Total Quality Management In The Manufacture Of Aerospace Parts - Issues And Problems

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Abstract: The implementation of quality management in the manufacturing industry culminating in an implementation framework detailing the order in which certain tools and techniques should be implemented. It is intended as a guideline to the industry in general and to the small and medium sized enterprises (SMEs) in particular. Lean Six Sigma can be implemented. The tools of each of the Six Sigma were clearly provided thus giving a broad idea to the reader. Moreover, it can be seen that in order to manage the quality management there is in need of Six Sigma which enhances the process and solves problem of the industry. Furthermore, the implementation and expansion Six Sigma techniques are being conducted widely in the aerospace industry from the last couple of years. As it allows the industries to know the shortcomings and also work on the shortcomings for a better development. The firm has benefitted by the implementation of Six Sigma by the reduction on unnecessary costs and time. Also, the process of how the aerospace industry implemented the Six Sigma is also clearly outlined.

IndexTerms **- Aerospace, Six Sigma, 5's, TQM.**

I. Executive Summary

The implementation of quality management in the manufacturing industry culminating in an implementation framework detailing the order in which certain tools and techniques should be implemented. It is intended as a guideline to the industry in general and to the small and medium sized enterprises (SMEs) in particular. Many companies, especially SMEs, are confused and unable to decide where to start, what and when to implement certain tools and techniques in their total quality journey. With a quality initiatives' implementation plan, the short and long term training needs are automatically identified and its implementation mechanisms designed. It is acknowledged that given the uniqueness of each potential organization, there is a need for a customized implementation through the critical diagnosis of its present strengths, weaknesses, opportunities and threats. A concept of productive maintenance aimed at achieving overall effectiveness of the production system through the involvement of all the people in the organization.

A management philosophy embracing all activities through which the needs and expectations of the customer and the community, and the objectives of the organization, are satisfied in the most efficient and cost effective way by maximizing the potential of all employees in a continuing drive for improvement.

The utilization of the tools that are currently being practiced by the modern enterprises of business such as TQM and Six Sigma have currently been tested as well as espoused predominantly in the aerospace industry. And discusses which actually provides an ultimate difficulty that ascends in ABC Aerospace in the attainment of a very high level stability levels in the process of heat treating.
Lean Six Sigma can be implemented and is clearly discussed The tools of each of the Six Sigma were clearly provided thus giving a broad idea to the reader. Moreover, it can be seen that in order to manage the quality management there is in need of Six Sigma which enhances the process and solves problem of the industry.
Furthermore, the implementation and expansion Six Sigma techniques are being conducted widely in the aerospace industry from the last couple of years. As it allows the industries to know the shortcomings and also work on the shortcomings for a better development. As seen from the study provided, the firm has benefitted by the implementation of Six Sigma by the reduction on unnecessary costs and time. Also, the process of how the aerospace industry implemented the Six Sigma was also clearly outlined.

II. Introduction

The Aerospace Industry

The aerospace industry's product line is broad because its primary products, flight vehicles, require up to millions of individual parts. In addition, many support systems are needed to operate and maintain the vehicles. In terms of sales, military aircraft have the largest market share, followed by space systems, civil aircraft, and missiles.

In 1958, the National Aeronautics and Space Administration (NASA) succeeded the National Advisory Committee for Aeronautics and initiated the Mercury manned space program. In 1959, the U.S. Aircraft Industries Association, which was formed in 1919 to promote American civil aviation, changed its name to the Aerospace Industries Association. U.S. aerospace industry interests are represented through the AIA, an aerospace-industry-funded organization that provides a forum for technical and policy issues, and whose membership consists of the major companies in the field.

The beginnings of the Indian aerospace industry dates back to 1940 when Walchand Hirachand set-up the Hindustan Aircraft at Bangalore. The corporation started with a modest history of building and overhauling monoplanes. History was written in golden words for the Indian aerospace industry when a Hindustan Aircraft Ltd built 'Curtiss Hawk P36' took to skies on 31st July 1942.With the onset of the World War II, the establishment was taken over by the allied forces. Hindustan Aircraft was given a major infrastructural boost. Over the course of the war it was converted to a mega aircraft overhauling centre by the allied forces. The organization became one of the biggest aircraft overhauling centre's in the Eastern Hemisphere.

Soon after independence the organization was taken over by the Indian government. The evolving Asian arms race meant India had to master the complex weapon manufacturing cycles to meet the needs of its armed forces. India set up multiple state-run Public Sector Undertaking (PSU) corporations to promote defense manufacturing industrial bases. These PSU's were designated as manufacturing hubs and they were to be supported by DRDO laboratories. Indian aerospace. Aeronautical establishments were working with zeal to put India on the global map. In July 1970, HAL started the helicopter division to locally manufacture rotary aircraft. Under this division India mass produced the Chetak and Cheetah helicopters. To date, these copters serve the armed forces at some of the most inhospitable conditions.

HAL apart from this also started setting up dedicated Research and Development (R&D) centre's throughout the country. These centre's were aimed at meeting the increasing technological demands of the armed forces. These centre's were manned by some of the most intellectual brains and gave path blazing technologies. HAL also concentrated on setting up vast Maintenance, Repair and Overhaul (MRO) bases which have overhauled countless aircraft of the IAF.

The country's aeronautical outreach was being defined by the tedious Transfer of Technology (ToT) agreements. Engineers and strategic planners had for long advocated of mastering the complex technologies by building in-house developmental centre's. With the MiG-21's nearing their shelf life, India stared at the prospectus of locally manufacturing a fighter aircraft. HAL had acquired substantial knowledge during the Marut project.

The material selection for aerospace components needs to be reviewed. It has been highlighted that a precise understanding of operating conditions that are vital in the selection of structural components for aerospace applications such as stresses, temperatures, environmental conditions, moisture, air flow, radiation, and maintenance are essential parameters that is to be worked on for the better efficiency. Different grades of aluminum alloys, and special alloys and their applications in the field of defense, sonic, supersonic, and aerospace have been discussed. Conventional materials tend to possess high strength with low damping. At higher temperatures, conventional materials lose their stiffness due to internal molecular movement, thereby affecting their performance. In order to increase performance without affecting functionality, it becomes mandatory to replace conventional materials with advanced composite materials for improved properties and applications. Usage of advanced composite materials for aerospace structures, to ensure high strength, stiffness, temperature, wear and corrosion resistance. Replacement of conventional materials with advanced composites brings in weight reduction, in turn enhancing fuel efficiency without affecting flying performance, at the same time ensuring sustainability.

Characteristics Of Aerospace Components Favouring Additive Manufacturing

Aerospace components usually have the following characteristics, which make them highly suitable for fabrication

Components have a complex geometry or a large volume envelope–to–volume ratio: Aerospace components often have complex geometries because aerospace applications usually require components with integrated functions. Furthermore, geometric specifications of parts may be defined by complex mathematical formulae based on, for example, fluid flow. On the other hand, many aerospace components have a large volume envelope–to–volume ratio, as in thin-walled structures for example, combustion chambers or a turbine blade. Those features make the tool path planning algorithm very complicated, time-consuming, and material-consuming by conventional computer numerical control (CNC) machining. The capability for freeform fabrication makes AM very suitable for these kinds of aerospace components.

Implementing A Quality Management System

The company is satisfied with the quality management strategy that they have developed, the action plans must be implemented, evaluated and maintained. This process will be described in more detail in the methodology phase of this thesis as the development of the quality management system. The maintenance of the system includes the continuous monitoring of the plan as well as any adjustments that need to be made for improvements and to reach the quality objectives.

The major clauses and sub-clauses of the current revision of AS 9100 quality management systems requirements are:

1. Scope
2. Normative references
3. Terms and definitions
4. Quality management system
5. Management responsibility
6. Resource management
7. Product realization
8. Measurement, analysis and improvement

III. Challenges Affecting Aerospace Industry

There are challenges in every industry sector, but with the aerospace industry having a larger international footprint than any other sector, it is understandable that it is facing a multifaceted and complex future. As technology and other factors change, develop and grow the following challenges are expected to play a significant role in shaping the future of the Aerospace Industry.

1. Supply chain and Digitalization:

The aerospace supply chain often spans the entire globe, and which incorporate closer collaboration than ever, tight deadlines and an extreme high level of digitalization. It clearly indicates that the ongoing changes of digitalization across all levels of the supply chain is one of the factors most important in meeting future challenges. 1 in 3 companies are still working offline, with email, fax and telephone being the most widely used means of collaboration. Rest of them are least digitalized, their collaboration with customers, however, those who ignore this will often stumble into many obstacles. The vast majority of suppliers want a stronger relationship with customers.

2. Cyber Security

Cyber security is one of the biggest challenges, especially with the continuing development of technology. Almost every industry works with some sort of technology. The aerospace industry, being strongly linked to the defense industry has always had a focus on promoting strengthening policies. The cyber threat to the aerospace industry is real and it is current. While it is generally consumer-facing breaches who make the headlines, other organizations in the industry are continuously under attack by sophisticated parties who use tools such as cloud computing and viruses. The need to amp up investments in cyber tools will always be a big challenge to the industry which is why their connection with the defense industries is important.

3. Data Requirements:

On a larger scale, the computer power required for supply chains is enormous, and the ability to scale is critical to success. The amount of data stored on these systems is of impressive magnitude and with the explosion of demand and supply across all chains, maintaining its capability is a constant challenge. To overcome this challenge, companies must make sure to use the best technologies to support scalability and performance. After all, the aerospace industry is data-intensive.

IV. Factors Affecting Manufacturing Of Aerospace Parts

1. Man power:

Selection of right man for a specific job and to apply TQM and lean six sigma in the industry must be properly trained to do work in a proper order.

2. Equipment & Machines

The number of machine tools their capacity and accessories required replacement policy of the organization and maintenance schedules

- Input materials
- Appropriate quality of materials
- Material requirement planning
- Substitute of materials being used
- Inspection of input materials at various parts
- Cost of materials procurement and handling up stores

3. Time

- Inspection of input materials i.e raw material and semi-finished product or finished items for assembly
- Production time
- Time for repair and maintenance
- Floor Area or Space
- Total area covered by the administrative block, Production block and inspection and quality control departments
- Other space covered by plant layout.

4. Finance

Finance is the key required to maintain all the above requirements. The management should be for minimum rather than optimum Finance Movement of Man & Material. The reduction of the manufacturing depths lead to an increase of the proportion of purchased parts and consequently increases the dependency on suppliers therefore the success of a company is determined on the higher side by the abilities of its suppliers. By changing the productivity, by having minimum labor, so that the fiancé required for it can also be less in quantity.

5. Quality of machine:

Basic productivity is calculated by comparing the amount of goods and services produced by the inputs that were used in production. This results in a basic productivity formula of;

Productivity = Output/Input

This basic productivity formula can be used to calculate the productivity of your complete production process, or of a particular process or machine within your production process.

Output:
The output must be expressed as a numerical value, and is the finished value of goods or services produced by a person, machine, or process. It should be maximum for minimum input resource
Input:
Input must also be expressed as a numerical value and is the value of input that was used to produce the output, such as labour, materials, machine time. It should be optimum as compared to the output driven.

6. OEE (Overall Equipment Effectiveness) Calculation:

Data analysis:
For a more comprehensive productivity calculation OEE should be used. OEE takes into account the speed at which the machine or factory runs, the quality of the finished products produced and the actual machine operating time versus the available operating time. OEE is best calculated per machine rather than across the whole factory as it is then easier to identify where improvements need to be made to help improve productivity. OEE is calculated as:

Performance x Availability x Quality:
Performance - is the speed at which the machine or work station runs expressed as a percentage of the speed it is designed to run.

Availability - is the asset operating time expressed as a percentage of available operating time.
Quality - is the total number of good units produced expressed as a percentage of the total number of units that were started.

Below we have calculated overall equipment effeteness calculation of an aerospace manufacturing company.

Availability – The widget making machine is capable of producing 100 units every hour. The production day is 8 hours, so the machine is capable of producing 800 units per working day. But, today there is a downtime of 1 hour due to maintenance and a shortage of materials so this means that the machine will only be working for 7 hours.
Actual Operating Time (7 hours)/Available Operating Time (8h hours) = Availability of 87.5%

Performance – During the 7 hours of operating time that were available today, the machine produced 625 units. The amount of units the machine is able to produce within an hour is 100. So the theoretical time need to produced 625 units is 625/100 = 6.25 hrs. The performance of the machine is;
Theoretical time (6.25 hrs)/Available time(7 Hrs) = 89% Performance

Quality – Of the 625 units produced today, only 600 of the units were of good enough quality to be sold. The other 25 units need to be reworked before sale or scrapped. This means that the good units expressed as time is 600 units/100 units per hour = 6 hours. So the quality is;
Good Units expressed in time (6 hrs)/Performance time (6.25 Hrs) = 96% Quality

So our final OEE calculation is,

Performance (89%) x Availability (87.5%) x Quality (96%) = 75% OEE

This calculation shows that the total losses during the day for this machine were 25% which equates to 2 hours of lost production time. Over time, this adds up to a large amount of lost production time, therefore decreasing the profits that could be made if the productivity of the machine was higher. It is therefore very important to identify the root causes of this loss and to then implement the necessary measures to reduce or eliminate the losses.

There are many ways of improving performance, availability and quality, some of which are outlined below,

- Performance of machinery can be simply improved by production monitoring systems that enable to quickly identify, track and rectify faults or bottlenecks in the process. They also motivate workers associated with the process to hit targets.
- Performance and availability can both be improved by automating the machinery and production process. Automation helps to increase available working hours Quality can be improved by using vision inspection throughout the production process. Vision inspection during the production process enables to identify and eliminate faulty products earlier in the process.

Maintaining an efficient throughput is essential to the success of any manufacturing facility. In order to remain competitive production must be sustained at a certain level to keep a steady flow of goods heading out to customers. Any break or delay within the factory can have a negative effect on the rest of the supply chain, creating delays and complications with clients who might begin to shop around for a better service.

Quickly identifying issues within the production cycle that may be preventing the system from maximising throughput will create an efficient manufacturing process and reduce the possibility of customer complaints. As a brief overview, we are going to cover a number of ways in which can improve the throughput capacity of your machinery.

7. **Failure Mode:**

The failure mode is also known as the anti-function and is a statement of the requirements not being met. There are five varieties of failure modes:

- Full Failure
- Partial Failure
- Intermittent Failure
- Degraded Failure
- Unintentional Failure

Effects of Failure:

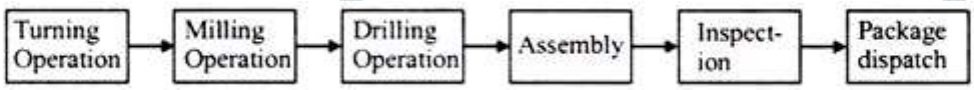
The effects of failure are focused on impacts on the process, subsequent operations and / or potential customer impact. Many effects may be possible, however all effects should appear in the same cell next to the corresponding failure mode.

8. **Severity:**

The severity of each effect is selected. The severity ranking is typically between the scale of 1 and 10.

9. **Internal Logistics:**

A] Product layout: In this type of layout, all the machines are arranged in the sequence, as required to produce a specific product. It is called line layout because machines are arrange in a straight line. In RPM services industry all the lathe machines are arranged in a section, then the CNC machines and in the order VMC machines. The raw materials are fed at one end and taken out as finished product to the other end. For example, the below block diagram will represent the process; Hence in an internal logistics the care must be taken accordingly;



B] Process layout: To design process layouts is to place resources close together based on the need for proximity. This need could stem from the number of trips that are made between these resources or from other factors, such as sharing of information and communication.

In RPM engineering services the process layout is done in the same manner like to gather the information, have a look on the specifications required, demand, etc

There are three steps in designing process layouts:

Step 1 Gather information.

Step 2 Develop a block plan or schematic of the layout.

Step 3 Develop a detailed layout.

C] Fixed position layout: A fixed-position layout is where the product stays stationary while workers come to the product site to build it. Fixed-position layouts are ideal for products that are large, heavy, or too fragile to move. But in aerospace parts manufacturing industries the fragile part is not there or the case of heavy equipments is not so possible.

D] Minimum logistics: The ultimate goal of logistics is, To coordinate all efforts of the company to maintain a cost effective flow of goods..

E] Minimum and flexible movement for man power: In this principle there is very less movement of parts or goods in order to avoid waste or damage to the end product. This care is taken by the company.

10. **Industrial Logistics:**

- Industrial logistics plays a major role in providing a competitive advantage for companies in a networked economy and market. Industrial logistics systems consist of resources such as
- People,
- Organisation and technology,
- Including information technology/
- Systems for managing the inbound logistics,
- And production and outbound logistics to create value for customers.

Industrial logistics systems have become an important part of competitive manufacturing and service organizations. When manufacturing/service activities are decentralised and geographically dispersed, the role of logistics becomes much more important in reducing the time to reach the market by effectively managing the information and material flow along the supply chain.

Concepts such as industrial logistics systems that takes place for the proper and smooth internal logistics that should take place for proper decision-making.

Industrial logistics systems strategies are as follows that can be implemented can be,

- Performance measures and,
- Qualitative and quantitative evaluation techniques,
- Technology management in logistics,
- Warehousing and material handling systems,
- Global operations and logistics management,
- Enterprise resource planning (ERP),
- Warehouse management systems (WMS) and
- Tool management systems (TMS) in logistics,
- Logistics information systems,
- Relationship management and logistics systems,
- Decision support systems for truck/vehicle and freight management,
- International logistics systems,
- Operations and management,

There is growing interest in the analysis and measurement of performance, because performance analysis allows the development of decision support systems for the design, planning and management of the supply chain. Green supply chain issues have generated a lot of curiosity in recent years with growing awareness of environmental concerns.

Following this, recycling has become an integral component of the supply chain and poses a significant challenge to manufacturing industries. It addresses the different aspects of recycling such as waste classification, recycling, logistics and reuse of the products. Also, it discusses how the agent communicates and acts autonomously to facilitate the efficient logistics of materials between different units. The proposed agent architecture can assist manufacturing industries to efficiently manage their green supply chain system and complex logistics issues.

11. Reverse logistics (RL):

The objective is to determine the size of the shipments, backorder and inventory in each period, so that the total cost incurred during the entire period towards transportation, backorders and inventory is minimized. Same in the RPM engineering services they also have the path of reverse logistics, in case of any part gets damaged they can have reverse logistics system.

Points such as:

- Knowing the important decision-making factors enables companies to select their optimal distribution structure including DC location(s). This is important for several reasons. First, a good structure is essential to meet customer service levels, for example, by delivering the right product on time
- Second, good decisions can reduce logistics costs by bundling goods or reducing inventory
- Third, it helps companies to adapt to rapid changes in consumer preferences.
- Distribution structure selection is a strategic decision that asks for substantial investments. From a public policy perspective, knowledge on decision-making factors can help policy makers to better predict DC location patterns, which facilitates the design of sustainable transportation.
- Factors may drive decision-making on distribution structures, e.g. logistics costs factors, including transport costs, inventory costs and handling costs; service level factors including delivery lead time and delivery reliability; and local attractiveness factors for warehouse settlements.

13. Supply chain management:

Decision-making on distribution structures including DC locations is an important research topic in the SCM research stream, as decisions influence logistics costs and service levels along the supply chain. Frequently recurring factors include demand characteristics (temporal and spatial patterns), logistics service level, logistics costs (transport, inventory, warehousing) and product characteristics.

In cases of high volume and spatially dispersed product demands, multiple distribution centres can be used because economies of scale reduce transport costs; also this allows fast deliveries (high service). Here, companies will choose a decentralised distribution structure the main service level dimension is lead time or delivery time. In general, decentralised distribution structures with multiple DC locations shorten delivery times but increase logistics costs, i.e. a trade-off exists between the required service level and logistics costs

Logistics costs include transport costs, inventory costs and warehousing costs (handling, storage). The trade-off between logistics cost categories will indicate the optimal number of distribution centre major factor involves the product characteristics value density and packaging density. Products with high value and packaging density are typically stored centrally to minimize inventory and handling costs.

V. IMPLEMENTING 5-S

The 5S methodology is a system for handling workplace organization. It includes 5 steps known as the 5 S's that turn organization into a step-by-step system for people to follow. This methodology is often considered the foundation of Lean manufacturing because for a workplace to reduce waste and become more efficient, it needs to first be organized.

The purpose of 5S is to make a workplace function better by making it an easier place to work. This occurs by making spaces make sense; tools and materials are placed in logical locations based on who needs them, how frequently they're needed, etc. Spaces are cleaned regularly. Cleaning and organization become habits. When used correctly, 5S ultimately makes processes safer and more efficient

In RPM Engineering services this concept is worked and looked upon at a very minute level such as,

- They practiced the sustainability to maintain that particular part and to avoid waste,
- They have ISO standards to follow for the manufacturing of the particular parts.
- This industry needs to sort the raw materials according the designed and alligns pattern for the manufacturing purpose according to the dye set or the machines or the workers assin .Hence sorting is done on this bases.
- During the process of set in order this industry all items are organized and each item has a designated place. Organize all the items left in the workplace in a logical way so they make tasks easier for workers to complete..
- The place is kept clean and maintain according to the standards also. In this way the shine is been practiced.

Before and After 5S Implementation
Before:

1. Inventory stacked far out of reach
2. Unused older inventory
3. Safety hazard; boxes stacked in aisles
4. No discernable organization such as bar-coding, inventory dating, color coding, or naming convention
5. Trash and debris allowed to accumulate

After:

1. Uniform bins and racking
2. Date tracking of inventory
3. Bin contents are labeled
4. Bins, racks, and floors are kept clean and in good repair
5. Lighting in facility is sufficient
6. Racks are low enough that ladders are not required to access inventory

The 5S methodology

The 5S Methodology is a systematic approach to workplace organization. This method includes the five steps of Sort, Set in Order, Shine, Standardize, and Sustain. Generally speaking, the steps of 5S involve going through items in a workspace, removing what's unnecessary, organizing items, cleaning, performing maintenance, and making sure these things become habits. These steps should occur in this order, and there must be a plan in place for performing the tasks associated with these steps on a regular basis. At the end of of a 5S implementation you will see characteristic things such as policy manuals, glow-in-the-dark tape or photo luminescent tape on the floor, colored bins, red tags, and 5S walks taking place. In the end, it should all add up to efficiency.

The 5S methodology originated in Japan and was first implemented by the Toyota Motor Corporation. The methodology was developed as a way to make just in time (JIT) manufacturing possible. This type of manufacturing intends to produce only the amount of a product that is needed, when it is needed. Having an organized workplace that utilizes visual cues to maintain itself allows JIT manufacturing to proceed more smoothly; in this type of environment, it's easier to see problems and move materials efficiently.

How to get started:

- Educating employees.
- Providing examples and a framework for success.
- Allowing employees to discuss the potential barriers and pitfalls of the recommendations.

- Providing insight about how the process will actually operate to help alleviate some of the unknowns that could hinder the process.

5S methodology has expanded from manufacturing and is now being applied to a wide variety of industries including health care, education, and government. Visual management and 5S can be particularly beneficial in health care because a frantic search for supplies to treat an in-trouble patient (a chronic problem in health care) can have dire consequences. Although the origins of the 5S methodology are in manufacturing, it can also be applied to knowledge economy work, with information, software, or media in the place of physical product.

VI. ABC CONCEPT

The ABC inventory planning method is simple, yet allow us to manage the inventory more smartly.The basic idea is to divide the inventory items into groups that will have different inventory policies. Each group has different importance from the most important GROUP A to the least important GROUP C or D.

Suppose we work on an organization that has more than 1,000 items. Every purchase order that we make comes with a cost, mostly that of time. When we place an order we have to

1. Create the purchase orders
2. Follow up on each purchase order to make sure it will arrive on time
3. Handle the papers of each item if it needs to go through customs
4. If we have a long lead time, we will have more than one purchase order open at the same item. We will need to schedule them so that we do not have too many or too few of each item. That is a time-consuming operation.
5. When the item arrives we need to do acceptance tests and log the new inventory.

So if we have fewer purchase orders and each purchase order has more material, then we will need to take the 5 steps above in less time.

But inventory costs money, needs warehouse floor that costs money, and increases the cost of insurance.

So if we have a 1,000 or 10,000 items that we need to manage, it is impossible to treat each item the same. So we use Pareto. In most cases 20% of the items will be close to 80% of the cost of all items. That is the motivation for using the ABC model.

Let’s divide all our items into 3 groups: A , B and C (and I also add a group D).

Group A contains the most expensive items or ones that require a lot of warehouse space. These will be the items that we will carefully monitor. We will follow each of them daily or weekly (depends on the sensitivity of your organization). About 10%-20% of the items will be in this group.

Group B contains the cheapest and simple items that don’t need much follow-up, only to make sure that they will always be available to production. This group will have 50%-70% of items.

Group C contains the remaining items between group A and group C.

Group D is a subgroup of group C. Some items have very low value and we can hold a year’s worth of inventory at almost no cost.

Classify items into Groups algorithm:

1. ***Calculate the yearly /monthly cost of all items*: ** Take the current price of the item and multiply it by the number of items used (in production) at that period of time. Don’t use the quantity in the purchase order. Use only the quantities from the work orders.

2. ***Sort the items***: from the highest cost to the lowest cost.

3. ***Classify*:** each item to a group according to the figures decided before (see the summary table above). Items with the annual cost of 400,000$ and more in the example above will be called group A.

4. Use the ***summarize table*** function to make sure you get a reasonable output.

ABC Analysis of XYZ Company:

Item Name	Unit cost in Rs	Annual Demand	Total Cost	% of Total Usage
Right lever 50	140	5000	700000	3.87596899
Nut 100	60	16000	960000	5.315615
Bushing 147	90	9000	810000	4.48505
Rivet 50	30	12500	375000	2.076412
Handel 20	900	4500	4050000	22.42525
Steal body 10	8000	550	4400000	24.36323
Knurled nut 50	700	4200	2940000	16.27907
Spacers 50	250	7900	1975000	10.93577
Piston 10	1350	800	1080000	5.980066
Bolt 50	70	11000	770000	4.263566
			Σ18060000	

Item Name	Unit cost in Rs	Annual Demand	Total Cost	% of Total Usage	Cumulative % of total
Steal Body 10	8000	550	4400000	24.36323	24.36
Handel 20	900	4500	4050000	22.42525	46.78
Knurled nut 50	700	4200	2940000	16.27907	63.05
Spacer 50	250	7900	1975000	10.93577	73.98
Piston 10	1350	800	1080000	5.980066	79.96
Nut 100	60	16000	960000	5.315615	85.27
Bushing 147	90	9000	810000	4.48505	89.75
Bolt 50	70	11000	770000	4.263566	94.01
Right lever 50	140	5000	700000	3.87596899	97.88
Rivet 50	30	12500	375000	2.076412	99.95
			Σ18060000		Σ 100 approx

Category of Items

	Item Name	% of Usage	% of Items
A	Steal body, Handel, Knurled nut	63.05	20%
B	Spacer ,piston, nut, Bushing	26.7	40%
C	Bolt, Right lever, Rivet	10.2	40%

Summary:

The ABC inventory planning model allows us to focus our planning efforts on items that have an effect on the cost of inventory. We will usually deal with groups A and B. We will deal with groups C only a few times a year, although they contain most of the items. The items covered under group D are obsolete items. Obeisance of group D items it happens because of Machine updating Replacement of old machines and part de- generation. With the ABC analysis even VED analysis can also been done and hence the vital part for the RPM engineering services are as – Valve, Valve assembly, Valve body. The essential parts of the RPM engineering services are – Piston, Rivert, Steel body, Nut.

VII. Inventory Management In Aerospace Industry

Valuable inventory has to be carefully managed for regulatory, financial and operational reasons**.** Aircraft parts have the distinctive feature of being expensive and therefore must be handled within short cycle times/turnaround times (TAT) in order to reduce inventory costs. Aircraft inventory control is therefore a critical activity to ensure both effective maintenance and a profitable use of multiple aircraft assets.

Some trends are developing and establishing critical mass with regard to aircraft maintenance inventory control, and they include software solutions, radio frequency identification (RFID) and the use of automation.

Best practices:

1. When it comes to managing aircraft parts inventory, there is a set of best practices to follow. In general, standard software applications, such as warehouse management systems (WMS) and transport management systems (TMS), are suitable and widely available to manage inventory.

2. We find that the passive RFID and barcode in combination with enterprise resource planning (ERP) and WMS programmers' should give a more reliable stock and make it available more quickly,"
3. Good inventory control must include regular stock audits or cycle counts.
4. Storage conditions, such as temperature and *humidity control*, should be continuously monitored and maintained within regulatory requirements. Controls such as 'first in, first out'(FIFO) and 'last in, first out' (LIFO) and shelf life reporting can play a big part in control of stock wastage and costs,"

Specific requirements:

1. Airlines and maintenance organisations have multiple requirements in terms of inventory control and software solutions are increasingly helping to meet these requirements the warehouse management process
2. In general, must meet many specific requirements and regulations from our industry, for example, temperature and humidity control, dangerous goods handling, provision of a bonded warehouse, transport of spare parts on both land and air side. In turn, this requires a secured supply chain for airport supply, import and export customs clearance, air freight-specific material handling
3. Visual management and automated processes to ensure fast and accurate picks are two of the main requirements. Software should help the employee to make it better for the worker. Requirements like workload and number of picks are important to be displayed,"
4. Holding excess stock for too long can be seen as dead money, so holding sufficient stock with excellent supply chain partners can help in having just in time stock.

VIII. LEAN SIX SIGMA IN AEROSPACE MANUFACTURING INDUSTRY

We had for many years developed and deployed Lean improvement teams in we in the form of Kaizen Blitz teams. Therefore, we were used to implementing basic Lean techniques such as 5S, TPM and visual management boards. However, we often employed these approaches in an unstructured and piecemeal way and, much of the higher level thinking strategies around waste reduction and identifying customer preferences and value were not being employed. This was amply exemplified through a discussion with a shop floor worker who stated 'we can save $2 on a bolt by changing supplier but miss the delivery point with our customer costing us thousands of dollars'.

Attempts to employ Six Sigma in to we was introduced a number of years later where a simplified DMAIC approach was used to systematically reduce quality related problems around their CNC facility. This brought modest savings but no major impacts to the production system. Six Sigma was initially employed to try and aim for OTIF so that missed delivery points with AoGs could be avoided. However, once it was found that Six Sigma could not in itself provide the solution, the approach was then employed on individual areas of production rather than where it needed to be used in order to benefit the whole production system. This meant that company moved towards multiple Lean and Six Sigma applications rather than a strategic and systematic approach to their application.

Furthermore, we was now operating two separate improvement strategies which caused confusion and a lack of a single top-down, management supported and committed improvement strategy. This often led to confusion and conflicting opinions on which was the most effective improvement approach to employ.

Following detailed discussions with we management, a series of scoping studies which focussed on analysing the operational systems in we were employed and, an outline LSS implementation framework was proposed (see Figure 2 and Table 5). The Framework was developed after a number of meetings with top and middle level management and engineering staff of we where the key processing parameters were identified and quantified so as to obtain a clear picture of the true extent of the operational systems employed.

Prior to the implementation phase being adopted, all of we's staff were trained in order to prepare for changes that they were going to encounter. The work of Kumar and that of Kumar and Antony and Spina, stress the issue of ensuring company 'preparedness' before venturing in to the full implementation programme. Therefore, an awareness raising programme was initiated and ran for three months in which the implementation process was outlined and where all staff were given the opportunity to contribute to the implementation process and to jointly discuss the direction of travel. Work Based Learning training sessions were introduced for staff in order to develop expertise in LSS implementation. Also, the project team delivered practitioner level training to production staff who would need to carry out much of the practical tasks (autonomous maintenance, problem resolution through Six Sigma teams etc). Most importantly, the senior management and board members of we were given awareness sessions. Once we were in a position to move to the implementation phase, the first LSS workshop commenced which was focused on the first Lean cycle element (Specifying value). The following section outlines the key work undertaken in each phase of the LSS cycle.

The next key stage in the process was to clearly identify the LSS tools and techniques to be employed in the project. In identifying early the typical tools and techniques to be employed, suitable and timely training on them could be executed.

With these issues in mind, the project team mapped the tools and methods required for each stage of the LSS cycle. The aim was to minimize the over-use of tools and techniques so as to develop a core set of key tools for implementation. Therefore, within the Lean and Six Sigma phases of this work, the project team firstly analyzed the range of tools available and then settled on a coherent set that were capable of driving change. These were: Kano, Quality Function Deployment (QFD), VSM, Optimized Production Technology (OPT), Design of Experiments (DoE), Kanban systems, Poka Yoke and Control Charts. Table 5 shows at which stage each tool and technique was employed.

Stage 1 Lean Cycle Specify Value:

Define: A focus group made up of end users was arranged and a 3 day conference held in which customers (airline flight attendants and engineers) were asked to discuss the key Critical to Quality issues and the value adding features that they required from the product. The focus group followed the Kano approach and listed the key Basic, Performance and Delighter features required. Table 2 highlights the key issues from the Kano study.

Measure: The key features were identified and the focus group asked to rate we's performance on providing those features against those of their major competitors in order to measure their performance and assess the gaps in product and service performance.

Analyze: Following the 'measure' stage, we undertook a Quality Function Deployment (QFD) Exercise at HOQ 1 level in order to establish the key customer requirements and to map those requirements to how we could meet the customer needs. Figure 2 shows the QFD chart. Key QFD outputs included the systematic reduction of OTIF target down to 45 days from current 57 days with a cost saving on product being 20% lower than current price and, a 5% reduction in price year on year for five years after.

Improve: We then identified the key product and process features required and assesses capability to deliver the new requirements. Any key investments were identified and balanced against return on investment. The key outputs included; a 10 day reduction in production lead times achieved through Lean design, a 2 day reduction in design lead time to achieve cost reductions and to enable production to start earlier in order to meet the stage gate deadlines. This also highlighted the need for OTIF delivery of designs (and CNC programmes) to the production facility with zero variation on target.

Control: These new requirements were then locked in to the ERP system and the designs and production plans were then developed. Senior management signed up to achieving the new KPIs and agreed to manage progression against the targets.

Basic	Performance	Delighter
Achieve build time of 57 Days without variation. Achieve 100% OTIF Maintain Quality, Cost and Delivery KPIs at current state. Achieve consistency.	Provide greater range of product options on assembly	Reduce Build Time to 45 Days without variation. Achieve 100% OTIF Reduce product cost by 20% Reduce product weight by 5%.

Table 2 Outputs from Kano Study

Stage 2 Lean Cycle – Align Internal Value Stream:

Define: From stage 1 of the process, the project was defined as ensuring that a ten day reduction in we's manufacturing operations was to be achieved with a further two days from is design process. This paper will focus on the reduction in manufacturing process time and, in achieving the OTIF delivery target on a consistent basis of 45 days +/- 0 days variation.

Measure: A Value Mapping (VM) exercise was conducted by a multi-disciplinary team of engineering and production staff. The processing times as well as the VA/NVA activities at each stage of the manufacturing process were calculated and key process areas identified for further analysis. Figure 3 shows the VM exercise undertaken and Tables 3 and 4 show the VA/NVA analysis stages on the current and future state analyses respectively.

Analyse: The multi-disciplinary team identified that a significant area for improvement would be in removing the cycle circled on the VM. This was to remove the need to reassemble the structure after first stage inspection. If this could be achieved then we would come close to meeting the ten day reduction target. The team focussed on this area and set up an improvement group to resolve the issue. Figure 4 shows the graphical representation of the VA and NVA on the current state Value Analysis. Here it is possible to see that the issue of dis-assembly is seen as highly wasteful since it necessitates the build team to disassemble the whole structure once it has been passed as being correct by QA (further information provided later).

Improve: The improvement team worked on providing a solution of removing the need to disassemble the structure and then reassemble again with adhesive. This work cost we 2 days to disassemble and a further five days to reassemble with adhesive. The focus was to develop a process whereby adhesive could be applied immediately after the structure had been dry assembled and subsequently passed by QA.

This was achieved by modifying the tongue and slot arrangement to allow adhesive to be injected in to the rear of each tongue and slot through a series of injection holes that were drilled in to the slot faces at the CNC cutting stage. In so doing, we could build the structure in its dry condition and move straight to adhesive application following inspection.

Control: Process engineers developed an adhesive injection procedure including investments in the new machinery and systems to support adhesive injection. The engineering team also developed specific test procedures to test the injected tongue and slot arrangement to ensure new test data is made available to the design department and regulatory authorities.

Stage 3 Lean Cycle – Create Flow

Define: The aim of this stage was to create fast flexible flow of parts through the production system. In order to do this, the team focused upon providing a solution to removing the system constraint of dismantling and rebuilding the structures. Therefore the 'define' stage was to ensure that the joint strength obtained from the adhesive injection method was at least comparable to the traditional manually applied method thus achieving significant savings in build time whist ensuring joint strength is left unaffected.

Measure: Laboratory tests were undertaken on the new injection process to ensure product integrity could be maintained. At this point however, the process showed that adhesive injection method produced a joint strength value which was 1.5kN lower than the traditionally applied joint application method. Therefore, a CTQ issue arose at this point which needed eradication before the process could be accepted.

Analyse: Macroscopic analysis of the failed joints identified that using the current joint design did not allow sufficient adhesive ingress in to the slot when the injection method was used. Joint redesign was required which enabled an improved flow of adhesive in to the slot without affecting the integrity of the joint. An experimental design study was undertaken where each of the key joint variables were changed in order to identify the optimal joint settings. The experimental design stage needed to find a single joint arrangement which would provide the appropriate strength values for the joint under three loads of; Transverse, Longitudinal and Tensile. A multi-disciplinary team used Pareto and C+E analysis to identify five key variables of; slot length, slot width, tongue depth, tongue length and, adhesive type. Two interaction effects of slot length x tongue length and tongue depth and slot width were also considered. An eight experiment array (L8) was developed at two levels. An ANOVA for each load condition was also applied.

Improve: The experimental design study yielded a new joint arrangement which could potentially be used to resolve the strength issues around the joint. A confirmation run with the new joint arrangement was made, the results of the confirmation run identified that the new joint design enabled improved adhesive ingress with joint strength being within 2% of the traditionally applied adhesive. Homologation testing was subsequently undertaken to achieve aviation standards approval. A simulation of the production flow using the expected new processing times was undertaken in an attempt to identify any further system constraints which could be reduced or eliminated. A further two days reduction in processing time was achieved through increasing flow through the paint shop whilst the amount of inspection reduced due to the elimination of the need to rebuild the structure. This brought the build time down to 46 days in total, one day short of the target build time.

Control: The new joint arrangement was tested further to ensure it met homologation standards. The new joint parameters were then sent to the design engineers who then updated the standard operating procedures. The production engineering department subsequently changed the CNC programme codes for the new joint design thus freezing the new design arrangements going forward.

Stage 4 Lean Cycle – Create Perfection

Define: We decided that at 46 days build time, the remaining one day reduction in build time could be achieved through minor continuous improvements on the shop floor. However, at this stage there was a need to ensure that the build time of 46 Days was achieved on a consistent basis and, variation in build time was to be reduced

Measure: The build time values were measured for the next ten parts coming off the production line. The variation in build time was measured as 46 Days + 1 day, - 0 days with earlier stage parts being manufactured closer to 48 days before systems started to operate correctly thus moving the variation closer to the 46.5 day marker (See Figure 5).

Analyse: Most variation was created from the lack of synchronicity between sub-assembly build and the final build which in turn caused stock shortages at final build stage.

Improve: A detailed study of the CNC router area identified key issues around panel set-up times being far too long. This impacted upon build throughput time which led to final build shortages. An industrial engineering study was undertaken by a Lean Six Sigma Blitz team which reduced panel build set-ups using Single Minute Exchange of Die (SMED) principles. A further ten build times were measured and a market improvement was seen on OTIF values although some further improvement is still required. Figure 6 shows the twenty sequential parts that were built showing the systematic reduction in build time variation.

Control: SMED procedures were consistently applied and continuous measurement and systematic continuous improvement was undertaken to reduce variation further.

Figure 6 Build Time Variation of Consecutive Parts.

Results and performance of SLSSF Implementation

Table 2 outlines the initial set of client performance measures that we worked towards achieving. The initial focus was to drive towards delighting the customer and to achieve a 45 day build time. In achieving this target value, greater shop floor capacity would be released thus enabling we to reduce production cost. With a clear focus being taken to reduce total build time, four key measures of performance were used to assess the effectiveness of the SLSSF implementation. Figure 7 shows the improvements made:

- Build time reduction - 58 days to 46 Days (20.5%)
- OTIF improvement – from 72% to 98% (26%),
- VA time reduction - 41 Days to 39 Days (5%)
- NVA time reduction -18 Days to 10 days (44.5%).

These measures were selected since the OTIF and Build Time Reduction KPIs were identified from the early stage customer analysis. The VA/NVA measures were used as a means of tracking the effectiveness of the waste reduction strategies employed during the implementation stages. Figure 7 provides a graphical representation of the performance improvements achieved

By the end of the project, we had not met the customer delighter target for build time reduction. This was set as 45 Days whereas we achieved 46 Days by the end of the project. However, we were confident that through continuous improvement, the 45 Days target would be reached comfortably. Likewise, the OTIF target of 100% was not fully achieved by the end of the project. However, the improvement trends seen following LSS implementation suggest that 100% OTIF is likely to be achieved within the next 15 aircraft sets as the new production system settles down and experience of new build assembly improves.

The ability to reduce its build time by eleven full days and achieve consistency of delivery around 46 days has significantly improved the financial viability. Whilst still in its early stages, we expects increases in sales of some £3Millon over the next year due to increased responsiveness to customer demands brought about by improved productive capacity. Likewise, a reduction in cost per aircraft set totaling some £45000 has been achieved with an estimated annual total saving of £2.8Million likely.

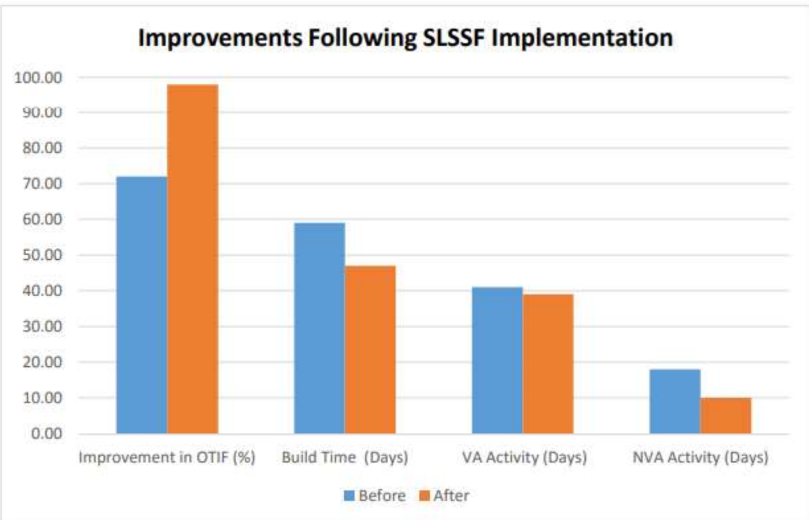


Figure 7 Improvements in Production Performance Following SLSSF Implementation

Limitations with the SLSS Framework

A number of valuable lessons were learned from this project. Highlighting these issues within this paper is critical in that it offers a perspective to other LSS implementers of the key issues that should be taken care of while starting the new project.

- In this case, convincing top management was the most difficult task. Although initially the management were enthusiastic towards implementing the SLSSF, when it came down to the full implementation and, the issue of changing the build stage to allow for adhesive injection, it became increasingly difficult to motivate management towards maintaining focus on the SLLSM.
- We felt that investing in a new build method would adversely affect the quality. When it was found that the initial injection approach did not provide the strength characteristics of the traditional system, the project nearly collapsed. However, through continued discussion and through a single minded determination to resolve the strength issues of the new adhesive injection method, the team was able to keep the LSS project on track. Therefore, the issue of ensuring that strong leadership and a single minded attitude to succeed must be seen as critical to any LSS implementation project.
- A second major issue was in encouraging staff to adopt more advanced Lean and Six Sigma methods. As a company, only basic lean tools and techniques had previously been employed (5S, TPM etc). Therefore, trying to implement strategic thinking tools such as Kano, QFD and, statistical tools such as experimental design techniques was a significant challenge. Largely seen as an approach which could only been really applied in large manufacturing companies, the authors had a significant challenge to convince both management and shop floor personnel that LSS is an effective approach that requires time and commitment but not necessarily the capital expenditure they initially imagined if the projects are well thought out and solutions are sought that do not need significant capital spend.

IX. Future Scope

1. India's Strong Framework

India has a strong framework to provide all requisite resources for this industry — research and development capabilities, leading information technology and engineering services, manufacturing expertise with global firms located in India, and a huge pool of semi-skilled manpower. Entrepreneurs, who want to enter this field, and even existing players must recognize the opportunities with the most yield.

2. Government Policies

Favorable policies made by the government have promoted expansion and growth in this sector. The recent "Make in India" initiative has acted as a push for airframe manufacturers to increasingly use indigenous aerospace suppliers. The policies introduced by the Ministry of Civil Aviation have set a predecessor for government initiatives that would boost aerospace manufacturing.

3. India as an aerospace hub

India's aerospace and defense manufacturing sector continues to grow and expand through partnerships, new factories and research facilities. The flurry of activities in the recent past has helped the country earn the recognition of being one of the world's major aerospace hubs. The combination of public and private players playing an active role has ensured this.

Telangana boasts of the country's first Aerospace and Precision Engineering SEZ Park. Karnataka has also encouraged SEZs to be set up in various smart cities.

In the private sector, Reliance Defense Limited had announced plans to launch a global aerospace technology research center in Bengaluru.

Boeing also has continued to expand its footprint in the country in the form of the Boeing Research and Technology India Center, which is the Indian counterpart to its research and technology organization in the US. **Aequs Aerospace** had launched its aerospace ecosystem in Belgravia which has attracted several contracts to India.

4. Growing Competition

There are more than three million parts in a plane that requires hundreds of vendors to complete. While competition may be perceived as negative in most sectors, it is positive sign for the Indian Aerospace & Defence industry. The sector encourages more players to invest in and optimize the manufacturing process. A competitive market promotes innovation and mutual growth. The aerospace sector is heavily dependent on the supply chain and with increased players, more components can be manufactured within India. This way, there will also be specialization in manufacturing of certain critical components.

There is also huge scope for other industries to contribute to this sector. However, despite India's information technology sector being globally recognized, the Aerospace& Defence industry is yet to leverage this strength.

5. Capabilities and Capacity

India has always had ample capacity to produce components at low costs. Considering the labour cost is very low and there are enough resources, manufacturing in aerospace is possible with relative ease as compared to other countries.

However, since India is still at a nascent stage, there is a dearth in available technology. Internationally, countries like France and USA have been able to innovate with technology over the years and optimize procedures.

This ensures highly efficient processes that ensure highest quality of product. With international partners, there is a possibility technology transfer and at the same time, the partners are able to take advantage of the low cost of production. Being focused on two key areas, increasing internal capabilities and building smart partnerships, is what helps increase the margins. Specializing and being competitive globally is important.

X. Conclusion

1. The instruments for measuring TQM implementation and overall business performance are reliable and valid, and can be used by other researchers to test the effects of TQM implementation on overall business performance. The reliable and valid instruments can also be used in testing the time dimension of TQM implementation.
2. TQM implementation has positive effects on employee satisfaction, product quality, customer satisfaction, and strategic business performance.
3. Leadership has positive effects on employee satisfaction and strategic business performance.
4. Employee participation, recognition and reward have positive effects on employee satisfaction; Education and training does not have a positive effect on employee satisfaction.
5. Supplier quality management, evaluation, product design, and quality system improvement do not have positive effects on product quality.
6. Vision and plan statement, process control and improvement have positive effects on product quality, Quality system improvement has a positive effect on strategic business performance, and Customer focus has a positive effect on customer satisfaction.
7. Employee satisfaction has positive effects on product quality and customer satisfaction, Product quality has positive effects on customer satisfaction and strategic business performance; and Customer satisfaction does not have a positive effect on strategic business performance.

XI. References

[1] International Journal of Marketing & Technology (IJMT) ISSN: 2249-1058 Vol. 5 Issue 07, July-2015 *Inventory Management Best Practices for Aircraft Servicing INDUSTRY IN INDIA*

[2] Strategic Inventory Management in an Aerospace Supply Chain -By Joseph Mauro

[3] A study on technique of inventory management system with respect to aviation spare parts https://doi.org/10.1504/IJSOM.2017.083778

[4] https://www.sciencedirect.com/science/article/pii/S2214785317314864

[5] https://www.ease.io/core-lean-manufacturing-principles-for-aerospace-manufacturers/

[6] https://www.sciencedirect.com/science/article/pii/S2214785317314864

[7] https://www.tandfonline.com/doi/full/10.1080/21693277.2017.1417179?af=R

[8] https://www.unipointsoftware.com/blog/quality-management/3-tips-for-total-quality-management-in-the-aerospace-industry/

[9] https://www.unipointsoftware.com/blog/quality-management/3-tips-for-total-quality-management-in-the-aerospace

[10] https://www.aia-aerospace.org/wp-content/uploads/2016/06/TOTAL-QUALITY-MANAGEMENT.