MILITARY AEROSPACE SUPPLY CHAIN

SAMIR CHABRA

INTRODUCTION

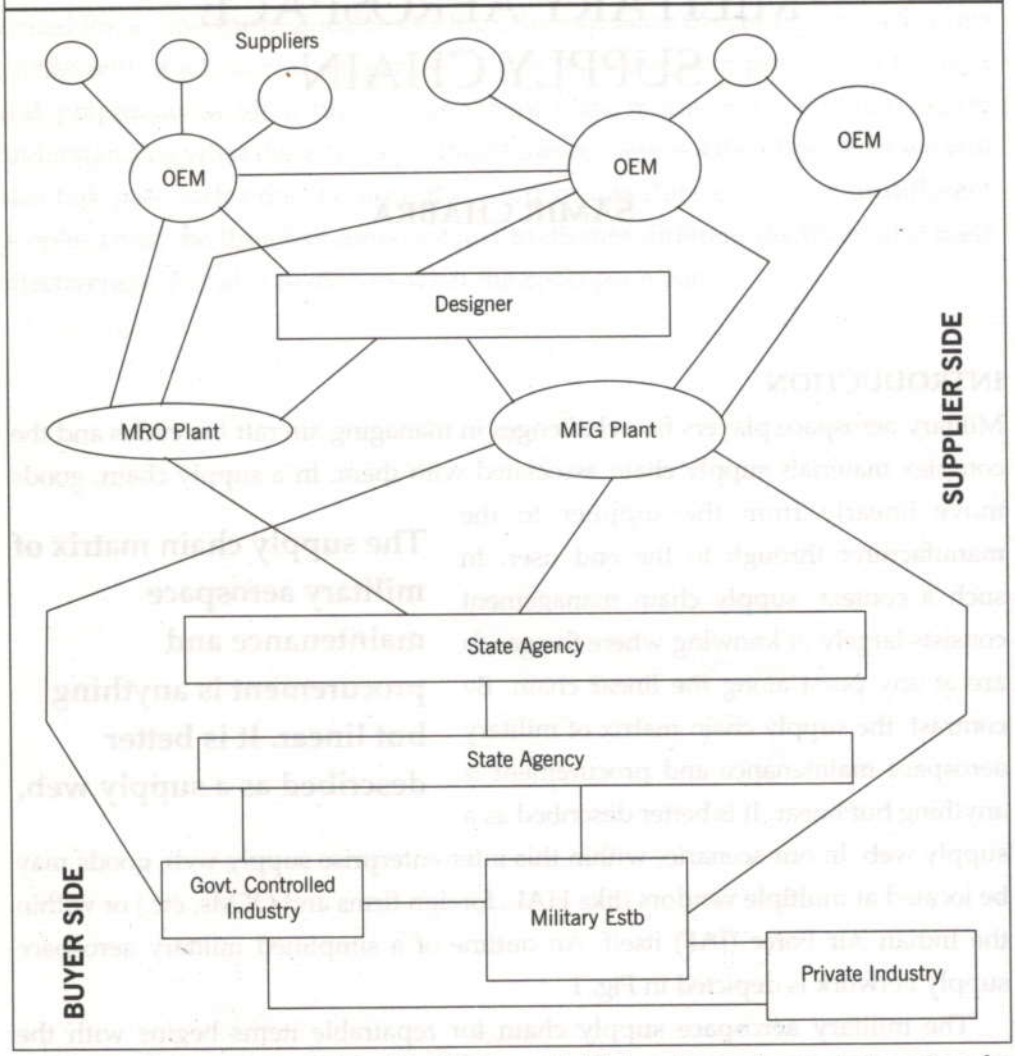
Military aerospace players face challenges in managing aircraft life cycles and the complex materials supply chain associated with them. In a supply chain, goods move linearly from the supplier to the manufacturer through to the end user. In such a context, supply chain management consists largely of knowing where the goods are at any point along the linear chain. By contrast, the supply chain matrix of military aerospace maintenance and procurement is anything but linear. It is better described as a supply web. In our scenario, within this inter-enterprise supply web, goods may be located at multiple vendors (like HAL, foreign firms and OEMs, etc.) or within the Indian Air Force (IAF) itself. An outline of a simplified military aerospace supply network is depicted in Fig. 1

The supply chain matrix of military aerospace maintenance and procurement is anything but linear. It is better described as a supply web.

The military aerospace supply chain for repairable items begins with the forecast, purchase, manufacture, and distribution of a part; continues with its delivery to a source of repair; and ends with the distribution of the now serviceable asset to retail accounts (wings) and maintenance customers (squadrons) in order to return weapon systems to mission capable status. Managing the reverse supply chain is equally important in this context.

Wing Commander **Samir Chabra** is a Deputy Director (Engineering) at Air HQ, New Delhi.

Fig. 1: Simplified Military Aerospace Supply Chain



The main concerns which affect both cost efficiencies and responsiveness of a military aerospace supply chain are poor communication throughout the chain, back orders, long lead time, excessive inventory, unsatisfactory customer service, high supply chain costs and underutilised assets.

This paper suggests the need for creating a supply chain orientation in the context of Indian military aerospace and discusses various drivers which govern

the performance of a supply chain. Various supply chain competencies needed from the Indian military aerospace perspective have been examined. In Section 2, the peculiarities of a military aerospace supply chain and the need for supply chain orientation in the Indian military aerospace context are discussed. Section 3 discusses various supply chain drivers and suggests ways to optimise these drivers in our context. Finally, in Section 4, an approach towards designing the supply chain is briefly explained.

2
PECULIARITIES OF THE MILITARY AEROSPACE SUPPLY CHAIN

The military aerospace industry offers certain unique challenges from the supply chain perspective, as enumerated below.

- The defence sector is not as open to public influence as other aspects of the public sector and there is close monitoring of defence companies by the government.
- There is a regular dependence on OEMs as complete design and repair capabilities are not transferred to even major buyers, even under licensed production and transfer of technology arrangements, for commercial, strategic and technological reasons.
- The characteristics of airborne equipment with an emphasis on factors like weight, speed, strength and performance lead to quality and price difference, when compared to ground-based equipment. This is mainly due to stiff screening/environmental testing requirements for airworthy material qualification.
- Procurement is more of joint military-industry partnership and there is a strong dependence on government sales. This implies usually a longer order processing time and also, at times, has a restrictive influence on the adoption of procurement strategies purely on financial considerations. There is a tendency for the end user to keep higher levels of safety stocks, thereby, increasing inventory carrying costs.
- The product volumes are not very high like those of the automobile or retail industry and the demands are also cyclic. Therefore, competitive

manufacturing and vendor development strategies prevalent in the automobile or retail industry may not always be applicable here.

- The product cost and its life span are considerably high. Typically, a combat aircraft has a life span of around 30 years. Therefore, after sales support accounts for a significant portion of revenue in the industry.
- System reliability and maintainability are key drivers in determining spares requirements and life-cycle costs.
- The product support is also governed by a tight resupply window, particularly during operations. For instance, if a spare part required for a combat aircraft operating from an aircraft carrier in a sea is to be drop shipped, the delivery options are limited.
- Demand-supply lead time is generally high due to a combination of various factors. In some cases, OEMs have military as well as commercial aircraft parts production facilities multiplexed for better commercial viability and there may be an order queue for made to order parts.
- Managing obsolescence throws up many challenges. Earlier, an OEM would offer end of life sales to its customers before closing down a product line. Now, there is an effort towards transferring design and technology to a customer for sustained production of spare parts which are under obsolescence. However, this is restricted to smaller parts which do not require intensive capital investments for setting up production facilities.
- Accurate spare part forecasting is a major area of concern not only for customers and main suppliers but even more for tier-I and tier-II suppliers. The main reasons are application of antiquated techniques in demand forecasting by end customers and lack of inter-organisation information sharing due to security restrictions.
- Most of the countries permit military hardware/ software sales through designated state agencies, mainly for monitoring purposes. This brings in intermediatories between a customer and an OEM, reducing visibility and increasing the bullwhip effect.

Need for Supply Chain Orientation

Traditional logistics management focusses on integration of materials across procurement, operations (assembly/manufacturing) and distribution sub-systems and on minimising inventory buffers between these stages through better information, as shown in Fig. 2; while a supply chain aims to optimise inventory flow from the vendor through the firm all the way to retail accounts, as shown in Fig. 3. The information flow minimises inventories at all levels and the focus is on the level as well as the velocity of the inventory. The customer

Fig. 2: Logistics Domain

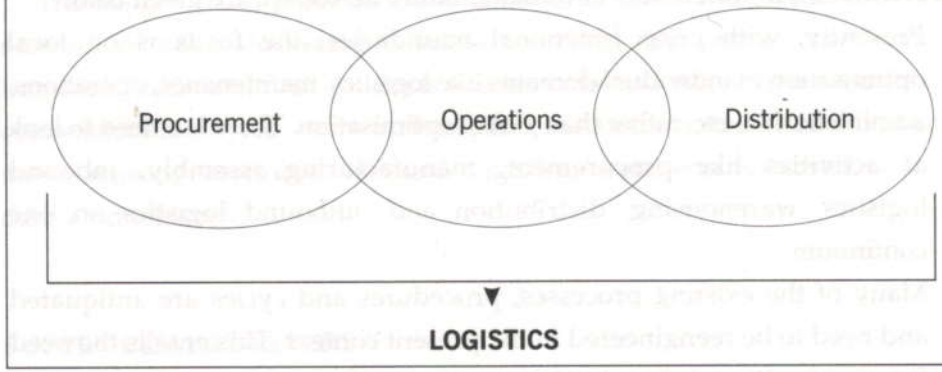
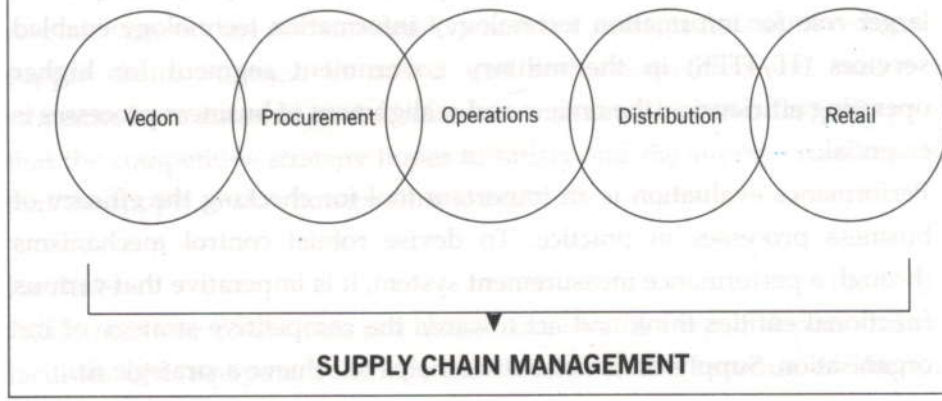


Fig. 3: Supply Chain Domain



value is seen as motivation to improve and it is this perception that has brought supply chain management to the forefront of business management activities.

To begin with, we need to create a supply chain orientation by sensitising ourselves to the issues involved, reviewing interconnection of entities and creating customer-supplier matching. The arguments in favour of creating a supply chain orientation in the context of Indian military aerospace are given below.

There is a need to look at activities like procurement, manufacturing/assembly, inbound logistics, warehousing, distribution and outbound logistics on one continuum.

- Presently, with crisp functional boundaries, the focus is on local optimisation in individual domains like logistics, maintenance, operations, administration, etc. rather than global optimisation. There is a need to look at activities like procurement, manufacturing/assembly, inbound logistics, warehousing, distribution and outbound logistics on one continuum.
- Many of the existing processes, procedures and cycles are antiquated and need to be reengineered in the present context. This entails the need for reviewing existing business processes, weeding out redundant processes, reviewing connections between entities and reengineering these processes.
- To implement supply chain management (SCM) strategies and invoke a larger role for information technology/ information technology enabled services (IT/ITES) in the military government segment for higher operating efficiencies, the review and realignment of business processes is essential.
- Performance evaluation is an important tool for checking the efficacy of business processes in practice. To devise robust control mechanisms through a performance measurement system, it is imperative that various functional entities think and act towards the competitive strategy of the organisation. Supply chain orientation helps to achieve a strategic fit.

Supply chain management evolves through several stages of increasing intra and inter-organisational integration and coordination in its broadest sense and implementation. It spans the entire chain from the initial source (supplier's supplier, etc.) to the ultimate consumer (customer's customer, etc.). In our case, the supply chain may involve many independent organisations. Thus, managing intra and inter-organisational relationships is essential. It includes the bi-directional flow of products and information, as well as the associated managerial and operational activities. It seeks to fulfill the goals of providing high customer value with an appropriate use of resources, and of building a competitive chain advantage.

The supply chain process can be considered as an integrated, coordinated network of value delivering business processes that procure raw materials, transform them into final products and services and deliver the product to the customers. Broadly, it covers various processes in the activities of procurement, manufacturing/assembly, inbound logistics, warehousing, distribution and outbound logistics.

3

SUPPLY CHAIN DRIVERS

This section focusses on key supply chain drivers viz. facility, inventory, information and transportation. The design, planning and operation of these drivers govern the performance of a supply chain to a large extent. These drivers not only determine the supply chain's performance in terms of efficiency and responsiveness, they also determine whether a strategic fit is achieved across the supply chain. Strategic fit means that both competitive and supply chain strategies have the same goal. It refers to consistency between customer priorities that the competitive strategy hopes to satisfy and the supply chain capabilities that the supply chain strategy aims to build.

Facilities

Facilities in our context are production facilities like repair depots and storage facilities like equipment depots, etc. Whatever the function of the facility,

decisions regarding the location, capacity and flexibility of facilities have a significant impact on the supply chain's performance. Macro-economic factors, geographical depth, availability of infrastructure, proximity to the network, quality of local support in terms of industry and workers are decision elements for location of an MRO facility.

After the setting up of a facility like a repair depot, vendor development should be the thrust area. Different kinds of strategies need to be adopted here. Some of the technically sound vendors may require some financial support and a positive business outlook to make investments. Some vendors may need help to interact with OEMs for better understanding of the products, while others may need the use of certain in-house resources like machine centres, drawings, airworthy materials testing facilities, etc. Our vendor development programme is governed largely by inflexible regulations, adversarial relationships and inconsistent business potential. Therefore, often we end up with rather unreliable and less capable local partners. Some of the suggestions to improve indigenous support for our facilities are mentioned below.

- Concerted efforts towards vendor development, encouraging multiplexed production with commercial products for sustainability. Change in framework/holding patterns to allow partnerships between private players and defence public sector undertakings (DPSUs). The offset contracts must be used only for technology incubation in critical areas like universal engine test beds and PCB repairs, etc.
- The gate-keeping function, to decide on the course of action during reverse logistics, should be as close as possible to the customer's location (squadron). For instance, an enhanced 'I' level troubleshooting capability at wing level, backed with spares support, can drastically cut down equipment shuttling between retail accounts and the repair agency. This will reduce the need for higher rotable floats, MTTR and can simplify associated processes like premature withdrawal analysis, order processing and demand management.
- Use of simulation modelling tools before altering, augmenting or creating a new facility. It is economical and faster to use simulation techniques to

analyse system behaviour or compare scenarios before actually adopting a system. The possible scenarios could be an additional warehouse or a test facility or buying a costly machine. Many packaged softwares allow analysis through simulation modelling.

- It might be worthwhile to think of promoting ex-workers of our plants to become partners as entrepreneurs in supplying general engineering items like nut, bolts, washers, seals, rivets, ground equipment, etc. Some of our underutilised facilities like machine shops, special treatment plants, moulds, etc. can be leased to them. In such a scenario, certain airworthy materials, metals, alloys or rubber, etc. may have to be provided to them but that is quite feasible. This can improve cost efficiencies and provide tighter production schedule compliance.
- Contract services for allied activities like aircraft painting, including materials, plant maintenance (compressors, cooling towers, SFCs, etc.) and packaging, etc. can help to improve quality in these areas. A specific contract mechanism towards this end may have to be evolved.
- Managing obsolete parts through the life-cycle of an aircraft by collaborative product commerce (CPC). Rather than making an end-of-life purchase or having a vendor reverse engineer an item, obsolete designs and specifications can be transferred to small aftermarket production facilities. This reduces the need to reverse engineer components and decreases the time and cost to reproduce the components. Such an arrangement can be beneficial for high failure rate modules of communication equipment, navigation gear or RF devices where technology has evolved rapidly.
- The vendor managed inventory (VMI) model can be successfully used for products like aviation fuel, atmospheric gases and lubricants.

Inventory

The problem of demand forecasting in a military aerospace maintenance environment is characterised by stochastic intermittent demands, stochastic lead times, multi-item and multi-level inventories and certain intangibles like threat

perception, geo-political dimensions, which have a direct bearing on utilisation rate. The current methods of demand forecasting in military aerospace maintenance are based on regulations and somewhat expert knowledge but are largely arbitrary. The forecasts are largely governed by past consumption patterns, stock positions and future equipment usage envisaged. Although there is dependence on historical data, forecasting decisions are significantly influenced by judgment.

In industry, many current solution methods for demand forecasting and determining optimal stocking quantities are based on the assumption that parameters are known deterministically. In some cases, sensitivity analysis has been performed on inventory models in stochastic environments. Spare parts provisioning models based on the Poisson process and renewal theory are also quite popular. The Poisson process can be used whenever the failure rate is constant.

The current methods of demand forecasting in military aerospace maintenance are based on regulations and somewhat expert knowledge but are largely arbitrary.

The main factors which influence demand patterns of an item required in military aerospace MRO are past consumption, procurement lead time, utilisation rate, reliability, quantum of back orders, fill rates envisaged, assigned life of the component, residual useful life, etc. Since some of these factors have probability involved, use of stochastic demand forecasting models or customised models based on the fuzzy logic approach will provide better forecasting.

As a universal principle, forecasting is always error prone and gets worse with a longer time horizon. There is a need to reduce the MPE length by considered reductions at different stages and supporting strategies to bring it to half of the present span. Significant reductions in internal processing time and transportation time are possible. Similarly, external lead times can be compressed through vendor alliance, EDI and information sharing.

In the military aerospace environment, the procurement risk for an item as well as its influence on product support may vary over a large spectrum. If the

procurement risk is high and its influence on product support is also high, alliance contracts and long-term agreements are better suited for such strategic components. For leverage components, with low procurement risk and high influence on product support, the price leverage strategy is suitable. Substitution and risk hedging are seen to be the right strategies for bottleneck items which have a high procurement risk but low influence on product support. The bottleneck segment should be the first target for indigenisation efforts.

In the military aerospace environment, the procurement risk for an item as well as its influence on product support may vary over a large spectrum.

Visibility and traceability are two technology-related issues that are driving forces in supply chain improvements. Visibility allows an organisation to track a part or order as it passes through the supply chain. Traceability, on the other hand, allows firms to trace individual components. IT/ITES are playing the role of crucial enabler towards achieving greater visibility and traceability in our transactions and managerial decisions.

Information

The major concerns in the military aviation supply chain performance are primarily due to uncertainty, lack of integration and coordination. IT/ITES can be utilised for better upstream and downstream information flows. Once the business processes have been reengineered and reconfigured, the next step would be to minimise manual interventions in coordination. This can be achieved through an implementation of integrated SCM/ERP solutions. An intra-organisation supply chain software should be allowed to mature as the first stage and in the next phase, inter-organisation IT/e-commerce solutions like EDI should be adopted. The areas where IT/ITES would serve as supply chain enabler are discussed below.

- *Transactional*. The operating logs, equipment state, spares consumed, demands raised, etc. are captured real-time/near real-time for monitoring and further processing.

- *Informational*. Stock balances, price catalogues, availability status, contract details, numbers and statistics, etc. are available for better appreciation and planning.
- *Analytical*. Tools and data availability for determining EOQ, vendor selection, task generation, reliability monitoring, calculating activity-based costs and analysing performances, etc.
- *Tracking*. Visibility of orders can reduce a lot of uncertainty in the supply chain, traceability of components can help in maintenance decisions and RFID techniques can transform warehousing functions.
- *Automation*. Generation of various reports, flight data analysis and component change/servicing due dates monitoring, etc. can cut down the clerical staff and improve the managerial functions.
- *Simulations*. The effect of parametric changes in assembly line, comparison of options, optimisation and facility planning, etc. can be done in a cost and time effective manner through packaged softwares for model building and simulations.

4

SUPPLY CHAIN DESIGN

A practitioner's approach towards this endeavour would be, first, to analyse various processes in five different domains viz. plan, source, make, deliver and return in "as-is" (existing) form. The redundant and non-value adding activities can be dropped from the future scheme of things after such an analysis. The next stage would be to formulate "should-be" processes in these five domains (plan, source, make, deliver and return). Business process reengineering (BPR) will help to achieve a "strategic fit" between our competitive strategy (through which the organisation seeks to achieve its goals) and its functional strategies (like operational, maintenance, human resources, accounts, administration, etc.). IT/ITES is perhaps the biggest enabler for achieving seamless supply chain integration. Therefore, this resource (IT/ITES) requires adequate effort in design and implementation. The present IT/ITES endeavours are inadequate towards the vertical and

horizontal integration being envisaged. Modelling and simulation can play an important role in an envisaged supply chain design. The proven design and optimisation techniques like deterministic, stochastic, economic and simulation-based models may be used towards supply chain design.

CONCLUSION

This paper highlights the peculiarities in the military aerospace domain from the supply chain perspective and the need for supply chain orientation in Indian military aviation. To accomplish this, we must critically look at changes in current doctrine and organisational processes that will enable transformation. Change must occur quickly, and this will help to change antiquated cycles and processes. There is a need for BPR so that all entities have the same view of business processes and there is seamless integration. Technology and use of ERP/SCM software will play a lead role in such an endeavour.

REFERENCES

1. B.M. Beamon, "Supply Chain Design and Analysis: Models and Methods," *International Journal of Production Economics*, 55:281-294, 1998.
2. S. Chopra and P. Meindel, *Supply Chain Management: Strategy, Planning, and Operation*, Prentice Hall, Delhi, India, 2002.
3. I. Fan, S. Russell, and R. Lunn, "Supplier Knowledge Exchange in Aerospace Product Engineering," *European Business Review*, 72(1):14-17, 2000.
4. M.T. Farris, M. Wittmann, and R. Hasty, "Aftermarket Support and the Supply Chain: Exemplars and Implications from Aerospace Industry," *International Journal of Physical Distribution and Logistics Management*, 35(1):6-19, 2005.
5. A.A. Ghobbar and C.H. Friend, "Sources of Intermittent Demand for Aircraft Spare Parts Within Airline Operations," *Journal of Air Transport Management*, 8.
6. B. Ghodrati and U. Kumar, "Reliability and Operating Environment Based Spare Parts Estimation Approach," *Journal of Quality Maintenance Engineering* , 11(2):169-184, 2005.
7. B.C. Giri and K.S. Chaudhuri, "Heuristic Models for Deteriorating Items With Shortages and Time-Varying Demand and Costs, *International Journal of Systems Science*, 28(2):153-159, 1997.
8. G. Graham and G. Hardaker, "Defence Sector Procurement and Supply Chain Relationships." *European Business Review*, 3(3):142-148, 1998.
9. W. J. Kennedy et al, "An Overview of Recent Literature on Spare Parts Inventories," *International Journal of Production Economics*, 76(2):201-215, 2002.
10. A. Lockamy III and K. McCormack, "Linking Scor Planning Practices to Supply Chain Performance," *International Journal of Operations and Production Management*, 24(12):1192-1218, 2004.
11. D. Manchester and B.H. Kleiner, "What Defence Companies Have Done to be More Commercially Successful," *Aircraft Engineering and Aerospace Technology*, 69(3):282-286, 1997.
12. D. Simchi Levi, D.P. Kaminsky, and E. Simchi Levi, *Designing and Managing the Supply Chain: Concepts, Strategies, and Case Studies*, Irwin McGrawHill, Singapore, 2000.
14. P.R.J. Trim, "Public-Private Partnerships and the Defence Industry," *European Business Review*, 13(4):227-233, 2001.