



The Operation Management Model of Aircraft Maintenance, Repair and Overhaul (MRO) Business

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Abstract: The aircraft maintenance, repair and overhaul (MRO) is important to the airline operation. The C check and D check need the longer lead time and higher cost than A check and B check. It is the good opportunity for professional MRO Company to get the business from airlines. This study propose the Operation Management Model, which introduce the concept of lean production and sustainable development into the maintenance process and management process for MRO Company. Thus the MRO Company can increase the performance and competence in the competitive market.

Key words: aircraft, MRO (Maintenance, Repair and Overhaul), Operation Management Model, Lean Production, Sustainable Development.

capital investment required. Hence outsourcing is considered as an alternative to vertical integration (Heikkila and Cordon, 2002). Many airlines started to take advantage by outsourcing non-core intensive labour activities and focusing on fewer value-added MRO activities (Rosenberg, 2004). Base on the above analysis, the maintenance, repair and overhaul (MRO) business of aerospace industry is a major portion of operating cost. This study propose the concept of High Efficient MRO Operation Management Model for aircraft industry.

1- Introduction

The maintenance, repair and overhaul (MRO) business model for airlines is a combination of an airline's technical capability and logistics configuration, including the degree of supply chain vertical integration and outsourcing practices (Hamad Al-kaabi et al. 2007). The importance of MRO can be judged by the fact that it constitutes typically 10-15 per cent of an airline's operating cost (Seristo, 1995). Base on the Airline Operational Costs Breakdown from IATA (Chris MARKOU, 2012), maintenance cost is 12% of airline operational cost, refer to Figure 1.

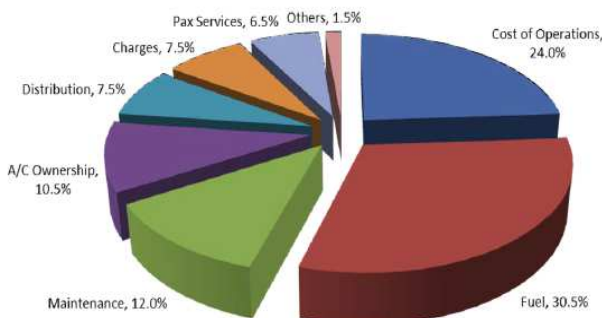


Figure 1 IATA Airline Operational Costs Breakdown (Chris MARKOU, 2012)

2- Operation Management Model

The procedures of aircraft MRO Company include the physical flow and information flow. The physical flow is the aircraft maintenance process, which are composed of professional methodology, material, machine, manpower, and environment. The information flow is the company management process, which are based on plan, do check, and action cycle.

This study construct and propose the High Efficient MRO Operation Model, shows as Figure 2. We describe the customer demand in section 3, explain the maintenance process in section 4, design the management process in section 5, and summary the customer satisfaction in section 6.

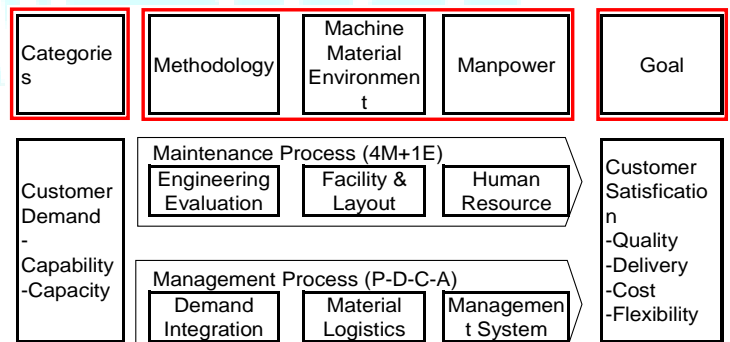


Figure 2 High Efficient MRO Operation Model

Establishing an airline MRO process is therefore associated with high investment in capabilities. For many airlines, especially new entrants, this is not possible due to the large

3- Customer Demand

The importance of MRO can be judged by the fact that it constitutes typically 10-15 per cent of an airline's operating cost (Seristo, 1995).

The MRO Company should focus on the current market and forecast the future demand. Setup the long term, medium term, and short term development plan. Review and adjust the capacity and capability periodically to fulfil the customers' demand and sustainable development.

3.1- Capability

The full certification of the aircraft include the type certificate for design, production certificate for manufacturing process, and airworthiness certificate for aircraft.

Every country or airline has his own regulation and requirement. The global MRO Company need to be audited and get certified by various airworthiness authorities. Also, the MRO Company have to create and integrate his own standards to meet the requirements of different customers.

The quality system of MRO Company should be certified by aviation administrator, such as FAA and EASA. Manpower, facilities and equipment also need to be qualified to proceed the relative maintenance operations.

3.2- Capacity

As system complexity increases, greater technical maintenance expertise is needed along with sophisticated test equipment (Esker et al., 1990).The maintenance resources include:

1. Hangar space: the hangar space can proceed the aircraft maintenance and turnover.
2. Qualified equipment: include testing and measuring equipment (e.g. NDI, coordinate measurement machine...etc.)
3. Qualified manpower: include engineering evaluation manpower, inspection and testing, structure repair, part fabrication, painting, harness, avionics technicians...etc. Maintenance manpower must be trained, expertise, and licensed in specific equipment/operation for maintenance.

The MRO Company should analysis the workload and capacity of the maintenance value stream, and trace/monitor the constraint and eliminate bottleneck. Then construct the balanced

4- Maintenance Process

The main procedures are review flight history, determine maintenance items, receiving process, disassembly, inspection and testing, assembly, functional test, flight test, and delivery. The General Maintenance Process of Aircraft show as Figure 3.

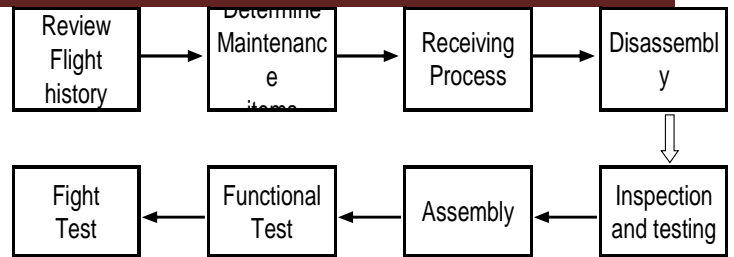


Figure 3 General Maintenance Process of Aircraft flow shop.

1. Review flight history: Review the logbook of aircraft and previous maintenance records, evaluate the current status of specific aircraft.
2. Determine maintenance items: Base on the maintenance requirement of aircraft manufacturer and engineering evaluation of current status, determine the maintenance items.
3. Receiving process: Receive the aircraft from customer, clean the aircraft, and then load on assembly jigs and setup tooling.
4. Disassembly: Remove the fastener and door/skin of relative maintenance area.
5. Inspection and testing: Apply the NDI equipment and processes to inspect and test the key parts of aero-structures/components. Utilize the testing equipment to verify the function of hydraulic, electrical, wiring, avionics systems...etc. If find the defective parts or malfunction, it should repair/fabricate new parts/module for replacement based on the engineering evaluation and disposition.
6. Assembly: Replace and assembly the relative parts and components in specific aircraft.
7. Functional test: Implement the relative functional test after assembly.
8. Flight test: Proceed the flight test to ensure achieve the original performance requirement.

4.1- Engineering Evaluation

The Engineering department base on the maintenance requirement of aircraft manufacturer (Airbus/Boeing...etc.), flight records (flight hours, flight cycle, and calendar time) and previous maintenance records (A/B/C/D check), proceed the engineering evaluation of current status, then determine the maintenance items and develop the maintenance program.

The engineer also has to evaluate the pros and cons of the new aircraft add to the fleet of airline. Develop the new ground equipment to support the operations of all fleet.

Due to the airline and MRO Company have to consider the aircraft availability, reliability, maintenance duration, and maintenance cost. The engineer should improve the competence to develop customized maintenance program to meet the requirement of airlines.

4.2- Facility and Layout

The Massachusetts Institute of Technology Lean Aerospace Initiative (MIT, 2005) found the following benchmark:

1. Labour hours: 10-71 percent improvement;
2. Costs: 11-50 percent improvement;
3. Productivity: 27-100 percent improvement;
4. Cycle time: 20-97 percent improvement;
5. Factory floor space: 25-81 percent improvement;
6. Travel distances (people or product): 42-95 percent improvement;
7. Inventory or work in progress: 31-98 percent improvement;
8. Scrap, rework, defects or inspection: 20-80 percent improvement;
9. Set up time: 17-85 percent improvement; and
10. Lead time: 16-50 percent improvement.

Facility should apply sustainable development concept to reduce the energy consumption, show as Figure 4. The following options can be taken:

1. Utilize the sun light through the hangar design to increase the illumination and brightness of workspace and decrease electrical energy consumption.
2. Collect the clean energy (solar energy) by using solar panel to support lightening system.
3. Develop new test methodology/equipment to reduce fuel/energy consumption.

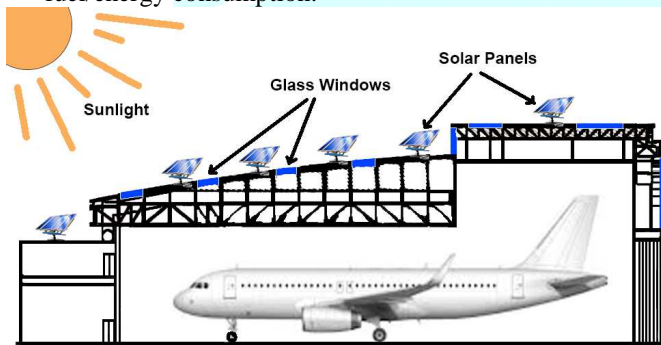


Figure 4 Sustainable Development Concept for MRO Hangar

Layout should apply Lean Production Concept to reduce the maintenance lead time, shows Figure 5 and describes as followings:

1. The management and professional functional groups are located in the center of the MRO hangar, they can monitor the maintenance progress and provide the technical supports to both side right away.
2. The receiving warehouse is centralize and the movement of material flows are radical toward to each aircraft during maintenance.
3. Apply the concept of point-of-use to create the feeder line to support assembly line. According to daily requirement of detail production schedule of maintenance, pick up the requirement detail part in the handcart and delivery to shop floor just-in-time. Also collect the unserviceable part from each aircraft and storage in fixed storage area for disposition.

4. The removable equipment dis-assembly from aircraft can temporarily storage in both side of hangar, where near the maintenance aircraft.

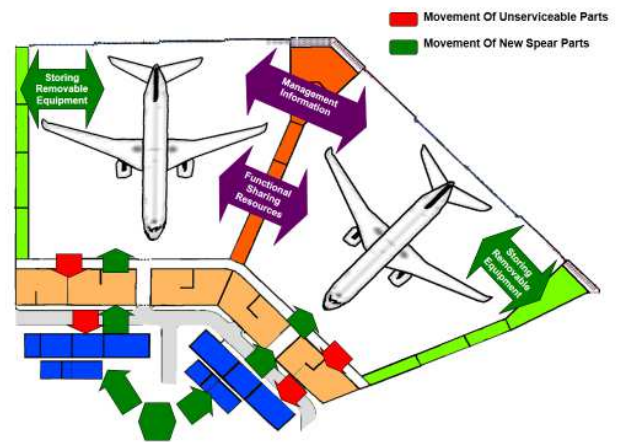


Figure 5 Lean Production Concept for MRO Hangar layout

According to the future demand and market forecasting, the MRO hangar also keep the possibility for future expansion, show as Figure 6.

The advantages of the expansion layout are:

1. Centralized warehouse and radical distribute to each aircraft base on daily maintenance plan and requirement.
2. Centralized the management and functional resources.
3. On-site support the progress of each aircraft.

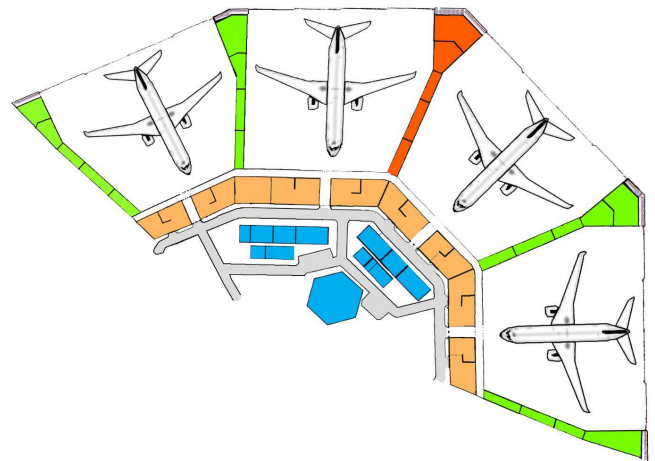


Figure 6 Reserve Expansion Opportunity for future development

The Detail Layout for MRO Hangar refer to Figure 7 (the first floor) and Figure 8 (the second floor). The ground rule describe as follows:

1. The onsite support team, composed by functional /technical groups, which related to maintenance operation should located near to the aircraft.
2. The professional workshop, includes avionics, electrical, hydraulic, mechanical...etc., should connect with the relative warehouse and aircraft.
3. The shop manager and management team/supporting departments, includes engineering, production planning, procurement, marketing, financial department...etc.,

should get together to reduce the communication interface and increase management effectiveness.

4. Arrange customer's office for better communication and negotiation.

- 1 Avionics Workshop
- 2 On-site Support Team
- 3 Electrical Workshop
- 4 Hydraulic Workshop
- 5 Cabin interior Workshop
- 6 Tool Control
- 7 Engine Workshop
- 8 Structure & Machinist Workshop
- 9 NDT Workshop
- 10 Avionics Testing Shop
- 11 Electrical Store #1
- 12 Mechanical Store #1
- 13 POL Room #1
- 14 Cabin Store #1
- 15 Electrical Store #2
- 16 Mechanical Store #2
- 17 POL Room #2
- 18 Cabin Store #2
- 19 Avionics/Electrical Warehouse
- 20 Engine Warehouse
- 21 Mechanical Warehouse
- 22 Paint Shop
- 23 Warehouse Central Office

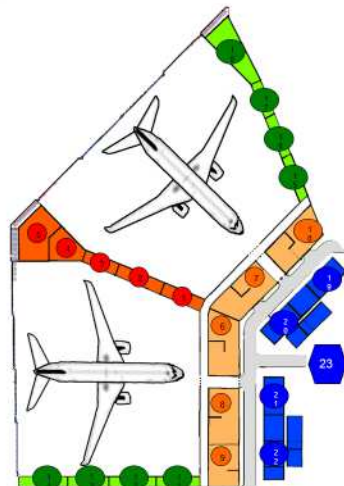


Figure 7 Detail Layout for MRO Hangar (The first floor)

- 1 Engineering chief
- 2 Shop Manager
- 3 Engineering Control Room
- 4 Production Control
- 5 Security Office
- 6 Human Resource Department
- 7 Finance Department
- 8 Procurement Department
- 9 Marketing Department
- 10 CEO / Conference Room
- 11 Client Office #1
- 12 Rest Room
- 13 Additional Office
- 14 Client Office #2
- 15 Rest Room
- 16 Additional Office

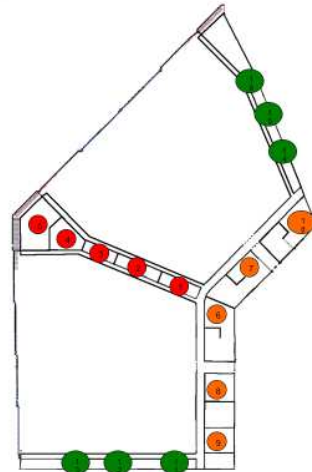


Figure 8 Detail Layout for MRO Hangar (The second floor)

Apply the information technology to construct Maintenance Management System, show as Figure 9(overall progress) and Figure 10(specific aircraft).

Figure 9 shows the overall progress of aircraft inside the MRO Hangar. From the screen, the information of customer, aircraft serial number, plan delivery date and estimate complete date. The color code show the maintenance progress is on schedule (green color) or behind schedule (red color).

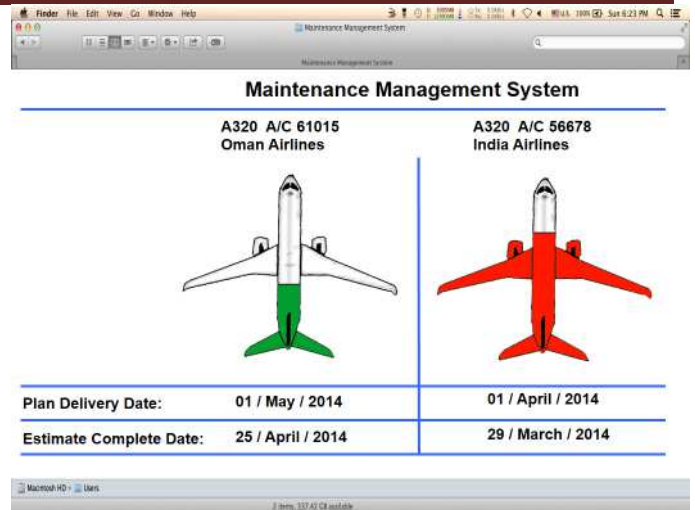


Figure 10 shows the progress of specific aircraft inside the MRO Hangar. From the screen, the information of customer, aircraft serial number, plan progress and current progress, detail information related to working hour, shortages, and quality. The color code show the current maintenance progress is normal (black color) or abnormal (red color).

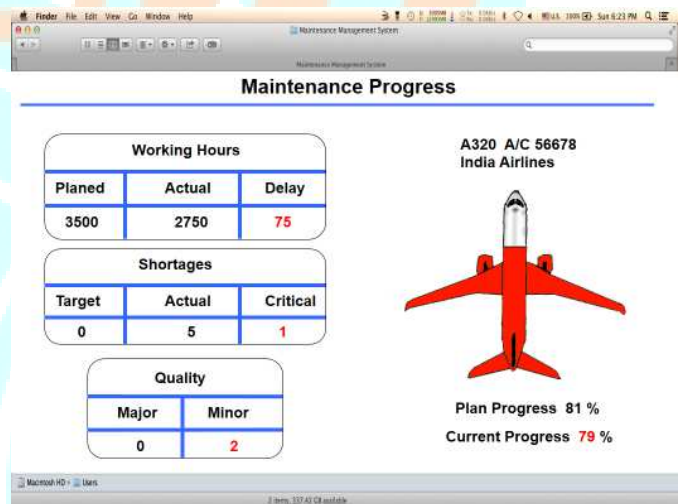
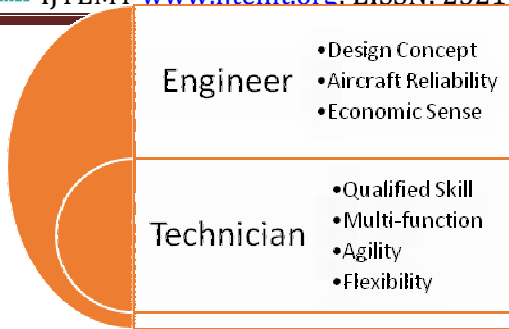


Figure 10 Maintenance Management System-Specific Aircraft

The following actions can be taken in each functional workshop:

1. Construct the Shop Floor Control System (SFCS) to monitor the maintenance activities. Base on the detail production schedule of maintenance, setup the online LCD (liquid crystal display) to demonstrate the visibility and monitor the relation between plan schedules versus current progress. Highlight the current critical issues (such as quality defect of detail parts, shortages...etc.) and potential risk in the future. Also mention the responsible person/organization of relative issues, need date, and complete.
2. The shop floor control system collect the labor working hour daily and convert to the performance measurement report to support shop manager take actions in daily operations.



4.3- Human Resources

The critical human resources of MRO Company are the experienced engineer and qualified technicians, the major roles of engineer and technician are describe as Figure 11:

1. Engineer: The engineering not only experience the design concept, regulation, specification to maintain the reliability of aircraft, but also aware the newly development technology and economic sense to make appropriate design (tolerance, material, geometry, manufacturing methodology...etc.) and disposition. Engineer also provide technical support for trouble shooting and maintenance plan development.
2. Technician: The qualified technicians cover several categories, describe as Table 1. The manpower had better to be trained as multi-skill workforce to keep the agility and flexibility in the shop floor.

Figure 11 Major Roles of Engineer and Technician

Table 1 The Qualified Technicians in MRO Shop

Type	Catégories
Mechanic	Structure repair, Painting, Assembly
Electric	Avionics, Harness, Wiring
Testing	NDI, functional Test

5- Management Process

The managers' main problem is to find a good match between workload and workforce. The elements that play a role in this match are time tables, maintenance norms, and contracts for the workload, shifts, and teams of the workforce. The quality of the match in a certain planning period (day, week, or month) is expressed in terms of the service level and the utilization rate. (MATTHIJS C. ThDIJKSTRA et al., 1994)

This study utilized the P-D-C-A (Plan-Do-Check-Action) cycle and propose the Management Process of MRO Company, shows as Figure 12. It includes the major functions of demand integration and material logistics, which describe in section 5.1 and 5.2 respectively.

5.1- Demand Integration

The demand integration include the following steps:

1. Delivery schedule: Receive the orders from different customers with quantity, delivery date, model type, and conditions. Summarized the overall demands and link to the business plan and investment plan.
2. Rough-cut capacity: Base on the overall demands and relative information, calculate the rough-cut capacity for long term and midterm. Observe the load versus capacity chart, we can find the load trend and come out the corresponding strategy to solve this situation. Then level the peak load versus low load and reflect to the human resources plan.
3. Material requirement planning (MRP): After the load levelling and applying the management strategies, the load can match demand and become balanced and feasible situation. Material requirement planning system receive the input from engineering evaluation (Bill of material, BOM), current inventory (part list, quantity), and current capacity (equipment, manpower), then can come out the detail production schedule.

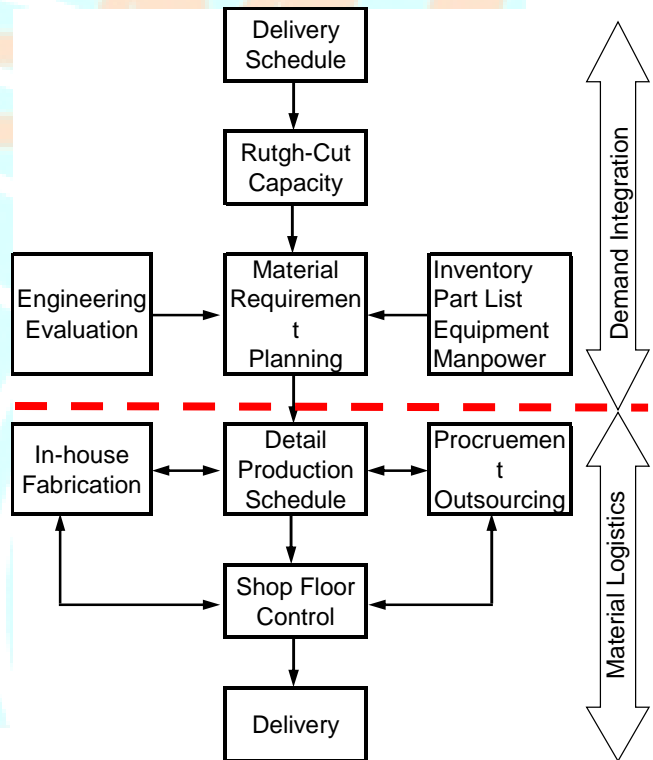


Figure 12 Management Process of MRO Company

5.2- Material Logistics

The material logistics include the following steps:

1. Detail production schedule: After the material requirement planning, we can obtain the detail production schedule. It base on the required lead time of detail parts, outsourcing parts, procurement parts...etc., and figure out the feasible production schedule. All of the resources (material, manpower, machine...) will support the production activities. Especially specific critical parts/components may impact the assembly /maintenance progress need to close watch and control.

2. Shop floor control: The fabrication progress of detail parts and the maintenance status of each aircraft should be monitor by Manufacturing Execution System (MES) to fulfil the delivery schedule. The shop floor manager receive the daily performance and progress report and arrange the suitable resources to meet the detail production schedule.
3. Delivery: After the assembly, functional test, and flight test, the aircraft complete the maintenance schedule. It should prepare the relative document and quality records for reviewing and approval.

5.3- Management System

The Management System of MRO Company should include seven key modules-Company Objectives, Order Management, Procurement Management, Inventory Management, Production Management, Quality Management, Risk Management, and



show as Figure13.

Figure 13 Key Modules of Management System

The detail function of Key Modules for Management System describe as following:

1. Company Objectives: Base on the long term development plan and market demand, set up the objectives for long term, medium, and short term objectives of company and functional department.
2. Order Management: Integrate the orders come from different customers, manage the order receiving and delivery and flow down the requirement to functional groups after harmonization.
3. Procurement Management: Base on the master production schedule and procurement the material/device/component, outsourcing the details to suppliers.
4. Inventory Management: Base on the demand quantity and unit price to categorize the A-B-C type of material. Apply the RFID (Radio Frequency Identification) system for the inventory management.
5. Production Management: Base on the Master Production

Schedule (MPS) to proceed the production activities, monitor all the detail parts production and assembly progress. Including maintenance planning, manpower planning, material planning, machine and facility planning, production scheduling and control, performance measuring.

6. Quality Management: Manage the quality system, operation procedure, process control and relative quality document/record and disposition to secure the reliability and safety. Including: liaison with regulatory authority, inspection methodology and standards, quality assurance audit...etc.
7. Risk Management: Monitor the internal and external environment and market. Identify the severity and probability and prepare the mitigation plan to get rid of the risk.

6- Customer Satisfaction

The main role of an airline's MRO is to provide a fully serviceable aircraft when it is required by the operators at minimum cost and optimum quality. Principal activities include: servicing, repair, modification, overhaul, inspection and determination of condition (Knotts, 1999).

The MRO Company should focus on the delivery, quality, cost, and flexibility to meet the customer satisfactions, shows as Figure 14.

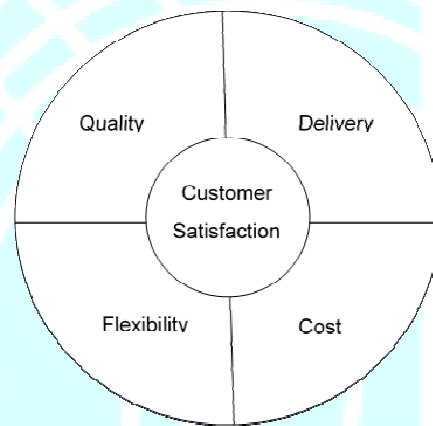


Figure 14 Customer Satisfactions of the MRO Company

6.1- Quality

The safety and reliability are the basic requirement of aircraft industry. The MRO Company should construct integrated quality system to fulfil the different aviation administrators, as well as different airlines. Thus, it will reduce the management cost and increase the overall revenue.

6.2- Delivery

The aircraft availability is an important factor for the airline operation. The MRO Company should integrate the maintenance process, management process, and material logistics to meet the detail production schedule

The MRO Company should build the risk management mechanism to secure promised aircraft delivery schedule. Once raise potential risk, it need to prepare the action plan or backup plan to mitigate the risk to secure promised aircraft delivery schedule.

6.3- Cost

The MRO Company should apply the lean concept to simplify the physical and information flow to increase the cost competitiveness.

We also need to introduce the concept of sustainable development. It can utilize the sun light through the hangar design to increase the brightness of workspace and decrease electric energy consumption. Also collect the clean energy (solar energy) by using solar panel to support lightening system.

Base on the analysis of IATA (Chris MARKOU, 2012), the average maintenance unit costs of narrow body aircraft is \$893 per flight hour, shows as Figure 15. The benchmark of inventory level per aircraft of narrow body aircraft, including A320 family, B737 classic and B737NG, the decreasing trends show as Figure 16.

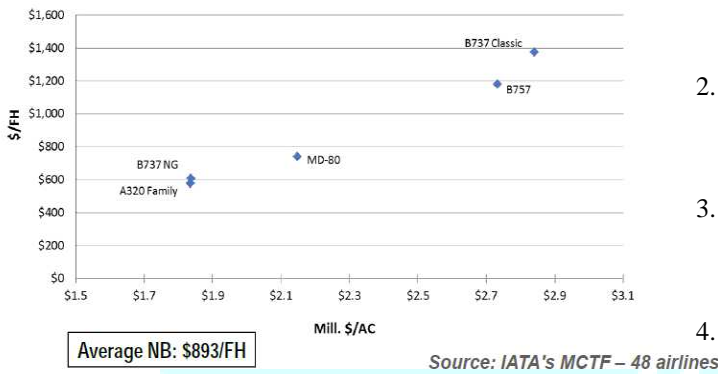


Figure 15 IATA Airline Average Maintenance Unit Costs of Narrow Body Aircraft (Chris MARKOU, 2012)

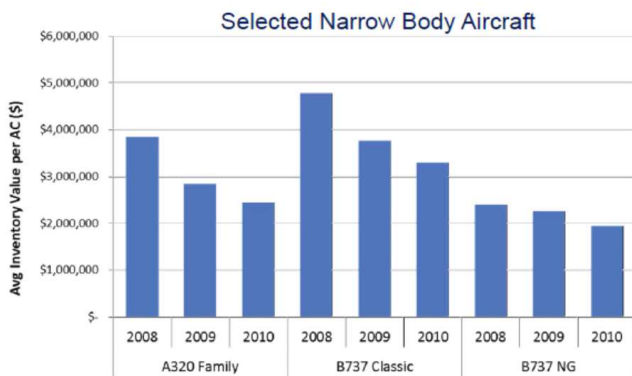


Figure 16 IATA Airline average maintenance unit costs of narrow body aircraft (Chris MARKOU, 2012)

6.4 Flexibility-

The MRO Company should develop the customized maintenance program to meet the policy and demand of different airlines to increase the revenue.

The part fabrication shop or maintenance shop should reserve contingent capacity to react and tolerance some unpredictable issues.

7- Conclusion

The aircraft maintenance, repair and overhaul (MRO) is important to the airline operation. The C check and D check need the longer lead time and higher cost than A check and B check. It is the good opportunity for professional MRO Company to get the business from airlines.

This study propose the Operation Management Model, which introduce the concept of lean production and sustainable development into the maintenance process and management process for MRO Company.

The MRO Company should focus on the delivery, quality, cost, and flexibility to meet the customer satisfactions.

1. Quality: Construct integrated quality system to fulfil the different aviation administrators, as well as different airlines. Thus, it will reduce the management cost and increase the overall revenue.
2. Delivery: Integrate the maintenance process, management process, and material logistics to meet the detail production schedule. Also build the risk management mechanism to secure promised aircraft delivery schedule.
3. Cost: Apply the lean concept to simplify the physical and information flow to increase the cost competitiveness. Also introduce the concept of sustainable development to saving energy consumption.
4. Flexibility: Develop the customized maintenance program to meet the policy and demand of different airlines to increase the revenue. Also reserve contingent capacity to react and tolerance some unpredictable issues.

Thus, The MRO Company can increase the performance and competence in the competitive market.

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