Supply Chain Optimization within Aviation MRO

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Abstract - Maintenance Repair and Operations (MRO) supply chain not only provides one of the best opportunities to reduce cost of operation and increase productivity but also offers complex challenges such as end to end integrated planning, increased availability of assets, inventory optimization and effective spend management. This paper gives an overview of the challenges faced in MRO supply chains and highlights some of the approaches to meet these challenges, drive efficiencies and optimize the entire supply chain.

Keywords- ERP; Supply chain, MRO, Aviation, Implementation

I. INTRODUCTION

A supply chain consists of all stages involved, directly or indirectly, in fulfilling a customer request. The supply chain not only includes the manufacturer and suppliers, but also transporters, warehouses, retailers, and customers themselves. The systemic, strategic coordination of these stages and the tactics across these supply chain stages within a particular company and across businesses within the supply chain, for the purposes of improving the long-term performance of the individual companies and the supply chain as a whole can be termed as 'Supply Chain Management'. Airline Industry is one of the biggest industry employing vast aspects of supply chain management and thus makes it more important to study the supply chain within airline industry more closely especially after September 11 attacks in U.S. Within the last few years several changes have been made in the traditional business model of an Airline Industry which has been influenced mainly due to the economic pressure from worldwide. The three major changes that have taken place are;

- Business models developed recently include point-to-point low fare carriers, which aim to eliminate complex ticketing agreements and sell direct to the consumer, offering value over comfort. Low fare carriers tend to favour streamlined operations, with a single aircraft type and the attendant efficiencies in purchasing power, maintenance and crew utilisation.
- Aircraft technology has changed since the 1980s in that maintenance, in particular where engines are concerned, has a lower fixed-schedule component (i.e., "planned preventative") and a greater diagnosed, or measured performance element (referred to as "on-condition" scheduling). As newer aircraft employ more solid-state systems with fewer mechanical instruments and controls and improved material and system design, their overall maintenance needs are less. Many older generation aircraft were retired in recent years due to a drop in utilisation following the Gulf War. Further, while a five-year-old airplane performs the same task as a thirty-year-old, lower ownership costs, lower maintenance costs and lower fuel costs have led to a demographic shift to younger fleet in recent years. The consequence for maintenance costs has been pronounced, and the value of the aircraft MRO (maintenance, repair and overhaul) market fell to $34.6bn in 2003 from $43bn in 2001 (Back, 2003). There is continuing consolidation in the market, with constant pressure to innovate and create competitive advantage.
- This is where the third major environmental change comes into play: supporting technology for the maintenance side of the industry, where airlines are the customer at the end of a supply chain. In particular inventory management of spare parts for aircraft, which are not consumed and replaced; instead they are repaired and re-stocked, making the decision process for inventory planning different to the conventional production-based view of ERP systems. While many information systems functions are internal, clearly there are opportunities to link information systems to external processes.

These major changes took place during economic recession. However, global commercial aviation markets have seen an unprecedented dynamic in growth during the last 20 years after the deregulation and liberalisation activities started in the US in 1978 and in the EU in 1988. In challenging economic times, companies look for new ways to control costs and improve efficiency. To address these issues, manufacturers are taking a hard, strategic look at Maintenance, Repair and Operations (MRO) supply. Commonly known as "indirect materials," MRO supply includes a vast array of items

that support internal operations, ranging from safety gloves and office supplies to spare parts for mission-critical industrial equipment and tooling. Dynamic and liberal markets have led to strong competition among the established carriers and numerous newcomers, resulting in tremendous cost pressure for all airlines and consequently for th e technical aftermarkets. These technical aftermarkets embrace the maintenance, repair and overhaul (MRO) business and provide the following main services:

- Scheduled checks of the airframe, engines, landing gears, components and cabin interiors, ranging from a brief pre-flight check to a D-check, an overhaul lasting up to six weeks for the complete aircraft;
- Repair and modification programmes including engineering services;
- Cabin completion and life-cycle aircraft services for the fast-growing VIP aircraft market; and
- Combinations of these different MRO services, which add up to total care packages like United Services' Total Support, SR Technics' Total Care or the Lufthansa Technik Total Technical Service TTS.

In the MRO industry, the market structure is highly competitive. Lufthansa Technik AG is the global market leader with a market share of approximately 10%. Other strong players are Air France Industries, ST Aerospace, FLS Aerospace and, for the engine overhaul market, the manufacturers General Electric Engine Services, United Technologies/Pratt & Whitney and Rolls Royce.

The aircraft fleet is by far the most important asset for an airline, and punctuality of flights is of highest importance for the customers. As a result, the top priority in the MRO industry is to provide both safe and reliable aircraft in order to fulfil the airlines' preconditions. Therefore, all spare parts have to be available immediately whenever and wherever they are needed to make the aircraft fly. In the past, this has often led to excessive safety stocks no matter what costs were implied. High stock values are not only a result of limited cost awareness, but also a consequence of a significant portion of non-routine work included within major MRO tasks, with only limited predictability of parts needed to be replaced during a specific event. In combination with partly excessive lead times for aircraft parts of up to one year, MRO shops have a wide range of parts available, many of them being slow movers. For example, Lufthansa Technik AG keeps detailed information on 775,000 parts within its enterprise resource planning system.

In addition, for aircraft safety reasons, each of these aircraft-related parts needs to be certified by the aviation authorities and requires full traceability back to origin. These high standards for production and approval of parts, as well as other quality regulations for suppliers, in combination with high investment costs, generate an overall highly oligopolistic – and, for key parts, even monopolistic – market structure for the supply of aircraft parts and services. In fact, the aviation industry is suffering from an on-going decline of average yield per passenger for the airlines due to the economical downturn after 11 September 2001, a recession in the business cycle of the world economy and increasing competition by new market entrants such as low fare carriers Ryanair and Easyjet in Europe. The combination of these factors has massively increased economic pressure in the new millennium. This scenario highlights the importance of installing ERP Systems within an organisation.

II. Impact of ERP in Aviation Industry

This brings us to the question of what exactly are ERP systems. ERP systems are designed to integrate and optimize various business processes, such as order entry and production planning, across the entire firm (Mabert et al., 2001). Enterprise Resource Planning (ERP) and its predecessor, Manufacturing Resource Planning (MRP II) are helping to transform our industrial landscape. It's making possible profound improvements in the way manufacturing companies are managed. It is a strong contributor to America's amazing economic performance of the 1990s and the emergence of the New Economy. A half century from now, when the definitive industrial history of the twentieth century is written, the evolution of ERP will be viewed as a watershed event. (Akkermans et al.,2003; Hsu et al., 2009; Sanders, 2007).

An ERP system can be described as set of management tools that balances demand and supply, containing the ability to link customers and suppliers into a complete supply chain, employing proven business processes for decision-making, and providing high degrees of cross-functional integration among sales, marketing, manufacturing, operations, logistics, purchasing, finance, new product development, and human resources, thereby enabling people to run their business with high levels of customer service and productivity, and simultaneously lower costs and inventories; and providing the foundation for effective e-commerce. The vendors of fully integrated software offer software that is capable of processing all commercial functions of any company, no matter how large, diverse or geographically disparate the company's components may be. Moreover, the software is not limited to specific industry sectors: it can be configured for retail industries, mining companies, banks, airlines etc. ERP market leaders (Piszczalski *et al*.) are SAP AG (39% of the world market) Oracle Corporation, PeopleSoft Inc , Baan Co and Ramco Systems Ltd.

These remarkable features of an ERP system show its importance, in terms of implementing these systems, to an airline industry.Typically, airlines feature highly complex business processes, supported by specialized IT systems that reside in functional silos and lack cross functional integration. In fact, more than 60 percent of airlines' software is custom-built, versus less than 40 percent in other industries. By and large, airlines have not adopted the ERP systems that other industries, such as automotive and consumer products, have deployed to radically streamline and integrate their processes. Instead, airlines have mostly custom-built their applications to conform to their processes and have not changed this approach with new applications. The typical airline pays a steep price for maintaining its process complexity and IT legacy systems. For example, an airline that has not renovated its processes and systems for flight planning and dispatching requires up to five times as much staff time to dispatch its fleet as an airline that has redesigned and automated these processes using state-of-the-art IT systems. This is as shown in Fig.1.

III. ERP Benefits and Its Impact On SCM

For years organizations have striven to realize the benefits of ERP, ES and IT investments. Integrated ERP systems affect all aspects of a business. It has been found that real benefits reside not within the IT domain but, rather, in the changes in the organizational activities that the IT system has enabled.

Several researchers have classified the types of ERP benefits, and have indicated that some approaches may be appropriate techniques for evaluating the performance or benefits of ERP systems. Irani and Love (2001) proposed a framework for meeting the challenges associated with categorizing benefits that is based on the work of Harris (1996). Mabert et al. (2000) surveyed about 500 business executives, and revealed the following performance outcomes of ERP: quickened response time, increased interaction across the enterprise, improved order management, improved customer interaction, improved on-time delivery, improved supplier interaction, lowered inventory levels, improved cash management, and reduced direct operating costs. Many researchers have given many theories and competency constructs to argue that firm's ERP competency must be used effectively in order to truly harness the capabilities of an ERP system for competitive advantage .Several authors have classified the different types of ERP benefits into five groups as follows: IT infrastructure, operational, managerial, strategic and organizational benefits.

In recent years, supply chain design and its competencies and performance have received much attention from researchers and practitioners. From the Resource-Based Viewpoint, all firms have capabilities; however, a firm will usually focus on certain capabilities consistent with its strategy, and the firm's most important capabilities are called competencies. Accordingly, competencies emphasize technological and production expertise at a specific point along the value chain. Although the initial focus of ERP is ''within the organization," many organizations have addressed supply chain challenges with their ERP systems. Several studies have demonstrated a relationship between ERP benefits and SCM. Although there is no analytical framework for measuring the impacts of ERP systems on

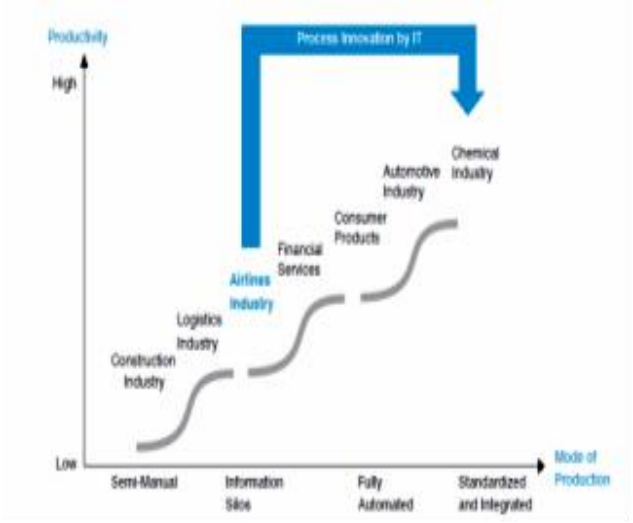

Figure 1. Airlines Can Capture Productivity Gains by Using IT to Standardize and Integrate Processes

SCM competencies, several researchers have examined how the antecedents, IT department technical quality, IT plan utilization, and top management of IT positively affected IT impact on the supply chain. Some researchers have critically examined that ERP plays a modest role in improving future supply chain effectiveness, and a clear risk of ERP actually limiting progress in SCM.

Researchers have defined the operational process involves the processes that facilitate order fulfillment and replenishment across the supply chain. Effective order fulfillment requires coordination both within a firm and among supply chain partners. Within the operational process, firm competencies include customer integration, internal integration, and supplier integration. Extending the relations from simple buyer–supplier cooperation to a whole supply network from raw material suppliers to final customers provides several advantages that include for the buyers a large pool of

suppliers, reduced transaction costs, market transparency, purchase transparency, lower prices, dynamic pricing models, control of maverick, buying, and lower inventory costs. For the suppliers the benefits among others are large pools of buyers, real time information, time to market, aggregation of small orders, efficient fund transfer. Today's ERP solutions offer even more benefits. Many vendors have begun to enhance their offerings with extended supply chain applications in an effort to create a seamless, integrated information flow, from suppliers through manufacturing and distribution. . However for this supply chain cooperation their are some potential disadvantages like for the buyers unqualified suppliers, miscommunication, failed promises, hidden switching costs, missed value-creating opportunities; for the suppliers the disclosure of confidential information, pressure for price reductions, easy supplier switching, loss of established relationships, high initial investment. ERP is a suite of application modules that can link back-office to front-office operations, as well as internal and external supply chains. Since ERP systems can automate business processes and enable process changes, one would expect them to improve the SCM competencies in operational process and improve customer responsiveness.

IV. Implementing ERP Systems within an MRO and its Challenges

The success of implementing an ERP system within an organization has to be analyzed, both, for short- and long impact. In the past decade, nearly all literature on ERP has focused on reasons for implementation and on the challenges of the implementation project itself. Although the initial focus of ERP was ''within the organization," many organizations have addressed supply chain challenges with their ERP. Several studies have demonstrated a relationship between ERP benefits and SCM. The implementation of ERP enables the companies to move towards an extended enterprise business model that enhances value across the total supply chain. In order to gain supply chain efficiencies, MRO needs to exchange large amount of planning and operational data, ranging from information for annual contracts and periodic progress reporting to real-time delivery and invoicing data.

There are many challenges which are faced by MRO especially when ERP systems are implemented within their organizations. Some of them are discussed as follows;

(1) *Lack of integration in MRO supply chain functions.* MRO supply chain consists of three key functions i.e. Asset Management, Inventory & Warehousing and Sourcing & Procurement. Traditionally, these functions are viewed in silos in the organizations. Although organizations are focused on integrating transactional processes such as work order execution, purchase requisition management, inventory issue/receipt/return and purchase order processing, they are yet to move forward to integrate end to end processes, right from the level of planning to the level of execution across all MRO supply chain functions. A lack of integration of processes specifically at the level of planning results in suboptimal inventory management, high procurement costs and higher unavailability of assets. Although ERP systems cater to the integration services lack of planning and training can also lead them to this problem.

(2) *Inaccurate and Incomplete Master Data*. Master data management activity is one of the most important activities in MRO supply chain and acts as a foundation stone for success of the planning and execution functions. Below are the key elements of master data which play a crucial role in MRO supply chain;

(a) *Asset Master.* Asset master is one of the most important elements of master data in the MRO supply chain. In asset master, most often than not, the Asset BOM (Bill Of Material) and spare part linkages are not defined, which results in inefficient inventory planning, high inventory obsolescence, non-availability of spares on time and increased maintenance costs in the long run. Other
missing and incomplete details in asset master such as associated down assets, asset hierarchy, etc also causes poor visibility for opportunity maintenance and material planning for associated assets and lead maintenance personnel to miss maintenance opportunities of these assets.

(b) *Incomplete or Inaccurate Maintenance Task BOM.* Maintenance task lists are one of the major components in maintenance plans and work orders. Once the task lists are defined along with BOM, these task lists then help in automating the planning to execution cycle and also provide help to plan the material in advance. If task BOM is incomplete and inaccurate then it may hinder the material planning, material requisition and reservation process.

(c) *Part Cataloguing.* One of the characteristics of MRO supply chain is that there are thousands of parts in the system with each part having unique characteristics & attributes. Proper and structured cataloguing of these parts is a major challenge. Inaccurate and incomplete cataloguing leads to the following;

i. Difficulty for the end user to search the material.
ii. Duplication of SKU codes.
iii. Increased chances of stock outs due to duplication.
iv. Increase in inventory due to duplication.

(3) *Lack of Demand Visibility from Asset Maintenance Plan.* Asset Maintenance, being the demand driver,

presents two types of demands in the MRO supply chain- Planned and Unplanned. Planned demand arises out of planned preventive/predictive maintenance plans, shutdown plans and field change orders whereas unplanned demand arises out of breakdown and unplanned maintenance. Demand invisibility in the supply chain may arise if the plans are not made in ERP/EAM (Enterprise Resource Planning/Enterprise Assets Management) systems or if the maintenance personnel carry out maintenance planning and work order management manually without entering the data into the ERP/EAM systems. The demand invisibility will affect Inventory management and sourcing processes significantly and will result in higher costs throughout the supply chain.

(5) *Difficulty in Managing Inventories*. MRO inventories are characterized by large numbers of SKU bases, different attributes and high demand variations ranging from non-moving SKUs to fast moving SKUs. Part criticality and demand unpredictability aspects further complicate the inventory planning process. All these factors require highly skilled resources to carry out planning and select the right stocking policy. Most of the ERP applications do not come with the features for dynamic inventory planning and hence it makes inventory planning more difficult. Due to ineffective planning, the following problems may arise;

i. Suboptimal inventories- Too high inventories for some parts while non-availability or too low inventories for other parts Duplication of SKU codes.
ii. Higher Inventory levels i.e. more than 1.5% of Asset Replacement Value (ARV)
iii. Lower service levels
iv. Higher level of non-moving and obsolete inventories.
v. Asset under maintenance for longer duration in case of non-availability of spare

(6) *Warehouse Inefficiencies and Inventory Inaccuracy* Since MRO materials are large in numbers and each material differs in size, shape and attributes ranging from gas to solid, light & simple parts to large and complex sub-assemblies, some parts being prone to pilferage, some perishable in nature with short shelf life, some parts requiring sophisticated preservation techniques and some parts requiring controlled environmental storage conditions. All these factors make the warehousing extremely complex & challenging and require highly skilled resources who understand commodities and warehousing requirements of such commodities. Some of the implications of these challenges are:

i. Non availability of the stock at right quantity at the right location leading to equipment under break down for longer duration.
ii. Non availability of spare parts at the right time leading to equipment under break down for longer duration.
iii. Availability of spare parts in unusable condition leading to order expending and equipment under breakdown for longer duration.
iv. Inventory Shrinkage due to pilferage and damages.
v. Maintenance personnel lose faith in system

(7) *Fragmented Supply Base*. Fragmented supply base across the categories is another challenge. Supply base is even more fragmented in organizations with multiple locations and decentralized procurement processes. At times there may be many codes for the same supplier. Due to fragmentation, there is a limited opportunity to leverage the spend value and get the most competitive prices and most favorable terms & conditions such as short delivery lead times, pay terms, return policy for obsolete parts, Vendor Managed Inventory (VMI) programs, etc.

(8) *Complex and Non-Uniform Procurement Process.* Value of MRO materials varies significantly, and so do the associated procurement and approval processes. It has also been observed that the approval & procurement processes differ significantly from site to site within the same organization. Complexity in procurement processes increase the internal lead time leading to increase in safety stock of the materials and add to the high purchase order processing costs.

V. Approach for Improving MRO Supply Chain Efficiencies

To address the challenges faced by an MRO as discussed above and drive efficiencies in MRO supply chain, organizations may use following approaches;

(1) IT Enablement. Most of the ERPs do not come with features such as dynamic inventory planning, parts cataloguing & e-procurement, which are highly useful & specific to MRO supply chains. With help of a consulting services provider, organizations can assess the portfolio of existing IT applications and identify the required tools. Once the required IT tools have been identified, the organization can look for IT services providers to implement and integrate bolt-on tools on the existing ERP/SCM applications. The benefits of using these IT applications are as follows;

i. Enriched parts catalogue with reduced chances of duplication of codes.
ii. Automated and dynamic inventory planning leading to optimized inventories.
iii. Automated procurement processes leading to reduced procurement lead times and PO processing costs.

(2) *Delivery through Offshore Model from Low Cost*

Countries. Organizations can identify processes, which can be executed from offshore location at a lower cost. These processes can be consolidated at a global level and can be moved to low cost countries. Organizations can not only reduce processing costs but also benefits from the high level of standardization and improved control attained by moving some of the processes to a centralized offshore delivery centre. Some of the processes, which can be moved from multiple locations and delivered from centralized offshore location, are as under. These processes can help the organization drive efficiencies and meet some of the challenges effectively in MRO supply chain such as;

i. Master Data Management
ii. MRO Supply chain planning
iii. Asset Maintenance, Inventory & category Planning
iv. Parts Pooling
v. Supply base rationalization
vi. Purchase Order Processing
vii. Disposal Management

(3*) Increase Focus on Master Data Management.* Master data is one of the most critical elements in the entire MRO supply chain and needs to be managed effectively. Organizations can review the existing master data management processes and systems, bring discipline in the whole process and focus on improving the quality & enrichment of the master data for Assets, Suppliers, Part catalogues, part categorization, Part & Asset BOM linkages and maintenance task BOMs on ongoing basis. If master data is being managed in different locations and systems then master data can be moved & managed at a centralized location. Benefits of moving to a centralized location would include increased accuracy &standardization of data set and increased accountability of the team.

(4*) Improve Integrated Planning.* Once the required master data is ready, organizations can assess the current state of planning processes, implement a well-defined process for annual & periodic planning for Maintenance and ensure that the processes are followed by maintenance planning teams. Annual & periodic maintenance planning will be one of the inputs for annual and periodic inventory and category planning. Benefits envisaged through this process are as follows;

i. Improved demand visibility
ii. Improved inventory planning
iii. Improved service levels
iv. Improved category planning and reduced cost of procurement

(5) *Develop Scientific Inventory Models.* MRO supply chains are characterized by high counts of parts with high variation in demand pattern and varied part criticality. Inventory planning team may evaluate the stocking policies and consistently update data such as required service levels for parts, criticality and demand predictability aspects in consultation with end users on an ongoing basis. Planning team can develop the questionnaire, rules and parameters to identify and measure the criticality, service level requirement and demand predictability aspects for the parts. The team can decide whether the part is stock or non-stock item based on the demand predictability and criticality. For example, if the demand of a part is not predictable and part is highly critical then it should be treated as stock item. Since the movement pattern of parts varies from no movement to fast movements, planning team can classify the SKUs based on movement and select the right stocking models for each of the movement class to come out the Reorder Quantity (ROQ) and Reorder (ROL) levels for the stock items. Stocking model differs based on movement classes; for example, for fast and regularly moving parts, normal probability distribution is appropriate in finding the right ROL whereas; for items with very slow movements, Poisson distribution is the most appropriate model. The benefits of using these approaches are;

i. Optimized inventory- neither too high nor too low
ii. Improvement in service levels
iii. Ease in identifying unplanned demand
iv. Streamlined processes

(6) *Initiate Part Pooling.* Organization with multiple locations and same sets of assets can reduce inventory of expensive parts and increase service level by leveraging parts pooling and exchange programs. A centralized inventory planning team of the organization can play a crucial role in the pooling processes right from identifying the pooling location, pooling stock and pooling quantity to supporting the locations in the day to day inter warehouse and inter location transfers.

(7) *Initiate Warehouse Productivity and Eliminate Inventory Inaccuracies* .Some of the approaches are;

i. Group the materials with respect to size, shape and physical storage requirements and keep the same material group at a designated single location.
ii. Periodic location auditing and implementation of preventive measures to reduce location discrepancy.
iii. Review existing cycle counting practices and audit the preventive measures
iv. Identify the parts that need preservation, and development & execution of the preservation plan to ensure that parts are in usable condition
v. Store materials such as Batteries, CDs, adhesives etc, which can be pilfered, under lock and key
vi. Monitor and improve Goods receipt to storage location and requisition to delivery cycle times

(8) *Improve tactical procurement processes.* One of the characteristic of MRO supply chains is significantly high counts of purchase requisitions leading to significantly high counts of Purchase Order (PO) generation. PO processing and post order expediting are highly cumbersome & transactional activities in nature. These activities consume most of the time of the procurement personnel, leaving them with limited time to focus on strategic aspects of sourcing. Organization can review the existing annual spend based on part criticality, cost, supply source, etc, simplify & automate procurement processes and select the suitable procurement methods. For example, organizations can cover the maximum numbers of the critical parts under pre negotiated contracts and can simplify the tactical procurement process by reducing the numbers of approval levels for release orders/POs for parts against pre-negotiated contracts. Simplification and automation in procurement processes will help in reducing the procurement lead times and PO processing costs.

VI. CONCLUSION

SCM relates to the co-ordination of products and information flows among suppliers, manufacturers, distributors, retailers and customers. An ERP system caters to the demand of SCM by integrating all aspects of business organization and thus is expected to yield many benefits, such as reduction of cycle time, faster transactions, better financial management, the laying of the groundwork for e-commerce, linking the entire organization together seamlessly, providing instantaneous information, and making tacit knowledge explicit. MRO supply chains processes are highly complex and time consuming. But if managed with structured and scientific approach then benefits such as low cost of procurement, optimized inventory and higher availability of assets, can be reaped. To manage MRO supply chains efficiently and improve continuously, organizations can also look forward to outsourcing services providers, who have pool of skilled resources and can provide cost effective end to end solution from transformation led IT initiative to MRO supply chain planning & execution processes.

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