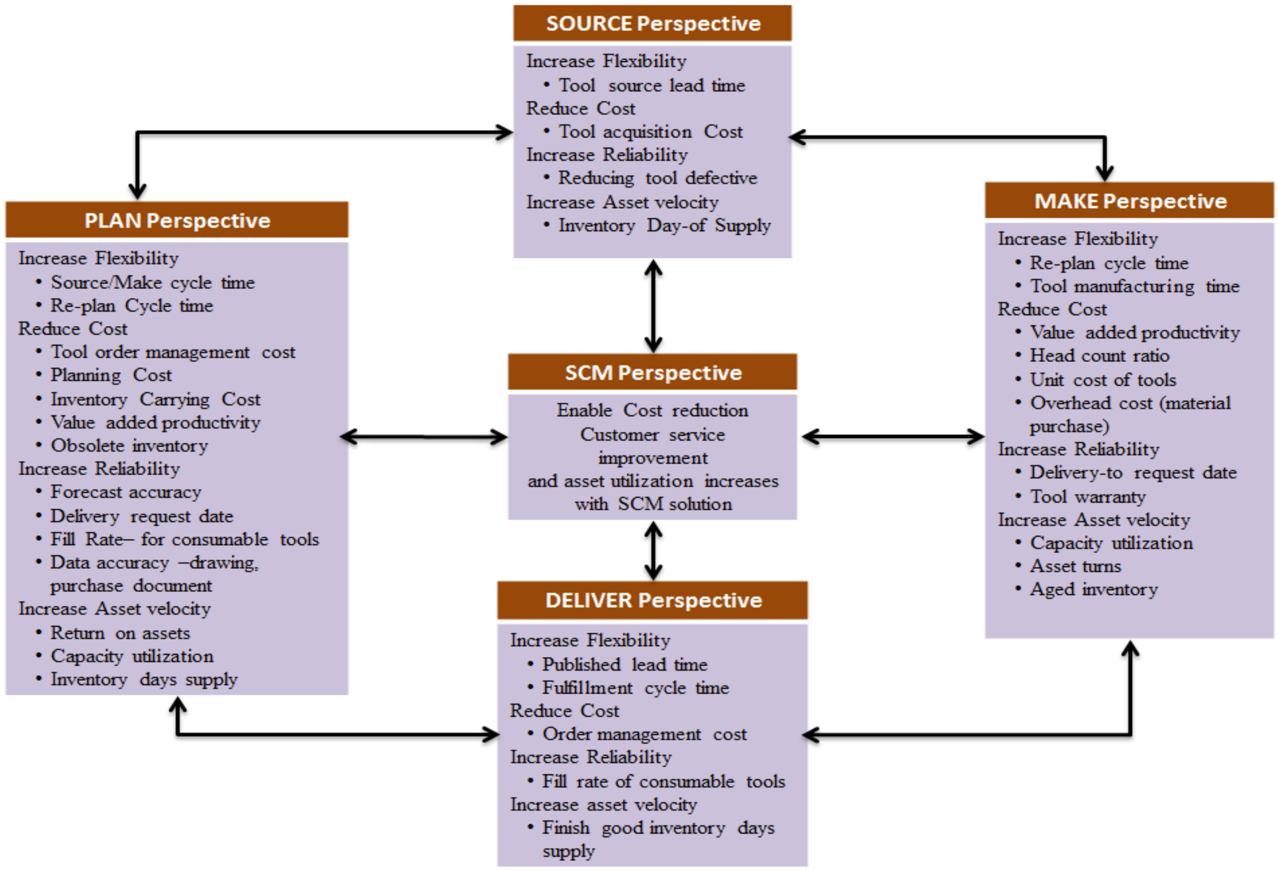


Figure 15: TE overall task requirements and its relationship through SCOR model



From the above developed SCOR model for Ethiopian Airlines-Tool Engineering section, the below points are covered when the model is used:

- ✓ The overall output of the above SCOR model is to enables cost reduction, to enhance: customer service, on-time delivery, quality service, asset utilization with supply chain management, & to reduce turn round time of the maintained aircraft, customer complain, etc.
- ✓ In the PLAN perspective of tool engineering SCOR framework: develop and planning tool requirements when aircrafts are introduced to the system. Define tool manufacture and suppliers that are qualified and recommended that provide aviation maintenance tools, beside secure loan agreement for those high asset tools. In this planning stage: maintenance tool flexibility enhance while sourcing tools trough purchasing or manufacturing, reduce costs, increasing flexibility, and enhancement of asset velocity on capacity utilization is done on the planning stages.

- ✓ In the Source Perspective of tool engineering SCOR framework: flexibility is increased while sourcing tools and comparison with its lead time, and reduce cost on the total acquisition cost if defined all tool requirements and sourced as a package form used to prevent unnecessary cost of shipment, communication, and etc. and reducing the tool defective as well.
- ✓ In the Make Perspective of tool engineering SCOR framework: flexibility also enhance on tool manufacturing lead time as tool manufacturing process is started before the aircraft maintenance time, and reduce tool purchasing cost if in-house tool manufacturing is done, besides it is one of the cost saving idea and also have a possibility to get currency if lending the tool to some other operators , as increase company asset value, increase reliability of tool warranty, and delivered to the requested date on-time .
- ✓ In the Delivery Perspective of tool engineering SCOR framework: tool should serviceable, complete, available and delivered on-time on the maintenance time, and flexibility enhanced, order management cost also reduce cost when it requested and delivered on time without expedite fee, and tool fill rate of consumable tools are increased as its inventory management techniques are enhanced.
- ✓ Due to the characteristics of tool engineering service that order planning process on tools are usually takes place when the service order information should be passed down along the supply chain, accurately, timely, and effectively. From this perspective Service Order entry method is vital as a metric of performance measurement of Ethiopian Airlines-Tool Engineering Supply Chain.
- ✓ Service order lead-time takes a great important in supply chain performance management and it is an influencing performance measure and source of the competitive process as in saving the order lead-time lead to improves in service supply chain response time, and improve the process efficiency.
- ✓ In order to achieve the qualified services demanded by the customers: other ET- engineering sections, technicians, PSCM and others ability to link and to collaborate effectively and efficiently with supply chains has become the issues of the supply chain management.
- ✓ A production performance is the series of activities carried out by Ethiopian Airlines Tool Engineering supply chain, and their performance has a significant impact on purchasing and manufacturing cost, quality, delivery reliability, and competence of the customer. Also, the production activities are the critical part of the total supply chain performance, and in this

context, the production performance is the essential part of the performance and it needs to be measured and improved continuously.

- ✓ Tool engineering organization which can produce wide range of engineering services should have sufficient enough resources and facilities; otherwise, the added value per employee will lead to less effective in performance than the strategically focused organization on product range of design and engineering.
- ✓ An effective of planning and scheduling of tool order is defined the set of activities to allocate tool engineering resources to perform the tasks over a given time to achieve the specific process objectives. Scheduling can have a significant impact on capacity utilization, process performance and customer satisfaction. It determines how the resources are to contribute effectively in the production processes.
- ✓ The performance of tool engineering supply chain is identified as the criteria of productivity, quality, agility and customer satisfaction. Also, the performance is measured and evaluated to fit with the strategic, operational and tactical level. Moreover, the performance metrics needs to include the categories of financial, financial/non-financial, and non-financial, as the part of the important performance criteria.

  **** Strategic level** of tool engineering includes and measures overall productivity, variation against budget, total cash flow time, order lead-time, and delivery performance.

  **** Tactical level** of tool engineering includes measures include accuracy of forecasting technique, supplier cost saving initiative, delivery reliability, order entry method, effectiveness of the master schedule, ability to respond to problems, responsiveness.

  **** Operational level** of tool engineering measures include cost per operation unit, supplier rejection rate, capacity utilization, quality of delivery, and delivery reliability.

With the above approaches of defining the measures and metrics dimension for evaluation of Ethiopian Airlines Tool engineering supply chain, and the hierarchical structure is structured for further process of SCOR+AHP performance measurement module creation.

4.5.2 Constructing AHP structure for tool engineering performance measurement

The performance evaluations in an engineering service supply chain specifically tool engineering section is complex and complicate tasks. The performance measurements involve multidimensional criteria, uncertainty and qualitative attributes that are difficult to measure directly.

According to (Buyukozkan G, Cifici Guleryuz, 2011), one of the most popular and effective multi-dimensional criteria evaluation method is Analytic Hierarchy Process (AHP) that has been used as a performance decision-making tool for years in a service sector. As AHP is a mathematical combination of pair-wise comparison models that reflect the primary weight of multi-dimensional problems

Moreover, it provides with an objective outcome for decision-making tool for solving the problems by a set of solution matrix. It was developed by Saaty in 1980, but it has been still effective and it has been used commonly in this field.

Step 1: **Selection of key performance criteria and sub-criteria**

The hierarchy structure of performance criteria and their performance metrics are established as described in below table, and three major performance criteria of *Tactical Level*, *Strategic Level* and *Operational Level* are settled up for major performance measurement framework of tool engineering supply chain in this case study. Those three criteria exemplify the accumulation of the metrics based on the practical working environment in agreement with the recent development of supply chain performance measures in aviation industry. The selected metrics are composed with the opinions and experiences of the design coordinators as well as design managers in the case company.

For the major criteria and sub-criteria performance data analysis and matrix calculation are conducted by mathematical computation that specialized in matrix calculation of business application for multi-criteria decision-making software. In this case study, the company AHP software has been utilized. The software program provides priorities, decision matrix and consistency ratios for analysis and decision-making solution on multi-criteria metrics.

The three selected key performance criteria's in this research and its sub-criteria's that decomposition are structured into two level hierarchy model as shown in the below table 15. These three criteria's are taken from other airlines as a benchmark.

Table 15: Tool engineering key performance criteria and Performance Metrics

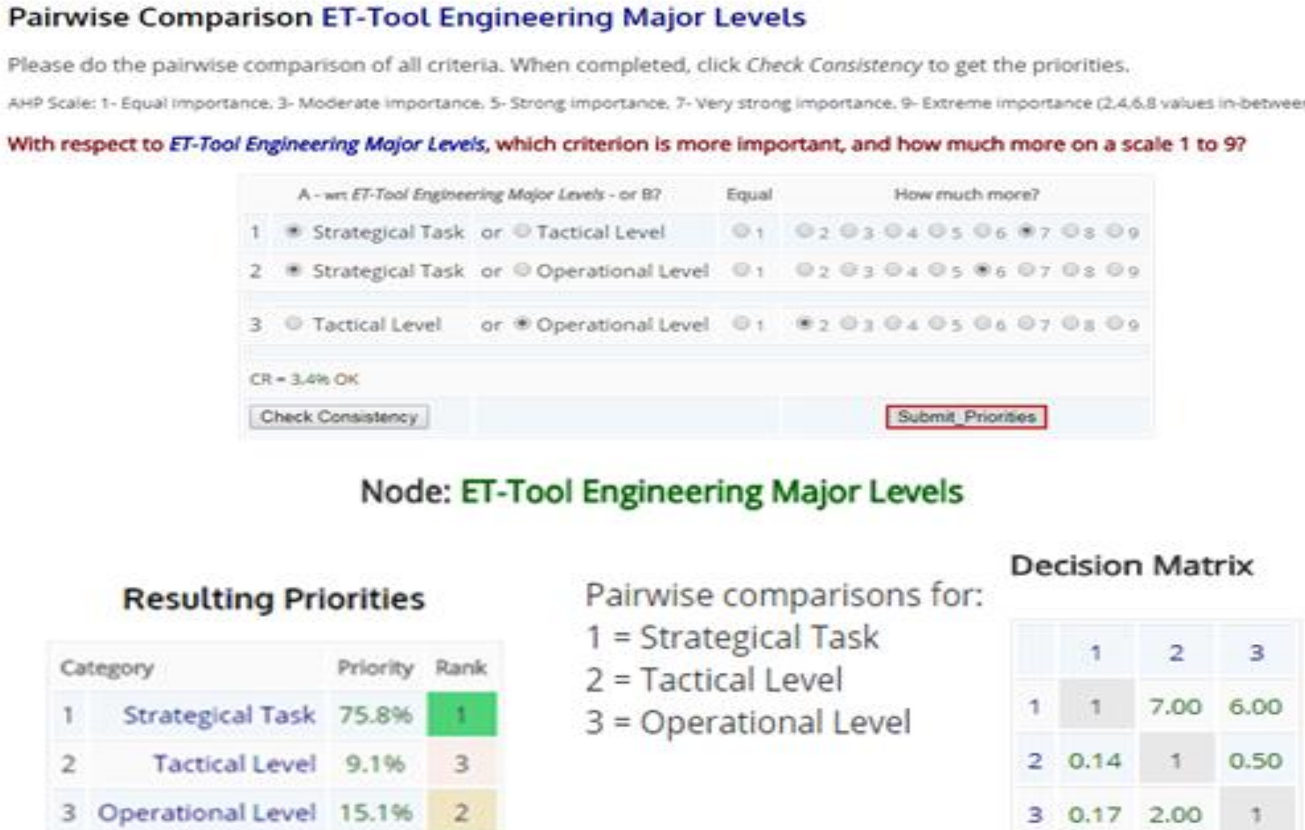
Tool Engineering Key Performance Criteria and Performance Metrics	
Tool engineering Key Criteria	***Tool engineering performance metrics***
Tool Engineering Overall Key Performance activities	❖ Strategic activities ❖ Operational activities ❖ Tactical activities
Strategic activities	❖ Productivity of the section ❖ Tool Purchasing/loan Variance against budget ❖ On-time delivery of tools ❖ Delivery flexibility for AOG tasks ❖ Defect free delivery of tools ❖ Tool order lead time
Operational activities	❖ Cost per manufacturing and purchasing time ❖ Capacity utilization ❖ Inventory management ❖ Effective scheduling ❖ Service delivery reliability
Tactical activities	❖ Cost saving initiative on alternative mechanism ❖ Purchase and manufacturing tool delivery reliability ❖ Tool order entry method ❖ Responsiveness on customer query ❖ On-time order fill rate

Step 2: **Overall key performance criteria priority weight and rating of tool engineering**

The Three tool engineering key performance criteria's: *Strategic Level*, *Tactical Level*, and Operation Level have been accepted out for the pairwise comparison design to define the relative priority weights and ratings in the section. The relative priority of the performance criteria has been based on the predefined priority scales by the discussion with the user section and other section which tool engineering section has a strong relationship. Below Figure shows how the comparison between the criteria has made and how the corresponding decision matrix, eigenvalue, consistency test result, and priority weight and ranking, are calculated.

The relative priority of the key performance criteria can be updated or benchmarked with the specific project by the decision of the management before execution of the actual project in due course.

Figure 16: Relativity priority weight of TE three key performance criteria's


Pairwise Comparison ET-Tool Engineering Major Levels

Please do the pairwise comparison of all criteria. When completed, click *Check Consistency* to get the priorities.

AHP Scale: 1- Equal importance, 3- Moderate importance, 5- Strong importance, 7- Very strong importance, 9- Extreme importance (2,4,6,8 values in-between).

With respect to *ET-Tool Engineering Major Levels*, which criterion is more important, and how much more on a scale 1 to 9?

	A - wrt *ET-Tool Engineering Major Levels* - or B?			Equal	How much more?
1	● Strategical Task	or	○ Tactical Level	○ 1	○2 ○3 ○4 ○5 ○6 ●7 ○8 ○9
2	● Strategical Task	or	○ Operational Level	○ 1	○2 ○3 ○4 ○5 ●6 ○7 ○8 ○9
3	○ Tactical Level	or	● Operational Level	○ 1	●2 ○3 ○4 ○5 ○6 ○7 ○8 ○9

CR = 3.4% OK

Check Consistency   Submit Priorities

Node: ET-Tool Engineering Major Levels

Resulting Priorities

	Category	Priority	Rank
1	Strategical Task	75.8%	1
2	Tactical Level	9.1%	3
3	Operational Level	15.1%	2

Pairwise comparisons for:
1 = Strategical Task
2 = Tactical Level
3 = Operational Level

Decision Matrix

	1	2	3
1	1	7.00	6.00
2	0.14	1	0.50
3	0.17	2.00	1

As the result, the priority weight and ranking of the key performance criteria are defined as: 1) Strategic task of 75.8%, 2) Operation task of 15.1%, and 3) Tactical task of 9.1% as showed on the above Figure 15.The resulting weights are based on the principal eigenvector of the decision matrix. This development result defines the collective performance criteria in supply chain performance management to manage with the tool engineering strategic planning of the project, where tool engineers, managers have to attain as the goal of the company objectives.

<u>Step 3:</u> **Tool engineering Strategic activity matrix priority weight and ratings (Sub-Criteria)**

Among the three key performance criteria that developed on Tool Engineering, the key performance criteria of Strategically activity consists of six key performance metrics of Productivity of tool engineering, tool purchasing and loan cost variance against budget, on-time delivery of tools, delivery flexibility for AOG and EO tasks, defect free delivery of tools and unavailable tools order lead time; those are inter-related and they are influenced to the key performance criteria. The six key performance parameters are passed through AHP pairwise comparison calculation to determine the weight and rating.

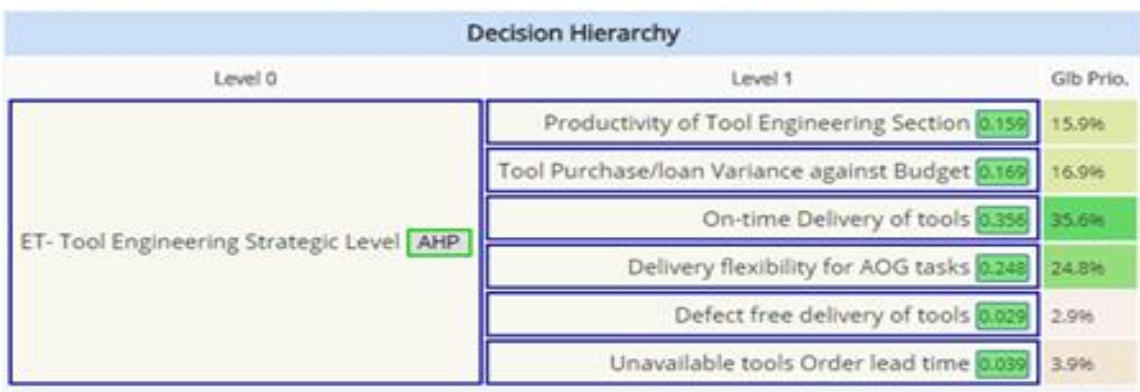
The strategic activities are relatively priority of tool engineering performance metrics that has been applied based on the predefined importance scales as the same practice for the key performance criteria. Figure 18 shows the result of tool engineering strategic level key performance criteria

As the same principle, the relative priority of the key performance metrics can be updated or benchmarked with the specific project by the decision of the management before execution of the actual project in actual process. As the results, the priority weights and rankings of each key performance metrics that embraced in Strategic actions are calculated and defined as: 1) On-time delivery of tool of 44.6%, 2) Delivery flexibility for AOG tasks of 24.8%, 3) Tool Purchase and loan cost variance against budget of 16.9%, 4) Productivity (effective servicing) 5) Unavailability tools order lead time of 3.9%, and 6) Defect free delivery of tools with 2.9%, as shown in Figure 17 below.

Figure 17: Relativity priority weight of TE Strategic level key performance criteria

Project: ET- Tool Engineering Strategic Level

ET- Tool Engineering Strategic Level Major requirements from user and company working process perspective.



Resulting Priorities

Category		Priority	Rank
1	Productivity of Tool Engineering Section	15.9%	4
2	Tool Purchase/loan Variance against Budget	16.9%	3
3	On-time Delivery of tools	35.6%	1
4	Delivery flexibility for AOG tasks	24.8%	2
5	Defect free delivery of tools	2.9%	6
6	Unavailable tools Order lead time	3.9%	5

Decision Matrix

	1	2	3	4	5	6
1	1	1.00	0.50	0.50	8.00	4.00
2	1.00	1	0.20	1.00	4.00	8.00
3	2.00	5.00	1	1.00	8.00	7.00
4	2.00	1.00	1.00	1	9.00	6.00
5	0.12	0.25	0.12	0.11	1	0.50
6	0.25	0.12	0.14	0.17	2.00	1

Step 4: **Tool engineering Operational activity matrix priority weight and ratings (sub-criteria)**

As the same process, the key performance metrics of corresponding Order progress performance of supply chain: 1) Cost per manufacturing and purchasing time, 2) Capacity Utilization, 3) Inventory management, 4) Effective scheduling, 5) Service delivery reliability, those are inter-related and they are influenced to the key performance criteria.an exclusive focus has been made to identify the relative weightings and ratings of the five key performance measures in the AHP's methodology. The performance metrics are the same as the key execution requirement, based on predefined prioritized scale, Figure 18 shows the outcome of the comparison between metrics and the corresponding decision matrix, eigenvalue, consistency ratio (CR), and priority weight and ranking.

Figure 18: Relativity priority weight of TE Operational level key performance criteria

Project: ET-Tool Engineering Operational Level

ET-Tool Engineering Operational level are focused on the specific procedure and process that occur in the section. And this is depend up on the company working process and the associated sections.

Decision Hierarchy

Level 0	Level 1	Glb Prio.
ET-Tool Engineering Operational Level AHP	Cost per manufacturing and purchasing time 0.463	46.3%
	Capacity utilization 0.089	8.9%
	Inventory Management 0.231	23.1%
	Effective scheduling 0.098	9.8%
	Service delivery reliability 0.119	11.9%

Resulting Priorities

	Category	Priority	Rank
1	Cost per manufacturing and purchasing time	46.3%	1
2	Capacity utilization	8.9%	5
3	Inventory Management	23.1%	2
4	Effective scheduling	9.8%	4
5	Service delivery reliability	11.9%	3

Decision Matrix

	1	2	3	4	5
1	1	5.00	2.00	4.00	5.00
2	0.20	1	0.50	1.00	0.50
3	0.50	2.00	1	3.00	2.00
4	0.25	1.00	0.33	1	1.00
5	0.20	2.00	0.50	1.00	1

As the results, the priority weights and rankings of each key performance metrics that embraced in Operation activity are calculated and defined as: 1) Cost per manufacturing and purchasing time rate of 46.3%, 2) Inventory management rate of 23.1%, 3) Service delivery reliability rate of 11.9%, 4) Effective scheduling rate of 9.8%, and 5) Capacity utilization rate of 7.8%, as shown in figure 18. This process result facilitates the common target of performance management criteria for the managers (design coordinators in case company-case section) to cope with the company strategy of the project, where the managers have to achieve as the goal of the business objectives.

Step 5: **Tool Engineering Tactical activity matrix priority weight and ratings (sub-criteria)**

As the same process, the key performance metrics of corresponding Service quality performance of supply chain: 1) Cost saving initiative on tool manufacturing and alternate mechanism, 2) Purchasing and manufacture tool delivery reliability, 3) Tool order entry method, 4) Responsiveness on customer query, and 5) On-time order fill rate Task defects rates, , those are inter-related and they are influenced to the key performance criteria. The four performance measurements have been made to compensate for the contrast in the AHP's analytical approaches based on the predefined priority scales. Figure 19 shows how the comparison between the criterions has made and the corresponding decision matrix, calculated eigenvalue, consistency ratio, and priority weight and ranking in this performance metric of supply chain. As the results, the priority weights and rankings of each key performance metrics that embraced in Tactical activity are calculated and defined as: 1) Responsiveness on customer query rate 46.5%, 2) Cost saving initiative on manufacturing and other mechanism rate of 32.3%, 3) Tool order entry method rate of 9.6%, 4) On-time order fill rate of 8.1%, and 5) Purchasing and manufacturing tool delivery reliability rate of 3.5% as shown below.

Figure 19: Relativity priority weight of TE Tactical level key performance criteria

Project: ET-Tool Engineering Tactical Level

ET-Tool Engineering Tactical level describe the organization plans to use to achieve the ambitions outlined in strategic plan. This depend on the company working process and affected sections.

Decision Hierarchy

Level 0	Level 1		Glb Prio.
ET-Tool Engineering Tactical Level AHP	Cost saving initiative tool manufacturing and	0.323	32.3%
	Purchase & Manufacture tool delivery Reliabil	0.035	3.5%
	Tool Order Entry method	0.096	9.6%
	Responsiveness on customer query	0.465	46.5%
	On-time order fill rate	0.081	8.1%

Resulting Priorities

	Category	Priority	Rank
1	Cost saving initiative tool manufacturing and	32.3%	2
2	Purchase & Manufacture tool delivery Reliabil	3.5%	5
3	Tool Order Entry method	9.6%	3
4	Responsiveness on customer query	46.5%	1
5	On-time order fill rate	8.1%	4

Decision Matrix

	1	2	3	4	5
1	1	9.00	5.00	0.50	4.00
2	0.11	1	0.20	0.11	0.50
3	0.20	5.00	1	0.17	1.00
4	2.00	9.00	6.00	1	5.00
5	0.25	2.00	1.00	0.20	1

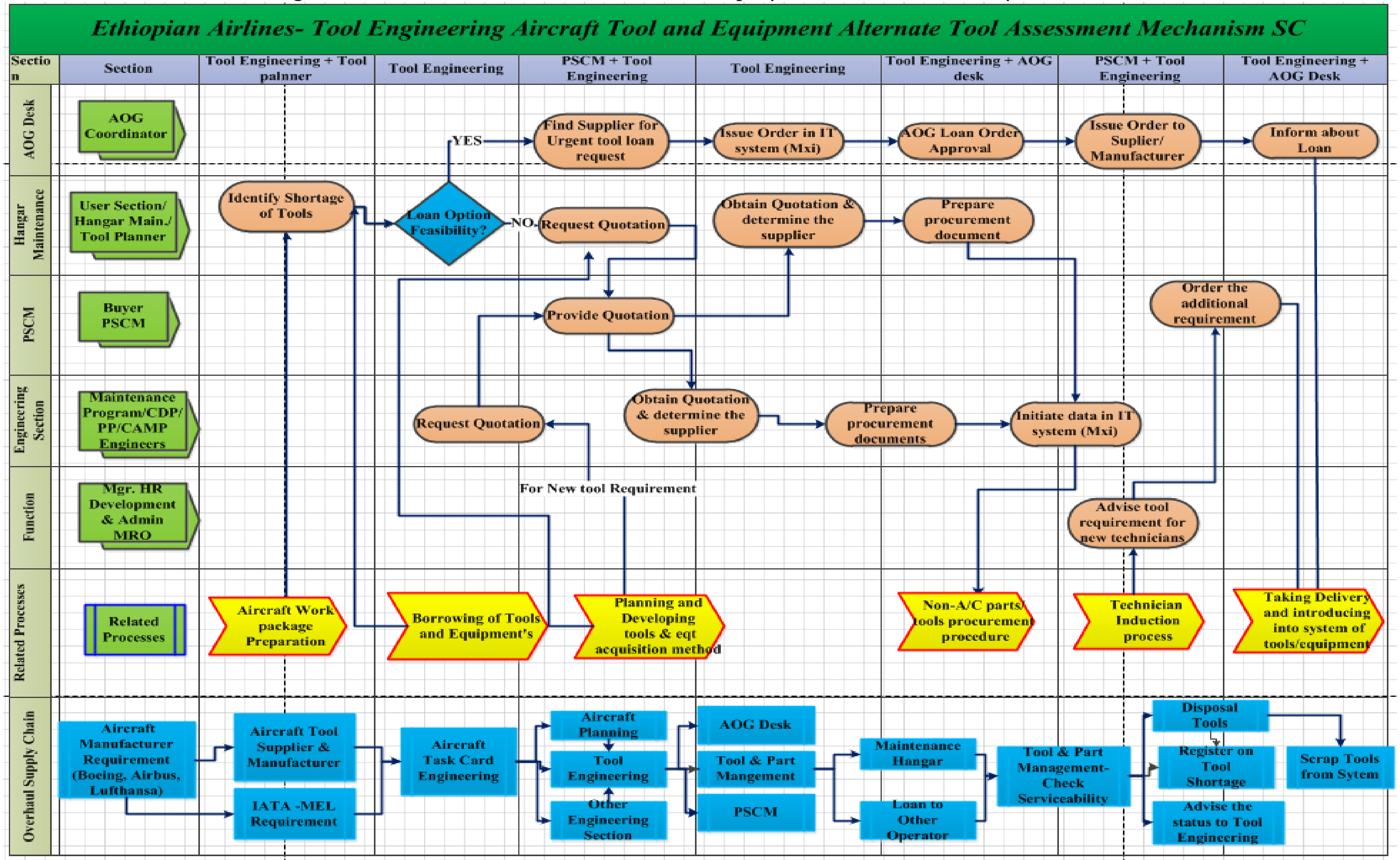
4 .6 Integrated Performance measurement of SCOR+AHP approach

From the above analysis, Ethiopian airlines tool engineering supply chain system and its integration within inter department and from external suppliers and customers are customized and summarized with Supply Chain Operation Reference (SCOR) model principle as a system of combining financial and nonfinancial measures of performance with the five perspectives of performance metrics as Plan, Source, Make, Delivery and Return perspective and give priority with Analytic Hierarchy Priority (AHP) principle as follows.

- **Strategic Level:** the primary goals and initiatives involved in EAL-TE section process that based on consideration of resources allocation and evaluation of internal and external customers and suppliers in which the section can compete.
    1. On-time delivery of tools
    2. Delivery flexibility for AOG tasks
    3. Tool purchase/loan variance against budget
    4. Productivity of tool engineering section
    5. Unavailable tools order lead time
- **Operational Level:** sit at the bottom of the totem pole; plans that are made by tool engineers. All operational plans are focused on the specific TE procedures and processes. Section team leaders and managers must plan the routine tasks of the department using a high level of detail.
    1. Cost per manufacturing and purchasing time
    2. Inventory Management
    3. Service Delivery reliability
    4. Effective scheduling
    5. Capacity utilization
- **Tactical Level:** managerial process of selecting among suitable ways and means of attaining a strategic plan or objective., and used to permits a manager to indicate the best methods or performance measurements for each process of chain that arises, rather than following a particular standard procedure on: 1. Responsiveness on customer query
    2. Cast saving initiative tool manufacturing and alternate evaluation methods
    3. Tool Order Entry method
    4. On-time order fill rate
    5. Purchase & Manufacture tool delivery reliability

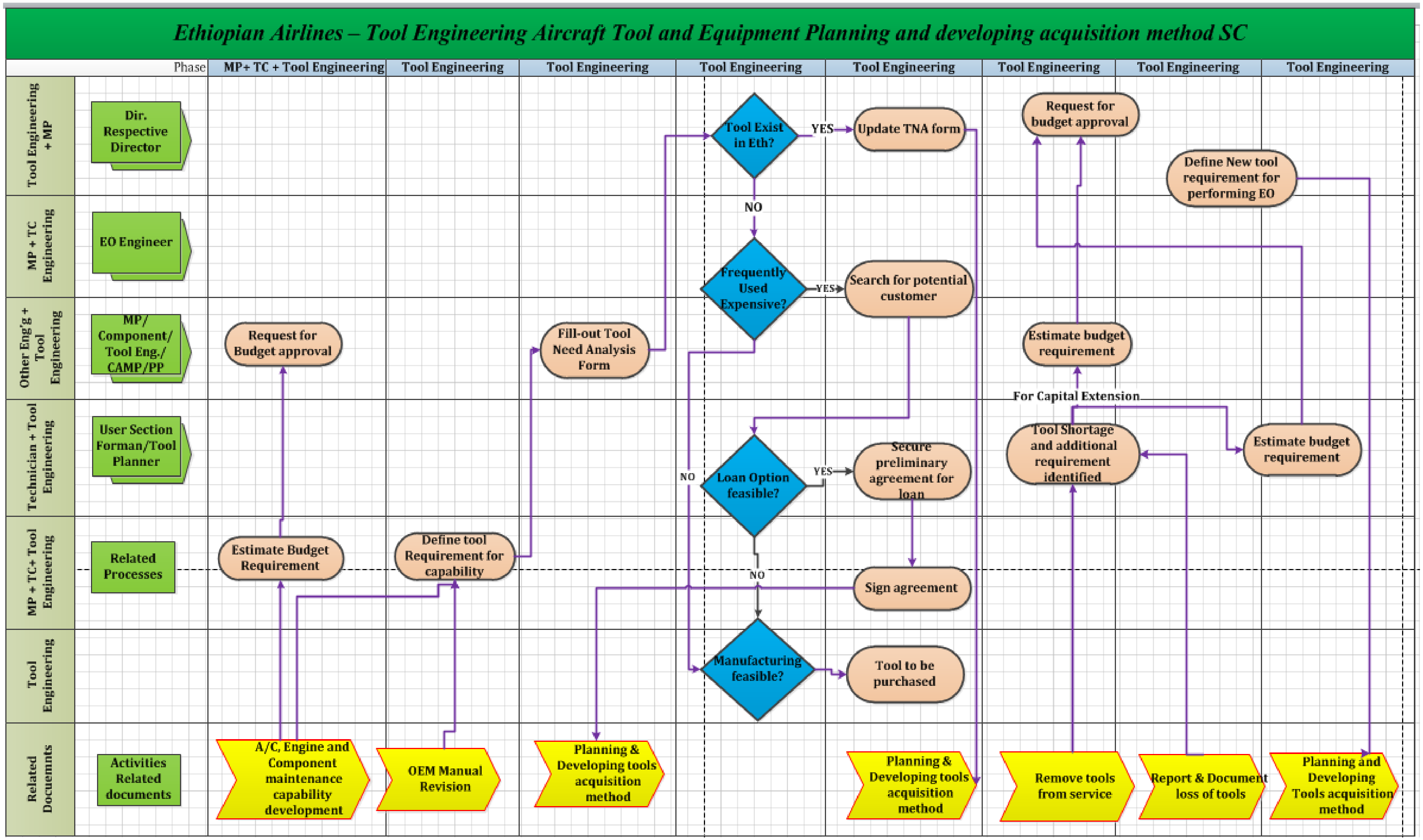
1] Ethiopian Airlines –Tool Engineering Aircraft Tool and Equipment Procurement Supply Chain System

Figure 20: EAL-TE A/C Tool Procurement SC performance enhancement framework



2] Ethiopian Airlines–Tool Engineering Aircraft Tool and Equipment Alternate Tool Supply Chain System

Figure 21: EAL –TE A/C Tool P & D acquisition performance enhancement framework



4.6.1 Major Function of Integrated Section

The below mentioned sections have a power and have a great impact on the improvement and have a power for the success implementation of the developed tool engineering performance measurement metrics and should be integrated to alive the model :

Aircraft Maintenance program & Task Card Engineering:

- ✓ Development of Maintenance Programs for aircraft, engines and components
- ✓ Development of Minimum Equipment List (MEL) to regulate dispatch of an aircraft
- ✓ Preparation of aircraft maintenance job cards that shows all steps inspection, overhaul, with defined requirements: tools, materials, parts, man-power and etc.
- ✓ Advice the overall aircraft maintenance tool requirements during aircraft entry to service time to evaluate further and to avail the tool on the future

Tool Engineering

- ✓ Evaluate and development for aircraft load carrying tools /Slings/equipment's program and proof load testing procedures per the manufacture advice
- ✓ Evaluate and development for those regular servicing request tools per the manufacturer and supplier tool maintenance manual
- ✓ Assessment of Maintenance Facilities, ground Support Equipment and Tooling Requirements
- ✓ Leads phase-in aircraft EIS (Entry in to service) projects mainly on aircraft tools that required for scheduled and unscheduled aircraft maintenance during new a/c introduction
- ✓ Develop and control Tool Need Analysis report (TNA) for scheduled and un-scheduled maintenance requirements for all Ethiopian operated fleets and customer aircrafts
- ✓ Evaluate and provide an assessment of maintenance facilities, ground support equipment and tooling requirement for aircraft capability development
- ✓ Design of special tools and/or test equipment by reviewing of manufacturer test procedures; or design specifications
- ✓ Develops alternate tool design, manufacture and authorizes equivalency certificate for damages, unavailable, unsafe tools to meet functional requirements
- ✓ Coordinate acceptance and support during receiving of tool and equipment, provides technical assistance to purchasing and suppliers management for tool and equipment warranty

Aircraft System Engineering Task:

- ✓ Performing Engine Monitoring & Diagnostics
- ✓ Handling engine Fleet Management
- ✓ Aircraft manufacturer airworthy directives and service bulletin monitoring , completion and reports preparation for the recommended critical tasks
- ✓ Reliability Analysis Modifications
- ✓ Incident/Accident Investigation / Assessment
- ✓ AC Configuration Management
- ✓ Give onsite technical assistance on some avionics related software's

Aircraft Maintenance Planning & Record Controls

- ✓ Define aircraft maintenance requirement based on the flight schedule (level of operation) or from the manufacture advice, and classified forecast with yearly, monthly, and 10 days.
- ✓ Prepare and post short term, mid-term and long term aircraft maintenance forecast on Ethiopian operated fleets and for other African total care supports airlines
- ✓ Prepare and release aircraft maintenance Man-hour Plan.
- ✓ Coordinate with commercial section to arrange ground maintenance time for passengers and cargo operated aircrafts maintenance checks.
- ✓ Define service level agreement (SLA) between major customers/suppliers of section and review the performance of the service level agreement through report
- ✓ Follow up, coordinate and monitor the timely performance of aircraft maintenance checks in base and line maintenance environment.
- ✓ Synchronizes with Integrated Operations Control Center (IOCC) to provide aircraft maintenance status and to get flight schedule for incoming or outgoing maintenance to/from maintenance hangar.
- ✓ Make sure the requirement part, tools and materials of aircraft maintenance work package are fulfilled
- ✓ Preparation of Job Cards or Customize third party customer Job cards per ET MRO standard for Maintenance, Overhaul, and Inspection requirements with task Procedures, Tools and Materials requirements after bid.
- ✓ Planning and Preparation of Work Package for aircrafts

Tool and Material Management

- ✓ Avail calibrated, serviced and operational tool to all hangar/dispatch maintenance
- ✓ Control and monitor the status of tools that are lent to Asky, Malawian, Camair, Equatorial Guinea, Rwandair, Congo air and other customer
- ✓ Controls the day to day binning and issuing of aircraft tools in accordance with established policies and procedure.
- ✓ Work with tool planners/material planners and production planners to confirm the availability, serviceability, and completeness

Production Planning

- ✓ Plan, forecast and schedules short and mid-term production plan, man power, man skill, skill requirements and hangar slot of scheduled and unscheduled maintenance
- ✓ Control compilation of aircraft records per industry standards and requirements of regulatory agencies carried out under respective hangars
- ✓ Establish maintenance performance standard
- ✓ Monitors maintenance trends by recording and analyzing utilized man hours to enhance productivity
- ✓ Ensures that the work packages are printed and delivered to hangar production controllers five days for c –checks and three days for A-checks ahead of aircraft input date.

4.7 Developed Framework Advantage

The aviation industry focused on reducing the maintenance cost, maintaining the highest level of utilization, and delivering the highest level of service. The above proposed model will have great opportunity to tool engineering section, other supporting section and for the company at all to do the maintenance operation smooth and effective since the output of one section will be the input for others. Moreover, the proposed developed model will answer those research questions that mentioned on Chapter one of this research.

The developed of SCOR+AHP integration can go into many levels of supply chain of tool engineering section in-detail; to analyze its supply chain performance measurement metrics. It gives companies an idea of how advanced its supply chain system is. The proposed chain helps Ethiopian airlines to understand how the five steps repeat over and over again between inter-departments, suppliers, the company, and customers. Each step is a link in the supply chain performance metrics that is critical in getting a product successfully along each level. The following major benefits will be gained from the developed supply chain performance model:

- **Enables supply chain performance and practice benchmarking**: Benchmarking and planning of tool engineering supply chain activities for aviation industries. The key measures include forecasting maintenance tool requirements, capacity management, analyses the maintenance demand patterns, addressing key bottlenecks like lead time, logistic, tool repair shop etc.
- **Used as tool Inventory Analysis** to determine the accuracy of stock, the quantity of items and its values. The aircraft industry is capital intensive with low profit margins; hence keeping an optimized inventory is very important. The value of the stock & the volumes are analyzed. The historical records are kept for analysis.
- **Track Lifecycle of aircraft maintenance cycle** using this developed model: the tools life cycle are managed with predictive alerts. Know when the tool is due for preventive maintenance or is past its useful life with predictive notifications. The items are tracked on a regular basis for proactive replacement of critical items.
- **Improves Company Productivity:** it is obvious that if aircraft availability for flight increased and reducing aircraft time at hangar for maintenance purpose without affecting maintenance operation, revenue will be generated and company productivity will be increased alongside. Proper utilization of resources will also have direct positive impact on the productivity and efficiency of the company. This is therefore, resource consumption at each stage of production planning and aircraft maintenance, and mainly tool engineering section tool availability will plays direct impact on aggregate effect on company's productivity.
- **Reducing Turnaround Time (TAT):** if maintenance work package commencement for tool engineering section released on time, lot of proactive preparation can be done and everyone will be aware of the maintenance check which will be executed and respective section will take proper plan accordingly during pre-event preparation. During actual execution, tool engineers will follow critical hold ups and provide quality, durable and assist technicians on spot directly that leads to minimize and optimize aircraft turnaround time
- **Manufacturer and Vendor Management** are integrated**;** the developed supply chain performance measurement model helps to communicate with tool manufacturer and managing them transparently. The integration of quality, flexibility, delivery time, warranty, durability, effectiveness of tools needs to ensure best results to achieve operational success.

- **Invoicing, Bills and stock management** of tools can be done with high accuracy. The invoices from multiple tool suppliers, manufactures from different countries are managed on a single platform. Ensure quality checks, receiving inventory items, flexibility and delivery time and processing tool purchasing using an integrated interface.
- **Boost Customer Service**: as the customer expect the correct tool assortment and assistance with quality tool deliveries, and availability at the right time, then the customer satisfies and will forward their aircraft for maintenance; and it is a great opportunity for Ethiopian airlines.
- **Delivering Airworthy aircraft:** if the maintenance tool is evaluated, availed either through purchasing or manufacturing or through alternate mechanism using them developed supply chain performance measurement, and the tool will has a feature of quality, flexibility, applicability, durability and warranty that will lead the maintenance personnel to work safely and release an airworthy aircraft into system. This will foster high safety margin for aircraft itself and for passenger and crew members.
- **Smooth Information/Material/Financial Flow:** since each section have its own communication flow and supply chain that, this proposed will decrease the request response time and makes room time and smooth flow for preparation for each departments. The information gained from each section will covers aircraft maintenance tool status, completeness, serviceability, quality, delivery time, manpower availability, content of maintenance work packages, hangar slot, ground service availability and facility handling, etc. Hence every department on the system loop may perform their intended function on time by taking those mentioned information as an input.
- **Reducing Operating cost**: this include decreasing of purchasing cost as if tool engineering used the proposed supply chain measurement model and will released to purchase the tool on time or manufacture or advice an alternate for it is on time are used as a preventive mechanism from incurring unnecessary expedite free, production fee of the required tools.
- **Responses for Critical hold ups**: during the actual maintenance execution related to tools, critical issues may happen that will potentially affect the allotted ground time for that particular project. In this case, respective fleet tool engineers will work solve the issue in short period of time as he/she defined an alternate methods/tools before the aircraft is inducted to hangar.
- Other related benefits of the developed supply chain performance model are; Enhance tool quality, Resource Management, Employee (tool engineers) satisfaction increase, Loan and manufacturing cost decrease, Reduce customer complies, Improve stock item controlling

mechanism, Reduce number of defect tools, Establishes a common repository of supply chain performance terms and toolsets, to identify supply chain problem easily, to enabling IT capability to optimize the supply chain measurement metrics through Maintenix (MXi), to identify a set of relevant KPIs to track for the company business result, To make standardized multi-level process performance metrics of tool engineering, to evaluate how well business goals are being met based on the performance indicators, to makes standardized supply chain process reference model and used as a reference for other supporting sections,

The developed SCP measurement model ensures not only optimized inventory, stock, streamlined procurement and improvised operations. Besides improved aircraft turnaround time, better insurance and contract managements resulting on the overall performance and productivity enhancement of Ethiopian airlines, and for unscheduled maintenance it has improved significantly on its performance and turnaround time.

4.8 Research Summary

SCPM is a fast gaining prominence in the aviation industry. There are constant pressures to reduce costs as competition, globalization as well and increasing fuel price set into play. This study was aimed at exploring the supply chain performance measures employed by Ethiopian Airlines-Tool Engineering section; and to identify the challenges encounter in measuring SCP.

Analysis of data obtained from the respondents and from the secondary data is revealed that the company has in place several objectives that it pursues as it works towards achieving its mission. The most important thing to be considered in tool engineering section is service standard delivery and providing the highest level of customer satisfaction. Other objectives include; developing a performance measurement model that delivers consistent level of profitability of the company.

Also highlighted in the study are some of the competitive strengths that tool engineering section should have in order to effectively and efficiently provide service for aircraft maintenance. These including: Reliability, Conformance, Durability, Serviceability, on time delivery of maintenance tools in order to minimize aircraft delay, and enhancement of internal and external customer satisfaction, harmonization and passenger security.

The company measures supply chain performance using the following dimensions; Quality of Purchases, Effectiveness of the procurement activities such as: Logistics, sourcing, negotiations, Stock turnover, number of supplies rejections, cost of materials/items, Flexibility of suppliers to changing demands pattern, supplier lead times, response time to user demands, no of days taken to clear imported non stocked tools. The equivalent indicators for these dimensions are over-consuming materials, buying and selling stocks and level of stock out, on time deliveries, excessive tools and other related metrics. Ethiopian airlines tool engineering section tasks and its supply chain performance measurements brings about several challenges, such as: customer value link measurement difficulty, uncertainty between supply chain partakers , difficulties to point performance results on particular team of the chain, organizational system and process inflexibility, cross functional conflict, distortion and incapable of information systems and primary measure of use of cost.

However, despite these challenges, tool engineering derives a lot of benefits from the developed framework of effective supply chain performance measurement. These benefits include: enhance customer satisfaction, reduce aircraft delay, achieving superior product quality, helps management in revising business goals, and reengineering business processes for competitive advantage, cost competitiveness, enhanced delivery performance. Performance measures can help identifies problems related to chain performance, better asset managed, short circuiting cycle for orders, improving link between members, and distinguishing success and potential of management strategies, and facilitating understanding of progress and position.

CHAPTER FIVE
CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The main contribution of research is to use SCOR principle to identify connections and logistics in the maintenance link chain within aircraft tooling servicing of aircraft maintenance organization, which particularly involved the application of the SCOR Model in all its stages of implementation, depending on the relationship level, identifying key performance indicators for supply chain disruptions and identifying what causes them, such as the link in the supply or supply, related to the achievement of the basic tool availability.

Generally, the SCOR model is a powerful tool of analysis to support the definition of competitive strategies for Ethiopian airlines. There will be many opportunities for improving the supply chain performance in the aviation area, and the overall supply chain management.

This research contributes to managerial insights as well as the theoretical implementation in the following aspects:

- ✓ Provide managerial implication with the physical measures and measurement solution by linking the SCOR perception and AHP methodology to articulate the measurement and metrics for managers to assess the supply chain process and to evaluate the performance in a systematic way of approach. The proposed SCP measurement framework facilitates the managers with the effective and efficiency measurement system as a common decision-making tool to align the objectives of the company strategy.
- ✓ This research employs the methodological approach by transforming the sub-criteria, key criteria and object module into the hierarchy of AHP model. Three SCOR+AHP modules are established for the most proper representation of the relevant key performance of the dedicated supply chain by formulation and integrating the multi-dimensional characteristics into each SCOR+AHP module. The performance metrics are inter-related and influenced each other, and they are eventually affected to the specific performances with the different level of weights. Therefore, the approach of this case study by identify, formulating, integrating of performance criteria, and transforming of the performance metrics into the SCOR+AHP model enables to articulate the supply chain performance more systematically.

- ✓ This research has been devoted to motivate researchers and practitioners to develop further in this area. This framework of performance measurement for tool engineering supply chain will be beneficial to researchers and corporate managers in identifying the opportunities for improvements in tool engineering supply chain performance.

Performance measurement in Ethiopian airlines tool engineering supply chain is not much developed and implemented in Ethiopian airline. Thus, this research is unique in some extent and contributes to aircraft maintenance aviation industry especially MRO tool engineering section.

5.2 Recommendation

Based on the current practices of tool engineering supply chain management process, their performance measurement metric, and from the findings reached it is better to implement and used the developed supply chain performance measurement model (SCOR+AHP). And if the company applies the new developed supply chain performance measurement model, the airlines will have effective aircraft maintenance time, internal and external customer satisfaction and other benefits that explained on the previous chapter and on the conclusion part in detail. In the same manner there are general recommendations that have high impact so as to minimize the aircraft turnaround time. The following points are suggested:

- ✓ The company need to develop and implement effective performance measurement approaches and appropriate performance measures and metrics for tool engineering supply chain based in the expertise of the research
- ✓ Tool Engineering have to be structured in hierarchy of metrics and measures in association with the key performance objectives and criteria to fit AHP analysis
- ✓ Recognized tool engineering three key performance modules (Strategically, Operational, Tactical) that level to fit SCOR+AHP approached that used to represent the performance of tool engineering supply chain.
- ✓ The key performance metric of each SCOR+AHP module has been defined the formulation on how to measure and evaluate the influences with the priority weights that are mathematically determined by pair-wise comparison method by Saaty’s nine scale ratings
- ✓ There should be standard operating procedure and service level agreement for those core processes of each department and should be revised continuously for improvement

- ✓ Avoiding local objectives and strive for common goal so that the company will achieve its target plan.

Aircraft maintenance service industry, special tool engineering service is characterized by continuous extension in supply chain outsourcing due to the globalization strategy and technological advancements. Therefore, implementation of effective performance measurement in aircraft maintenance organization supply chain emerge an essential tool to cope with these challenges. Beside the performance measurement of aviation industry supply chain is one of the critical topics for improvement of supply chain performance and managerial competitiveness.

5.3 Suggestion for Further Research

Supply chain performance measurement is the best concept that is fast gaining recognition in the aviation maintenance organization. The research design in this scenario was a case study on Ethiopian Airlines-Tool Engineering section. However, a survey should be conducted to determine the overall supply chain management and enforcement actions in the aviation industry entire operation. Moreover, the airline industry by its nature has a lot of environmental impact. As a general rule, the air transport system is based on major of the requirements, so multi criteria decision making tools, such as AHP, Fuzzy, DEA that can be used in order to develop and evaluate the overall performance of supply chain management as the supply chain management is an advanced and a possible idea that allow businesses to get know-how on their supply chain performance. This shows that there is a need to develop a model that reflects the impact of changes immediately though this impact would only reflect to the degree to which the criteria are important.

Developed models must identify and include all the essential requirements for the aviation industry's overall supply chain management performance

- ✓ Model should measure effective and efficient management across all supply chain initiatives in the overall aviation industry supply chain.
- ✓ The model should be used to evaluate the performance of the organization and benchmark its performance both externally and internally for the ultimate goal of continuous improvement.
- ✓ Model should also be beneficial even with a business model or size.

Further in-depth research also can be suggested on the development of evaluation approaches for the measures and metrics of tool engineering supply chain, that includes uncertainty, agility, responsiveness, sustainability, organizational culture, and human resource attributes.

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APPENDIX

The purpose of this questionnaire is for MSC thesis fulfillment. This questionnaire asks regarding to tool engineering supply chain performance measurement according to your experience so far. Your responses will be anonymous; your participation is absolutely voluntary. If there are items which are not related with your work areas please skip them. Thank your in advance for your cooperation!

Part 1: Background Information

1. Respondents Name (Optional)..

2. Section: ……............................... 3) Work Year…………..

5. Position: ………………………… 5) Assigned Fleet………..

6. In general terms, what is the strategic role of your department/section in the airline's operations? (Tick where appropriate).

   a) Core to the Ethiopia Airlines Maintenance operations ☐

   b) Supportive ☐

   c) Advisory ☐

   d) Other (specify)...................................

Part B: Supply Chain Integration.

1. Does a tool engineering supply chain firm establish more frequent contact with your section? Please forward your valuable ideas.

   ☐ Strongly Disagree ☐ Somewhat Disagree ☐ Neither agrees nor disagrees
   ☐ Somewhat Agree ☐ Strongly Agree

2. Does tool engineering section supply chain system create a compatible communication and information system while giving service? Please forward your valuable ideas.

   ☐ Strongly Disagree ☐ Somewhat Disagree ☐ Neither agrees nor disagrees
   ☐ Somewhat Agree ☐ Strongly Agree

3. Does tool engineering firm extends its supply chain beyond your expectation? Please forward your valuable ideas.

   ☐ Strongly Disagree ☐ Somewhat Disagree ☐ Neither agrees nor disagrees
   ☐ Somewhat Agree ☐ Strongly Agree

4. Does tool engineering participates in the critical issues and provide a good maintenance and support up on your request? Please forward your valuable ideas.

☐ Strongly Disagree ☐ Somewhat Disagree ☐ Neither agrees nor disagrees
☐ Somewhat Agree ☐ Strongly Agree

5. Does tool engineering participation in the sourcing decisions of its customers/suppliers and make a close follow up? Please forward your valuable ideas.

☐ Strongly Disagree ☐ Somewhat Disagree ☐ Neither agrees nor disagrees
☐ Somewhat Agree ☐ Strongly Agree

Part C: Performance measurement dimensions of tool engineering.

1. Based on the scale provided, what relative importance does Tool Engineering section place on the following dimensions?

   1 - Strongly Disagree 2 - Somewhat Disagree 3 - Neither agrees nor disagrees,
   4 - Somewhat Agree 5- Strongly Agree

No	**Dimension**	**1**	**2**	**3**	**4**	**5**
1)	Ability to respond to and accommodate demand variations, such as seasonality [un/scheduled, AD, EO]. - Responsiveness (Customer query time)					
2)	Manufacturing/Loan/Purchasing lead times to avail maintenance tool - effectiveness of scheduling techniques					
3)	Customer Complaints - Customer Service					
4)	Quality of Purchases'/Manufacturing/ Loan tools – Quality					
5)	Response time to user demands on regular time					
6)	Flexibility of the section while changing demands pattern					
7)	Days taken to clear imported non stocked items - Inventory Management					
8)	On time tool order fill rates					
9)	Cost associated with held inventory					

2. For each of the areas you have highlighted as very important in part C, list three (3) vital performance indicators that you measure as provided in the table below.

Dimension	**Indicators**	**Dimension**	**indicators**
1)		6)	
2)		7)	
3)		8)	
4)		9)	
5)			

PART D: Performance Measurement Challenges and Benefits

13. In your view what do you believe are some of the challenges that Tool Engineering is currently facing while carrying out supply chain performance measurement and write your expectation?

Dimension	**Your Challenges on Tool Engineering**	**Your Expectation and performance measurement indicators**
1)		
2)		
3)		
4)		
5)		

Pairwise Comparison AHP-OS

Pairwise Comparison ET-Tool Engineering Major Levels

Please do the pairwise comparison of all criteria. When completed, click *Check Consistency* to get the priorities.

AHP Scale: 1- Equal Importance, 3- Moderate importance, 5- Strong importance, 7- Very strong importance, 9- Extreme importance (2,4,6,8 values in-between).

With respect to *ET-Tool Engineering Major Levels*, which criterion is more important, and how much more on a scale 1 to 9?

	A - wrt *ET-Tool Engineering Major Levels* - or B?		Equal	How much more?
1	◉ Strategical Task	or ○ Tactical Level	◉ 1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
2	◉ Strategical Task	or ○ Operational Level	◉ 1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
3	◉ Tactical Level	or ○ Operational Level	◉ 1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9

Pairwise Comparison ET- Tool Engineering Strategic Level

Please do the pairwise comparison of all criteria. When completed, click *Check Consistency* to get the priorities.

AHP Scale: 1- Equal Importance, 3- Moderate importance, 5- Strong importance, 7- Very strong importance, 9- Extreme importance (2,4,6,8 values in-between).

With respect to *ET- Tool Engineering Strategic Level*, which criterion is more important, and how much more on a scale 1 to 9?

	A - wrt *ET- Tool Engineering Strategic Level* - or B?		Equal	How much more?
1	◉ Productivity of Tool Engineering Section	or ○ Tool Purchase/loan Variance against Budget	◉ 1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
2	◉ Productivity of Tool Engineering Section	or ○ On-time Delivery of tools	◉ 1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
3	◉ Productivity of Tool Engineering Section	or ○ Delivery flexibility for AOG tasks	◉ 1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
4	◉ Productivity of Tool Engineering Section	or ○ Defect free delivery of tools	◉ 1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
5	◉ Productivity of Tool Engineering Section	or ○ Unavailable tools Order lead time	◉ 1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
6	◉ Tool Purchase/loan Variance against Budget	or ○ On-time Delivery of tools	◉ 1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
7	◉ Tool Purchase/loan Variance against Budget	or ○ Delivery flexibility for AOG tasks	◉ 1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
8	◉ Tool Purchase/loan Variance against Budget	or ○ Defect free delivery of tools	◉ 1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
9	◉ Tool Purchase/loan Variance against Budget	or ○ Unavailable tools Order lead time	◉ 1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
10	◉ On-time Delivery of tools	or ○ Delivery flexibility for AOG tasks	◉ 1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
11	◉ On-time Delivery of tools	or ○ Defect free delivery of tools	◉ 1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
12	◉ On-time Delivery of tools	or ○ Unavailable tools Order lead time	◉ 1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
13	◉ Delivery flexibility for AOG tasks	or ○ Defect free delivery of tools	◉ 1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
14	◉ Delivery flexibility for AOG tasks	or ○ Unavailable tools Order lead time	◉ 1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9

Pairwise Comparison ET-Tool Engineering Tactical Level

Please do the pairwise comparison of all criteria. When completed, click *Check Consistency* to get the priorities.

AHP Scale: 1- Equal Importance, 3- Moderate importance, 5- Strong importance, 7- Very strong importance, 9- Extreme importance (2,4,6,8 values in-between).

With respect to *ET-Tool Engineering Tactical Level*, which criterion is more important, and how much more on a scale 1 to 9?

	A - wrt *ET-Tool Engineering Tactical Level* - or B?		Equal	How much more?
1	◉ Cost saving initiative tool manufacturing and	or ○ Purchase & Manufacture tool delivery Reliabil	◉ 1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
2	◉ Cost saving initiative tool manufacturing and	or ○ Tool Order Entry method	◉ 1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
3	◉ Cost saving initiative tool manufacturing and	or ○ Responsiveness on customer query	◉ 1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
4	◉ Cost saving initiative tool manufacturing and	or ○ On-time order fill rate	◉ 1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
5	◉ Purchase & Manufacture tool delivery Reliabil	or ○ Tool Order Entry method	◉ 1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
6	◉ Purchase & Manufacture tool delivery Reliabil	or ○ Responsiveness on customer query	◉ 1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
7	◉ Purchase & Manufacture tool delivery Reliabil	or ○ On-time order fill rate	◉ 1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
8	◉ Tool Order Entry method	or ○ Responsiveness on customer query	◉ 1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
9	◉ Tool Order Entry method	or ○ On-time order fill rate	◉ 1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
10	◉ Responsiveness on customer query	or ○ On-time order fill rate	◉ 1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9

Pairwise Comparison ET-Tool Engineering Operational Level

Please do the pairwise comparison of all criteria. When completed, click *Check Consistency* to get the priorities.

AHP Scale: 1- Equal Importance, 3- Moderate importance, 5- Strong importance, 7- Very strong importance, 9- Extreme importance (2,4,6,8 values in-between).

With respect to *ET-Tool Engineering Operational Level*, which criterion is more important, and how much more on a scale 1 to 9?

	A - wrt *ET-Tool Engineering Operational Level* - or B?		Equal	How much more?
1	◉ Cost per manufacturing and purchasing time	or ○ Capacity utilization	◉ 1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
2	◉ Cost per manufacturing and purchasing time	or ○ Inventory Management	◉ 1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
3	◉ Cost per manufacturing and purchasing time	or ○ Effective scheduling	◉ 1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
4	◉ Cost per manufacturing and purchasing time	or ○ Service delivery reliability	◉ 1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
5	◉ Capacity utilization	or ○ Inventory Management	◉ 1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
6	◉ Capacity utilization	or ○ Effective scheduling	◉ 1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
7	◉ Capacity utilization	or ○ Service delivery reliability	◉ 1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
8	◉ Inventory Management	or ○ Effective scheduling	◉ 1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
9	◉ Inventory Management	or ○ Service delivery reliability	◉ 1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
10	◉ Effective scheduling	or ○ Service delivery reliability	◉ 1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9

Glossary

Key performance indicators (KPIs) are business metrics used by corporate executives and other managers to track and analyze factors deemed crucial to the success of an organization. Effective KPIs focus on the business processes and functions that senior management sees as most important for measuring progress toward meeting strategic goals and performance targets.

Inventory management is the supervision of non-capitalized assets (inventory) and stock items. A component of supply chain management, inventory management supervises the flow of goods from manufacturers to warehouses and from these facilities to point of sale. A key function of inventory management is to keep a detailed record of each new or returned product as it enters or leaves a warehouse or point of sale.

Metric: In software development, a metric (noun) is the measurement of a particular characteristic of a program's performance or efficiency. Similarly in network routing, a metric is a measure used in calculating the next host to route a packet to. A metric is sometimes used directly and sometimes as an element in an algorithm . In programming, a benchmark includes metrics. And, Metric (adjective) pertains to anything based on the meter as a unit of spatial measurement.

Strategic Management: involves the formulation and implementation of the major goals and initiatives taken by a company's top management on behalf of owners, based on consideration of resources and an assessment of the internal and external environments in which the organization competes

Operational plans**:** sit at the bottom of the totem pole; they are the plans that are made by frontline, or low-level, managers. All operational plans are focused on the specific procedures and processes that occur within the lowest levels of the organization. Managers must plan the routine tasks of the department using a high level of detail.

Tactical Plan: administrative process of selecting among appropriate ways and means of achieving a strategic plan or objective. The use of tactical management in a business environment allows a manager to choose the best tactics or methods for each situation that arises, rather than following a particular standard procedure.

SCOR is an acronym for supply chain operations reference model, which was developed to assist businesses in understanding, structuring, and evaluating the performance of supply chains.

Performance attribute: a characteristic used to describe a strategy. Performance attributes serve as classification for metrics and formulate strategic direction