THESIS

SUPPLY CHAIN MANAGEMENT FOR SUSTAINABILITY OF AVIATION MRO INDUSTRY IN INDIA- A STUDY

BY

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UNDER THE GUIDANCE OF

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DECLARATION BY SCHOLAR

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person nor material which has been accepted for the award of any other degree or diploma of the university or other institute of higher learning, except where due acknowledgment has been made in the text.

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CERTIFICATE BY THESIS SUPERVISORS

This is to certify that the thesis entitled **Supply Chain Management For Sustainability Of Aviation MRO Industry In India- A Study** submitted by Chintaman S Sohoni SAP ID 500030884 to University of Petroleum and Energy Studies for the award of the degree of Doctor of Philosophy is a bona fide record of the research work carried out by him under our supervision and guidance. The content of the thesis, in full or parts have not been submitted to any other Institute or University for the award of any other degree or diploma.

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ACKNOWLEDGEMENT

I have been working on Maintenance, Repair and Overhaul (MRO) of fighter aircraft during my service in the Indian Air Force. I realized as I grew in service that in the Civil Aviation segment also there is a need for a good Indian MRO. I therefore decided to map my experience to the civil aviation segment mainly to enable Indian MROs to grow. I chose this topic only for that reason.

I had the privilege of working with two very good supervisors in Dr Ajit Nigam and Dr Sourabh Tiwari who relentlessly helped me in this endeavor of mine and not only helped me with the thesis but also successfully converted a Military man like me into an academician. I shall ever remain grateful to them for their contribution to my cause.

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I gratefully acknowledge the help and guidance I have received from my external supervisor Air Cmde (Dr.) Sanjay Kumar in identifying major issues with Indian Aviation Industry in General and Aviation MROs in particular. I also take this opportunity to acknowledge the support received from Gp Capt (now Air Cmde) Jaison Jose who provided library and other facilities of the IAF.

Finally I must also express my gratitude towards my wife Usha and daughter Chaitalee who kept pushing me in completing my thesis writing targets.

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EXECUTIVE SUMMARY

Introduction

Maintenance Repair and Overhaul (MRO) activity in the aviation sector has been done by the airlines themselves. They hardly outsourced any work to independent agencies. This has changed over time with increasing costs of fuel and other services. This has led to development of Specialist MRO companies, who use the high volumes of their work and specialisation to reduce costs. (Borkowski, 2005)

India has capability to be the third biggest aviation market by 2020. They can become the largest by 2030. (KPMG Report on Indian aviation sector , 2014) Indian carriers already have plans to increase fleet size to around 800 aircrafts by 2020. Domestic traffic is expected to reach 160 million to 180 million by 2020, with international traffic going up in excess of 50 million. Indian civil aviation industry rates in the top 10 in the world with a size of Rs. One trillion. However, India's present MRO market, which is around Rs 45 billion, is mostly carried out abroad. India's MRO segment will further grow at about 10% per year reaching Rs. 12 billion in the next 8-10 years. The volume of MRO work sent out of India is US$475 Million (Airframe Maintenance $30M, Engine Maintenance $300M, Component Work $125M and APU work $20M) (Mathews, 2012). In comparison Indian cost of labour is about 40% less than those in Middle East or even Southeast Asia. The difference much higher when compared to Europe of USA. Therefore, India has the potential to service not just Indian aircraft but also those from neighbouring regions. (Research and Markets)

Supply Chain Management needs a very high consideration by the MRO industry as spare requirement exists in all the three aspects of MRO, namely, Maintenance, Repair and Overhaul. This is explained below.

(a) Maintenance. For scheduled major maintenance activities, (other than overhaul) spares like seals, washers etc are required. A viable procurement plan to avoid delays during the major maintenance requires to be adhered to.

(b) Repair. The requirement during repairs mainly for LRUs (Line Replaceable Units) needs to be worked out based on the historical data of MTBF (Mean Time Between Failures) of the LRUs.

(c) Overhaul. Scheduled overhaul of aircraft based on the maintenance philosophy of the particular type / manufacturer is easy to predict based on the utilization of the aircraft. A readymade list of spares required to be replaced as part of the scheduled work can be prepared beforehand and items procured so that the overhaul process goes on unhindered.

MRO operations can be of two types. In the first case the MRO Company uses the product of the customer, carries out repairs/overhaul and returns the product. In the second, the product is owned by the MRO Company and a stock of the same is kept to be sold to the user as and when required. Manufacturers of aircraft instruments and LRUs (Line Replaceable Units) fall under this category. The first one is a closed loop supply chain. This generally encompasses all the activities namely, maintenance, repair or overhaul of the aircraft. The second one is an open loop supply chain. Here only remanufacture and refurbishment is carried out.

The Government in its defence offset policy requires a minimum 30% plough back of forex outflows from defence procurement into the Indian industry. The offsets offer a tremendous business opportunity to the Indian industry.

This brings us to the business problem which can be defined as "Inefficient Supply Chain of Aviation MRO Industry is Resulting In Increased Costs and Reduced Productivity Leading to Loss of Opportunity for Indian Aviation Industry" There is a need to further study this issue and find solutions.

Literature Survey

With the above business problem in mind, a literature survey was carried out. The amount of research that has been done in this area is comparatively negligible. Thus there is a large scope for research in this area to further improve the MRO industry. The themes that emerge after an analysis of the available literature are given below.

(a) Information Technology
(b) Supply Chain Organization
(c) Inventory Management
(d) Outsourcing
(e) Lean Management
(f) Lack of Integration

All these themes are directly or indirectly related to the variable of Inventory Management which leads us to the fact that the sustainability of MRO in India can be improved through better Supply Chain Management.

The Research Methodology

Despite the overall growth in Aviation, both in terms of number of aircraft as well as number of operators, the MRO business has not picked up. Though there are 21 active / semi active MRO companies in India carrying out MRO activities at various levels, these cannot be compared to more than 200 MRO companies the world over in terms of viability.

The research problem which then crops up can be stated as

How to improve the supply chain performance of Indian Aviation MRO business?

The research questions that need to be tackled out of this problem are:-

(a) What are the various SCM practices used by aviation MROs globally?
(b) What are the factors which will improve the aviation supply chain?
(c) How To Develop A System For Improved Supply Chain For Aviation MRO?

The research objectives that emerge out of this are:-

(a) To Study the various SCM practices followed by various MROs globally
(b) To Identify the Various Factors Affecting Aviation MRO in India
(c) To develop an improved SCM system for growth of MRO business in India

RESEARCH DESIGN

The three different types of research designs are, namely, qualitative research, quantitative research, and mixed research methods. Research design is a procedure for research which in turn is based on certain assumptions and also the method of data collection and its analysis. The final research design depends on which method is most suitable for the type of research. Since no research ever has been done in the area of SCM for MRO it was decided to carry out

only qualitative analysis for the present work. It was also felt that quantitative work will not yield any positive results as no prior work in this area has ever been done.

Research Methodology for Different Objectives

The research methodology to be followed is given in the following table.

Objective	Research Method
Study of SCM practices by Global MROs	Secondary Research of documents through document analysis
To Identify the Various Factors Affecting Aviation MRO in India	Primary as well as Secondary through Qualitative methods like questionnaires and interviews and applied through Grounded Theory
To develop an improved SCM system for growth of MRO business in India(New as well as existing)	Primary self work from the data collected so far through the qualitative research. The framework will be obtained by using solutions in the existing literature.

Table 1 Research Methodology

Theory of Supply Chain Management

A Supply Chain is the universal network which delivers products and services. The action starts from raw materials. It then flows to the final customers using an engineered flow of information, actual goods, and money. Supply chain management (SCM) consists of all the activities of the design and planning, followed by execution and control, and finally the

monitoring of all the supply chain activities. SCM is applied to the entire product life cycle, within and across companies.

Process View of a Supply Chain

There are two types of process views for a supply chain. In the Cycle view the processes are in a series of cycles into which a supply chain is divided. Every cycle is performed during two successive supply chain stages such as, say, supplier and manufacturer or customer and retailer. In the Push/pull view there are two categories into which the processes in the chain are divided. This depends on whether they are carried out in response to an order of the customer (which pulls the process) or in anticipation of a customer order (which pushes the process). Long term forecasts are generally used in a push-based supply chain to make production decisions. Just in Time is a concept which works on the principle of PULL. However, there are lot of difficulties in the implementation of pull-based systems which involve long lead times. This makes it impractical to react to information on demands. There are five main drivers of a supply chain they are namely, Production, Inventory, Transportation, Place and Information. All these drivers are interrelated.

Categories of Supply Chains

Supply Chains can be categorised in the following ways depending on various interpretations of Supply Chain. These are listed below.

(a) Raw Supply Chains. This is the legacy method followed by basic / ancillary production units.
(b) Ripe Supply Chains. These are oganised supply chains with good relationships between suppliers and distributors. These chains generally work in food industry.
(c) Internal Supply Chains. These are chains which are well coordinated and fine tuned internally, i.e., the suppliers and distributors are not into the chain. All types of companies in all sectors try to follow and achieve this type of supply chain.

(d) Extended Supply Chains. These extend beyond internal boundaries to include suppliers and distributors. These are also very highly IT compliant. The aviation sector generally must have these type of supply chains.
(e) Self Monitored Supply Chains. These are mainly company centric chains and customers are not given much importance.
(f) Outsourced Supply Chains. This is generally a third party logistics chain, also called 3PL company which takes care of inbound as well as outbound logistics and also information flow.
(g) Financial Oriented Supply Chains. This is generally followed by FMCG sector where working capital management is important.
(h) Production Oriented Supply Chains. In this chain all activities precede production. Here marketing and distribution are not very important.
(i) Market Oriented Supply Chains. Here customer is very important and the chain gets triggered whenever an order is placed. As these chains are very responsive these are also preferred by the aviation sector.
(j) Value Chains. This is a totally integrated and optimized chain, which is not very achievable.

SCM is a network of manufacturer's suppliers, suppliers' suppliers and customers' customers. This type of network is very important for the aviation industry.

Main Objectives of a Supply Chain Management

The main objectives of SCM can be listed as below.

(a) To reduce physical links of the supply chain.
(b) To define core competencies and responsibilities of particular supply chain links
(c) To ensure timely and quantitatively correct supply of products to end users in any part of the world.

To achieve these objectives the following activities need to take place.

(a) Planning a strategy to manage resources so that customer demands are met.
(b) Sourcing the goods and services as per requirements and specifications, and simultaneously controlling inventory.

(c) Manufacturing and converting raw material into finished product. This includes scheduling also.

(d) Distribution of end product is a major activity in the management.

The Theory of Inventory

Inventory costs consist of

(a) Order cost

(b) Storage Cost

(c) Shortage Cost

Generally One Item models are used for calculating these costs since each item individually contributes to the cost even in Multi item models. This is more applicable in the Aviation Sector. Revenue, Salvage and Discounts are not applicable.

The classical lot size model for ordering however cannot be used in aviation except for general spares like nuts and washers, due to the cost involved in ordering and storage. There is a balance required with the shortage cost. It may therefore be necessary to use other models depending on the size of the MRO.

The forecasting methods available in the Inventory theory are

(a) Weighted average for short term demands

(b) Regression or time series for medium term and

(c) Delphi or other expert methods for long term demands.

These forecasting methods are also applicable for aviation sector.

GLOBAL SCM PRACTICES

MROs all over the world follow SCM practices which suit their business. They therefore vary from one aviation company to other. This is given in the table below.

Theme	Global Practice
Ways of IT usage	IT is extensively used in identification of spare part availability through internet.
Method of Integration	Top down integration is the norm in all MROs

Use of Lean Management	Lean management is ensured through standardization.
Existence of dedicated Supply Chain Organisation	All MROs have a dedicated supply chain organization for spares as well as consumables
Outsourcing of systems	Hong Kong outsources transportation of spare parts
Methods of doing Inventory Management	Boeing does inventory management through vendor management Hong Kong does Inventory management through reorder point forecasting. Embraer encourages in house / in country manufacturing / repair of parts to ensure timely supply

Some additional inputs available from global practices are listed below.

(a) Government support exists for most of the international MROs through dedicated organisations and industry friendly regulations.
(b) Inventory management is done through categorization of spares in terms of costs and utility.
(c) Spare pools have been formed at hubs to reduce supply chain issues

MROs in India

Though MRO activities are listed to be carried out at many companies in India, most of them exist without carrying out any worthwhile work. Major MRO work in India is carried out by HAL and Air India in the Public Sector and Indamer, Air Works and GMR Aerospace in the Private sector. The most effective of these MROs is the GMR aerospace since it has the best supply chain. MRO practices, including the management of supply chain by these companies, are discussed in the subsequent paragraphs. Though the MRO association of India lists more than 20 companies many of these exist only on paper or carry out very insignificant work.

Details and Analysis of Data Collected

Due to non-availability of literature and other data, it was planned to interview various specialists in the field of aviation MRO. The Interview schedule is given below.

(a) How much experience you have in the field of MRO?
(b) What issues do you face in the course of MRO work on aircraft?
(c) If you face a problem of spares what do you do?
(d) Do you carry out repair of units in your company?
(e) If you face delays in receipt of spares what do you think should be done?
(f) Do you think outsourcing will reduce some delays?
(g) How much IT is used to identify and locate spares availability?
(h) What else do you think needs to be done? Is government helping in this?

All the above mentioned MROs were also visited to physically see the working of these MROs. As already mentioned these MROs were chosen as these were the only MROs functioning in India. There was therefore no requirement of any sampling and the universe was used for the collection of data. All the decision makers and department heads of these MROs were contacted and interviewed to find their opinion about working of MROS in India. About 10 functionaries were contacted at each of the MROs and their responses were tabulated and codified to understand the problems faced by Indian MROs. It must be stated that 100% respondents said that there is future for MROs in India. These questions were later also put to various Indian and Foreign experts during Interviews held during company visits as well as during MRO Asia Pacific conference in Singapore in 2015.

The responses were then analysed through grounded theory. The major factors that have emerged after analysis of axial codes and reiteration of the codification process are listed below. It has been established that for success of an aviation MRO the following are mandatory requirements.

(a) Improvement in forecasting and procurement methods.
(b) Improvement in Marketing
(c) Innovation and indigenization
(d) Outsourcing

(e) Changes in Government Regulations including custom clearances.
(f) Need for a strong SCM Organisation.
(g) Following Lean Management.
(h) Use of Information Technology
(i) Inventory Management

These are directly obtained from the selective codes obtained through working on the axial codes as well as discussion with experts, both Indian as well as International.

Conclusions, Findings and Recommendations

Based on the above the following can therefore be concluded.

(a) It is possible for Indian MROs to change their working methods to become more profitable.
(b) This is mainly possible through improvements in the procurement of spares to reduce cycle times and thus gain market standing.
(c) There is a need for Make in India to improve supply of spares.
(d) Government has already taken steps to support the Indian MRO industry. The National Civil Aviation Policy 2016 takes care of the MRO industry as well.

The Major findings of the research are listed below.

(a) There is lot of scope for Indian Aviation MROs to be profitable and there is a future for Indian MROs.
(b) The main stumbling block in the success of Indian MROs is Supply Chain.
(c) Various MROs have different procurement schemes for spares, which need to be improved.
(d) The Supply Chain Organisation of the MROs need to be strengthened.
(e) MROs are not utilizing the Information Technology to the proper extent to enable improvement in the Supply Chain.
(f) There is large scope for Innovation / Indigenization for aviation spares which would reduce procurement time for spares from abroad.
(g) There is a need for righteous approach to the Government to improve the regulatory and taxation system for the Aviation MROs. In fact Government regulations need to support Aviation MROs in India. The New Civil Aviation Policy partially takes care of this.

(h) The MROs need to market their capabilities to ensure Indian MROs utilize them.
(i) Lean Management and Standardisation will reduce losses of the MROs.

The recommendations flow directly out of the findings.

Contribution to Literature

There has been no work done in the area of Supply Chain for Aviation MRO. The thesis itself is a major contribution to literature. The thesis proposes methods to handle the requirements of Indian Aviation MROs to make them more viable and profitable. Because of its empirical nature, due to non-availability of literature in this area, this will help managers in this field to take decisions which will help their organization to flourish. The conceptual framework for SCM improvement for Aviation MROs will help old and new MROs to improve their Supply Chains and gain Market. This will lower costs of carrying out MRO activities'. The findings of this research will also contribute to the theory of Inventory. The methods to reduce inventories simultaneously improving supply chains is a major contribution to literature.

Grounded Theory was initially propounded for psychological analysis. This was later extended to various other areas like Nursing etc. Grounded Theory methodology for collecting and analyzing empirical data in this area can be considered a methodological contribution in the area of logistics and SCM where Grounded Theory is not a dominant approach,

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CHAPTER 1 - INTRODUCTION

1.1 Maintenance Repair and Overhaul (MRO) activity in the aviation sector has been done by the airlines themselves. They hardly outsourced any work to independent agencies. This has changed over time with increasing costs of fuel and other services. This has led to development of Specialist MRO companies, who use the high volumes of their work and specialisation to reduce costs. (Borkowski, 2005)

1.2 India has capability to be the third biggest aviation market by 2020. They can become the largest by 2030. (KPMG Report on Indian aviation sector , 2014) Indian carriers already have plans to increase fleet size to around 800 aircrafts by 2020. Domestic traffic is expected to reach 160 million to 180 million by 2020, with international traffic going up in excess of 50 million. Indian civil aviation industry rates in the top 10 in the world with a size of Rs. One trillion. However, India's present MRO market, which is around Rs 45 billion, is mostly carried out abroad. India's MRO segment will further grow at about 10% per year reaching Rs. 12 billion in the next 8-10 years. (KPMG Report MRO India, 2016) This is still about 50% of the actual MRO market. Simultaneously, domestic air traffic is expected to reach between 160 million to 180 million by 2020. The international air traffic will grow to more than 50 million. But Indian air operators mainly rely on foreign MRO service providers. This is due to lack of availability engine and component servicing in India.

1.3 As stated, therefore, India's present MRO market, is mostly carried out abroad. Volume of MRO work sent out of India is US$475 Million (Airframe Maintenance $30M, Engine Maintenance $300M, Component Work $125M and APU work $20M) (Mathews, 2012). In this changing market there are major challenges to the Indian aviation industry in terms maximizing fleet availability and simultaneously minimizing operating costs. At the same time there is a need to comply with with regulatory requirements. There is a need to quickly track and trace components and equipment for repair. And the inability to do so will impose expensive time penalties on the complete supply chain. A better coordination and collaboration between all stake holders is also needed. (Tewary, 2007). In comparison Indian cost of labour is about 40% less than those in Middle East or even Southeast Asia. The difference much

higher when compared to Europe of USA. This implies that India has the potential to service not just Indian aircraft but also those from neighbouring regions. (Research and Markets)

1.4 There is a general business downturn in the world and MRO business is also affected by it. MRO companies are therefore generally under pressure to cut costs and increase productivity. There are a lot of factors which contribute to the enterprise readiness of mobility. This includes the fact the hardware of this is not available and connectivity with network is not good. (Gupta, Dewangan, & Gade, 2009) Presently, it is cheap for Indian air operators to take empty aircrafts and pilots to MRO units abroad. This is due to the fact that the time taken for MRO work in India is much more than overseas, mainly due to shortage of spare parts. As per some sources, the work carried out in India by MROs for domestic airlines is only about 10 per. Indian MROs are therefore struggling for survival. Because of this they cannot focus on a strategic growth plan.

1.5 As already stated MRO stands for Maintenance, Repair and Overhaul (not Operations) and this is actually a part of the biggest aviation sector. Companies in the MRO field offer maintenance, repair and overhaul of aircraft to ensure safe delivery of goods and people to their appropriate places of destination. Companies in the MRO sector offer wide range of services like Helicopter MRO, Passenger-to-freighter conversion, aircraft interiors MRO, repair services, avionics maintenance, component/systems maintenance (including repairs), engine maintenance and airframe maintenance. It also includes structural repairs to the airframe and internal equipment like seats, in-fllight entertainment systems etc.

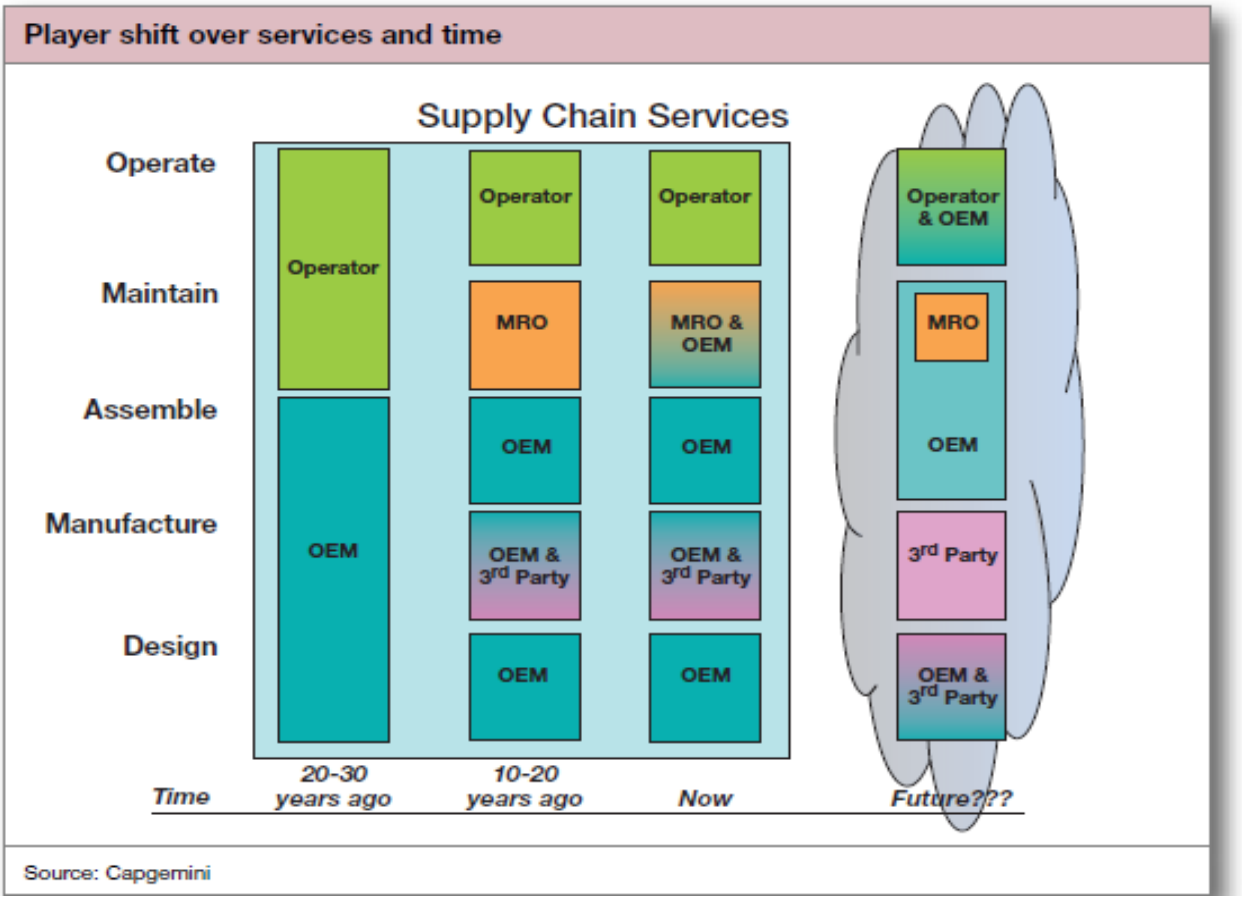


Figure 1.1 : Player Shift over Services and Time

1.6 Supply chain management (SCM) has generally been thought of as an extension of logistics, or similar to logistics. (Cooper, Lambert, & Pagh, Supply Chain Management: More Than a New Name for Logistics, 1997). In executing a request from a customer, all stages of a supply chain are directly or indirectly involved. The supply chain includes the producer, suppliers and transporters. This also includes the storage buildings, the sellers, and finally the clients. The systemic, strategic coordination of these stages and the tactics involved in these supply chain stages can be termed as supply chain management. This happens not only inside a company and but across all entities within the supply chain. This improves the performance of the companies in the long run. (Kashyap, 2012)‘. In other words, the supply chain is said to encompass all activities related to movement of items from the stage of raw-materials to the final consumer. (Sotiris Zigiaris, 2000) It is now not possible to keep the company under control and only rely on your clients and suppliers to follow suit. The benefits of collaborations with major suppliers and consumers in the supply chain, can no longer be ignored. This is

because optimisation of supply chains reduces costs by half. Therefore, the company is likely to lose in the competition with collaboration. (Kelly, 2009)

1.7 Supply Chain Management therefore needs a very high consideration by the aviation MRO industry as spare requirements exist in all the three aspects of MRO, namely, Maintenance, Repair and Overhaul. This is explained in the subsequent paragraphs.

1.7.1 Maintenance. For scheduled major maintenance activities, (other than overhaul) spares like seals, washers etc are required. A viable procurement plan to avoid delays during the major maintenance requires to be adhered to.

1.7.2 Repair. The requirement during repairs mainly for LRUs (Line Replaceable Units) needs to be worked out based on the historical data of MTBF (Mean Time Between Failures) of the LRUs.

1.7.3 Overhaul. Scheduled overhaul of aircraft based on the maintenance philosophy of the particular type / manufacturer is easy to predict based on the utilization of the aircraft. A readymade list of spares required to be replaced as part of the scheduled work can be prepared beforehand and items procured so that the overhaul process goes on unhindered.

1.8 MRO operations can be of two types. In the first case the MRO Company uses the product of the customer, carries out repairs/overhaul and returns the product. In other words the MRO company offers its service. In the second case, the product is owned by the MRO company and a stock of the same is kept to be sold to the user as and when required. Manufacturers of aircraft instruments and LRUs (Line Replaceable Units) fall under this category. The first one is a closed loop supply chain. This generally encompasses all the activities namely, maintenance, repair or overhaul of the aircraft. The second one is an open loop supply chain. Here generally only remanufacture and refurbishment is carried out. . In the closed loop system matching of the demand and supply for a product is done including the supply of a used component.

1.9 Aviation has a major part to play in facilitating the economic growth in India since it has an infrastructure segment within itself. A strong civil aviation sector allows for additional investment, trade and tourism. Aviation sector is a provider for air transport to goods and passengers. This also generates employment. Air travel enables nearly half of international

tourism in the world. Additionally, nearly 1/3rd of the world trade (by value) is also conveyed by air. However, the costs involved, especially in spare parts and fuel, and to some extent airport charges and salaries, make it difficult for the airline industry to remain sustainable and profitable.

1.10 There are long term prospects for MRO industry in India. This is because there is continuing growth in aviation sector. This is seen by the increase in air traffic and the fleet expansion programmes of all India based aviation companies. Again, India's lower labour cost advantage –roughly half of that in Europe and USA will make the MRO operations more profitable for service providers. At the same time it will result in cost saving (cuts in expenditure) for airlines in India on account of not being required to take the aircraft out of India for MRO services.

1.11 90% of indian MRO business which is nearly Rs. 4500 crores is presently spent outside the country– in Malaysia, Sri Lanka, UAE, Singapore, etc. The government is now interested to develop and Asian MRO hub in India. This is possible with our technology and skill base. (National Civil Aviation Policy 2016). Recently, the Government has also allowed foreign airlines to invest upto 49 per cent as FDI. Several concessions have also been given by the Government for the MRO business to grow and become competitive. The newly approved National Civil Aviation Policy (NCAP – 2016) has further extended the time period for utilization aircraft spare parts to three years. Some more concessions include duty free import of special tools for MRO, not requiring proof of necessity for import of spare parts, allowing import of repairble parts etc. It has also recommended easier visa regime for foreign pilots and engineers who come to deposit aircraft for MRO work. Some tax benefits as well as improved customs provisions have also been made. The industry has now to find ways and means to take advantage of these concessions and grow profitably.

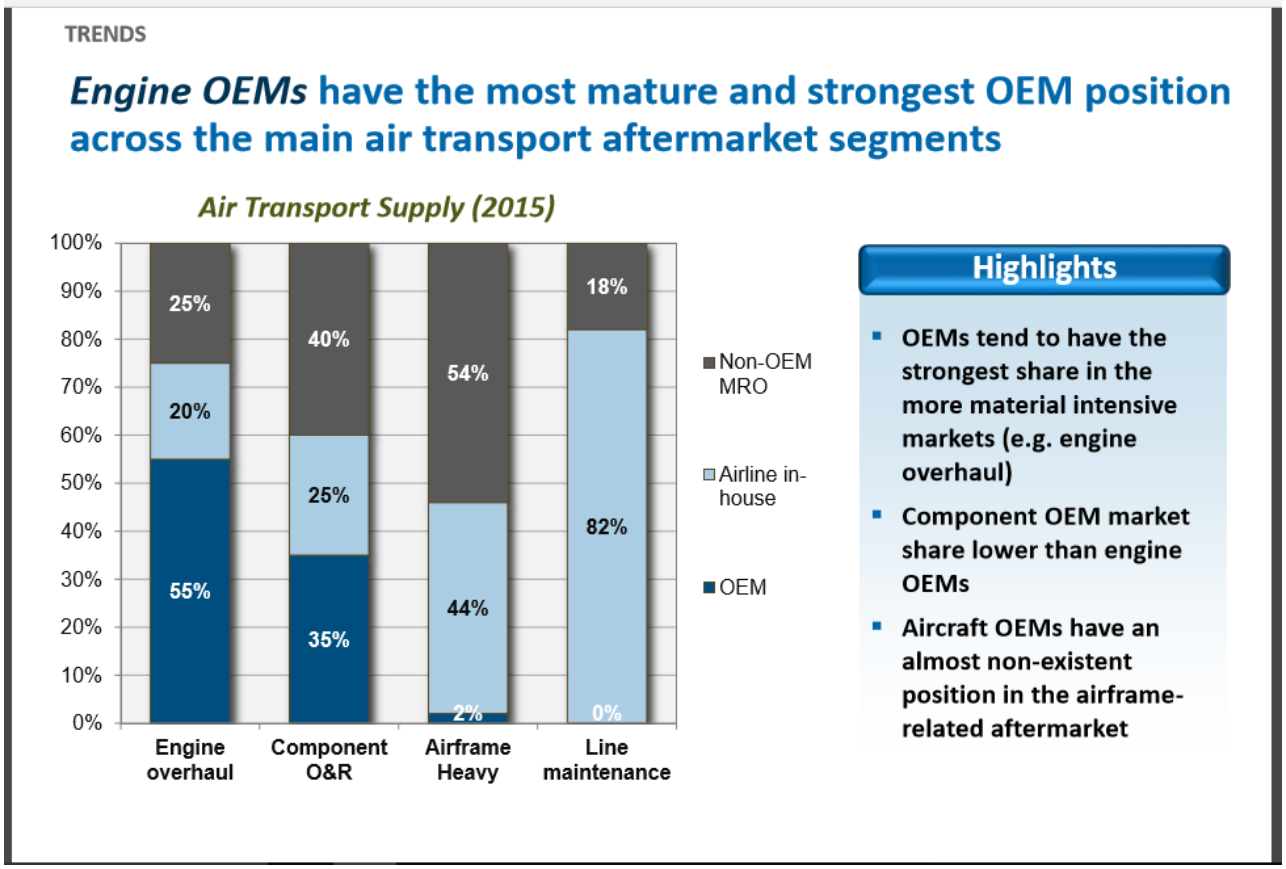
1.12 North America will no longer be the largest region for MRO spend by 2023, and will be taken over by Western Europe. High growth rates will also be seen in India, Middle east and Asia-pacific regions. Market share of China will also grow by more than four per cent to nearly $8 Billion. World competition is very high. Investments in facilities in Europe is down. With ageing facilities in Europe there is already a down ward shift of investments to low cost Asian countries. (Maintenance for Competitiveness, n.d.)

1.13 A Delphi analysis carried out in 1999 to suggest as to what would be the status of Indian Aerospace Industry has recommended leveraging the MRO sector in India as a high priority sector. This is suggested to be achieved through use of defence offset programme, R&D and innovation / indigenization (Moser, von der Gracht, & Gnatzy, 2010)

1.14 The defence offset policy of the Government by regulation necessitates a minimum 30% off set of forex outflows back to industries in India. The offsets will offer a great opportunity to the Indian aviation industry in general and MRO industry in particular. Contracts of nearly Rs.15000 crores have already been concluded after introduction of this policy. A further opportunity of nearly Rs 6000 crores will be available soon with the new procurements by the Indian Air Force. (Report of Working Group on Aerospace Sector, 2010).

1.15 The report has also indicated that the Indian MRO sector can absorb transfer of technology for aircraft as well as components, at depot level. This will make India an international hub for all major MRO needs leading to growth of India's MRO segment by at least 13% annually.

1.16 Maintenance operations especially MRO operations can be better effectively carried out through integrated supply chain optimization and synchronization. Proper synchronization across the material management, warehousing and procurement organizations is most essential in determining optimal maintenance plans and location schedules,. There is thus a requirement for an integrated approach to MRO so that a short and consistent turnaround time (TAT) is achieved. There is also a need to improve the design and planning of maintenance. The inventory needs to be reduced, while increasing service levels. The MRO industry must choose the correct MRO IT solution so as to get value from that investment. There is also a requirement to craft a fact-based outsourcing strategy (Reopel, 2012)



Source – ICF International

Figure 1.2 : Engine OEM Trends

1.17 This brings us to the business problem which can be defined as "**Inefficient Supply Chain of Aviation MRO Industry is Resulting In Increased Costs and Reduced Productivity Leading to Loss of Opportunity for Indian Aviation Industry**" There is a need to further study this issue and find solutions.

CHAPTER 2 - LITERATURE SURVEY

2.1 Basic Survey. With the above business problem in mind, a literature survey was carried out. While the aviation industry exists for over a hundred years and MRO industry for more than seven decades, the amount of research that has been done in this area is comparatively negligible. Less than 100 articles were available for the literature survey. Thus there is a large scope for research in this area to further improve the MRO industry. The variables/themes and then the gaps that emerge after an analysis of the available literature are given subsequently. This is also given in the table below.

S No	Areas	No of Papers	Inference	Theme
1	MRO and IT	7	Use of IT is essential	Information Technology
2	Supply chain integration	7	Higher level of integration is necessary in SCM	SCM Integration
3	Organisation for SCM	5	Need for SCM personnel at all levels	SCM Organisation
4	Outsourcing	5	Outsourcing is also an option in MRO	Outsourcing
5	Lean Management	4	Cost reduction through Lean	Lean Management
6	Competitive Environment	3	Necessity to cut costs	Inventory Management
7	Used parts Management	3	A method to cut costs	Inventory Management
8	Quality and MRO	2	Good quality leads to reduced costs	Inventory Management
9	Innovation in spare procurement	2	In house manufacture of spares reduces costs	Inventory Management

10	Methods of spares ordering	2	Each method of ordering has unique properties	Inventory Management
11	MRO in defence sector	2	Defence sector has its own SCM problems	
12	Strategic and Historical perspectives of SCM	2	Gives insight into SCM evolvement	
13	SCM of Global MROs	2	Global overview of SCM internationally	
14	HRD and SCM	1	Trained manpower produce quality output	
15	MRO and regulatory processes	1	Effect of Government regulations on MRO	
16	Contract management and SCM	1	For necessary backup support for spares good contractual agreements are necessary	
17	Theory of SCM	10	Theoretical/Academic discussions	
18	Theory of MRO	5	Theoretical/Academic Discussions	

Table 2.1 : Literature Review

2.2 Information Technology. These days even laptop and PDAs can be used to run MRO software applications. This has been possible through advances in mobile computing and communication technology. Enterprise mobility has grown in terms of affordability, capability and utility. (Gupta, Dewangan, & Gade, 2009) Information technology, or in other words, the Internet, has played a major role in improving integration of the supply chains. This can be seen from the fact that e-commerce has taken off in a long way in the business of retailing. It is therefore quite possible for Internet to have a huge impact on B2B interactions, especially so in the integration of supply chains. The Internet now will be able to define how back-end

operations of all activities including product design and development and procurement are conducted. This will also include production, inventory and distribution, as well as after-sales service support, and also marketing. This will enable quick process of information leading to cost efficiency and related competitive advantage. This will change the roles and the relationships of all related entities, and will develop new models for business including supply networks and services. This has famously been termed as "e-business". (Lee & Seungjin, E-Business and Supply Chain Integration, 2001). There are a number of organisational and technological challenges in using Supply Chains and E-business. This includes the requirement to change processes of business to support e-business technologies. IT is also used extensively in Integrated Material Management, also known as ERP. A web based system to cover the entire related MRO industry is also feasible. The MRO industry must therefore start using the Internet and related e-services as much as possible to improve the supply chain. This is one area which needs to be exploited to the maximum by the Indian Aviation MRO industry.

2.3 Supply Chain Organization. In the organisation for Supply Chain Management, there are two primary models. This has made supply chain management as a separate entity or function. In both these models, a supply chain management group is made responsible to achieve all organisational objectives.. This includes lead time for fulfilment of orders and on time deliveries to consumers. The main difference between the models is in management of resources. In the first model, the supply chain manager has less control over the resources which are responsible for carrying out the supply chain strategy. This is called Partially Integrated Organisation. Full control is available to the manager in the Fully Integrated Organization model. (Cohen, 2003) In the long run, the infrastructure of the organisation is very important to the organisation's success. Resources can be freed by streamlining the order-to-pay procurement cycle. This will also reduce cycle time and improve inventory positions. There is a need for the leadership to define a long term procurement strategy with its related consequences.

2.4 Inventory Management. There is a drastic need to reduce the role of inventory in all newer models of supply chains. If the supply and demand are in perfect sync then there is no need for buffer stocks in the inventory. Zero inventory means drastically reduced logistics costs and very simplified fulfilment. Many companies have not yet worked on their technologies and networks so as to remove completely the need for even a minimum inventory. Logistics managers need to routinely enact a fine balancing act, to match transportation costs with speed of fulfilment of delivery or receipt; inventory holding costs against risk of stock-

outs, consumer satisfaction against service costs, and finally profitability viz a viz new capabilities. Industry leaders and their consultants have given a lot of time and resources to identify and select the right suppliers and the related purchasing processes in order to finally reduce inventories. It is also necessary to improve underutilized distribution centres, and to improve the efficiency and effectiveness of Transportation modes. This has been partially possible with the increase of on line buying and sourcing of goods and services.

2.5 Outsourcing. MRO being a service industry, many of the activities of MRO can be outsourced. The outsourcing can range from fully outsourced to fully insourced. It is generally seen that activities which are critical such as line maintenance are generally in-sourced, while activities like engine maintenance which have low demand are generally outsourced (McFadden & Worrels, Global Outsourcing of Aircraft Maintenance, 2012). There has also been a significant change in the outsourcing of component repair and replacement. Outsourcing also leads to establishment and growth of Ancillary Industry. Approximately 15% of an airline's operational costs are consumed by aviation MRO. By identifying the strength and weaknesses of various MRO models, it is possible to evaluate alternative MRO strategies which will finally benefit the airline industry as a whole and different airlines in particular. As per official statistics, during January and April 2013 the domestic airlines carried more than two crore domestic passengers. This by itself should have made the industry sustainable but many airline operators still remain in red. Massive expansion in aviation industry resulted in large amount of aviation spares movement. This was necessary to support one of the largest industries serving almost every vertical of global trade. Practically, it was not possible for airlines to operate with fresh spares imports every time as those are very expensive & can increase operational cost rapidly hence almost every airline had started looking at use of reconditioned / repaired aircraft spares subjected to airworthiness certification from manufacture. The quickest an Indian airline can have access to spare parts from a foreign supplier is nearly one week. To build an in-house industrial base in the country the government has now deregulated the manufacture of aviation and defence equipment to all domestic and foreign companies. This will also reduce import dependence. Similar concessions already exist for commercial aviation sector and needs to be exploited.

2.6 Lean Management. A major factor for any MRO industry or for that matter in any industry to be sustainable is cost. One of the best approaches to reduce costs is Lean Production. Lean normally relates to best processes and practices, so as to optimize resources

and produce best products at lowest cost. Implementing lean management across the entire enterprise will reduce the possibility of overlooking at opportunities for further performance improvement. The companies will endeavour to move towards lean management due to the intense international competition. This will then make the aviation industry more sustainable, especially through an empowered MRO facility.

2.7 Lack of Integration. MRO supply chain consists of mainly Management of existing assets, Inventory &Stores Management and finally, the actual Sourcing & Procurement. Poor inventory management is a direct result of a lack of integration of processes at the planning level. This also results in, high procurement costs and higher unavailability of assets. The challenge facing the industry is a mature market, slowing growth and industry consolidation. This has put pressure on each layer of the chain to become cost effective as well as efficient. One of the newest and most comprehensive IT approaches to MRO improvement is called configuration-driven MRO – and interestingly enough, it can be used by owners and operators, third-party MRO suppliers and OEMs (looking to enter the MRO business) as a solution for implementing all four major MRO initiatives, namely, performance based logistics, total asset management, lean MRO and knowledge-based MRO enterprise transformation. (Powering maintenance, repair and overhaul for aerospace and defense, 2009).

2.8 Initial Conceptual Lens. Review of literature has resulted in six themes related to MROs across the globe emerging out. The themes which impact the activities of an MRO company are shown next diagrammatically as Figure 2. Gap exists in these which needs to be filled to find a benchmark for a successful MRO.

Figure 2.1 : Initial Conceptual Lens

2.8.1 This conceptual lens is directly or indirectly related to Inventory Management which leads us to the fact that the sustainability of MRO in India can be improved through better Supply Chain Management.

CHAPTER 3 - THE RESEARCH METHODOLOGY

3.1 Research Problem. Despite the overall growth in Aviation, both in terms of number of aircraft as well as number of operators, the MRO business has not picked up. Though there are 21 active / semi active MRO companies in India carrying out MRO activities at various levels, these cannot be compared to more than 200 MRO companies the world over in terms of viability. In fact there are only five functional MROs in India, two in the public sector and three in private sector. There is HAL and Air India in public sector and GMR, Airworks and Indamer in the private sector which have been producing some result though with time delays. The main reason for the non-functioning of these MROs is mainly the non-availability of spares and components required during the course of MRO activities. The shortage of spares and LRUs (components) is felt even by the functional MROs which has resulted in production delays in these MROs.

3.1.1 The research problem which then crops up can be stated as

How to improve the supply chain performance of Indian Aviation MRO business?

1.1.2 The research questions that need to be answered are:-

(a) What are the various SCM practices used by aviation MROs globally?

(b) What are the factors which will improve the Indian aviation supply chain?

(c) How to Develop a System for Improved Supply Chain for Indian Aviation MRO?

1.1.2 The research objectives which then emerge out of this are:-

(a) To Study the various SCM practices followed by various MROs globally.

(b) To Identify the Various Factors Affecting Aviation MRO in India.

(c) To develop a framework for an improved SCM system for growth of MRO business in India.

3.1.3 The research methodology and the expected outputs from study of each of the objectives are given in succeeding paragraphs.

3.2 Research Design. The three different types of research designs are, namely, qualitative research, quantitative research, and mixed research methods. Research design is a procedure for research which in turn is based on certain assumptions and also the method of data

collection and its analysis. The final research design depends on which method is most suitable for the type of research. Since no research ever has been done in the area of SCM for MRO it was decided to carry out only qualitative analysis for the present work.

3.3 Features of Qualitative Research. In qualitative research all questions are different. The researchers are also not similar. Therefore different approaches are required for doing qualitative research. Many characteristics of Qualitative research have been identified by various writers as to what they consider to be the prominent. Adopting a particular approach from the different approaches always implies a different "world view". The approach also influences how or where the findings are disseminated. Some of these have been listed below.

3.3.1 In Qualitative research the data source is the natural setting.

3.3.2 The researcher is the main person who collects data.

3.3.3 In Qualitative research generally inductive data analysis is done by the researcher.

3.3.4 In Qualitative research the reports are very descriptive. They incorporate the language of the participants.

3.3.5 The Qualitative research has the character of self-interpretation. It is mainly directed towards the discovery of the meaning of events which the participants have experienced. It then interprets those meanings as seen by the researcher.

3.3.6 Qualitative research does not have a predetermined design. The researchers generally focus on emerging process as also the outcomes or product of their research.

3.3.7 Qualitative research has an inbuilt criteria for trustworthiness and uses this for judging an event.

3.3.8 Qualitative research makes us understand the nuances of the world where we survive. Through this we also understand as to why things appear to be such as our perception.

3.3.9 Qualitative research is always useful where exploration or identification of concepts is involved.

3.4 Qualitative research. This is a type of scientific research which looks for answers to a problem by using a set of predefined procedures. It gathers proof, and produces results which were not found earlier. Additionally, it also looks to understand a research problem or a topic at hand. There are different ways through which a qualitative research is done and some of them are given in the following table.

Sl No	Type of Qualitative Research	Description
1	Ethnography	This is a methodology to study people and their culture in detail.
2	Case Study	This is in depth Study in which the researcher explores a program or an event, or even a process or activity, involving one or many individuals.
3	Grounded Theory	This is a Study where the researcher tries to derive a general, abstract theory of an interaction including process or actions, grounded in the views of individuals.
4	Narrative Research	This is a Study where the researcher studies the lives of individuals. He then interrogates one or more individuals to talk about their lives. The researcher then converts this information into a narrative in chronological order.
5	Interpretative Phenomenological Analysis	This is a Study which tries to perceive the experiences of people. It also recognises that this is a method of researchers' interpretation.

Table 3.1 : Types of Qualitative Research

3.5 Quantitative Research. On the other hand Quantitative research is used to test hypotheses, and specific variables are studied here. Quantitative data is normally based on measurements using structured data-collection instruments. There are possibilities of statistical relationships. The focus of research is narrow and the output is mainly a statistical report. There are no statistics involved in the present research. This is because statistical data is not available. Therefore neither quantitative not mixed approach was used for this research.

3.6 Basic research. Grounded theory is being proposed as no comparable work has been done in the area of Aviation MRO. Grounded theory (GT) is a systematic methodology in the social sciences involving the generation of theory from data. (Turner, 1986) It is generally used in qualitative research, but may also be used in quantitative research.

3.6.1 Status of MROs in India has been studied mainly through secondary analysis of the available literature and the websites of the MROs. Physical visits to the MROs were also made to see the working of the MROs in India to generate primary data. This primary data has already been supported through interviews with the concerned officials in the MRO. This study has been beneficial in indicating the Organisational Structure as well as profitability of the industry as a whole. There have been indications that organisational changes will be required mainly in the supply chain area which will be considered at the time of final recommendations.

3.6.2 The study of the SCM practices the world over has been done mainly through secondary sources which are available in plenty in various documents, journals and other literature. This study gives indications of the best practices followed across the globe and its applicability in the Indian scenario. Some of the major journals which have been studied are Aviation Week, Journal of Air Transportation, Journal of Logistics Management etc. A suitable combination of the study of the above objectives will lead to the development of a framework for a successful MRO in India.

3.6.3 The status of Indian MROs has been studied by primary work using Questionnaires and Interviews of personnel involved in the MRO industry. The various factors affecting the MRO industry in India have then been found out through study of available literature and the industry inputs obtained from questionnaires and interviews. These factors were then judged based on effectiveness of each factor in improving the profitability of an MRO. The output of this analysis has then formed the basis for development of an improved SCM system for Indian MRO industry. The Interview Schedule used for primary data collection is placed as annexure. This method had to be used in the absence of sufficient literature in the area of MRO and related SCM. It is felt that since qualitative research has been done it is more trustworthy and has helped in bringing out novel ideas.

3.7 Validity. Validity, in qualitative research, means whether the findings of a particular study are true and certain—"true" that research findings are accurately reflecting the situation, and "certain" in that research findings are supported by proof. Triangulation is a method generally used by researchers to confirm validity in their studies. This is done by analysis of a research question from various perspectives (Guion, Diehl, & McDonald, 2012).

3.7.1 As per Patton (Patton, 1990) there is a common misconception triangulation is used to arrive at consistency across all data sources. Actually, such inconsistencies are possible, due

to the relative strengths of various approaches. In the view of Patton, such inconsistencies should be seen as an opportunity and not be seen as weakening of the proof.

3.7.2 The Qualitative phase has helped in identifying the factors based on interview and questionnaire. The methodology adopted during this applied research is descriptive with some exploratory research and the data collection has been iterative in nature. Data was collected using the Interview Schedule as the base. The descriptive research then helped in describing the problem systematically. This has also provided information about the thinking in the MRO community regarding problems faced by them. There has also therefore been some correlational research to establish relations between the themes mentioned in the literature review. An effort has been made to explain the relationships between the themes leading to final analysis. Data was also collected during seminar on MRO Asia-Pacific at Singapore and India MRO 2016 at Bengaluru.

3.7.3 As mentioned earlier the research has been a structured approach through use of Interviews The different methods that emerged though interviews are also part of the qualitative research. In fact the design of the questionnaire has been such that both structured and unstructured responses were available to the researcher. A codified analysis of the responses was carried out based on the relationship developed out of the responses.

3.8 Grounded theory. This was introduced by Glaser and Strauss in their 1967 book, The Discovery of Grounded Theory. The book was based on a justification for using qualitative research to build up theoretical analysis. This was propounded as a sort of objection of researchers who felt that theories have to be tested only using quantitative procedures.

3.8.1 A "systematic, qualitative process used to generate a theory that explains a process, an action, or interaction about a substantive topic at the conceptual level." (Creswell, 2002, p.439). This methodology is called “Grounded” because it generates theory from research which is grounded in data. (Babchuk, 1997). This is a general method of comparative analysis to obtain four central criteria - work, relevance, fit, and modifiability (Creswell, 2002).

3.8.2 Grounded Theory was initially applied in psychological analysis by psychologists but the basic theory can be applied to any qualitiattive analysis and study. However, the two researchers separated in its early development only and a division of the theory enveloped (Glaser, 1992; Strauss & Corbin, 1990). Now there are two basic schools for Grounded Theory: the Glaserian School and the Straussian School (Stern, 1994). The differences, however, have a major impact in the direction and execution of the primary research. While

Glaser takes the stand that researchers should have an empty mind, while Strauss permits a general idea of the area under study. (Onions, 2006) . Major differences in the two theories are given in the table below.

'GLASERIAN'	'STRAUSSIAN'
Start with an open and empty mind	Generally know where to start.
It is considered to be an Emerging theory, with only neutral questions	The theory is forced, with totally structured questions.
This is the development of a conceptual theory	This is a description of situations. In other words this is a Conceptual description
Variables and relationships come from the detailed study of data itself. There is a need to perceive these correctly.	This theory believes that Theoretical sensitivity comes from the methods and Tools used.
The theory is grounded in the data	The theory is interpreted by an independent and neutral person.
The credibility of the theory, or verification, is derived from its grounding in the data	The credibility of the theory comes from the rigour of the method
The analysis must identify a basic social process.	In this theory Basic social processes are not necessary to be identified
The researcher is very passive and exhibits a disciplined restraint	The researcher is totally active
Data reveals the intrinsic theory	Data is structured to reveal the theory

Table 3.2. Comparison of Glaserian and Straussian theories

3.8.3 In the Glaserian method the coding is less rigorous and it compares incident to incident constantly. Whereas in the Straussian theory the coding is very rigorous and the technique of coding is the basis for making comparisons. In the Glaserian method, there are two types of

coding, simple and substantive where the data is fractured and then grouped to finally produce categories and properties. In the Straussian methods there are three types of coding; open, or initial, to identify and categorise phenomena; axial, where these codes are related to each other; and selective, to choose a core category and relate others with that.

3.8.4 In this paper the methodology of Strauss is adopted due to the fact that the researcher has a general idea where to begin. A structured interview schedule was used in collection of data and its analysis. The process followed is, Initial coding and categorization of data followed by Concurrent data collection and analysis. The theoretical sensitivity allows intermediate coding, also called axial coding. The axial coding was identified through networking of the initial codes. This is followed by identifying a core category through networking of the axial codes. This is then followed by generating the theory, through selective coding. The selective codes are also used to generate a structured framework for improving the MRO functioning. The research methodology to be followed is given in table 3.3.

Objective	**Research Method**
Study of SCM practices by Global MROs	**Secondary Research of documents through document analysis**
To Identify the Various Factors Affecting Aviation MRO in India	**Primary Data collection and Qualitative analysis through interview schedules applied through Grounded Theory**
To develop a framework for an improved SCM system for growth of MRO business in India	**Primary data collection and analysis through technological tools like Qualitative Data Analysis (QDA) miner. The framework will be obtained by using solutions in the existing literature and interviews with experts.**

Table 1.3 : Research Methodology

3.9 Research Methodology for study of SCM practices by Global MROs. As part of the document analysis it is necessary to study the document, summarise the information and interpret the data through questions. The questions for analysis of this data were formed based on the initial conceptual lens. The various practices followed globally formed the basic document for the document analysis. This will then be analysed and categorized using QDA miner software. Any additional categories or themes which emerge will be added to the initial conceptual lens for use in the second research objective of identifying factors affecting MRO operations in India.

3.10 Research Methodology to identify factors affecting Aviation MROs in India. This will be done by generating an interview schedule which will be used to get views and expert opinions from the field. The interview schedule will be validated through international experts. Since the universe of the MROs in India is small, experts and officials from all MROs will be interviewed. This data will be put through QDA Miner to obtain Initial and Axial Coding. The Initial codes will be networked to obtain Axial codes. The axial codes will then be again worked on through network analysis to get final or selective codes which will also become the factors affecting MRO business in India.

3.11 Research Methodology for Developing framework for Improved SCM System. After obtaining the factors, their relationships with SCM will be established by using existing solutions in the universe. The framework will indicate the inter relationship between the factors and how this will get used to define the improved system for overall development of MROs in India.

The flow chart of the research methodology is depicted as figure 3.1.

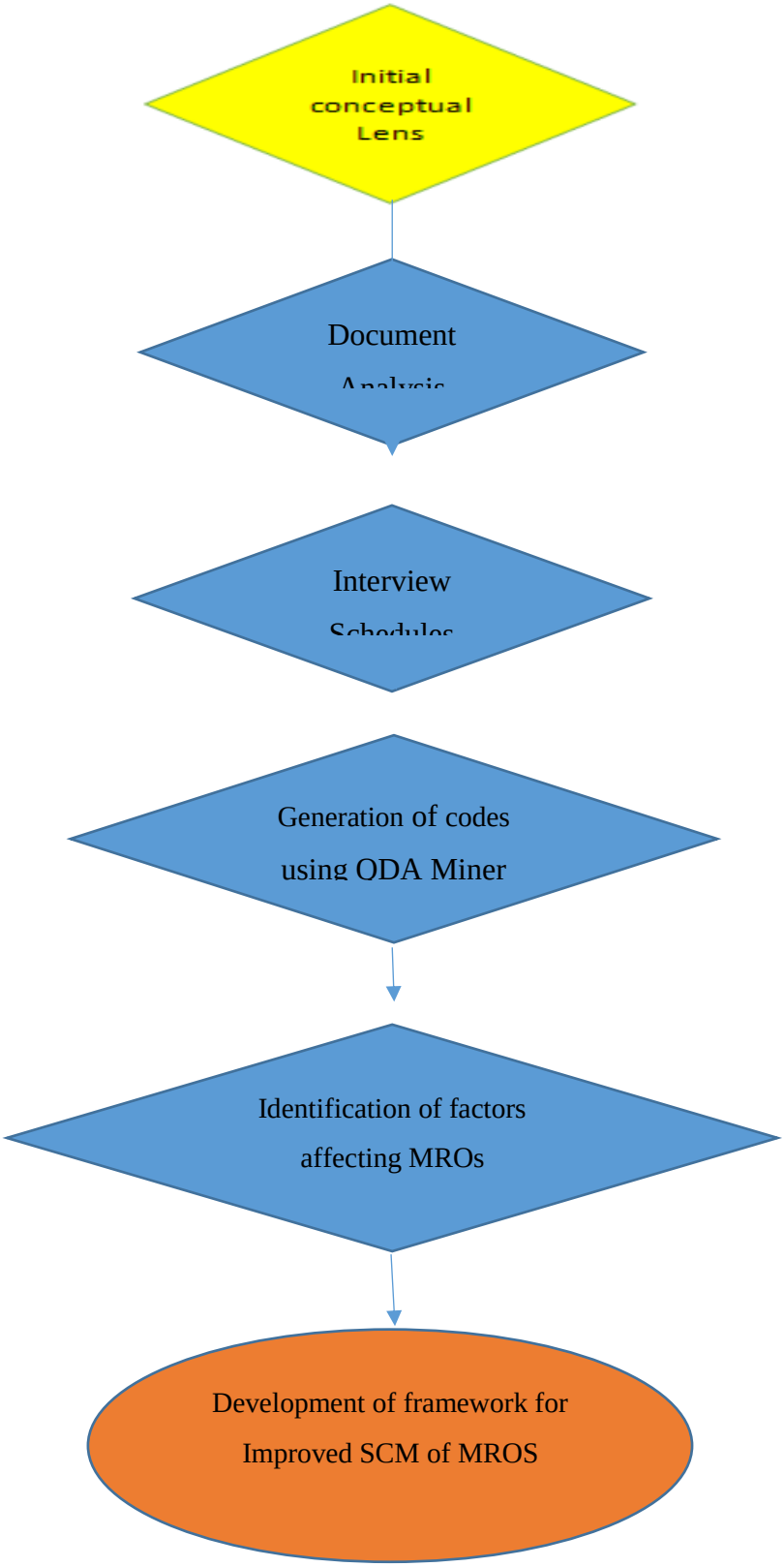


Figure 3.1: Flow Chart for Research Methodoloty

CHAPTER 4 - THEORY OF SUPPLY CHAIN MANAGEMENT

4.1 Supply Chain Management. In this chapter we will discuss what Supply Chain Management is and how it relates to the initial conceptual lens brought out by the Literature Review. Various books on Supply Chain Management were studied for this, and literature related to Supply Chain Management, the themes generated and their application to Aviation MRO was extracted. This is discussed in subsequent paragraphs.

4.1.1 The term SCM is generally used to explain the planning and the way materials are controlled. It also indicates the way of information flows as well as the internal logistics services of a company. It also explains these activities externally between companies as well. A Supply Chain is the universal network which delivers products and services. The action starts from raw materials. It then flows to the final customers using an engineered flow of information, actual goods, and money. Supply chain management (SCM) consists of all the activities of the design and planning, followed by execution and control, and finally the monitoring of all the supply chain activities. SCM is applied to the entire product life cycle, within and across companies as already mentioned. SCM is only about influencing behaviour in particular way and direction. Strengthening of Supply Chain enhances customer satisfaction, ultimately resulting in increasing profit for the company.

4.2 Cycle View of Supply Chain. As shown supply chain consists of Supplier, Producer, Distributor, Seller and Buyer. The main aim of the chain is to match Supply and Demand, so as to generate profits for products and services. This is essential to achieve so that the right Product from the right Store reaches the right Customer in right Quantity and at the right Price. This in turn generates higher satisfaction and profits for the organisation. In the aviation sector the customer is the flier and the supplier is the aircraft manufacturer. For the MRO however, the customer is the airline which finally provides the aircraft for the traveller to fly. The supply chain cycle holds good for any industry including the aviation MRO industry. Cycle view of supply chain in shown in the figure 4.1 below. Flows in a supply chain are shown in figure 4.2 below. It can be seen that the flows resemble a chain reaction.

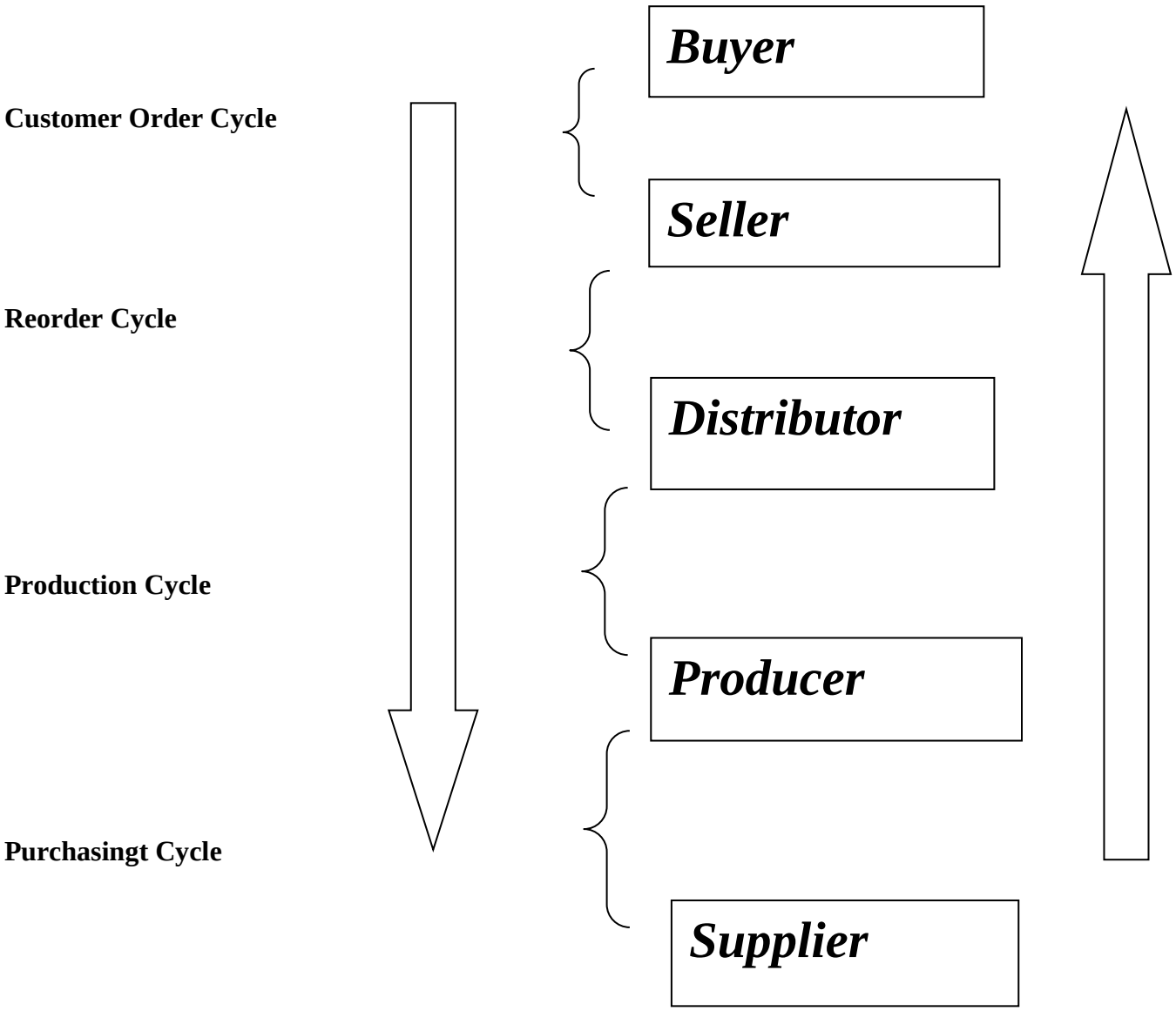


Figure 4.1: Cycle view of Supply Chain

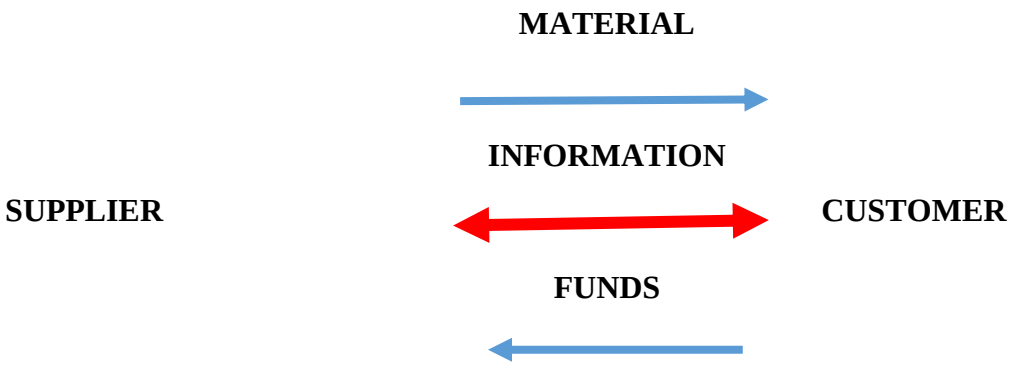


Figure 4.2: Flows in a Supply Chain

4.3 Process View of a Supply Chain. There are two types of process views for a supply chain. In the Cycle view the processes are in a series of cycles into which a supply chain is divided. Every cycle is carried out during two successive stages of supply chain such as, say, supplier and manufacturer or customer and retailer. In the Push/pull view there are two categories into which the processes in the chain are divided. This depends on whether they are carried out in response to an order of the customer (which pulls the process) or in anticipation of a customer order (which pushes the process). Long term forecasts are generally used in a push-based supply chain to make production decisions. Just in Time is a concept which works on the principle of PULL. However, there are lot of difficulties in the implementation of pull-based systems which involve long lead times. This makes it impractical to react to information on demands.

4.4 Supply Chain Management and Logistics. There are lot of differences between supply chain management and the traditional view of logistics. While Logistics refers mainly to functions within an organization, the supply chains refer mainly to networks of all organisations which work together to coordinate all activities to finally deliver an item, service or product to the customer. Traditionally, logistics looks after procurement, distribution, maintenance, and inventory management while Supply chain management also encompasses activities such as marketing, and also includes new product development. It also caters to finance, and customer service.

4.4.1 There are five main drivers of a supply chain they are namely, Production, Inventory, Transportation, Place and Information. All these drivers are interrelated and their interrelation is shown in the following figure 4.3

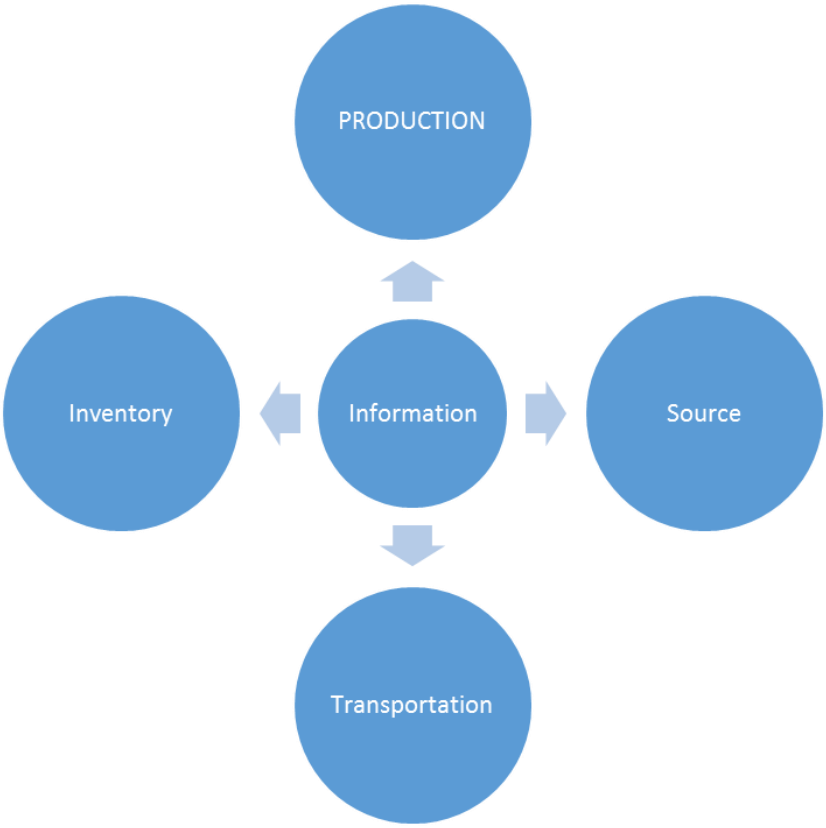


Figure 4.3: Relationship between Drivers

4.5 Categories of Supply Chains. Supply Chains can be categorised in the following ways depending on various interpretations of Supply Chain. These are listed below.

4.5.1 Raw Supply Chains. This is the legacy method followed by basic / ancillary production units.

4.5.2 Ripe Supply Chains. These are oganised supply chains with good relationships between suppliers and distributors. These chains generally work in food industry.

4.5.3 Internal Supply Chains. These are chains which are well coordinated and fine tuned internally, i.e., the suppliers and distributors are not into the chain. All types of companies in all sectors try to follow and achieve this type of supply chain.

4.5.4 Extended Supply Chains. These extend beyond internal boundaries to include suppliers and distributors. These are also very highly IT compliant. The aviation sector generally must have these type of supply chains.

4.5.5 Self Monitored Supply Chains. These are mainly company centric chains and customers are not given much importance.

4.5.6 Outsourced Supply Chains. This is generally a third party logistics chain, also called 3PL company which takes care of inbound as well as outbound logistics and also information flow.

4.5.7 Financial Oriented Supply Chains. This is generally followed by FMCG sector where working capital management is important.

4.5.8 Production Oriented Supply Chains. In this chain all activities precede production. Here marketing and distribution are not very important.

4.5.9 Market Oriented Supply Chains. Here customer is very important and the chain gets triggered whenever an order is placed. As these chains are very responsive these are also preferred by the aviation sector.

4.5.10 Value Chains. This is a totally integrated and optimized chain, which is not very achievable.

In simple words, SCM is a network of manufacturer's suppliers, suppliers' suppliers and customers' customers. This type of network is very important for the aviation industry.

4.6 Main Objectives of a Supply Chain Management. The main objectives of SCM can be listed as below.

4.6.1 To reduce physical links of the supply chain.

4.6.2 To define core competencies and responsibilities of particular supply chain links

4.6.3 To ensure timely and quantitatively correct supply of products to end users in any part of the world.

4.6.4 To achieve these objectives the following activities need to take place.

4.6.4.1 Planning a strategy to manage resources so that customer demands are met.

4.6.4.2 Sourcing the goods and services as per requirements and specifications, and simultaneously controlling inventory.

4.6.4.3 Manufacturing and converting raw material into finished product. This includes scheduling also.

4.6.4.4 Distribution of end product is a major activity in the management.

4.7 Factors affecting forecast. Some of the factors that affect any forecast are listed below.

4.7.1 History of past demand

4.7.2 Lead time of manufacture and supply

4.7.3 Marketing efforts

4.6.5 Competitors and their actions

4.7.5 Discounts offered

4.7 Forecasting Methods. The forecasting methods available are as follows.

4.8.1 Qualitative forecasting. This is generally subjective and is used when past data is not available or is scanty.

4.8.2 Time Series Forecasting. This is a statistical method using historical demand data.

4.8.3 Causal Forecasting. This method uses correlation between demand and environmental factors, like laws of land, economy etc.

4.8.4 Simulation Forecasting. This uses imitation of choices of consumers to arrive at a forecast. In the aviation industry this is used to forecast seat demands.

4.8.5 Costs are controlled by exploiting economies of scale for deciding lot sizes depending on expenditure for heads like fixed and variable costs. The economic order quantity depends on this analysis.

4.9 Different Types of Logistics Providers. The different types of Logistics providers are given in subsequent paragraphs. This is given figuratively in Figure 4.4.

4.9.1 A first-party logistics provider (1PL) is an organisation that needs to transport goods or products from a one place to another. Both the Cargo Receiver and the Cargo Sender are called first-party logistics provide. This term includes all those who manufacture, distribute, import, export or sell goods either wholesale or retail either nationally or internationally. It also includes government organisations and other such institutions. Anyone who gets goods moved from one place to another place is a first party logistics provider. This therefore can include families or individuals shifting places.

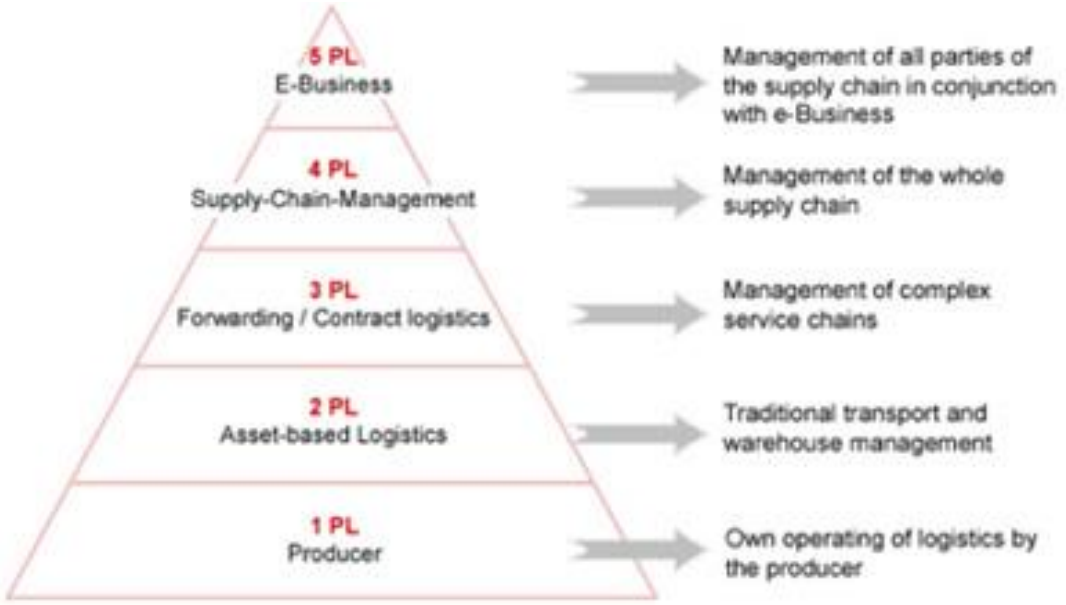


Figure 4.4: Different Types of Logistics Providers

4.9.2 A second-party logistics provider (2PL) is one who is the owner of the transportation equipment. Shipping companies or cargo airlines which own, lease or charter their ships or planes are examples of 2PL. Even truck companies who own or lease their trucks will be a 2PL company.

4.9.3 A third-party logistics provider (3PL) is one who uses outsourced logistics services to companies. Since he uses services of a third party for partial or total supply chain functions he is called 3PL. Most courier companies like DHL, FedEx are 3PL companies.

4.9.4 A fourth-party logistics provider (4PL) is an integrator. He coordinates the resources of many organisations including his own to develop a comprehensive solution for his clients. He is independent, and does not own assets but is accountable for all supply chain activities. He even coordinates 3 PL provider. In other words a 4PL provider is an accountable middleman providing supply chain services.

4.9.5 A fifth party logistics provider (5PL) aggregates the supply chain demands of his clients as well as other 3PL providers into bulk volume. This allows for negotiation of transportation rates with the airline or shipping companies. Since this is also Non asset based, it works continuously in all areas.

4.10 Aviation MRO Supply Chain. In the Aviation MRO industry a typical Supply Chain will consist of the following elements.

4.10.1 Suppliers' suppliers. These are the people who supply the raw materials like metal sheets, raw rubber etc to those who make components for use in aircraft.

4.10.2 Direct Suppliers. These are the ones who make the components and supply them to the MRO company.

4.10.3 Producer. Who carries out MRO activities on an aircraft. He could even be the OEM for the aircraft, but he will still require the first two.

4.10.4 Distributor. In the aviation industry it is the aircraft operator who provides the seats to the ultimate traveler.

4.10.5 Final consumer. He is the final traveler.

4.11 The Theory of Inventory. Inventory costs consist of

(a) Order cost
(b) Storage Cost
(c) Shortage Cost

4.11.1 Generally One Item models are used for calculating these costs since each item individually contributes to the cost even in Multi item models. This is more applicable in the Aviation Sector. Revenue, Salvage and Discounts are not applicable.

4.11.2 The classical lot size model for ordering however cannot be used in aviation except for general spares like nuts and washers, due to the cost involved in ordering and storage. There is a balance required with the shortage cost. It may therefore be necessary to use other models depending on the size of the MRO.

4.11.3 The forecasting methods available in the Inventory theory are

(a) Weighted average for short term demands
(b) Regression or time series for medium term
(c) Delphi or other expert methods for long term demands.

These forecasting methods are also applicable for aviation sector. Some other methods like moving average or exponentially weighted average methods are not suitable for aviation sector.

CHAPTER 5 - INTEGRATION BETWEEN SCM AND CONCEPTUAL LENS

5.1 SCM and Information Technology. Internal supply chains need to use Information Technology for direct or production goods during the enterprise resource planning (ERP) systems implementation. Use of IT for low volume and low value goods can bring about more visibility in the usage of Indirect goods. There is a need to exploit the internet to use the e-procurement systems (and IT) and its contribution to manage the supply chain of indirect goods. Thus SCM can improve through use of IT, and relation of IT to SCM cannot be under emphasised. It is perfect to say that Information technology, and in particular, the Internet, plays a major role to improve supply chain integration. IT can be used for all process including transaction processing, order tracking collaboration and planning of SCM, as well as delivery coordination. In the aviation industry therefore, use of IT for SCM is very important.

5.11 Use of IT for SCM will result in the following.

(a) Reduction of costs of operational processes (manual work),
(b) Elimination of manual errors and thus improve quality of information.
(c) Transfer of information between organizations is hastened.
(d) Helps in high volume of transactions.
(e) Supply chain coordination information is easy in environments like the aviation industry especially MROs, where everything very volatile and unpredictable, and is also logistically demanding.

5.2 SCM Organisation. SCM can be improved a lot if a dedicated organisation for management of supply chains is established. For correct and effective evaluation of performance of supply chain, it would be necessary to carry out organizational change as well. As the supply chain strategy and associated process design for an organisation evolve, there will be a requirement to include a new set of metrics so as to optimize performance for the company as a whole. If this is not done to facilitate achievement of these objectives, it may not be possible to reach target performance levels. This in turn will lead to questioning of the entire supply chain strategy. Any of the three Organisation models namely, centralised, decentralised and semi-centralised models will be suitable for SCM of Aviation MROs depending on the role of the organisation.

5.2.1 As the name suggests, a corporate-level department of purchase makes all the decisions of the supply chain. It also controls purchases throughout the company. Most organisation can leverage such spends and enable standard purchasing, processing, and engineering decisions. This then results in large scale procurement which in turn improves money power and automatically enhances knowledge sharing as well as effectiveness of operations. This also consolidates the supplier base. However, in complex, distributed enterprises, like an aviation MRO complete centralization is not always practical especially in a small or medium MRO. This type of organization is mainly suitable for companies which have similar business concerns with common requirements and is not suitable for small and Medium MRO as already stated.

5.2.2 In a decentralized supply chain organization, all the procurements are carried out at the local level. This enables autonomy to the working level in terms of control over purchase, production, and engineering decisions. This type of organisation however has no information sharing or any type of coordination or between individual units and sites. This model therefore is not suitable for MROs where there is diversity of product and at the same time there are no multiple functions carried out. Total independence in procurement is thus not suitable for small aviation MROs.

5.2.3 A semi-centralised supply chain organization uses all the best practices of corporate level supply chain strategies. There is knowledge sharing at all levels while procurement is planned and carried out. This model thus provides the advantages of the both the centralized and decentralized models. There are very few disadvantages. In the semi-centralised structure, wherever strategic sourcing is required the corporate spend can be leveraged. All the non-strategic purchases which are not suitable for centralized sourcing can be pushed to the local units. This increases Operational efficiencies at the same time reducing overall procurement costs. The company simultaneously retains the capability to react fast to sudden changes in demand or supply. This results in performance being maintained at consistent level. This type of organisation is therefore very suitable for aviation MROs.

5.3 Integrated SCM. Integrated SCM relates to the organisational changes needed to be brought about for improving the supply chain. Integration is also required external to the organisation in terms of information sharing mainly regarding quality and quantity of spares and consumables required for the MRO process, which an SCM manager needs to control. Inter relation also exists between Integration and an integrated Supply Chain Organisation in

the paragraph on supply chain organisation. Integration is required in Information Sharing, Planning, Workflow streamlining and coordination. Integration means tight linking of all the activities involved in the Supply Chain Management. It also means open sharing of information and all levels even laterally. An integrated SCM uses ERP (Enterprise Resource Planning). This removes multiple systems within an organisation to facilitate relationships with all suppliers as well as distributors. In an Integrated Supply Chain the main activities are storage, procurement of goods, transportation and logistics. It also includes development of supplier relationships. An additional benefit in Integrated SCM is reduction in costs, since volumes can be managed in this system. In the aviation MRO this is essential as connected suppliers will improve receipts of components and spares, and connected distributors in relation to Aviation MRO are the airline themselves.

5.4 SCM and Inventory Management. A lot of people tend to mix up the definitions of Inventory Management and Supply Chain Management. It has to be clearly understood that inventory management, logistics management and supply chain management are totally different subjects. Supply chain management encompasses both the inventory management and logistics management. Traditional method like Reorder-point procurement which is part of inventory management is also part of good supply chain management. Inventory plays a critical role in supply chains. Good Inventory management balances demand and supply in that it manages customers' demands and vendors' supply. In this we can manage stock in hand, dues-in supplies as well as work in progress. Good inventory management also enables good forecasting and in turn enables planning for future procurement. In the aviation MRO industry inventory management becomes all the more important because of the high cost items required for MRO operations.

5.5 SCM and Outsourcing. There are four levels of MRO outsourcing. These vary from fully outsourced to fully in-sourced. It has been revealed that low demand activities at airline level are often outsourced for example engine maintenance. At the same time critical MRO activities like line maintenance are generally insourced. (Al-kaabi, Potter, & Naim, 2007). Analysis has also indicated that fleet size, fleet mix, number of leased aircraft and the main airline business model impact the decision making on outsourcing. Various check servicings (Periodic servicings) are also outsourced these days. While there is a possibility of relative costs of the MRO increasing due to this, this is far outweighed by improvements in technical punctuality.

5.5.1 It is the decision of the management to either outsource or SCM or both depending on the readiness of the management to face the consequences. It is known that outsourcing increases operational flexibility. Simultaneously it transfers the operational risks to another party. While SCM utilises all available resources to give the organisation direct involvement with all the stages of every process and function. This allows a better picture and direct control over all improvements. An example of such a situation is an organisation having all resources to serve all levels from raw materials to the final customer. All processes however trivial are the responsibility of the company and are carried out by its own workers and staff. It may also happen that a company which has been practicing SCM all along could end up exercising both SCM and outsourcing. In such a situation the company may outsource the SCM itself. This will make the SC Manager responsible for all external processes, information and material flows to meet the needs of the company. The main company can then focus on its core competencies simultaneously watching the performance of SC manager. This can be done by setting a basic minima which will have to be met by the service provider. In this situation, the Service Level Agreement will be very important to maintain the relationship. Outsourcing can also be a major tool for companies practicing SCM to profit as much as possible. Generally as a rule only the non-core elements in the supply chain are outsourced.

5.5.2 In an outsourcing program, the external and internal drivers that impact sourcing decisions must be understood by the management. On the external side, it is very important to understand the industry structure. The supplier's bargaining power must be analysed. There is a need to select the right emerging technologies and substitute products. It is essential to forecast new entrants who may enter the market. It is also necessary to analyze the customers' bargaining power. Internally, it is necessary to understand the strategic direction of the company. It is also important that the tactical actions which are followed in the areas of technology development, engineering, materials management, manufacturing, distribution, and field service are also understood.

5.6 SCM and Lean Management. Lean is a production practice in which expenditure of resources in any activity other than value addition is considered wasteful and needs to be eliminated. In the paper "Supply chain management in line balancing to reduce cycle time and increase productivity" this aspect has been brought out very clearly when through improved supply chain manpower and tools could be reduced to increase output in the defence MRO. Thus the relation between SCM and Lean practices is very strong and must be utilised fully to improve profits. Lean relates to those processes and practices, which optimises resource

utilisation and improve production. Supply chain management itself can become lean through use of strategic outsourcing and long term supplier contracts. The selection of suppliers has to be based on performance if the costs are to be brought down. A synchronized production and delivery system automatically brings lean system as also brought out in the above cited paper. Some other areas where Lean can be practised is in the offices. It is well known that one of the leading source of waste is lack of organisational focus. While on the shop floor people continuously think of Lean, whereas in the offices, especially the support services lack this thinking.

CHAPTER 6 - ANALYSIS OF GLOBAL SCM PRACTICES

6.1 Global Aerospace Industry. For the Research Objective 1 data for global SCM practices was collected through existing literature available from various sources including the sites of aircraft manufacturers. This is elaborated in subsequent paragraphs.

6.1.1 MROs all over the world follow SCM practices which suit their business. They therefore vary from one aviation company to other. An overview of the various such Global practices is given in this chapter. The status of global aerospace industry is shown in the table 6.1

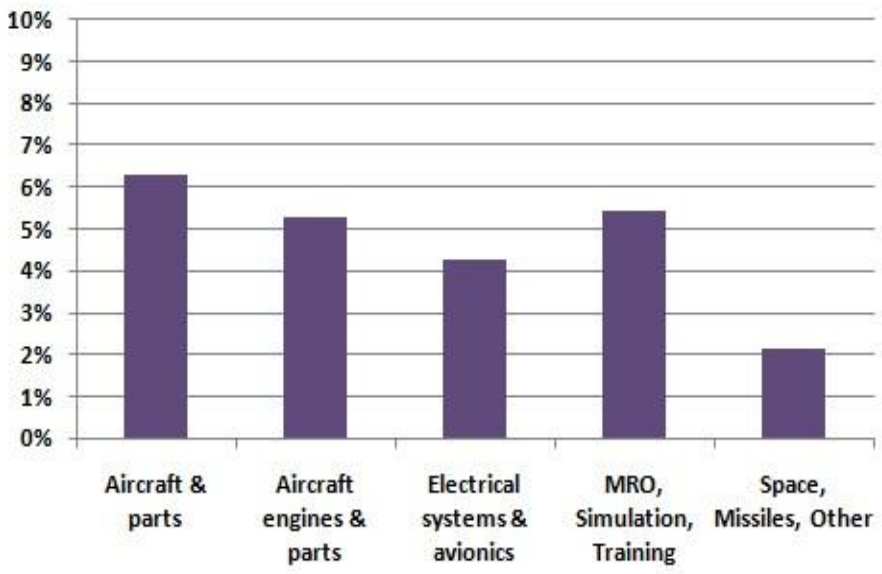
Rank	Country	Revenue ($US B)
1	USA	$204.0
2	France	$50.4
3	UK	$32.7
4	Germany	$32.1
5	Canada	$22.3
6	Japan	$14.1
7	China	$12.0
8	Russia	$10.0
9	Italy	$9.9
10	Brazil	$7.6
11	Spain	$6.1
12	Singapore	$4.3
13	India	$4.0
14	Netherlands	$3.4
15	Mexico	$3.0
	Others	$34.2
	TOTAL	~ $450

Source – Deloitte Papers (2014)

Table 6.1 : Global Aerospace Industry

6.2 International Practices at Different Countries

6.2.1 Canada. There are many MRO companies in Canada but they do not rank at the top s for MRO investment. One of the main reason for that is that the Canadian Dollar has appreciated which has reduced the competitiveness of Canada for aircraft heavy maintenance which is labour intensive MRO work. Recently, engine MRO supplier Standard Aero has made a significant investment in Canadian MRO. They have also recently planned large expansion project in support of future CFM56 MRO work at their Winnipeg facility.



Source – Canadian Aerospace (2014)

Figure 6.1 : Global Segmented Market Share - Canadian Aerospace Industry

6.2.1.1 Canadian economy is quite dependent on aerospace. The industry earned nearly $25 Bn CDN in 2008. Of these exports were nearly $20 Bn CDN, which is nearly 82% of the total figure. More than 83000 workers are employed in this field. By market segment this works out to; aircraft and aircraft parts 51%, aircraft engine and parts (15%), MRO activities (18%), with avionics and electronics systems etc comprising the rest.

6.2.2 Hong Kong. In Hong Kong the procurement is by Normal replenishment. There is some initial provisioning but special provisioning is also done for AOG management.

Inventory Management is done by monitoring stock turnover and orders are placed once reorder point is reached. There is some safety stock to reduce downtime. Since there are only 128 aircraft presently in Hong King, spares are also borrowed from other airlines or from International Airline Technical Pool, a depository of spare parts. Repair Management is done through on ground diagnosis. Individual repairables are shipped to repair houses through hubs to reduce lead times. They have a data base of over 300 repair shops to enable quick repair of parts. At times the transportation is also outsourced to third party logistics companies to get a quicker response.

6.2.3 China**.** China will become the world's second biggest aviation market in the next 20 years. It will therefore have a natural requirement for expansion in its spare parts market. By 2030, the fleet of Chinese aircraft will increase by nearly three times. The existing aircraft fleets are ageing and therefore they will need higher number of spare parts and equipment for maintenance and repairs. As per forecast by Airbus, China will need more than 4,000 hundred seater aircraft by 2030. At the same time Boeing says that nearly 5,000 will be needed. Although there are many parts producers in China, they might not be able to match such a demand. Therefore, the growth may still be heavily dependent on outside components in the immediate future. In the last 10 years, the Chinese market has grown nearly four times in terms of aviation parts and components This will further increase the demand for spare parts in this area.

6.2.4 Malaysia**.** The Malaysian Aviation Industry is making a lot of effort so as to reach out in the world market. It had plans to be a major aerospace player by 2015 which it has nearly achieved. Malaysia has a National Aviation Blueprint which has four focus areas for growth. These are listed below.

(a) Components and Parts manufacturing

(b) MRO

(c) Integration of Avionics and systems

(d) Training Aviation maintenance activities.

6.2.4.1 Towards this end, the country has created a national steering committee called The Malaysian Aerospace Council. The MAC has the Prime Minister as chairman with representation from other govt agencies and industry. The main objective of the council is to

provide direction of the national aviation industry. It also provides policy guidelines.with a secondary objective to provide policy guidelines to identify priority of aviation activities. Malaysia has now come into top ten places for MRO industry start ups. It has many global investors like Eurocopter etc. Additionally it has also received production investments from Boeing, Airbus, Rolls-Royce, etc.

6.2.5 Singapore. Singapore is now Asia's important MRO hub. Very quickly it has converted itself to become the success story of Asian Aerospace. There are more than 30 major MRO facilities in Singapore. It also has the biggest engine and component MRO capability. It is now an aviation industry with an annual turnover of more than USD 4 billion. Many world class design and manufacturing industries related to aerospace are now based in Singapore. In 2007, Rolls-Royce has based its US$300 million assembly and testing facility for aero engines in collaboration with Seletar Aerospace Parker of Singapore. This was the first such facility in Asia. Several major aerospace firms have now established R&D centres in Singapore.

6.2.5.1 The main factors for Singapore's success include a highly respected legal system. It also has a very flexible workforce, and a transparent government which is corruption free. The most important factor which has led to success of aerospace industry here is the planning effort of the government of Singapore in collaboration with the industry which is led by the Economic Development Board (EDB) of Singapore. There are other organizations supporting the MRO industry which including the Ministry of Transport. There are several other government and private agencies. The EDB of Singapore understands the need to assign a premium on the integrating needs of industry, so it has a bottom up approach for its planning.

6.2.6 Mexico. Mexico has become a very big aerospace industry in a short time.. Mexico has nearly 200 aerospace firms with total employment of more than 20,000. It has achieved exports in excess of $3 billion during the same period.

6.2.7 Portugal. MRO services in Portugal are provided mainly by TAP which is an offspring of Air Portugal. With the technique developed over a period with parent airlines and other operators in the world, TAP Maintenance & Engineering offers MRO services and modification for a large number of components equipping Airbus, Boeing and Embraer fleets and their engines. It is this capability of component overhaul which has put Portugal quite high in the map of Global MROs. It had conducted a pilot project in May 2014 involving aircraft

inspections to obtain a 30% reduction in the downtime of aircraft. TAP has proved that Lean and six sigma can be effectively used in Aircraft MRO also. They also have an engine repair facility. The turbo-fan engine centre is located in Lisbon, Portugal, while the turbo-prop engine centre is located in Porto Alegre, Brazil.

6.3 Practices of International Airlines

6.3.1 Etihad Airways.

Etihad Airways is a fast growing airline in the world and also one of the youngest. It is based in Abu Dhabi, United Arab Emirates. It currently has 150 office locaions. The airline started flying in 2003. It presently covers 103 destinations across 63 countries. It has recently joined hands with Jet Airways of India. Maintenance Spare Parts are procured to ensure no delays in flights. To ensure timely availability of material and spares they conduct periodic meetings with contractors and subcontractors. For purchasing consumables, the airline has an effective monitoring and control system placed in action. The Warehouses and facilities of the airline are close to airport to ensure smooth supply of items. The SCM system of Etihad airline is based upon participative efforts of the company with its partners as well as key stakeholders.

6.3.2 Cathay Pacific.

The spare parts were divided into five categories in this company, namely, Rotables, Repairables, Expendables, Consumables and Expendable – Repairable. The most complex parts like Engine which were costly as well as long lasting were grouped as Rotables. Some other items like Line Replaceable Units (LRUs), End Items etc. were also grouped into this. Rotables were those items which could be overhauled and put back into circulation to match the life of the aircraft. All unserviceable rotables were routed to the repair/overhaul shop and were reutilised after repair/rectification/overhaul. Repairables were items like fuel pump, hydraulic pump etc. which could be repaired economically and put back into service in a fully serviceable condition. Expendables were those items which were thrown if found unserviceable or worn out. These were generally low cost items like bearings, springs etc. Some of the expendables were reused if they could be brought back into a serviceable condition economically. These were also included in the expendable-repairable category. Consumables were items which get consumed like greases, oils etc. All the spares were also divided into critical and non-critical components. Critical components were those essential for

the safety of the aircraft like, electronic fuel controller. The non-critical parts were items like in-flight entertainment system components which did not affect the flight worthiness of the aircraft. All efforts of the supply chain were directed mainly towards critical rotables and repairables.

6.3.3 Lufthansa**.** Lufthansa has its own supply chain service called Lufthanss Technik Logistik Services (LTLS). They provide all logistics services to the aerospace sector. LTLS manages the total logistics value-added chain in the area of MRO. Lufthansa Technik Logistik Services was founded by Lufthansa Technik AG and Lufthansa Cargo AG (LCAG) as ajooint venture in 1998. By 2002 LTLS doubled its turnover from 50 Million Euros to over Euro 100 million. LTLS is now a major provider of logistics services to the international aerospace sector with a market share of nearly 8%. Major work of LTLS is from MRO activities, as well as engine and component repair. They have added many more customers through the extension and development of logistics as a specialized business segment. Their customers include Airbus and Rolls-Royce among others. DHL, FedEx and other such logistics providers are also the customers of LTLS.

6.4 Practices International Aircraft OEMs

6.4.1 Airbus and Boeing. Both Airbus and Boeing follow largely similar Supply Chain Management Practices. The Supplier selection by both follow a typical competitive bid process during initial phase. The selection is mainly based on best-value basis. Boeing has a list of pre-qualified vendors which is not there at Airbus. Major vendors of both companies participate early in their design and development process. Both have long-term, reliable and stable relationships with everyone. The suppliers also need to demonstrate credible long-term business interest. Boeing and Airbus use RFID tags for their 787 and A380 programs. Both Airbus and Boeing have outsourced mainly to south east Asian countries like Japan, China and to some extent even India. Managing inventories is a costly and complicated process for all airlines and their supply chain managers. Spares pools and spare hubs can reduce this problem to some extent. Third-party suppliers are now very popular due to this. Example of this is A J Walter Aviation (AJW) which has secured many new contracts.

6.4.2 Boeing. Boeing calls their SCM practice “Partnering for Success (PFS)”. With this, Boeing aims to assist its vendors to lower costs by optimising their supply chains and get more business from Boeing. However, not all revenue-positive MRO moves are related to increased

spending on maintenance and there is still some scope to reduce inefficiency. Some analysts however feel that PFS may damage relations with suppliers as the picture painted by Boeing may not be that rosy. Boeing demands reduced profit margins from suppliers in return for high orders. Boeing has also put in lot of effort to have a flexible maintenance plan, as well as a good supply chain for the new aircraft.

6.4.3 Embraer. Embraer has two supply chains, one for the domestic and other for international market. The first chain has nearly 75 suppliers who work as subcontractors to process the raw materials provided by the Company. The selection consists of evaluations based on costs, quality, reliability productive and technical capacity, financial health, logistics, certifications, risks, socio- environmental responsibility and experience to name a few. Embraer include clauses in the supplier contract models, like supplier's obligation to legislation governing its activities, as well as those which ban use of child and forced labour. They also have programs which are aimed to increase use of local Brazilian content in the purchasing processes of the company. When the supply department cannot find domestic suppliers for some components, they set up initiatives for developing potential partners both international and domestic.

6.4.4 Bombardier. Bombardier ATR is an aircraft manufactured in Northern Ireland capital Belfast. They have given contracts worth about £70 million to relating to two of Bombardier's aircraft programmes.

6.5 Document analysis. Document analysis is a form of qualitative research where the researcher interprets the documents to give meaning and voice around a particular topic. This analysis of documents involves coding content into themes. Document or Documentary analysis is very vital research tool. This interprets data generated from the physical examination of documents and records by using different procedures relevant to a particular study. (Adams, 2010) The analysis of the above documents is given in the following table. QDA miner software was used to identify the links to themes.

Theme	Global Practice
Ways of IT usage	IT is extensively used in identification of spare part availability through internet.
Method of Integration	Top down integration is the norm in all MROs
Use of Lean Management	Lean management is ensured through standardization.
Existence of dedicated Supply Chain Organisation	All MROs have a dedicated supply chain organization for spares as well as consumables
Outsourcing of systems	Hong Kong outsources transportation of spare parts
Methods of doing Inventory Management	Boeing does inventory management through vendor management Hong Kong does Inventory management through reorder point forecasting. Embraer encourages in house / in country manufacturing / repair of parts to ensure timely supply

Table 6.2 : Result of Document Analysis

6.5.1 From the above analysis it can be deduced that the factors of initial conceptual lens (themes) are essential for improvement MROs in India. Additionally, a spare hub, a component repair facility and government support is necessary. These points have therefore been added in the next step of research (for RO 2).

CHAPTER 7 - FACTORS AFFECTING INDIAN MROS

7.1 Data collection For Research Objective 2. For RO 2 data was collected by direct visits to all the existing MROs in India. Details of the Indian MROs and details of data collected is given in subsequent paragraphs

7.1.1 Though MRO activities are listed to be carried out at many companies in India, most of them exist without carrying out any worthwhile work. Major MRO work in India is carried out by HAL and Air India in the Public Sector and Indamer, Air Works and GMR Aerospace in the Private sector. The most effective of these MROs is the GMR aerospace since it has the best supply chain. MRO practices, including the management of supply chain by these companies, are discussed in the subsequent paragraphs. Though the MRO association of India lists more than 20 companies many of these exist only on paper or carry out very insignificant work. The five companies listed above have been selected because these are the only companies doing significant measurable MRO work in India.

7.2 Visits to Indian MROs

7.2.1 Hindustan Aeronautics Limited. HAL first started aircraft manufacturer in the 1940s when they manufactured the Hindustan Trainer named HT-2 for the Indian Air Force. HAL is now a manufacturer of fighter aircraft as well as transport and helicopters. They manufacture MiG and SU series of fighters, Chetak, Cheetah and ALH helicopters and Dornier DO-228 transport aircraft. They also manufacture Kiran Trainer aircraft for the IAF. HAL in addition also carries out MRO activities mainly on Fighter aircraft of the defence services. In the civil MRO role they carry out MRO of Advanced Light Helicopter (ALH) which they have supplied to Civil agencies in addition to the defecence services. Being a manufacturer through transfer of technology it has its own problems of Supply Chain. This is mainly in the area of raw material. HAL therefore has to plan procurement of raw material mainly from abroad much in advance, not only for manufacture but also for repair and replacement. They therefore have a long term procurement plan based on the manufacturing and repair orders. Since HAL has the defence sector as its captive market, (nearly 95% of MRO work of HAL is for the IAF and the Indian Army) the profitability of this public sector unit is not very much affected. Because of

this, the effectiveness of the SCM system of the company could not be constructively measured. The costing policy of HAL is also such that it can never go in loss no matter how much business it does.

7.2.2 AIR INDIA**.** Air India MRO carries out MRO activities mainly for its own aircraft including those of the Air India Express. It has facilities for MRO work on Boeing and Airbus series of aircraft as well as ATR and CRJ class of aircraft. It also does repair of some engines and components. In the recent times therefore, it has tried to get some business from other carriers for their MRO work. This is however not successful mainly due to the fact that PSUs have their own problems mainly of the bureaucratic nature. Air India has entered into contracts with various suppliers for supply of spares and have generally managed the supply chain well due to this. It also however suffers from problems like custom clearances, duty waiver constraints etc. Air India MRO however does not suffer from financial problems since this is also a public sector unit and the Government routinely supports them through equity infusion. It was therefore very difficult to measure the effectiveness of Air India MRO.

7.2.3 INDAMER. Though Indamer was formed in 1947 it has started doing measurable work only recently. It is thus a relatively new player in MRO activities. Director General of Civil Aviation has approved Indamer under Civil Aviation Requirements (CAR 145) for the maintenance and repair of fixed and rotary wing aircraft and is a Continuing Airworthiness Management (CAMO- CAR M subpart G) certified organization. Though it has works at various places in India, the works based in Ahmedabad was visited since most significant work of this company is carried out there.

7.2.3.1 Indamer presently carries out MRO activities on defence transport aircraft like Embraer, MRO facilities for which are not available with the government. They also maintain aircraft of many business houses, charters etc. The company however does not have a proper SCM policy due to low turnovers. This however leads to delays during MRO. The company needs to improve its Supply Chain for increasing returns. The company has been therefore found lacking in effectiveness. The financial condition of the company is not good though it is supported by the Government of Gujarat. More details about this were however officially not made available.

7.2.4 Air Works. Air Works is based at Hosur near Bengaluru and also has hangars at New Delhi and Mumbai for carrying out MRO activities. They also carry out line maintenance

activities for some private jets. The company is generally doing well mainly due to multi location activities. They however also suffer from Supply Chain problems as they have to procure spares through OEMs or spare suppliers located outside India. This company is certified by Centre for Military Aircraft (CEMILAC) for carrying out work on defence aircraft. They also offer turnkey maintenance solutions to private aircraft operators.

7.2.4.1 Comparatively lower scales of work prevent this company from stocking up resulting in delays due to transit of spares from abroad. Recently Economic Times has reported that the company may be for sale.

7.2.5 GMR aerospace. Located near Rajiv Gandhi International Airport, GMR Aerospace is the busiest MRO Company in the Indian Private sector. Initially started with the co-operation of Malaysian Airlines as MAS-GMR Aerospace Engineering Company, the company is now a full GMR owned company. The company has a good supply chain, in that they have a contract with the suppliers for provisioning components and spares as replacement for unserviceable components. They also have a predictive procurement policy where they stock spares based on Poisson distribution probability. This allows some flexibility in the production when spares are readily available during MRO activities, thus reducing delays. This company is the most effective MRO in India mainly due to its good supply chain policies, though they also have their own problems of spares management.

7.3 Data Collection. Due to non-availability of literature and other data, it was planned to interview various specialists in the field of aviation MRO. Towards this end an interview schedule was made which was referred during interviews of the specialists. The schedule is given at annexure B. These questions were later also put to various Indian and Foreign experts during Interviews held during company visits as well as during MRO Asia Pacific conference in Singapore in 2015. The interview transcripts are placed in subsequent paragraphs.

7.3.1 All the above mentioned MROs were also visited to physically see the working of these MROs. As already mentioned these MROs were chosen as these were the only MROs functioning in India. There was therefore no requirement of any sampling and the universe was used for the collection of data. All the decision makers and department heads of these MROs were contacted and interviewed to find their opinion about working of MROS in India. About 10 functionaries were contacted at each of the MROs and their responses were tabulated

and codified to understand the problems faced by Indian MROs. It must be stated that 100% respondents said that there is future for MROs in India.

7.3.2 The universe for the study has been very restricted, but by a 100% interaction lot of responses were obtained. A total of 142 responses were received and these were reduced to 37 when duplicate responses were removed. These automatically became the initial codes for the research. These were merged into 15 axial codes by networking. The flow chart for data acquisition and analysis is given below.

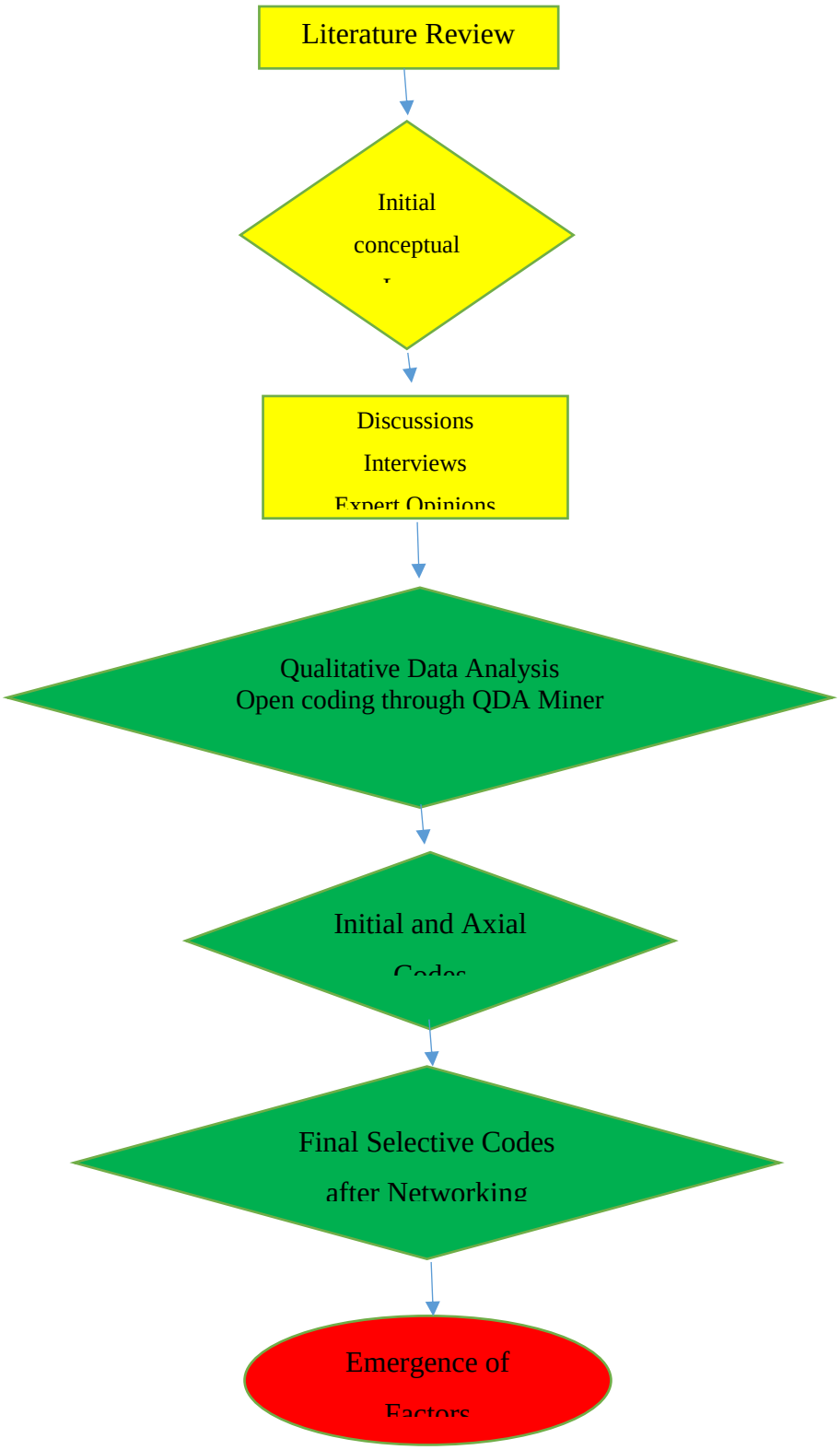


Figure 2: Flow Chart for Data Acquisition and Analysis

7.4 Initial Codes. The initial codes so obtained are listed in Table 7.1 below. The network diagram is at Fig 7.1

Sl No	Response (Initial Codes)
1	All routine spares are available readily but non- routine spares take 4-7 days
2	Stocks are maintained as per forecast requirements
3	There is automatic replenishment of routine spares
4	Statistical forecasting should be continued
5	There is follow on support from OEM / Supplier for spares
6	Supply Chain can be improved through innovation / indigenization
7	There is need for component repair to be done in India
8	All defective LRUs are supplied by customer
9	LRU replacement is done by demanding from OEM
10	For immediate requirement some LRUs are removed from other ac on servicing
11	LRUs are sent to OEM for repair and changed on receipt
12	Delays in receipt of spares could be reduced by change in procurement schedule
13	Delays could be reduced through change in forecasting system
14	Changes in management system will improve supply status
15	Supply chain improvement can be achieved through use of online research engines to check availability of spares

16	Supply chain can be improved through more structured planning and changes in the organization
17	Supply chain can be improved through integration of procurement process
18	There is need for dedicated carriers and forwarding agents
19	Outsourcing may be resorted to, so as to avail knowledge / technology transfer.
20	Floats need to be maintained to reduce delays
21	Supplier needs to be bound legally to fulfil supply schedules
22	LTRAs need to be signed with suppliers
23	Carriers use MRO facilities abroad due to lack of awareness of indigenous facilities
24	Operators have a mindset that whatever foreign is good
25	Operators do not want to change from foreign MRO
26	Indian MROs have not marketed themselves properly
27	Quality of training and expertise of Indian labour is of good standard
28	Indian MROs have required capability and equipment to carry out necessary tasks
29	There is lack of certification and production units in India
30	Buildings, special tools and testers are required for component repair
31	Delays could be avoided by making spare hubs across the country
32	Infrastructure requirement for foreign MROs high to operate from India

33	Present aviation policy of the govt needs to change
34	Govt taxation policies need review
35	Difficulties are faced in getting custom clearances for repaired LRUs / Spares
36	Progressive servicing should be introduced to reduce unnecessary work
37	Standardisation of components across fleets be done

Table 7.1 : List of Initial Codes

7.5 Axial Codes. The initial codes were networked to get 15 axial codes as indicated by the networking diagram at Fig 7.17. In the figure the initial codes are indicated by rectangles and the axial codes by ellipses. The axial codes are listed in table 7.2.

Forecasting is proper
Innovation and Indigenisation
Improvement is needed in marketing
Forecasting methods need review
Use of IT for SCM
Improvement in contract management
Non core Competency can be outsourced
Quality of Indian Product is good
Organisation needs revamp
Lean Management is essential
Infrastructure improvement
Organisational Changes are required

LRU availability is of concern
Government Policies hinder supplies
Inventory management

Table 7.2 : Table for Axial Codes

7.6 Selective Codes. The axial codes were further worked on to get Nine final (selective) codes. This networking is at Fig 7.1. The final codes are the factors that need to be addressed to improve the working of Indian Aviation MROs

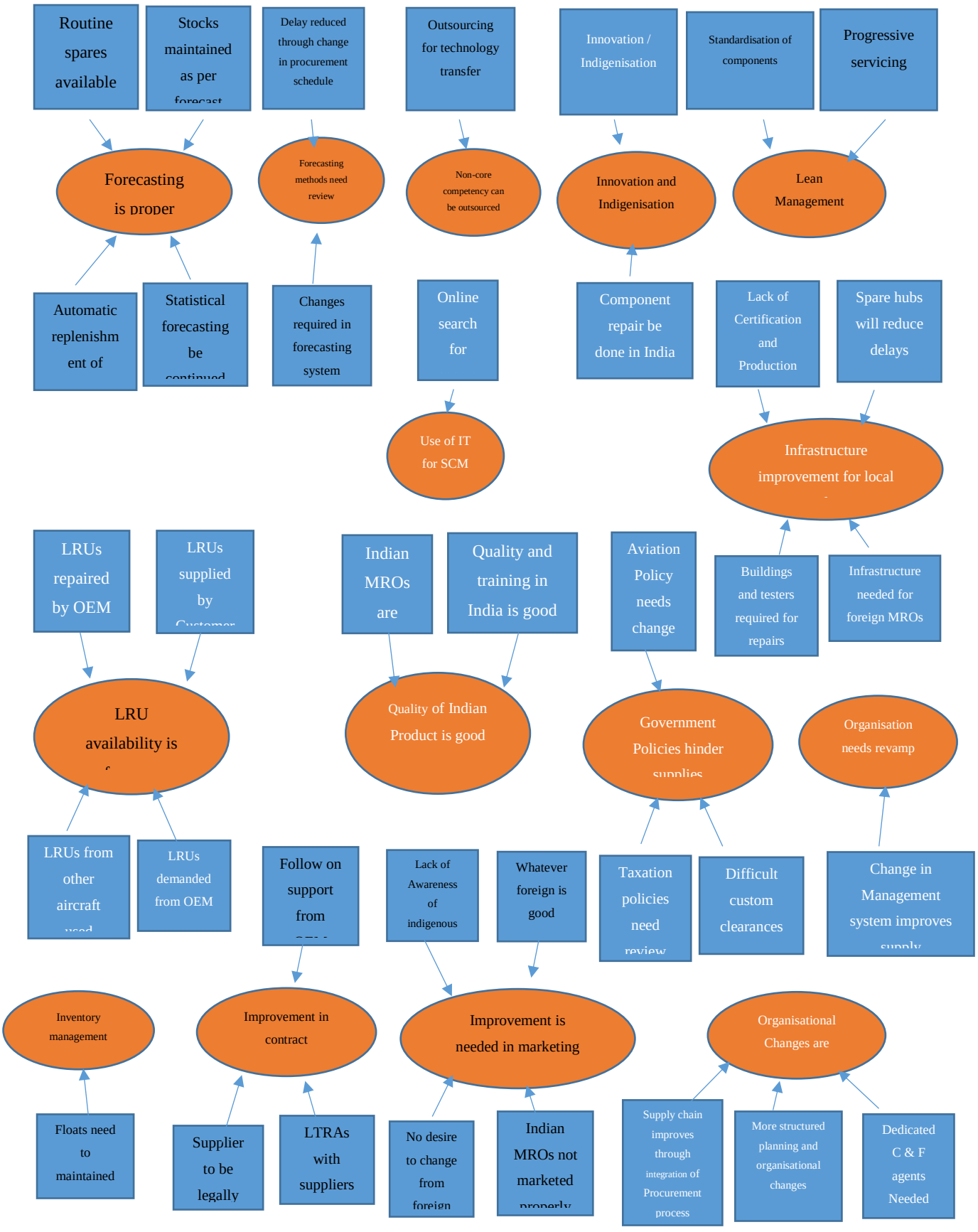


Figure 7.1 : Complete Network Diagram

For the sake of clarity the network diagram for the initial codes has been broken down into individual networks. These are given below at Fig 12 to Fig 26.

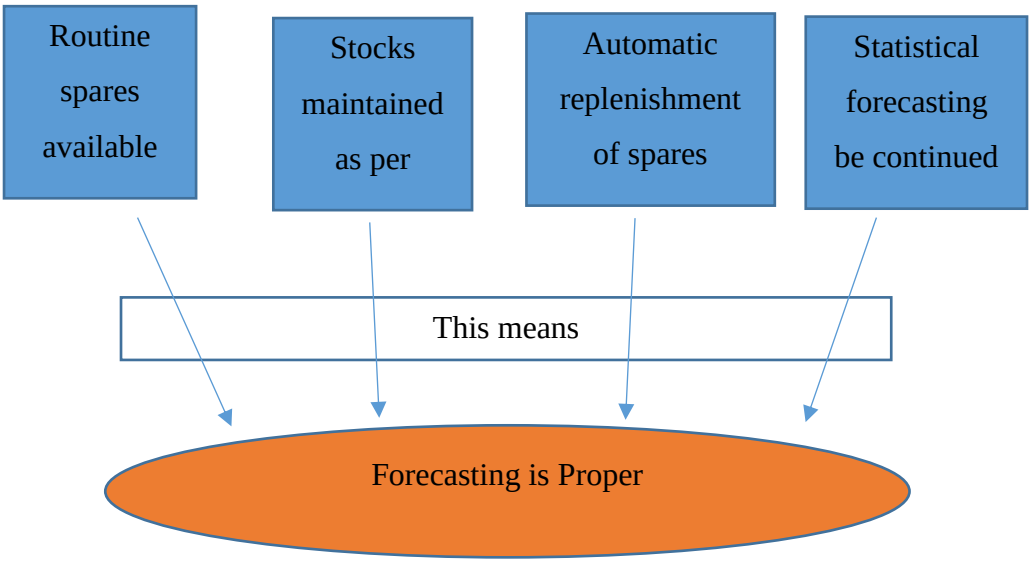


Figure 3 : Network Diagram of Forecasting

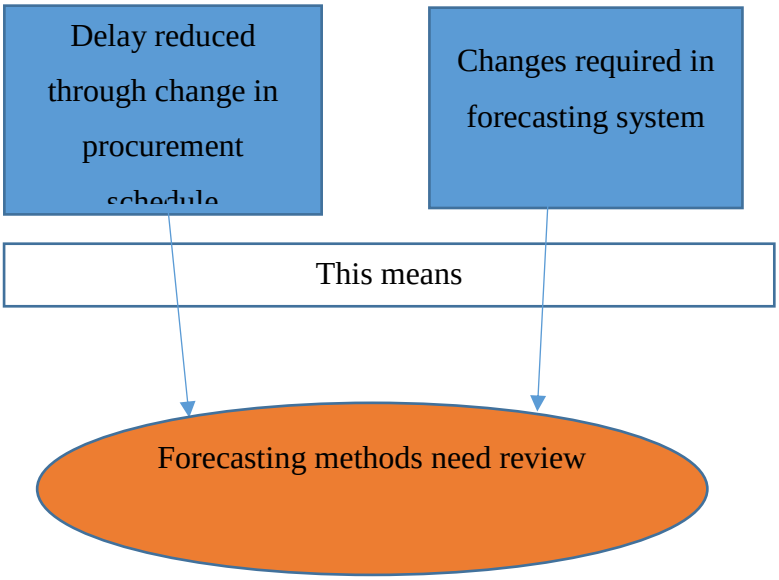


Figure 7.3: Network diagram for Forecasting Review

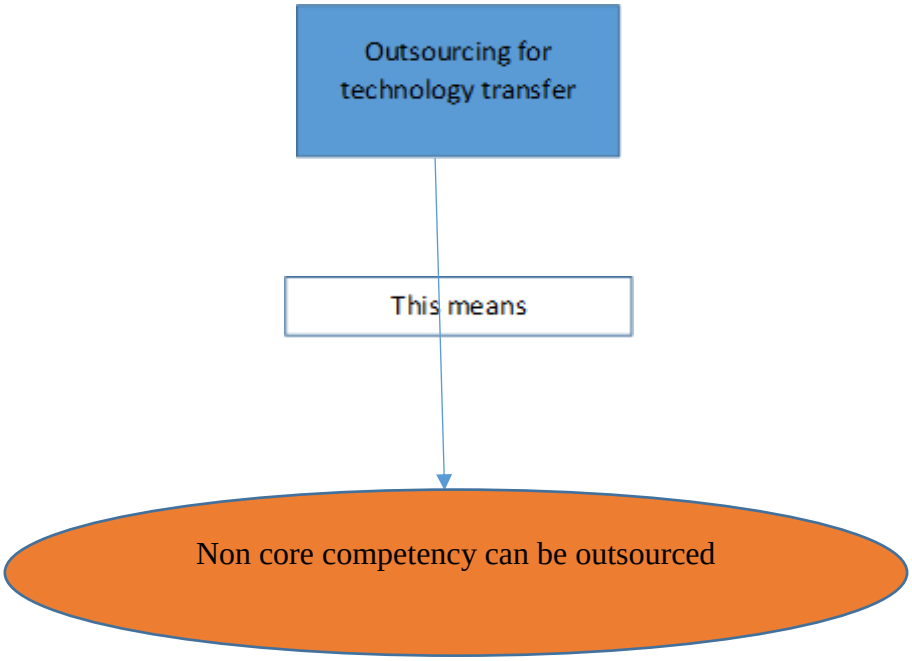


Figure 4 : Network Diagram for Outsourcing

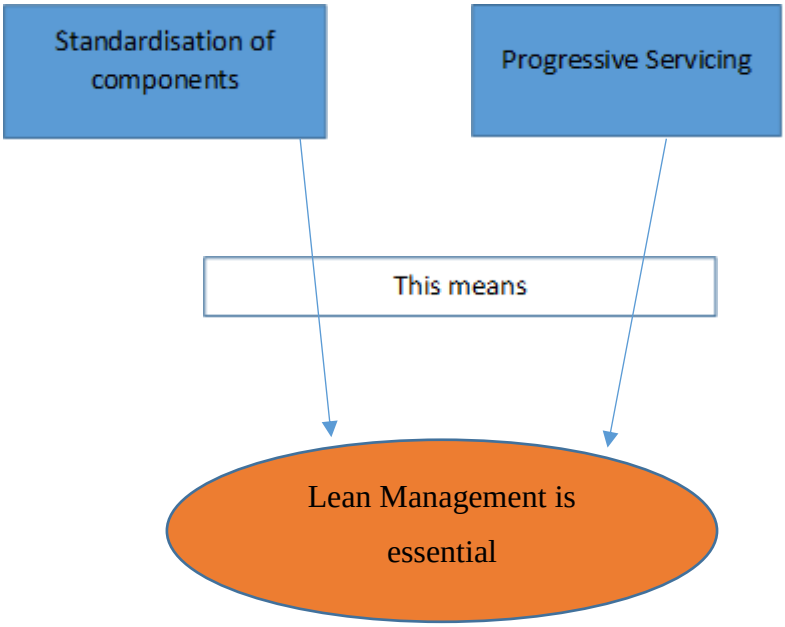


Figure 7.5 : Network diagram for Lean Management

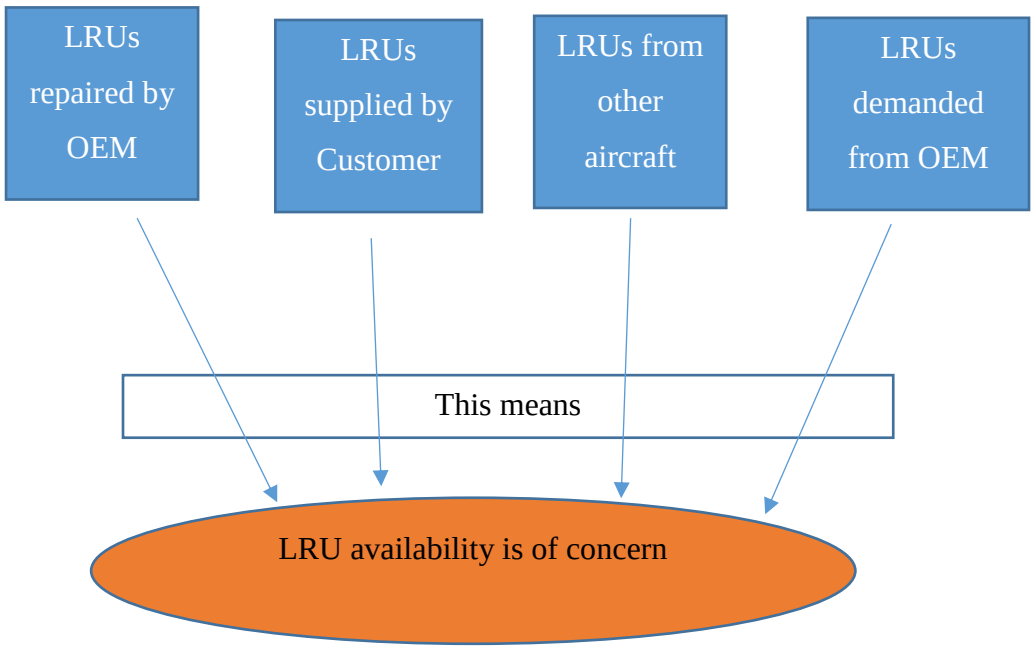


Figure 7.6 : Network Diagram for LRU Availability

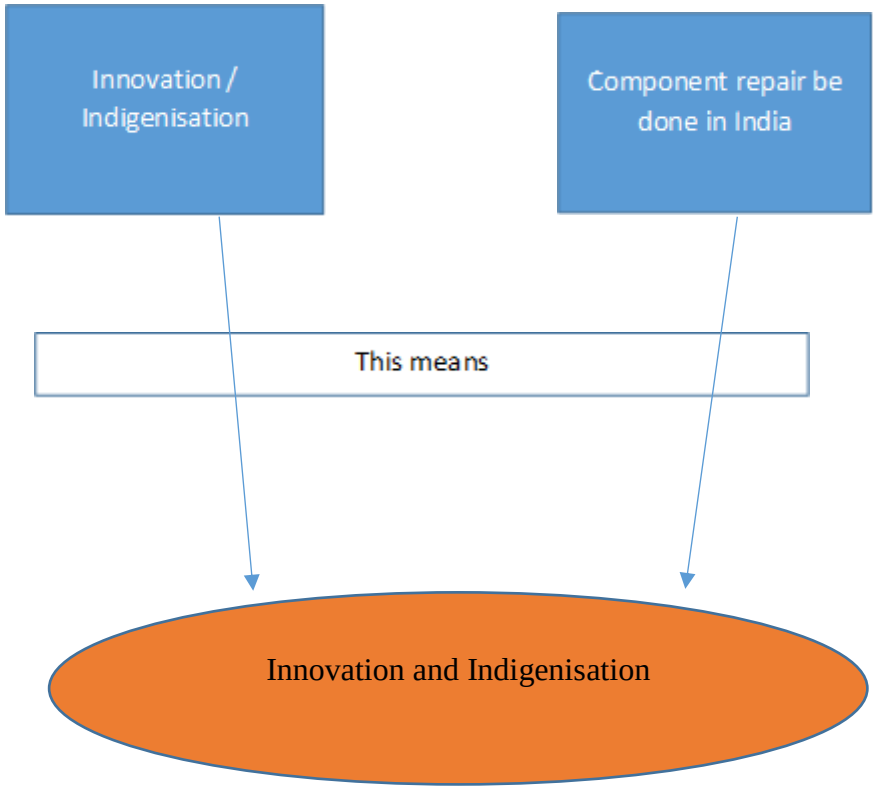


Figure 7.7 : Network Diagram for Indigenisation

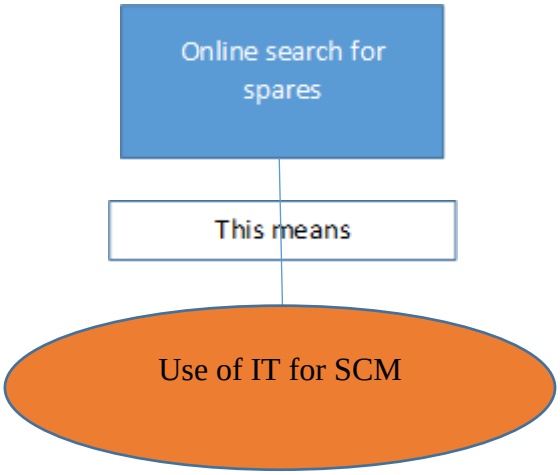


Figure 7.8 : Network Diagram for IT

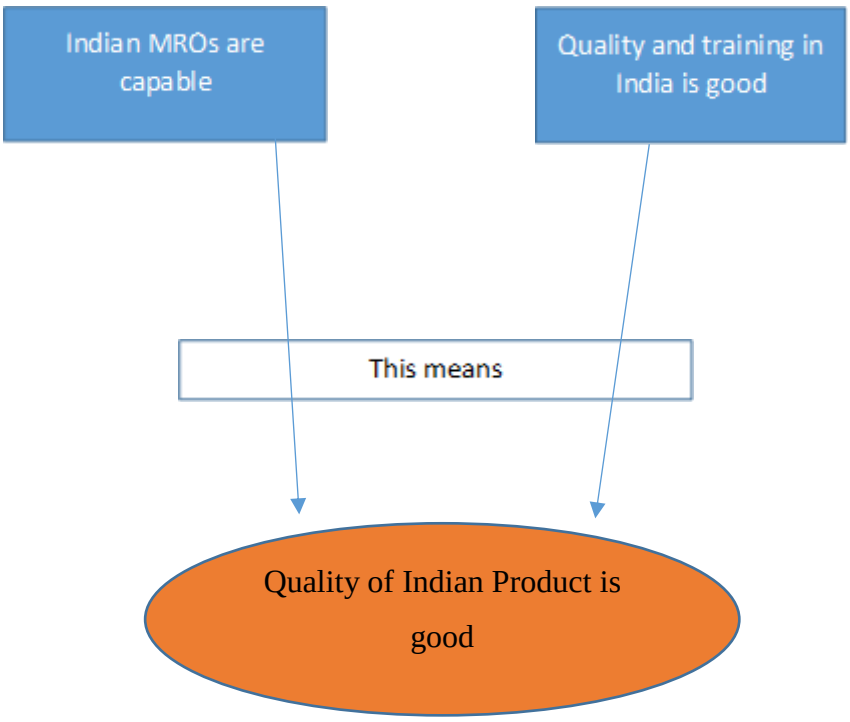


Figure 7.9 : Network Diagram for Quality

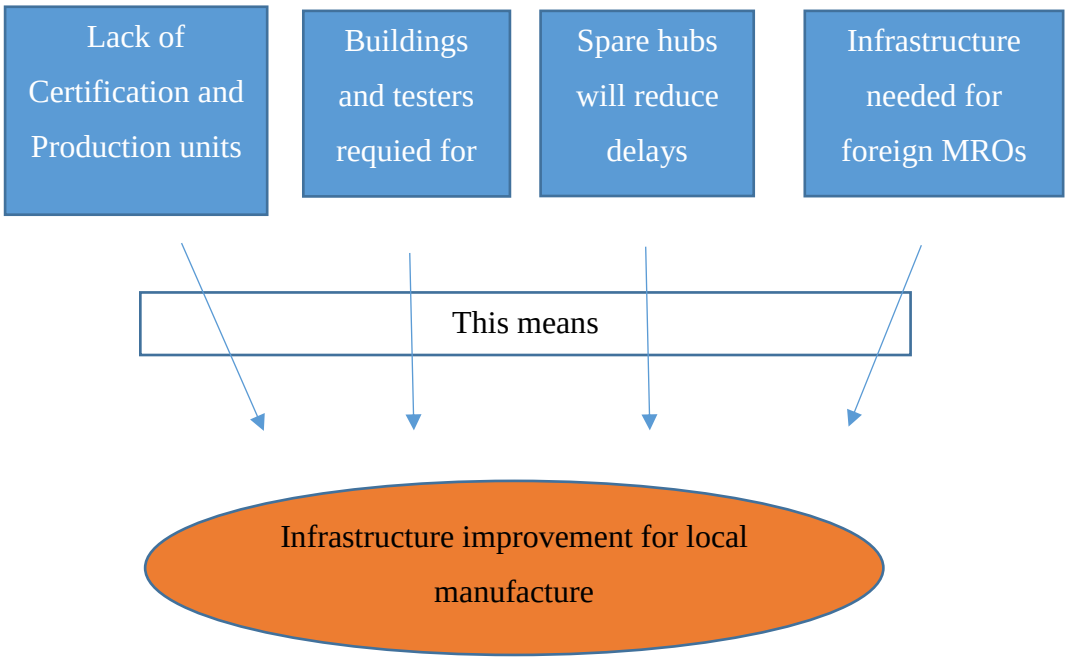


Figure 7.10 : Network Diagram for Infrastructure

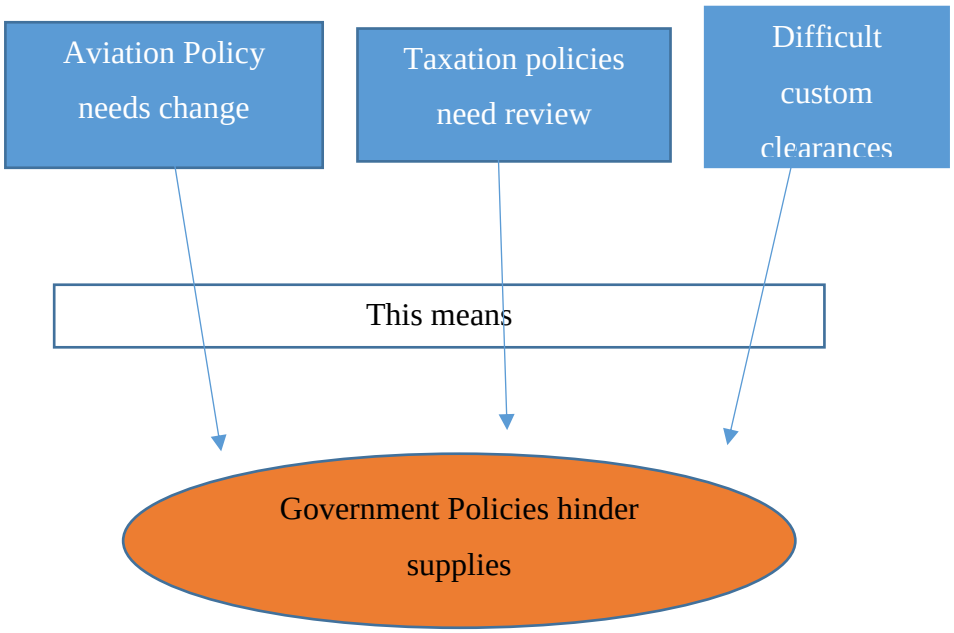


Figure 5 : Network Diagram for Government Policies

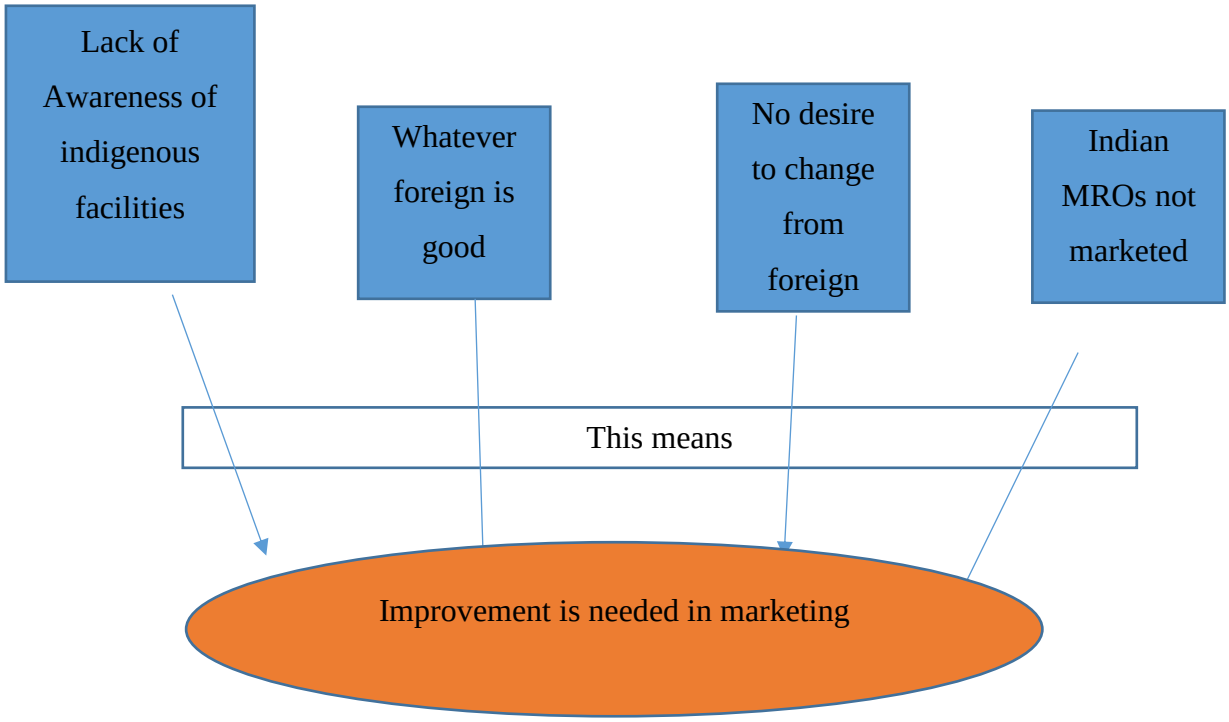


Figure 7.12 : Network Diagram for Marketing

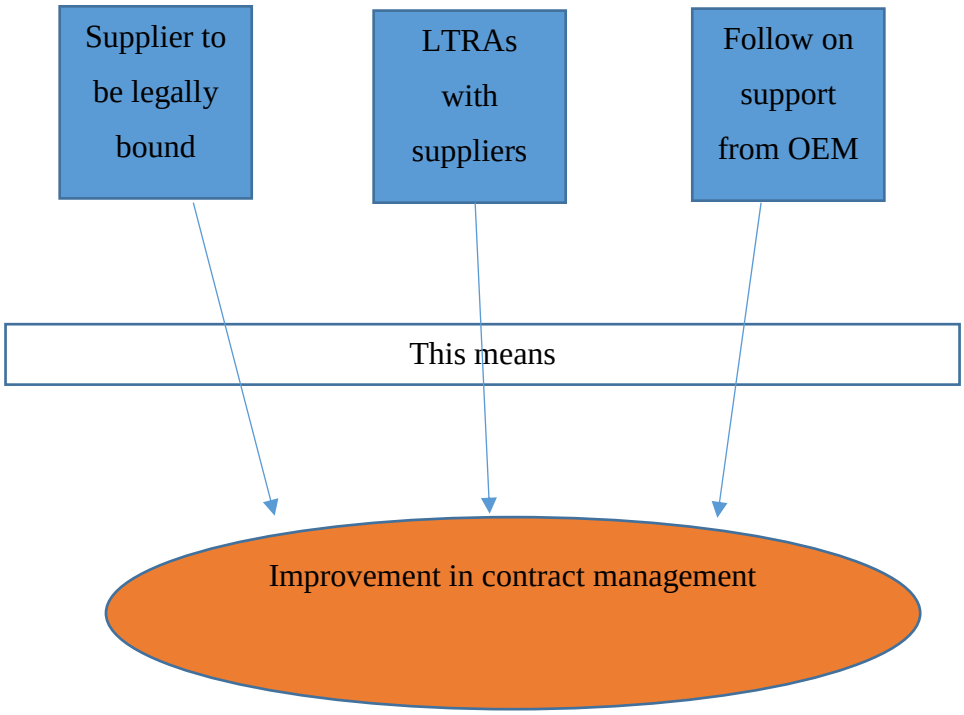


Figure 7.13 : Network Diagram for Contract Management

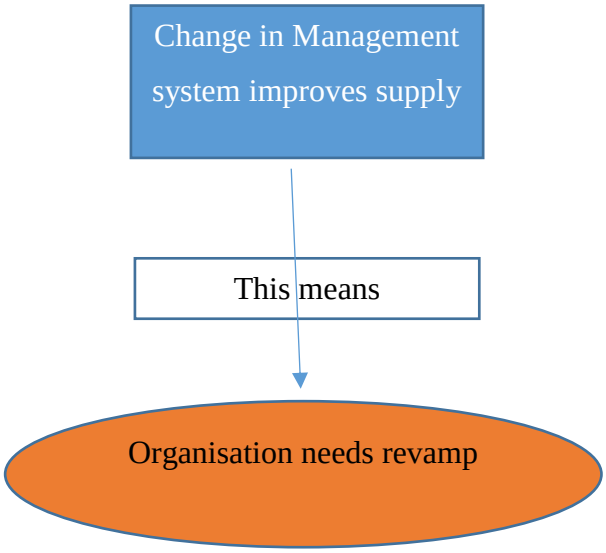


Figure 7.14 : Network Diagram for Organisation

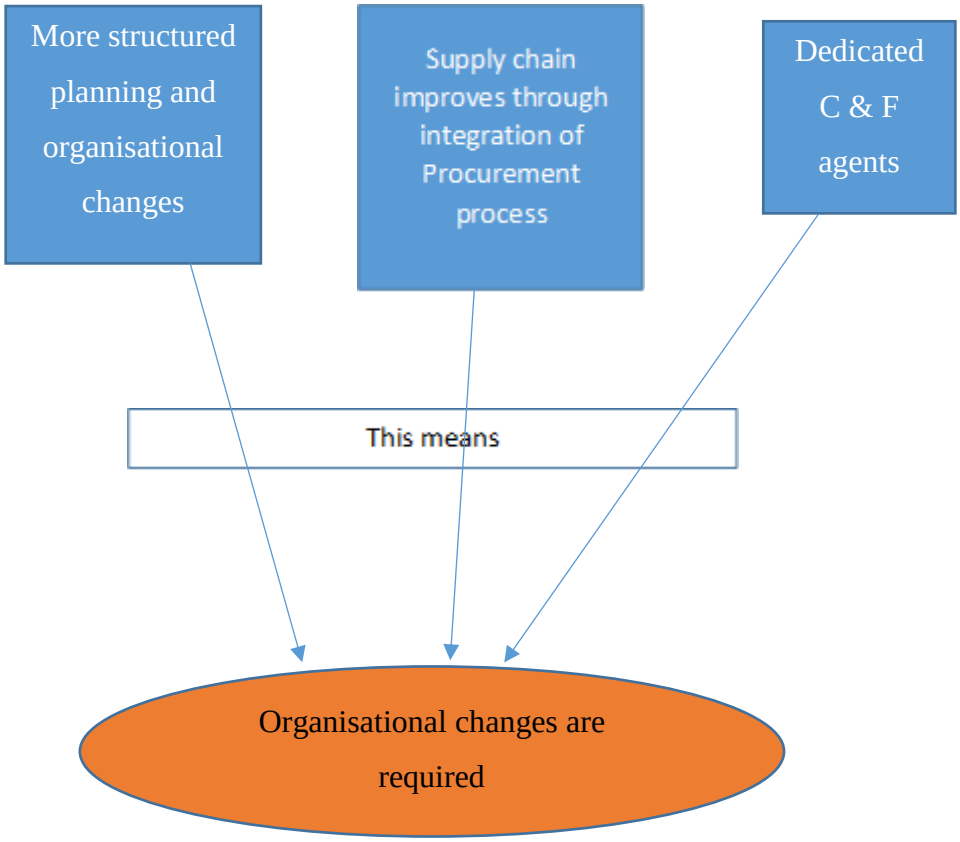


Figure 7.15 : Network Diagram for Organisation change

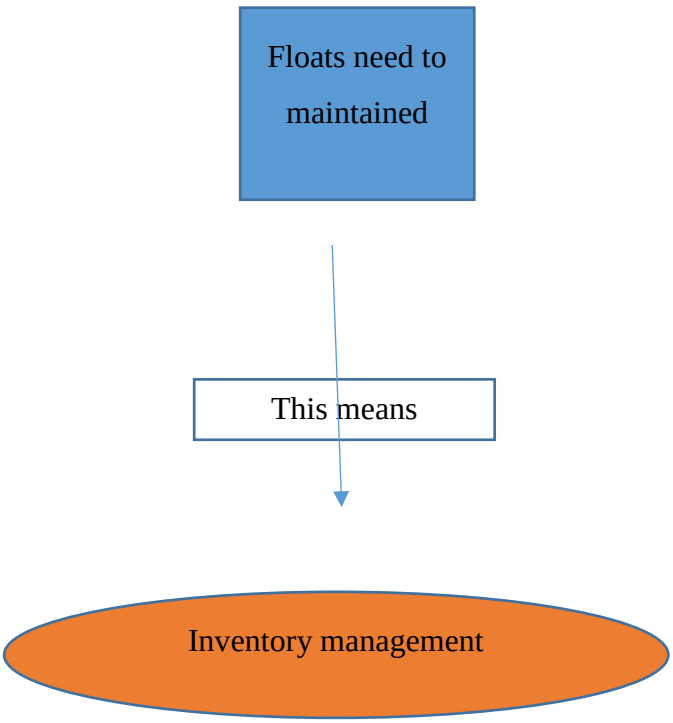


Figure 6 :Network Diagram for Inventory Management

As stated earlier this is further networked to obtain axial codes as given in Fig 7.17 below.

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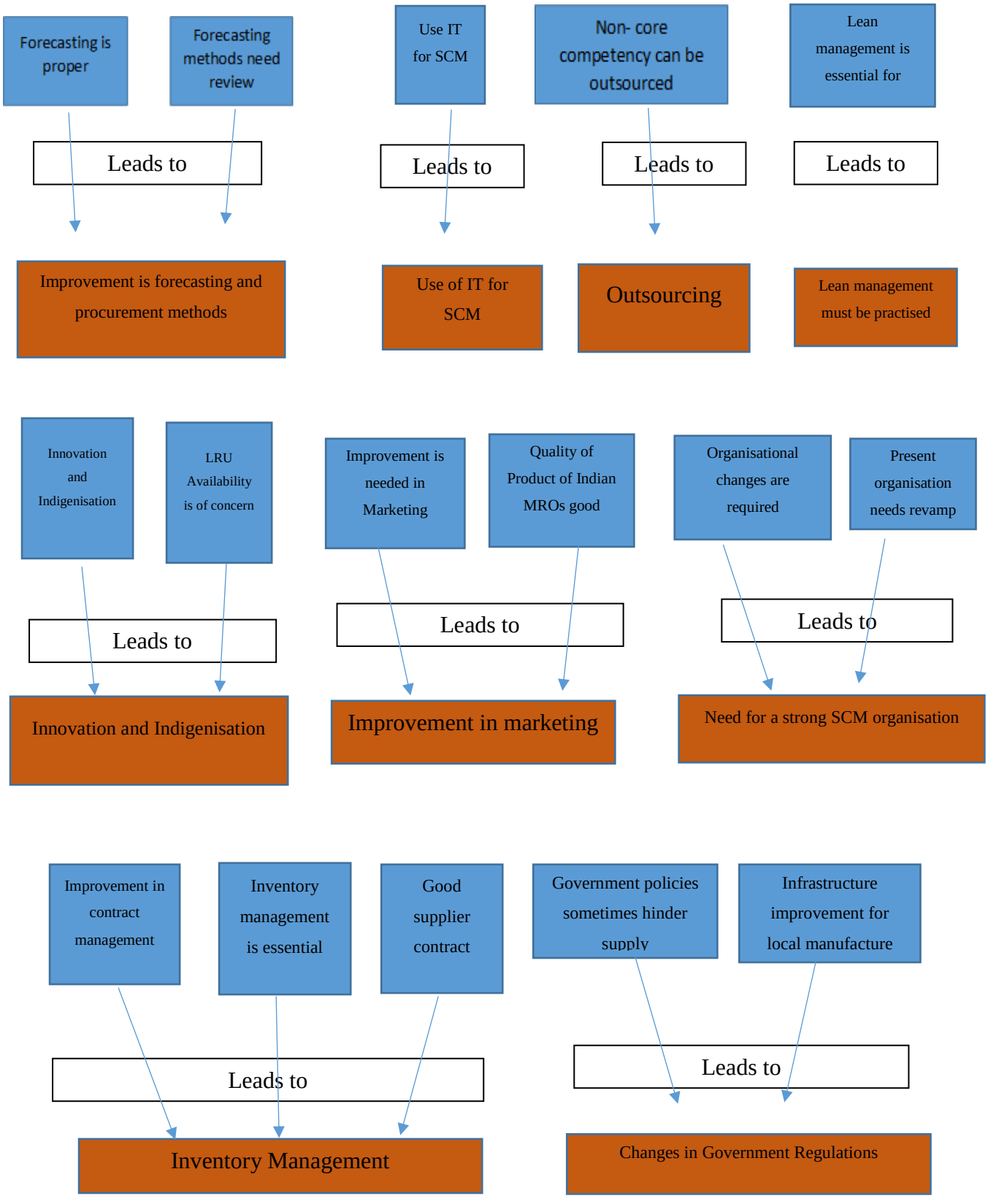

Figure7.17: Netwoek for axial codes

7.6.1 The final (selective) codes were also mapped against the output of the Document analysis (RO 1). This has then helped in getting the selective codes.

7.7 Requirements for Success of MROs. The discussions with the decision makers in the Indian MROs has also helped the researcher to validate the selective codes from the axial codes above. A deeper study of the axial codes also helped in indicating the selective codes. These were then merged with the initial conceptual lens (the themes) to obtain the factors that affect aviation MROs in India. This is also seen in the network diagram used for codification analysis. It is seen that Three factors in addition to the conceptual lens have emerged after data analysis. The major factors that have emerged after analysis of data and reiteration of the codification process are listed below. It has been established that for success of an aviation MRO the following are mandatory requirements.

(a) Improvement in forecasting and procurement methods.
(b) Improvement in Marketing
(c) Innovation and indigenization
(d) Outsourcing
(e) Changes in Government Regulations including custom clearances.
(f) Need for a strong SCM Organisation.
(g) Following Lean Management.
(h) Use of Information Technology
(i) Inventory Management

7.7.1 As can be seen these are directly obtained from the selective codes obtained through working on the axial codes as well as discussion with experts, both Indian as well as International. Some of the discussions are also placed below after the validity tests.

7.8 Validity Check. **Maxwell** (1992) identifies **five types of validity** that should be examined in qualitative research:

(a) Descriptive validity
(b) Interpretive validity
(c) Theoretical validity
(d) External validity or Generalizability
(e) Evaluative validity

7.8.1 For this research interpretive validity is used which means investigating whether the phenomenon is being explained based on the participant's perspective rather than the researchers.

7.8.2 All applicable tests of validity were applied to the Interview Schedule to ensure that the construction of the questionnaire is valid and reliable responses would be available from it. To be successful, the Interview Schedule should be comparatively short and simple i.e., the size of the questionnaire should be kept to the minimum. (Kothari, 1990) The schedule was therefore restricted to only eight questions. The codes so obtained earlier were then validated by the senior officials in the MROs that the researcher visited. Some of these discussions are given below.

7.9 Improvement in Forecasting and Procurement Methods.

7.9.1 Many of the experts talked about improvement and forecasting methods one of the quote is given below.

Mr T Ravikumar AGM HAL

"Delays in procurement can be partially offset by maintaining a float of spares. The supply chain can be improved by proper forecasting and ordering for spares in advance".

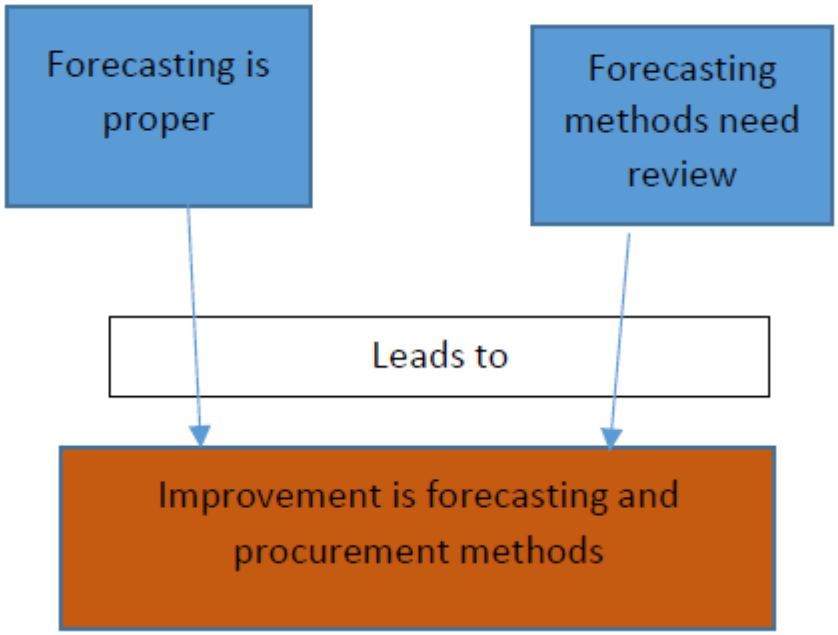

Figure 7.18 : Axial Network for Improvement in Forecasting

7.10 Improvement in Marketing

7.10.1 This has also been given importance by some experts. They felt the MROs are not marketing themselves well.

Aravind Singh Production Manager Indamer

"Indian MROs are not being chosen due to lack of marketing".

K Vasantha Kumar Manager Production HAL

"Marketing of quality and expertise is also required"

Figure 7.19 : Axial Network for Improvement in Marketing

7.11 Innovation and Indigenisation

7.11.1 Indigenisation / Innovation is one way of reducing delays through local manufacture.

B Shyamsundar DGM Production HAL

"Innovation/indigenisation/local manufacture will improve the supply chain."

TE Manivannan Procurement Manager Indamer

"Innovation/Indigenisation iAxials one way of improving supply chain."

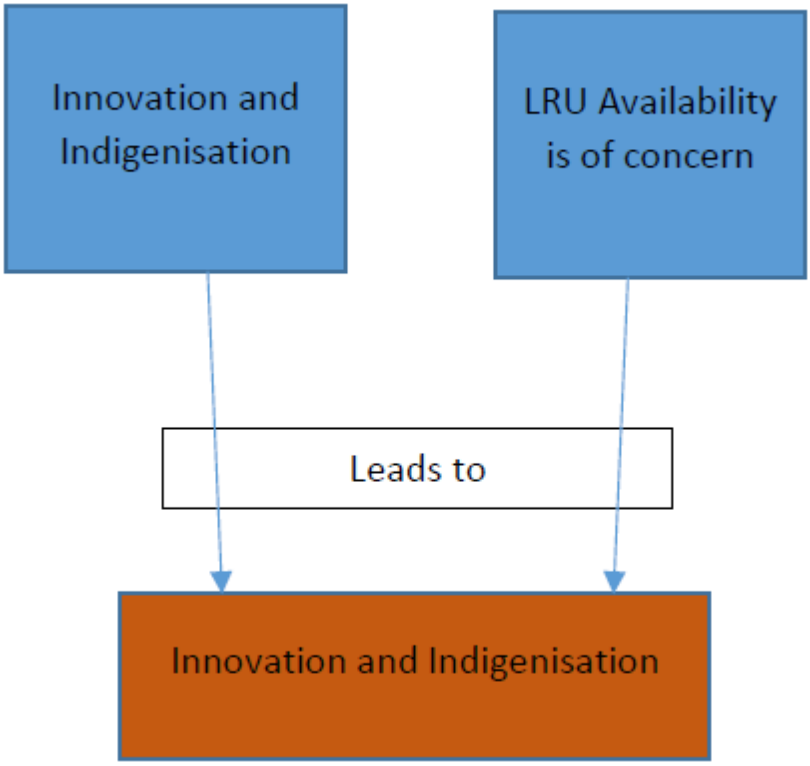

Figure 7.20 : Axial Network for Innovation and Indigenisation

7.12 Outsourcing

7.12.1 Outsourcing of non core activities will reduce work load. Also if outsourcing included transfer of technology in adds to capability of the MRO.

NV Subramanian Manager Production HAL

"Outsourcing can improve the supply chain it will also increase level through TOT."

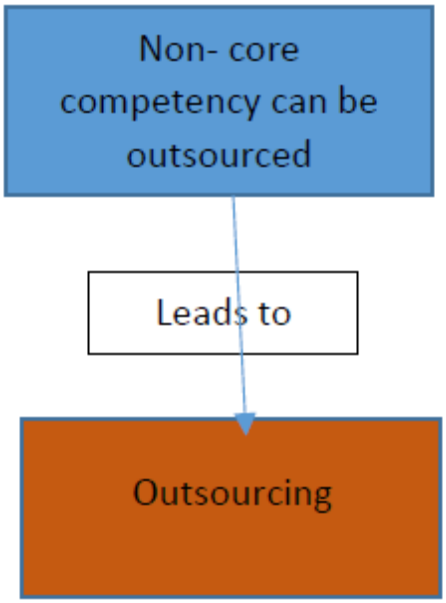

Figure 7.21: Axial Network for Outsourcing

7.13 Changes in Government Regulations

7.13.1 Government has recently introduced the National Civil Aviation Policy 2016 which is likely to help the MROs considerably.

MK Srivastava Manager Air works

"Lack of Government policies prevent work being given to Indian MROs."

R Ravindra Floor Manager Indamer

"One of the main reasons for MROs delays is tax structure."

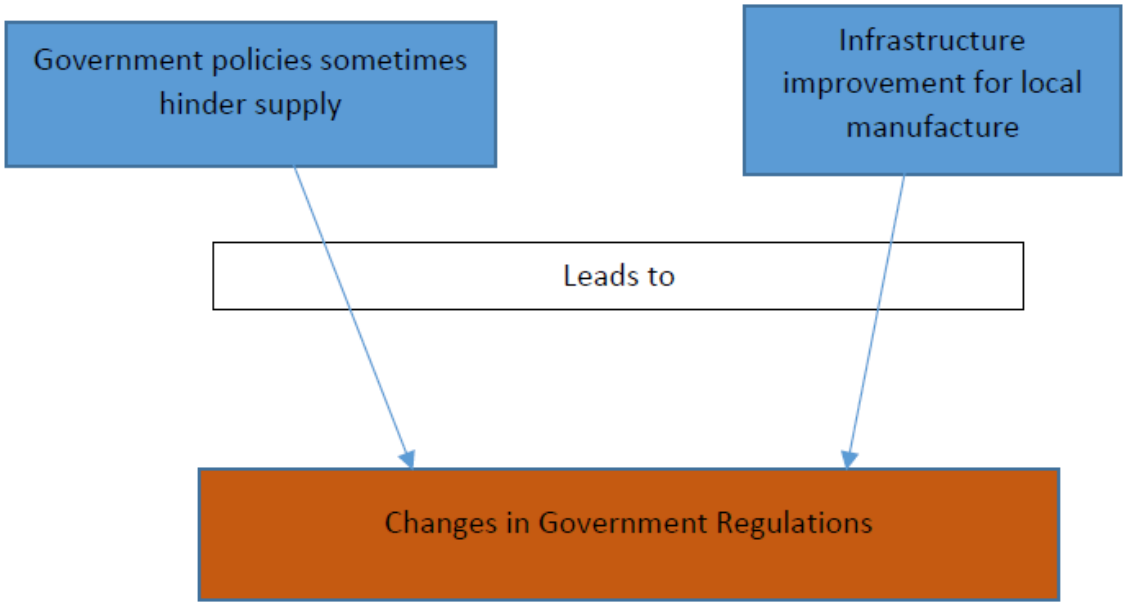

Figure 7.22 : Axial Network for Change in Government Regulations

7.14 SCM Organisation

7.14.1 SCM organization needs to be changed through integration of procurement and forecasting processes.

Wg Cdr NM Rai (retd) Chief of Quality Airworks

"There is a need to change the procurement system and the supply chain can be improved through integration."

Sylvan Nau Head of Materials Airbus

"Spare provisioning starts from design stage. Long preparation is required for short supply time. Increased reliability means more expensive parts and higher engineering. Integration is openly sharing information and needs."

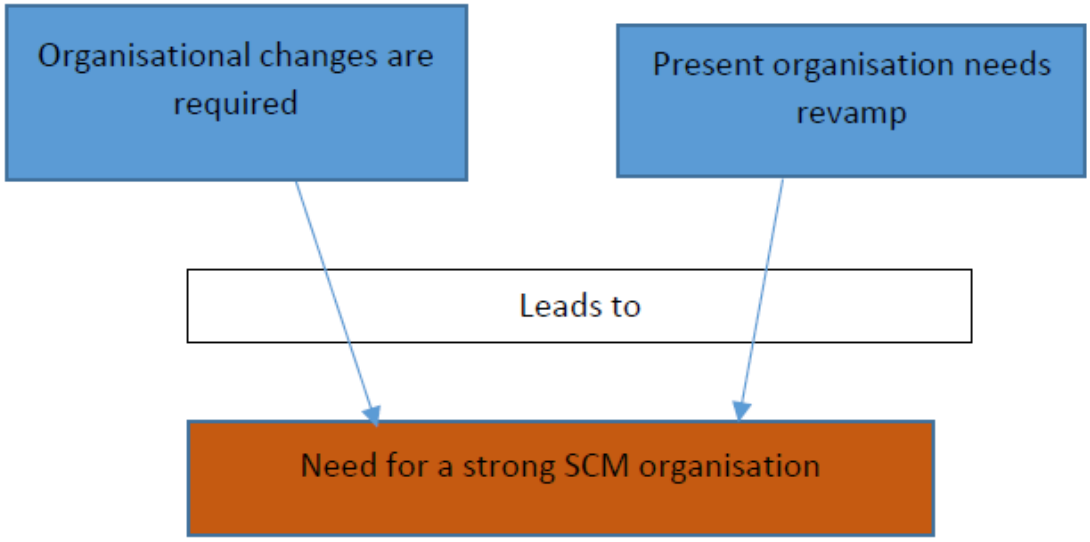

Figure 7.23 : Axial Network for strong SCM Organisation

7.15 Lean Management

7.15.1 Lean Management reduces unnecessary work and thus reduces cost and time. It can be achieved through standardization and progressive servicing.

Rebecca Merkel Boeing

"Many airlines have now gone into the philosophy of progressive servicing rather than check A, B or C etc".

Figure 7.24 : Axial Network for Lean Management

7.16 Use of IT

7.16.1 Use of IT for e procurement as well as for on line spare availability reduced procurement time.

B Rajini Production Officer Airworks

"Delays can be reduced through on line e procurement"

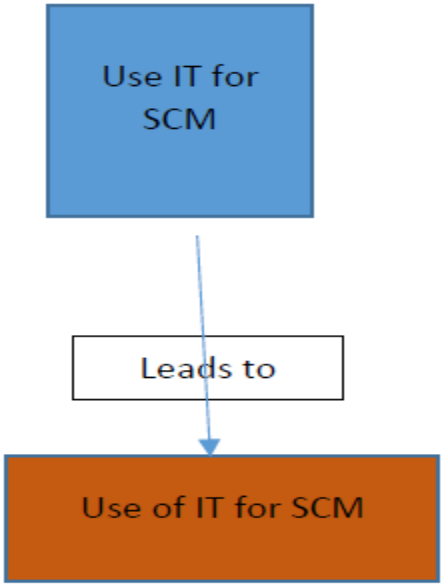

Figure 7.25 : Axial Network for Use of IT

7.17 Inventory Management

7.17.1 Inventory management can be achieved through maintenance of floats but care should be taken not to increase costs heavily.

BK Tripathy DGM HAL

"There is a possibility to maintain floats."

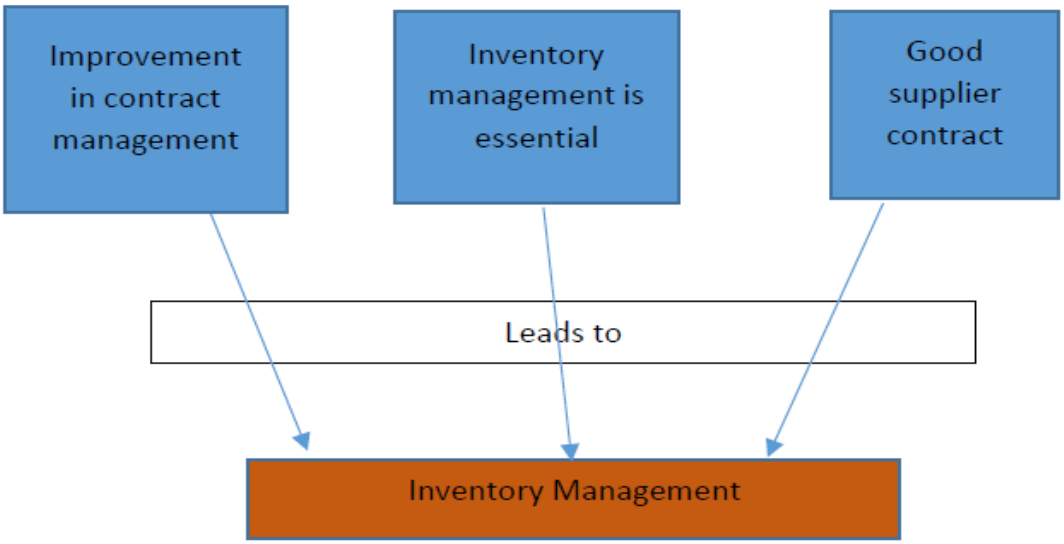

Figure 7 : Axial Network for Inventory Management

7.18 Discussions with experts

7.18.1 Transcripts of some more opinions of experts are given subsequently

Mr KV Krishnan VP at Air Works Hosur.

"Normally, the quote for MRO work includes cost of consumables and labour only. Other than simple parts like batteries and heat exchanger we do not repair any components of aircraft. The supply chain can be improved by having dedicated freight forwarders and clearing agents. Though we have talent in our country because govt policies and regulations we suffer. Aviation MRO has a great future in India. The main reason for Indian MROs not doing well is that our stakeholders (The Airlines) are not prepared to explore and use local facility. There is craze from going abroad and laziness to change,"

Mr NV Subramaniam ED at HAL.

"Outsourcing is one of the options which would give us the knowledge transfer and would derive price, product and promotion strategies and cost benefit in the long run. Repair of components is done only where transfer of technology has been done by the OEM. We need to deliver services by balancing quality, quantity and velocity parameters in our process".

Mr M Muthukrishna GM (Production) at GMR

"GMR is doing well in aviation MRO because they have good contractual agreements with suppliers who deliver at very short notice. My company uses statistical forecasting methods for advance demanding of spares."

Ms Vandana Rao GM Procurement at Air Works

"The main hurdles in the functioning of MRO are lack of awareness, taxation systems, bureaucracy, and the mindset of existing operators".

Rekhi T DGM (Overhaul) HAL

"Supply chain can be improved by joint working of customer and HAL and sharing inventories as being done by US Airforce".

Mr Yogendra Kumar VP Indamer

"Supply chain can be improved by identifying dealers who stock goods for OEMs. It is also possible to utilise online search engines like ILS, PartLocator etc to check availability of spares with various stockists".

Mr GR Dharnidhar, GM (prod) Indamer

"Mindset and culture in Indian Aviation is to be blamed. Foreign Items are always valued higher than Indian. This should change."

Mr David Stewart VP at ICF International

"The strongest drive they give is to Engine and Component overhaul. The component overhaul follows the path of Engine Overhaul. The new generation ac that are coming up mainly require repairs to components rather then check servicings. These aircraft are a catalyst to change the MRO supply mould and creating new opportunitites to aftermarket providers. Component and Engine overhaul infrastructure needs to be developed. Aircraft OEMs believe that their scale of operations and position in market control data inputs."

Simonas Sileikis Director, Asia Pacific Division of FL Technics

"All component MROs must develop core competency in this type of work to sustain such operations. It is possible to spread out to the world once you have such competency".

Mr Robert Haag Business Development Leader at Rockwell Collins

"The main problem is setting up component repair shops is infrastructure. However initially it should be possible to set up component stock hubs in India".

Mr Daniel Kraft of Lufthansa Technik

"For the new generation ac when data about operations is low a good Supply Chain should know about availability of stocks, details of operations and infrastructure for both aircraft and component MRO. There is going to be very limited availability of MRO services for new aircraft, also the experience of operating new ac will be low, which will lead to high prices. Also for contracted MRO rather than inhouse MRO, there will be unpredictable Turn Around Time, high dependency on shipping and little control over everything else. Inhouse MRO on

the other hand will have stable TAT, low shipping and high control. An inhouse component MRO will reduce TAT by as much as 75%".

7.18.2 The view of experts in the field the world over proves that for an MRO to be viable it must excel in its supply chain management. It can thus be seen that the future of MROs in India will be improved through better supply chain management especially through components and engine overhaul.

CHAPTER 8 - FRAMEWORK FOR IMPROVEMENT OF SUPPLY CHAIN OF INDIAN MROS

8.1 Steps for Improvement. For RO3 existing literature was used as basis to formulate a plan to improve the status of MROs. We will now see how the final codes can help in the sustainability of MRO industry in India.

8.2 Improvement in forecasting and procurement methods

8.2.1 Changes in forecasting and procurement methods will depend on the type of work carried out and size of the MRO. Some of the methods which could be applied are

(a) Provisioning Review. Based on previous data a weekly, monthly or annual forecast of spares can be done and procurement initiated. This system is suitable when there is known spare market dealers and generally supply periods are also known.

(b) Follow on Support. A contract is signed with the OEM / Supplier for supply of important spares immediately on demand as per a list agreed by both parties.

(c) LTRA. Long Term Repair Agreement is signed with the OEM / Repair agency for repair / replace items on an immediate basis.

(d) Reorder Point. For consumables and general spares like nuts, washers etc. a stock is maintained and orders placed depending on balance stock and supplier's delivery schedule.

8.2.2 The forecasting /procurement should depend on whether the requirement is

(a) Immediate. Procurement should be on as required basis to avoid AOG (Aircraft on Ground) situations.

(b) Short term. Simple and / or exponentially weighted averages may be used.

(c) Medium term. Regression or Time series analysis be done for forecasting and procurement.

(d) Long Term. DELPHI or think tanks must be used so that unnecessary inventory buildup is not there. (Markus, 2007)

8.3 Improvement in Marketing.

8.3.1 The MRO needs to market itself to prove that it can deliver at the right time and of the right quality. For this initial work may have to be carried out at discounts to capture the market. Once credibility of the MRO is established the volumes will increase. The procurement methods will require to be tweaked regularly depending the work at hand and expected / contracted so that delivery schedules post MRO work are met. Brochures giving achievements and capabilities of the MROs need to be circulated to all the aviation companies. The analysis of the requirements of different customers must always be done and a marketing strategy document be brought out. Following 20-80 rule, the aim should be to put most of the efforts into those 20 per cent of customers who provide 80 per cent of profits. (Crown, 2009)

8.3.2 Some of the marketing strategies which could be employed are

(a) Direct Interaction with customers.

(b) Help customers solve a problem.

(c) Collaborating with influential people of the industry.

(d) Partner with natural allies.

(e) Generate data to target customers. (Murray, 2015)

(f) Pricing strategy to enter into competitiveness simultaneously maximising profits.

(g) Give a good name to your company so that it is retained by the customer.

8.4 Innovation and indigenization

8.4.1 Indigenisation means substituting an imported item with one that is manufactured within the country. The item manufactured within the country need not be a replica of the imported item. It could be functionally the same, but could have more modern, energy efficient

and reliable parts that could be either imported or indigenous. Spares could be locally manufactured through reengineering. This reduces dependability on supplier especially if the supplies are ex-abroad. There could be issues of certification but these could be overcome through persistent efforts. Various government schemes like offsets from foreign vendors could be utilized for setting up the infrastructure for this. The present "Make in India" slogan of the Government should encourage the MROs or their ancillaries to produce spares locally and benefit the company. Use of additive manufacturing is one of the best methods of indigenization.

8.5 Outsourcing

8.5.1 Outsourcing was once only an option. But today it has become imperative in the competitive world. With the presence of the Internet, added with customer revolution, it is necessary that the companies especially aviation MROs focus on core competencies rather than vertical integration. Therefore original equipment manufacturers (OEMs) / MROs must give contracts for majority of non-core manufacturing operations. Contracts must also be given for other non core operations in the areas of assembly, distribution, and support All outsourcing contracts should also include technology transfer with a view to enable manufacturing / repair inhouse. As already stated, all non-core work should in any case be outsourced. A transfer of technology clause during outsourcing will enable the MRO company to get into manufacturing of these spares. Outsourcing could be selective, through licensing or contracting. (Doug, 2017). This also ensures that the output of the MRO meets all the quality requirements of aircraft maintenance. This is also applicable to Indian MROs as well.

8.5.2 The most important reason to outsource is to reduce administrative burdens and focus on strategic areas. There are many other reasons for outsourcing and these are listed below.

(a) Reduction in costs**.** Costs can be reduced by purchasing assets from a company and then lease the assets back as a part of an outsourcing deal. This is being regularly followed by aviation companies.

(b) Focus on core functions**.** A company generally has a few functions that are key to its survival while other functions or activities are needed but are non-core. There may also be a requirement to outsouce core functions which may become less

important in future. A company must keep those core functions which they can do better than any service provider.

(c) Acquire new skills. This is a very common reason for outsourcing. This is used for outsourcing activities which need very high skill levels, such as in the areas of computer software and hardware services as well as engineering services. This need not be outsourced once internal skills are developed.

(d) Acquire better management**.** In case the company feels that some functions are not upto the expected level expected due to lack of management support or individual or combined incapability these could be outsourced to gain access to the management skills of the supplier.

(e) Avoid labour issues. If there are labour issues due to which a company is constantly bogged down then outsourcing is a viable option.

(f) Strategic Focus. This does not require an explanation.

(g) Avoiding major investments. Outsourcing a function that requires major investment is best to be outsourced. For example, by outsourcing transportation activity expenditure on can be avoided.

(h) Improve flexibility in working. This also does not require explanation.

(i) Enhance credibility. This can be achiebved by using outsourcing as a marketing tool by quoting names of major companies as suppliers.

(j) Improve performance. By wanting to outsource a non-performing function a company may induce its staff to do better so that they do not lose their jobs.

8.6 Changes in Government Regulations including custom clearances

8.6.1 This is a topic which has to be dealt with at a very high level. During interaction with authorities at MRO it was brought out that MRO Association of India has been formed and it interacts with the government for easing regulations about MROs. The custom clearances will also get expedited once the Government is brought on board. With “Make in India” and other innovative ideas the custom clearance problem in any case will get automatically resolved. The government has already addressed this issue through the NCAP – 2016 (National Civil Aviation Policy). Some of the major benefits given by the Government which will benefit Indian MRO industry are as follows. These steps wil definitely ease work and provide incentive to MRO opeators.

(a) Tools and tool kits used by MROs are exempted from customs duty.
(b) MROs are not required to give proof for requirement of parts and certification by DGCA is enough.
(c) Restriction on use of duty free spare parts is extended from one year to three years.
(d) Advance export of serviceable parts has been allowed.
(e) Allowing Foreign aircraft to stay in India till MRO work is over.
(f) Visas and entry passes for foreigners for carrying out MRO work in India have been liberalised.
(g) MRO service providers will be allocated adequate land to carry out their work.
(h) Royalty and handling charges at airports will not be levied on MRO operators.

8.7 Need for a strong SCM Organisation

8.7.1 The need for a strong SCM organization cannot be refuted. This is however a management decision and will depend on the requirement of the organization based on the workload. A plan for organizational restructuring to cater for Supply Chain Management should at least be ready for future expansion. A typical SCM organization should consist of a Supply Chain Manager with a Despatch section, a warehouse and a Procurement section. It can be centralized or decentralized as per requirement of the company. (Julian & Jarosch, 2012)

8.8 Following Lean Management

8.8.1 Lean should be a way of life in any organization, and this should be inculcated at all levels in the company, including offices. Standardisation must be a part of lean management wherein use of standard parts and components will reduce requirements of additional training as well as reduce stocks. Value analysis and value engineering will also contribute to lowering of costs. Some other lean techniques are Just-in-Time, reducing waste, automation etc. (Vorne, 2011). Lean Management generally gives positive results, however at times this does not address typical issues such as operational bottlenecks and delays due to outsourcing. This can then be addressed through dynamic scheduling and techniques like time slicing which are part of lean management.

8.9 Use of Information Technology

8.9.1 As brought out earlier use of information technology to track spares availability is the need of the hour as many companies list availability of their spares on many websites. Many software are also available on the market for this purpose. Other IT tools which can be used are for capacity planning, master scheduling, display of standard work etc. which directly improve the performance of the MRO.

8.10 Inventory Management

8.10.1 Inventory management is an essential part of Supply Chain, in that the supply chain managers need to keep the inventories to a minimum. Various standard methods of Inventory Management are available, some of which have already been discussed.

8.11 Framework for Improved MRO. A suggested framework for an improved MRO is shown below in a diagrammatic form.

8.11.1 It can be seen from the framework that Government Regulations are at head and Marketing is the feet of the framework, but Supply Chain related factors are the heart of the framework.

Figure 8: Framework For Viable MROs In India

8.12 Takeaways from the Framework

8.12.1 Following will be the takeaways from the new framework when implemented properly.

(a) Indian MROs will get global recognition

(b) There will be more of “Make in India”

(c) With more work quality of workers will improve further through experience.

(d) Since cost of MRO work in India will be cheaper, the viability of Indian Aviation operators (Airlines) will improve.

CHAPTER 9 - CONCLUSIONS, FINDINGS AND RECOMMENDATIONS

9.1 Conclusions

9.1.1 Modern aviation operations are much more complex than perceived. This increases the requirements of supply chain to be speedier, agile, resilient and accurate well beyond the limits of conventional operating models. Therefore, instead of a piecemeal approach to logistics reform, a comprehensive reform program is the best option for multi-fold efficiency gains so as to match the dynamics of modern operations. There is thus a need for an Integrated Materials Management programme which encompasses all the above quoted parameters. It has to be however kept in mind that it would be effective and sustainable only if the entire logistics system is subjected to an integrated analysis as discussed above. All aircraft operators will need to develop, implement and encourage best practice among industry partners across sustainable development issues. Based on the above the following can therefore be concluded.

(a) It is possible for Indian MROs to change their working methods to become more profitable.

(b) This is mainly possible through improvements in the procurement of spares to reduce cycle times and thus gain market standing.

(c) There is a need for **Make in India** to improve supply of spares.

(d) Government has already taken steps to support the Indian MRO industry. The National Civil Aviation Policy 2016 takes care of the MRO industry as well.

9.2 Findings

9.2.1 The Major findings of the research are listed below.

(a) There is lot of scope for Indian Aviation MROs to be profitable and there is a future for Indian MROs.

(b) The main stumbling block in the success of Indian MROs is Supply Chain.

(c) Various MROs have different procurement schemes for spares, which need to be improved.

(d) The Supply Chain Organisation of the MROs need to be strengthened.

(e) MROs are not utilizing the Information Technology to the proper extent to enable improvement in the Supply Chain.

(f) There is large scope for Innovation / Indigenization for aviation spares which would reduce procurement time for spares from abroad.

(g) There is a need for righteous approach to the Government to improve the regulatory and taxation system for the Aviation MROs. In fact Government regulations need to support Aviation MROs in India. The New Civil Aviation Policy partially takes care of this.

(h) Lean Management and Standardisation will reduce losses of the MROs.

9.3 Recommendations

9.3.1 Major recommendations flow directly from the findings. These are listed below.

(a) For success of MRO improvement in the Supply Chain is most essential. Once this is achieved delays in production and related costs will reduce.

(b) The different procurement schedules as well as forecasting methods need to be improved drastically.

(c) Integration on the supply chain process is essential and strengthening of the Supply Chain Organisation is therefore required.

(d) The Supply chain managers need to use the IT sources effectively to locate and procure spares at the cheapest price and by the fastest means.

(e) The MROs companies must look for outsourcing and simultaneous Transfer of Technology to ensure components and spares are available locally.

(f) Innovation / Indigenisation through reverse engineering must be resorted to reduce dependence on foreign suppliers.

(g) The Government has already started the process of streamlining the process of taxation and other related regulations, the MROs must exploit these to the maximum extent.

(h) MROs must look for standardization and process simplification including progressive servicing to reduce costs and losses.

9.3.2 Political concerns make the aerospace supply network very complex. There is increased competition for aviation companies of the US and Europe mainly from the futuristic aerospace development programs of many emerging economies. US and France have given stimulus packages to their companies which have partially offset the government-funded schemes in India and China and other south east Asian nations. Successful management of supply chains always provides a sustainable method for maintaining competitive advantage. Some of these concerns later go down to the OEMs and their suppliers, as the end consumers of the supply chain. They in turn have to face pressure so as to remain sustainable and improve their design and production processes. Schemes like Make in India need to be promoted not only in word but also in spirit, through Government incentives.

9.3.3 The predominant cause of the operational delays are the disruptions that occur in the aerospace supply chain. These can be a result of natural disasters leading to subsequent transportation challenges. The production line may also be stopped due to reasons like labour unrest, strikes and other financial difficulties and resource constraints.

9.3.4 More effective workflows can come from communicating and collaborating with suppliers especially when it comes to sourcing and procurement. It also provides an insight into on sourcing processes and procedures in a number of key areas, such as the purchase orders status and incoming shipments. This also enables better managing of schedules, subcontract deliverables and changes within them. When information is available instantly it proactively improves management of the supply chain. It also controls their outputs and simultaneously encourages successful delivery to agreed service levels. Supply chain managers can establish greater transparency when they work in tandem with logistics service providers. This is especially in the status and location of goods in transit which enables real-time and accurate forecasting of delivery schedules. Similarly providing suppliers with visibility into production schedules of clients can help in planning to serve the OEMs as well as MRO's production and

shipment targets more effectively. This will also avoid the shortages which bring assembly or production to a complete stop. (Behrens, 2010)

9.4 Contribution to Literature

9.4.1 There has been no work done in the area of Supply Chain for Aviation MRO. The thesis itself is a major contribution to literature. The thesis proposes methods to handle the requirements of Indian Aviation MROs to make them more viable and profitable. Because of its empirical nature, due to non-availability of literature in this area, this will help managers in this field to take decisions which will help their organization to flourish. The conceptual framework for SCM improvement for Aviation MROs will help old and new MROs to improve their Supply Chains and gain Market. This will lower costs of carrying out MRO activities'. The findings of this research will also contribute to the theory of Inventory. The methods to reduce inventories simultaneously improving supply chains is a major contribution to literature.

9.4.2 Grounded Theory was initially propounded for psychological analysis. This was later extended to various other areas like Nursing etc. Grounded Theory methodology for collecting and analyzing empirical data in this area can be considered a methodological contribution in the area of logistics and SCM where Grounded Theory is not a dominant approach.

9.5 The Way Ahead

9.5.1 There are many more related factors, especially the role of quality in the supply chain management process. Although there are advances made in individual areas; for example, in process quality control; by many companies, there is still a scope for improvement. The relevance of manufacturing and repair methods for the aviation spares is a problem as this also contributes towards the costs of the spare inventory. As mentioned earlier, an area which needs to be studied as to why development in MRO (Maintenance, Repair and Overhaul) facility for aircraft operated by Indian (both private and public) aviation industry is not taking place. A developed MRO facility will ensure that the supply chain is effectively and efficiently managed through it, rather than directly by the Original Equipment Manufacturer. The nearer and more

developed the facility the faster will be the support in terms of spares and repair availability. This aspect therefore needs to be considered as a problem for the Indian Aviation to be sustainable.

9.5.2 Some more topics that may be studied to address the unique characteristics of MRO supply chains are:-

(a) Proactive and strategic inventory management

(b) Comprehensive link between service levels and inventory investment across the distribution network

(c) Workload assessment and prioritization

(d) Financial planning

(e) Preparedness and contingency planning issues.

9.5.3 These topics themselves can become subjects for further research and hence have not been discussed in this study. Some other related activities that could be carried out are :-

(a) Mapping of a comprehensive end-to-end process across all activities and players involved in logistics and consider the entire life-cycle of materials and processes to reduce inventory carrying cost.

(b) Designing suitable models to establish roles and responsibilities which challenge the traditional approach to planning inventory management, and maintenance.

Annexure A Bibliography

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Annexure B Interview Schedule

The Interview Schedule has been based on the initial conceptual lens and has been validated through expert opinions. The schedule is given below.

1. How much experience you have in the field of MRO?
2. What issues do you face in the course of MRO work on aircraft?
3. If you face a problem of spares what do you do?
4. Do you carry out repair of units in your company?
5. If you face delays in receipt of spares what do you think should be done?
6. Do you think outsourcing will reduce some delays?
7. How much IT is used to identify and locate spares availability?
8. What else do you think needs to be done? Is government helping in this?

Annexure c List of papers surveyed

S. No	Topic	Author	Year	Theme	Journal
1	Supply Chain Optimization within Aviation MRO	Aditya Kashyap	2012	MRO and SCM	International Journal of Computer Applications in Engineering Sciences [VOL II, ISSUE II, JUNE 2012]
2	Integrated MRO supply management	Thomas Terfehr		integrated SCM	Genesis Solutions
3	MRO Supply chain optimisation	Lalit Khandelwal	2011	SCM and MRO	Infosys White Paper
4	RFID the future of MRO supply chain management	Aviation Today	2004	IT	www.zebra.com
5	MRO Practices and their Link to Improved Competitive Performance	Patricia M. Swafford. Ph. D.	2003	Inventory Management	From Ph.D Thesis University of Texas at Arlington
6	An Exploration of Supply Chain Management	Mohit Tiwari	2005	SCM practices	From ME Thesis Massachusetts

	Practices in the aerospace industry and in Rolls Royce				Institute of Technology
7	Aerospace MRO supply chain: Track and trace with SAP RFID platform	Dr Ashish kumar tiwary	2007	IT	Infosys View Point
8	Air Transport MRO Outlook	Aviation week	2010	Outsourcing	Aviation Week MRO Europe 2010
9	Aerospace Standard for Maintenance, Repair & Overhaul	Sidney Vianna	2009	quality	(http://www.qualitydigest.com)
10	Supply Chain Design and optimisation	Stewart Kelly	2009	SCM Organisation	THE OLIVER WIGHT – WHITE PAPER SERIES
11	Lean manufacturing approach in aircraft maintenance repair and overhaul	Gabriela Nanova et al	2012	Lean Management	RECENT, Vol 13, No 3(36), November 2012
12	Supply chain management	Sotiris Zigiaris,	2000	IntegratedSCM	INNOREGIO project report

13	Supply Chain Management: More Than a New Name for Logistics	Martha c cooper et al	1997	SCM Theory	International Journal of Logistics Management, The, Vol. 8 Iss: 1
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