

TLI – Asia Pacific White Papers Series

Framework for Managing Service Parts in Automotive and Aerospace Industries

Volume 10-Oct-SCI01



A Collaboration Between





FRAMEWORK FOR MANAGING SERVICE PARTS IN AUTOMOTIVE AND AEROSPACE INDUSTRIES

Disclaimer, Limitation of Liability and Terms of Use

NUS own the copyright to the information contained in this report, we are licensed by the copyright owner to reproduce the information or we are authorised to reproduce it.

Please note that you are not authorised to distribute, copy, reproduce or display this report, any other pages within this report or any section thereof, in any form or manner, for commercial gain or otherwise, and you may only use the information for your own internal purposes. You are forbidden from collecting information from this report and incorporating it into your own database, products or documents. If you undertake any of these prohibited activities we put you on notice that you are breaching our and our licensors' intellectual property rights in the report and we reserve the right to take action against you to uphold our rights, which may involve pursuing injunctive proceedings.

The information contained in this report has been compiled from sources believed to be reliable but no warranty, expressed or implied, is given that the information is complete or accurate nor that it is fit for a particular purpose. All such warranties are expressly disclaimed and excluded.

To the full extent permissible by law, NUS shall have no liability for any damage or loss (including, without limitation, financial loss, loss of profits, loss of business or any indirect or consequential loss), however it arises, resulting from the use of or inability to use this report or any material appearing on it or from any action or decision taken or not taken as a result of using the report or any such material.

ABSTRACT

Service parts logistics is a growing business in the Asia-Pacific region and Singapore being the regional logistics hub in Asia, could well position itself to be the hub for supporting Asia Pacific after-sales operations in some of the industries. This paper summarizes some of the findings from the industry on service parts logistics, particularly in the automotive and aircraft industries in the Asia Pacific region. Specifically, it highlighted companies practice with reference to a proposed service parts logistics management framework. This paper also identifies the trends and opportunities for service parts logistics business in Singapore.

1. INTRODUCTION

Service parts logistics is becoming an important aspect of supply chain management. The size of service parts market has grown significantly in the last decade estimated to reach \$150 billion worldwide and is increasing at five to nine percent annual growth rate (Patton, 2006). According to Deloitte Research, service revenues make up an average of 25 percent of company's total business (Outsourced Logistics, 2008). Firms have begun to benchmark their service parts logistics operations against best-in-class operators and third parties specializing in this field have seen an increase in the demand for their services. More companies are recognizing the strategic value of having an excellent service parts logistics system to ensure part availability and shorter customer response time.

With that realization, more companies these days are providing good after-sales service, which will help to extend the lifecycle of products and extract the maximum value from high value equipments. After-sales service is a high margin business and accounts for a large chunk of corporate profits. Thus companies are being triggered to pay more attention to their after-sales costs and service level. After-sales services have become a unique selling point, especially for the automotive and aircraft industries. Since lifecycle of product in these industries are long, companies will find more opportunities in after sales service down the line. In addition, increasing sales of service parts cost businesses far less than finding new customers (Cohen et al., 2006).

'Service parts logistics' or the management of service parts for after-sales service encompasses planning, fulfillment and execution of service parts through activities like

demand forecasting, parts distribution, warehouse management, repair of parts and collaboration processes with all the relevant parties in the after-sales service supply chain. It has been attracting more attention recently as companies strive to overcome increase competition and attain a sustainable competitive advantage by offering their customers better after-sales service. With a desire to retain existing customers, the aircraft and automotive industries are exploiting new solutions to provide cost-effective and efficient after-sales service to their customers.

This paper provides a literature review of service parts logistics and presents a framework consisting of key considerations when setting up a service parts logistics hub. Case analyses from companies are included, highlighting opportunities and challenges faced by companies in setting up their regional logistics hub in Singapore. Recommendations are proposed for companies interested in setting up a regional logistics center (RLC) for service parts management in Asia Pacific.

2. RESEARCH METHOD

Data were obtained primarily through interviews with key executives working in the automotive and aircraft industries. Interviews were conducted for 3 automotive companies, 2 aircraft companies and 1 logistics provider over a period of 2 months involving three researchers from TLI – Asia Pacific and two researchers from NTU Center for SCM.

The objectives of this research were:

- a) To understand the various service parts logistics practices in automotive and aircraft industries in the Asia-Pacific region.
- b) To understand the process flow for service parts logistics in the two industries.
- c) To identify trends and opportunities for service parts logistics business in Singapore.

3. LITERATURE REVIEW

Industries measure service quality by means of response time, defined as the time it takes for a technician to arrive at the customer site with a spare part to fix the machine after the customer reports a failure. To provide high-quality service, manufacturers aim to keep response time to each customer short by stocking parts at their warehouse. However, spare parts are expensive and components have high depreciation and obsolescence costs. Therefore, it is imperative that manufacturers maintain their inventory level at the central warehouse and field depots at the lowest level possible.

Thus, the ability to meet the response time constraint depends mainly on inventory policies employed at the field depots and central warehouse. If the required spare part is in stock at the field depot, the customer is served immediately and the response time is negligible. On the other hand, if the requested part is not available at the field depot, the response time includes the repair time as well as the travel time to and from the central warehouse (to obtain the part).

The automotive and aerospace industries are characterized by hundreds of parts and customers, low part failure rates, tight response times, numerous service centers and a base stock policy for each part at each warehouse. To control the quality of service, companies prefer to keep their average response time to each customer below a threshold level, say 24 hours.

Multi-echelon spare parts inventory systems have been analyzed quite extensively in the literature (Diks et al., 1996). One of the earliest works in this area was Sherbrooke's METRIC model. In his classical paper, Sherbrooke (1968) considered a two-echelon spare parts inventory system for repairable items. Other related works that study multi-echelon resupply systems with budget considerations include Muckstadt and Thomas (1980) and Hausman and Erkip (1994).

There are a few researchers who have considered multi-echelon spare parts inventory systems with service constraints. Cohen et al. (1990) developed and implemented Optimizer to determine inventory policies for IBM's periodic review, multi-item, multi-echelon spare parts inventory system. They solved the problem by using level-by-level decomposition of facilities and by assuming infinite supply at the replenishment sources. Cohen et al. (1999) reported a

successful implementation of two basic inventory models to improve a complex spare parts system.

Numerous inventory models have been developed in the area of spare part inventory management (Silver et al., 1998). Spare part inventory management is often considered as a special case of general inventory management with special characteristics such as low and sporadic demand volume. However, the objective of both is synonymous, that is to achieve the desired service level with minimum cost.

Mathematical models are usually aimed at optimizing the tradeoff between inventory investment and service levels, while considerations of administrative efficiency have led to different types of classifications of inventory items. While efficient computers make complex modeling possible, activities such as choosing control parameters, allocating control resources, making purchasing decisions, and thinking about different policies for different types of items still need to be done manually. For this purpose, item classification is an important aspect.

As most of the past researchers focus on specific areas in service parts logistics, it is useful to examine the various factors affecting the service levels and proposed a framework that give a holistic view of service parts logistics.

4. PROPOSED FRAMEWORK FOR MANAGING SERVICE PARTS LOGISTICS

The key components for an efficient service parts supply chain based on inputs from the companies as well as from the latest research works are depicted in Figure 1. Each of the components provides a foundation that ultimately delivers the customer service goals. Although the framework applies to both mature and emerging markets, it is especially critical in mature markets given the importance of efficiency in a price-driven environment. Companies' practices will be presented to support the proposed framework and interviewed companies can be found in Appendix A.

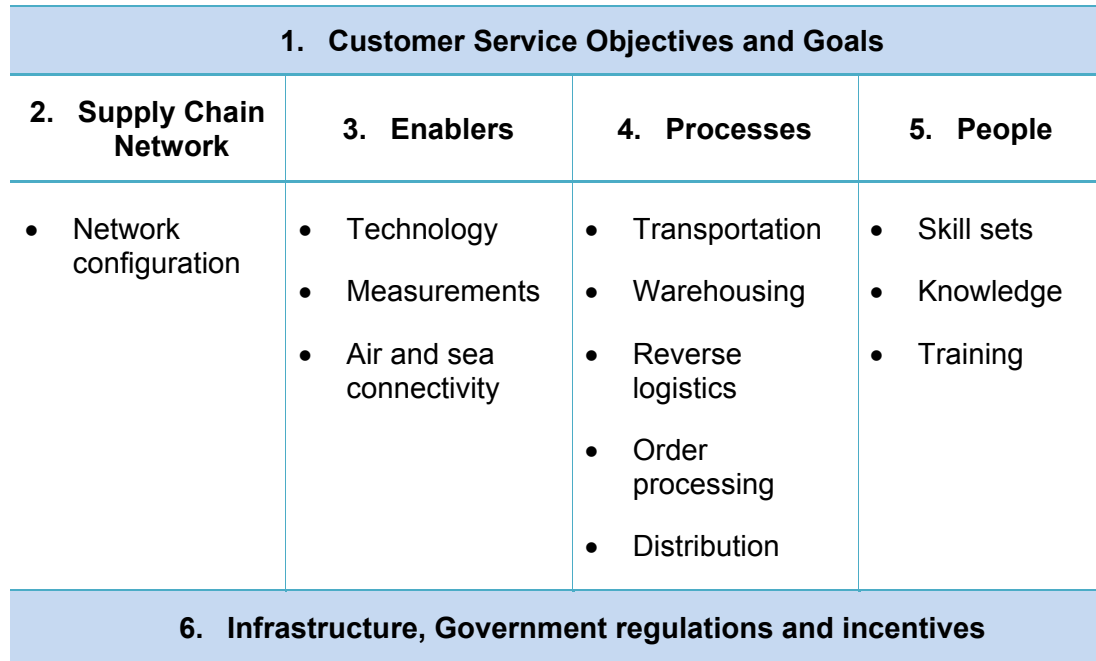


Fig. 1: Service parts logistics framework.

4.1 Customer Service Objectives and Goals

The goal for any service parts business is to create value for the company's customers and shareholders. That goal is both the starting point for service parts strategy, and the ultimate objective for operations. In addition, companies should design a portfolio of service products (Cohen *et al.*, 2006) as each customer segment demands a different level of service. Customer will decide their preferred level of service by weighing the level of response they need against the prices they are willing to pay.

The amount of time it takes to restore a failed product is often seen as a key performance indicator. Most customers demand fast response time with nearly 70 percent requiring less than 48 hours of response time as shown in Figure 2. Since profits, especially in the aerospace industry is dependent on utilization rate, any part unavailability translates into hundred thousand dollars of incurred loss.

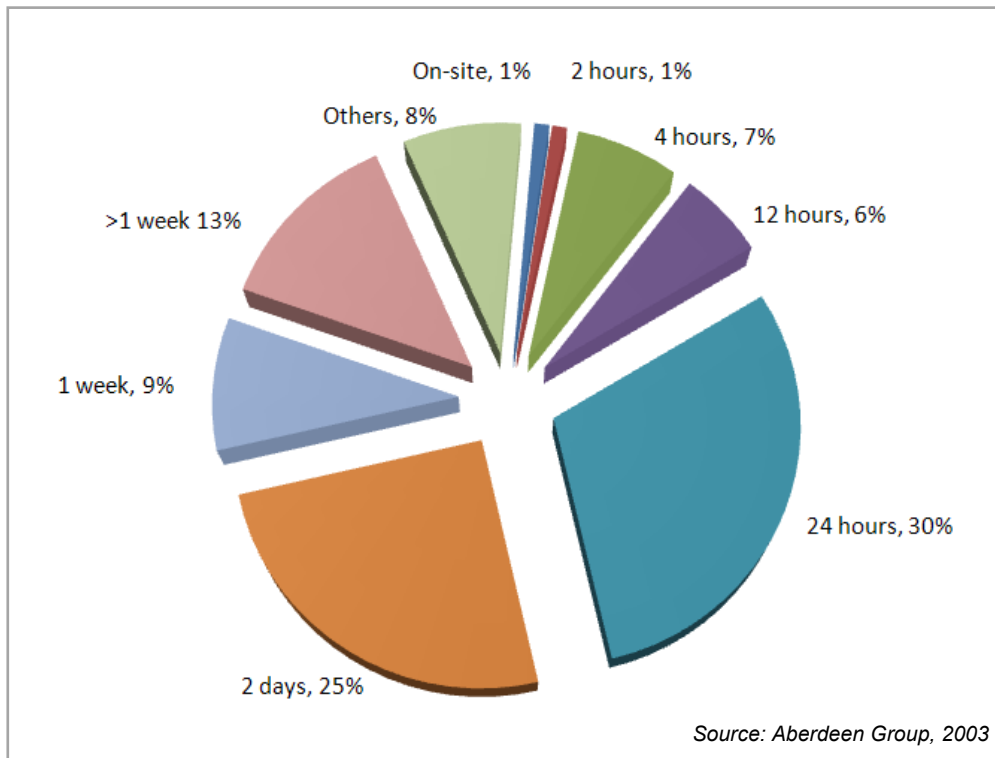


Fig. 2: Customer required response time

In general, both automotive and aircraft companies offer three different level of service. Table 1 and 2 summarizes the types of service each industry provide to their importers and dealers. The different level of services offered is in close relation to the criticality of the spare parts. Criticality of a part is defined as the consequences caused by the failure of the part in case a replacement is not readily available (Huiskonen, 2001). A practical approach to measure criticality of a part is to relate it to the time in which the failure has to be corrected. If three level of services are considered, then based on criticality, the levels are characterized as follow:

- Level 1: Failure need to be corrected and supply of replacement parts should take place immediately
- Level 2: Failure can be tolerated for a short duration of time while waiting for the replacement parts to arrive

- Level 3: Failure does not affect other processes and repair can be done when the parts arrive i.e. no urgency

Customers are aware of the tradeoff between fast response time and high repair cost. Hence, 'Power by the hour' concept is currently gaining popularity in aerospace industry. The key feature is that it undertakes to provide the airlines with a fixed maintenance cost over an extended period of time. Airlines are assured of an accurate cost projection, thus avoiding the high costs associated with breakdowns.

Type of Service	Lead Time	Processes & Cost
Vehicle Off Road (VOR) <ul style="list-style-type: none"> – Customers require their vehicle to be fixed as soon as possible. Parts are ordered on a daily basis. VOR shipment is done as a packaged delivery. 	Within 24 hours.	Highest cost and transportation mode is by air.
Emergency <ul style="list-style-type: none"> – Customers require a part soon but can afford short waiting time. 	Two to four days.	To decrease shipment cost, parts requisition from the same warehouse are consolidated at the RLC first before shipping out. Main transportation is via air.
Regular	Seven days.	Least cost. Orders are consolidated and shipped out via sea.

Table 1: Service level in automotive industry

Type of Service	Lead Time	Processes & Cost
<p>Aircraft on Ground (AOG)</p> <ul style="list-style-type: none"> – An AOG situation occurs when the aircraft problem is serious enough to prevent it from flying. Since this would cause the company to incur great loss, special arrangement will be made to deliver parts on-site; often RLC has its own private fleet to cater for this purpose. 	12 hours.	<p>Most costly. To avoid the hassle and costs involved in AOG, companies recommend that airlines keep some spare parts on hand to minimize delay. However some airlines prefer not to invest in expensive parts.</p>
<p>Critical</p> <ul style="list-style-type: none"> – Airlines need the parts soonest possible but can allow half day of waiting time. 	24 to 48 hours.	Less costly
<p>Ordinary</p> <ul style="list-style-type: none"> – Parts that are normally used for servicing. 	One week or as promised.	Least costly

Table 2: Service level in aerospace industry

4.2 After-sales Supply Chain Network

Companies should set up a distinctive after-sales service supply chain that differs from the manufacturing supply chain (Saccani et al., 2007). This supply chain should be continuously optimized for speed and efficiency as the industry is transforming itself.

A typical after sales supply chain network constitutes four entities namely the parts supplier or OEM, the Regional Logistics Center, the importers or country warehouses and the dealers. The companies in this study adopt either one of the following network configuration:

Centralized

In this configuration, parts from suppliers will be stored in RLC and delivered directly to the dealers whenever demand arises. Toyota has a policy that all spare parts are kept centrally at their warehouse as part of their Just-In-Time (JIT) philosophy. They tend to buy these parts in small lot sizes frequently from the manufacturer (as opposed to large lot size). The warehouse has an average of 6 stock turns per year. There are however some products that move slowly and others that are fast moving parts, such as filters, which are purchased on a daily basis. Borneo Motors has a program in place to manage these parts. Spare parts for car models manufactured less than 10 years ago are held at the Senkee Logistics Hub in Singapore. If an older car needs a part, Borneo Motors will verify with Toyota in Japan to determine whether the part is still available. This will help decrease the number of spare parts type stored in the warehouse.

Decentralized

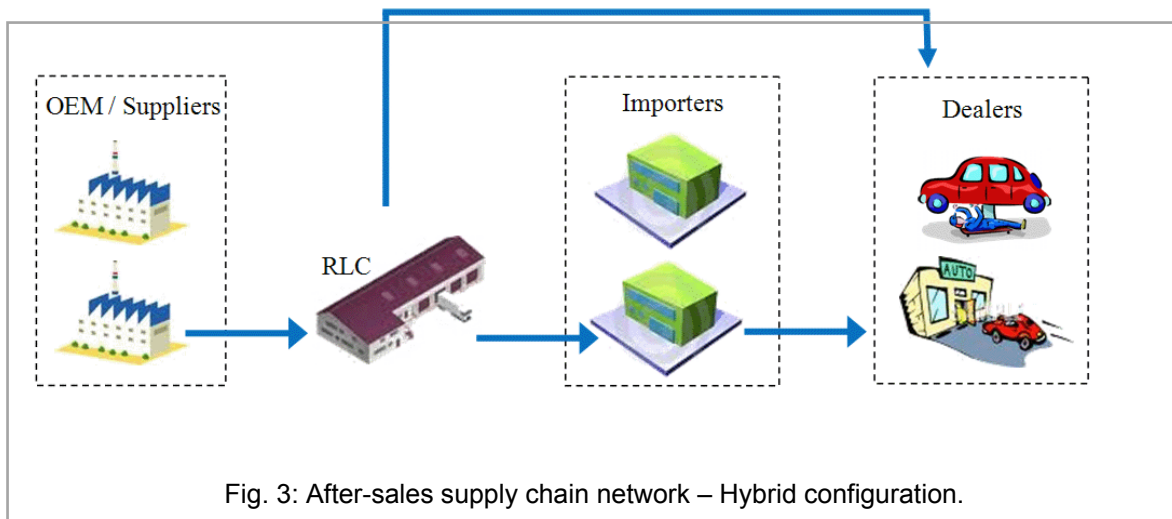
Most companies adopt this configuration. Parts from supplier will be forwarded to RLC first. RLC usually follows the 'break-bulk' strategy; breaking the large shipments received from suppliers/ OEM and then sending the smaller shipments to various warehouses in other countries in the region. Some of these warehouses are owned by the company while others are outsourced to 3PL providers. These country warehouses are also known as importers. Volkswagen acquires all their genuine parts supplies directly from Kassel Parts Center in Germany. Parts are delivered regularly by ocean or airfreight to the warehouse in Singapore and subsequently re-distributed to the importers/ dealers in the region. Orders are placed with suppliers once a week unless serious shortages arise. From Singapore, parts are shipped directly to countries in Asia (e.g. India, Malaysia, and Thailand). Batteries are exception, where they are sent directly to dealers from suppliers because they require special handling.

Hybrid

This configuration combines the 2 networks above and is illustrated in Figure 3. For Mercedes Benz, the RLC seems to follow more of a 'break-bulk' strategy; receiving large shipments from Germany and then re-distributing smaller shipments to other countries. Each country has its

own warehouse, some are outsourced and others are owned by Mercedes Benz. After the parts arrive at the warehouse, they are usually forwarded to a network of privately owned dealers. Mercedes feels that it is easier to have the importer/ country warehouse as an additional part of the supply chain because if the RLC dealt directly with dealers, that it may create too much complexity and twice as much work for customs.

Inventory pooling of parts is possible at the regional distribution center. The region covers a large area and demand tends to balance out over a time. For example, in Japan, snow tires are in demand for certain part of the year while it is summer in Australia. Six months later, the seasons are reversed and snow tires are in demand in Australia. Furthermore, different vehicles have different popularities in different parts of the region. For example, the Mercedes S Class is particularly popular in China, the toughest country in the region to service. In Singapore, in addition to their general consumer market, they also supply army trucks to armed forces in Asia that may be customized. In Australia, where the highest number of Mercedes is sold, consumers tend to prefer lifestyle vehicles (SUV).



4.3 Enablers

Technologically, supply chain applications should be fully integrated with other enterprise systems with the flexibility to adapt to changing conditions. Many of today's systems are

standalone applications that have been rigidly coded to a particular supply chain structure. In addition, most available packaged software is only able to match service logistics companies' requirements up to 80 percent (Patton, 1997). Service parts management system should be able to aid management in executing the following tasks:

- Inventory tracking in the warehouse – how many and what parts are located in the warehouse, knowing where are the parts located on a real time basis
- Monitoring repair operations – which parts are sent to which repair center, when will the repaired parts be delivered back to the warehouse
- Generate reports – to reflect consumption of parts, to display figures reflecting performance indicators

All companies involved in this study utilize application packages such as ERP or SAP in their daily operations of managing the service logistics processes. Some, such as Mercedes Benz, has developed their in-house IT system. Most of these systems are standalone applications hence it does not provide visibility to other players in the after-sales supply chain network. Information such as inventory level needs to be shared with the RLC to aid inventory planning. Realizing this, Embraer, customized its SAP system to provide their 3PL more visibility to some of the relevant information while restricting other confidential information such as pricing.

Since customer expectations are continuously increasing, companies need to measure and monitor their performance of after-sales service (Gaiardelli et al., 2007). Subsequently, they need to compare themselves to other players in the service parts business, make a commitment and strive to improve from their current position.

Service logistics companies often used the following indicators to measure their performance (Patton, 1997):

- First Pass Fill Rate – this measures availability of parts in the stocking location nearest to the customer whenever a part request arise
- Logistics Service Level – percentage of time that a requested part is delivered to a customer location within the promised time period

- Response Time – the amount of time needed for the part to reach a customer location; calculated from the time service center receives a repair request from the customer
- Required Investment – amount of financial investment needed to provide the desired performance level of the above three metrics

In addition, metrics such as waiting time for delivery of parts or technical assistance can be used to gauge how well companies create values for its customers while those such as fill rates or parts obsolescence cost can quantify the way companies use their assets (Cohen et al., 2006).

Embraer measures their service logistics performance based on the following key performance indicator:

- Delivery performance (fill rate, ability to deliver as promised)
- Warehouse performance (inventory turn, obsolescence cost)
- Quality of inspection process
- Time needed to move a part out of the warehouse

In the case of Toyota, their key performance indicators include:

- Stock turn (this figure was recently at 2.27 months to turnover products)
- Logistics cost and profitability
- Number of errors per 10,000 lines picked
- Number of deliveries missed
- Housekeeping performance (zones of the warehouse are checked weekly by a team of 2 to 3 people)
- Worker Performance (including absentees and sickness)

4.4 Processes

Inventory management, order fulfillment, distribution, transportation and reverse logistics are the core supply chain processes for service parts logistics. In order to concentrate on their

core business and tap on 3PL expertise, it is common for companies dealing with service logistics to outsource their warehousing and distribution activities. Moreover, collaborating with 3PL create opportunities for generating synergies, pooling risks and achieving economies of scale. Table 3 summarizes the activities that some companies in this study outsourced to their respective 3PL.

Companies	3PL	Outsourced Activities
Mercedes Benz	Caterpillar Logistics	Outbound logistics – distribution from Singapore RLC to various importers in South East Asia
Volkswagen	Schenker	Entire service parts operations: <ul style="list-style-type: none"> • Warehousing: Storage, picking and packing • Customer service: Procurement, shipping, order processing and invoicing • Outbound logistics: Shipment via air, sea and/or courier from Singapore to various importers and dealers in Asia
Embraer	Menlo	Warehousing activities – storage, quality inspections, certificate issuance and packing

Table 3: Activities outsourced to 3PL.

On the other hand, Toyota believes in self-managing their warehouse. Employing various techniques such as Kaizen¹ and Toyota 7S principles, the company achieved 80 percent utilization of warehouse space which translates to high warehouse efficiency.

The 7S technique provides a guideline on how parts should be stored in the warehouse to allow easy and fast access to required parts whenever demand arises. Grouping similar parts together, storing heavy items on the lower shelves, segregating parts according to their numbers and ensuring that parts are stored within easy reach of workers are among the rules of the 7S technique. In addition, fast moving goods are placed closer to the entrance of the warehouse, while slower moving goods are placed at the rear. Palletized goods are positioned such that they are easily accessible to forklifts.

4.5 People

Service parts management is a people business. All the technology of computers, sophisticated equipment and models cannot accomplish much if good people are not involved. The abilities and motivation of logistic personnel is of vital importance. Hence, a service parts business requires top-notch people with the skills, experience and the right attitude to run the business. Putting the right people in a few key positions can help boost a company's overall performance.

Forecasting, inventory control, repair and warehousing management are among the essential skills required to manage a service parts business. Applying forecasting techniques and selecting the best inventory policy can be a challenge when dealing with service parts. Traditional averaging or smoothing type forecasting methods frequently produce inaccurate results since a relatively high percentage of service parts experience irregular demand. Unreliable forecast creates problems in deciding inventory policy variables such as how much to order and when to place an order, since determination of such variables must be based on some estimates of the future requirement.

¹ Kaizen, a Japanese term, stands for continuous improvement, and is a large part of JIT philosophy pursued at Toyota. A Kaizen Team was set up and has the daily task of relocating items in the warehouse, depending on how fast their turnover is.

The role of technicians has changed over the years. In the past, technicians were thoroughly trained in all aspects of repair and services. They are able to troubleshoot almost any fault on-site. Today, with the increasing importance of fast response time, technicians have become part changers on-site, while the faulty items are brought back to service center for repair. Continuous training and learning to think in new ways will provide more benefit than technological advances when talking about service logistics. Company leaders must motivate employees in service parts business to consider new ways to approach service parts. Improving service parts management will positively influence corporate profits.

According to most of the companies interviewed, recruiting a pool of knowledgeable and skillful employees in the service parts business is not much of a problem. However, employing experienced individuals is a challenge since the service parts business in Singapore is a small one. Companies also highlighted that it is not easy to recruit warehouse employees in Singapore as it is considered as a physically demanding job.

4.6 Infrastructure

Custom duties, tariffs, and government incentives are important consideration in configuring the service logistics network. For example, Singapore free trade zone is a huge incentive for the industry. As of April 2009, Singapore has introduced a GST suspension scheme for qualifying aircraft parts. Under the scheme, approved traders in the aerospace industry are exempted from paying GST when importing certain aircraft parts into Singapore.

Every process has to be in strict compliance with the requirements of national and international authorities (e.g. FAA for USA and EASA for Europe). In addition, existing airports and seaports, road conditions are some of the basic infrastructures that have an impact on the service delivery for service parts logistics. The stable political climate of a country is also important to minimize disruptions.

5. OPPORTUNITIES AND CHALLENGES

With Singapore's reputation for efficiency, ease of business, and network, choosing Singapore as a regional office was an easy choice for companies such as Embraer and Eurocopter. Singapore is ahead of the region in terms of logistics infrastructure. The port of Singapore is linked to over 600 parts in 123 countries and over 200 shipping lines call at the port. It handles the world's largest volume of containers which exceeded 30 million TEU in 2008 (AAPA, 2010). Changi Airport, on the other hand is ranked one of Asia's top ten in air cargo volume in 2008 (ACI, 2009). It has 4000 weekly flights connecting 182 cities in 57 countries. The airport and logistics infrastructure of Singapore is secure and not affected by political issues as in other countries in South East Asia.

Conversely, companies who intend to set up a logistics hub in Singapore need to be aware of the challenges. Among which are the tedious customs process. Each transaction of moving parts in and out of the port requires permits which could cost up to S\$30 per permit. Over time, import and export documentation cost might constitute a significant fraction of companies cost. The process of obtaining safety licenses for import, handling and storage of Dangerous Goods such as oxygen generators, fire extinguishers, explosive cartridges and batteries proved to be a challenge too.

As much as service logistic providers would like all their suppliers and OEM to set up repair capabilities in Singapore, the return on investment is low as the current repair volume in this region is not large enough to justify the cost of establishing a repair center.

Furthermore, aircraft industry is an over-regulated one in terms of safety with a lot of emphasis on training. There is a large gap in talent since the technical employees are either in their 20s or in their 50s. It is difficult to send the experienced employees for off-site visits while it takes a long duration to train the new employees and this is a costly process.

6. RECOMMENDATIONS

The four major issues below are prevalent in handling of spare parts especially in the aerospace industry:

1. Margins are lower, leaving less money to spend on inventory
2. High capital investment is needed to put all parts on the shelf. For example, wheels and brakes can cost US\$ 4M.
3. High cost of test equipments. With a limited number of customers, there are few units coming through the repair shop to justify investing in these equipments.
4. High obsolescence cost.

This has led some companies to move towards “Power by the Hour” concept. Customers are now trying to sell back and lease spare parts in the region. Therefore, the 3PL distribution model needs to be ready for such trend. The companies are moving away from a traditional “Just in Case” model to the current “Just in Time” (JIT) model. This means that the 3PL needs to be flexible to adapt to the JIT model.

3PL can also target the low cost carrier sector which is emerging in this region. Most of these companies are operating on “Power by Hour” concept to reduce cost. Customers and suppliers of mission-critical products, such as commercial aircraft and military weapon systems, are recognizing that the acquisition of world-class products is not sufficient, it is also imperative to provide superior, cost effective maintenance and support services throughout the after-sales phase of the customer-supplier relationship. A major focus of these efforts involves re-designing the contractual and implicit relationships between customers and suppliers in the service support supply chain.

3PL should also consider AS9120 accreditation in order to enter the aircraft industry. The accreditation is only awarded to facilities that comply with the stringent requirements of aerospace companies worldwide, in addition to the enhanced regulatory requirements for aerospace distributors. With the increasing aerospace logistics business in the region (Venkatesh, 2010), demand for aerospace logistics services are expected to grow in the coming years.

3PLs are also expected to provide full call-center based solutions to track aerospace customers' Aircraft -on-Ground (AOG), and regular day-to-day requests in seven languages to support countries in Asia Pacific.

Airlines may need to reorganize their supply chain to improve coordination with their freight forwarders. As airlines tighten their budgets, there will no longer be as many parts on their shelves to support repair activities. They will move to operate based on the JIT concept. Companies will need to determine which set of spare parts are most likely to be required and have the highest transactions to stock in their warehouse.

Technology called Aircraft Communications Addressing and Reporting System (ACARS) will be used for “health monitoring” of aircraft (ARINC, 2010). During flight, the central maintenance computer in the aircraft ensures that the aircraft is working as it should be. If there is any error, a message will be sent to the ground and to the aircraft. This message allows the company to troubleshoot and predict which part may be needed. This is not necessarily accurate but is sufficient to pre-empt various parties to prepare the necessary parts and manpower needed for the repair operations. In adopting such technology, aircraft companies hope to become more proactive and improve their preventive maintenance.

7. CONCLUSIONS

In this study, we have proposed a framework for managing service parts logistics that focuses on a few key components. The most significant component of the proposed framework is to quantify the customer service level for different customer segments, and provide the necessary processes, enablers and supply chain network to meet each service level. The proposed framework is highly dependent on infrastructures provided by each country and their constraints imposed for export and import. Based on the response gathered from the companies interviewed, it is useful to apply this framework when setting up the service part logistics hub in Asia instead of solely focusing on cost factors alone.

REFERENCES

- Aircraft communications addressing and reporting system (2010), available at: http://www.arinc.com/products/voice_data_comm/acars.html.
- Anon, (2008), "Spare-parts service management: Today's challenges and opportunities", Outsourced Logistics, available at: www.logisticstoday.com.
- Cargo Traffic (2008), available at: http://www.aci.aero/cda/aci_common/display/main/aci_content07_c.jsp?zn=aci&cp=1-5-54-4819-8814_666_2__.
- Cohen, M., Kamesam, P.V., Kleindorfer, P., Lee, H. and Tekerian, A. (1990), "Optimizer: IBM's multi-echelon inventory system for managing service logistics", *Interfaces*, Vol. 20 No. 1, pp. 65-82.
- Cohen, M.A., Agrawal, N. and Agrawal, V. (2006), "Winning in the aftermarket", *Harvard Business Review*, available at: www.hbr.org.
- Diks, E.B., Kok, A.G. and Lagodimos, A.G. (1996), "Multi-echelon systems: A service measure perspective", *European Journal of Operational Research*, Vol. 95 No. 2, pp. 241-263.
- Gaiardelli, P., Sacconi, N. and Songini, L. (2007), "Performance measurement of the after-sales service network – Evidence from the automotive industry", *Computers in Industry*, Vol. 58 No. 7, pp. 698-708.
- Hausman, W.H. and Erkip, N.K. (1994), "Multi-echelon vs. single-echelon inventory control policies for low-demand items", *Management Science*, Vol. 40 No. 5, pp. 597-602.
- Huiskonen, J. (2001), "Maintenance spare parts logistics: Special characteristics and strategic choices", *International Journal of Production Economics*, Vol. 71 No. 1-3, pp. 125-133.
- Lee, S. (1984), *Service Parts Management Principles and Practices*, American Production and Inventory Control Society, Houston, Texas.
- Muckstadt, J.A. and Thomas, L.J. (1980), "Are multi-echelon inventory methods worth implementing in systems with low-demand-rate items?", *Management Science*, Vol. 26 No. 5, pp. 483-494.
- Patton, J.D. and Feldman, H.C. (1997), *Service Parts Handbook*, The Solomon Press, New York.
- Joseph Patton, "Service Parts Profits with Best Practices", 2006 International Conference Proceedings, The Educational Society for Resource Management
- Patton, J.D. (2007), "Service Parts Balance", *APICS Magazine*, available at: <http://www.apics.org/Resources/Magazine/Past/>.
- Sacconi, N., Johansson, P. and Perona, M. (2007), "Configuring the after-sales service supply chain: A multiple case study", *International Journal of Production Economics*, Vol. 110 No. 1-2, pp. 52-69.

Service Parts Management – Unlocking Value and Profits in the Service Chain (2003), Aberdeen Group, Boston, Massachusetts.

Sherbrooke, C.C. (1986), “VARI-METRIC: Improved approximations for multi-indenture, multi-echelon availability models”, Operations Research, Vol. 34 No. 2, pp. 311-319.

Silver, E.A., Pyke, D.F. and Peterson, R. (1998), Inventory Management and Production Planning and Scheduling, 3rd edition, Wiley, New York.

Venkatesh, G. (2010), “Aerospace logistics”, Logistics Insight Asia, available at: <http://www.logasiamag.com/article-1874-aerospacelogistics-LogisticsAsia.html>.

World Port Ranking (2008), available at: <http://aapa.files.cms-plus.com/Statistics/WORLD%20PORT%20RANKINGS%2020081.pdf>.

APPENDIX A

List of companies who participated in the study:

Embraer

A Brazilian aircraft company specializing in private jets. It has become one of the largest aircraft manufacturers in the world by focusing on specific market segments with high growth potential such as commercial, defence and executive aviation. Embraer established their support center in Singapore in 2001.

Eurocopter

Eurocopter S.E.A. (ESEA), a subsidiary of EADS (European Aeronautic, Defence and Space Company one of the three largest aerospace groups in the world) was set up in 1977. ESEA is responsible for the sales and customer support activities for the entire range of Eurocopter helicopters for 15 territories in the region.

Mercedes Benz

A German manufacturer of luxury automobiles, buses, coaches and trucks. It is currently a division of the parent company, Daimler AG. The Mercedes-Benz RLC in Singapore is the regional hub for spare parts of car brands under the Mercedes-Benz Group in Asia.

Toyota

Toyota Motor Corporation is a multinational corporation headquartered in Japan. It is the world's largest automobile makers by sales and production. Distribution of spare parts for Toyota vehicles in Singapore is handled by Borneo Motors' Central Depot.

Volkswagen

Volkswagen is one of the major representatives of the German car industry founded in 1937. Its Singapore regional office serves importers and dealers in the Asia Pacific region.



A Collaboration Between



The Logistics Institute – Asia Pacific

National University of Singapore

21 Heng Mui Keng Terrace, #04-01, Singapore 119613

Tel: (65) 6516 4842 · Fax: (65) 6775 3391

Email: tlihead@nus.edu.sg · URL: www.tliap.nus.edu.sg