A Cross-Industry Analysis and Framework of Aftermarket Products and Services

by

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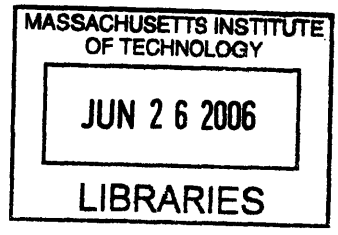
Submitted to the Engineering Systems Division in Partial Fulfillment of the Requirements for the Degree of

Master of Engineering in Logistics

at the

Massachusetts Institute of Technology

June 2006



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Abstract

This thesis looks at how supply chains of Aftermarket Products and Services are structured. The study includes an overall examination of the Aftermarket Function, as well as an overview and examination of Aftermarket Supply Chains in four different industries. The study includes general data about the four industries (Computers, Telecommunications Equipment, Automotive and Aerospace), along with examination of practices that are used in these industries. Finally, the thesis compares and contrasts the practices used in the industries and identifies underlying principles that unifies these otherwise diverse practices.

Thesis Supervisor: Dr. Lawrence Lapide
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Acknowledgements

First of all I would like to thank my advisor, Dr. Larry Lapide, for all his help and useful advice and guiding. His experience has been both helpful and inspiring. I would also like to thank all the Faculty Members, Research Associates and Students involved in the Supply Chain 2020 project for their meaningful criticism and advice.

I would like to specially thank Tim Andreae, Steve Aschkenase, Omar Bakkalbasi, Doug Derrick, Dieter Haesslein and Marc McCluskey that agreed to share with me their opinion and experiences through interviews and emails. Finally I would like to thank my friends and family for supporting me and believing in me throughout my research and studies during the MLOG '06 program.

Dedication

I would like to dedicate this Thesis to Dimitrios Andritsos, Simos Gerasimidis, Dimitrios Iliadelis and to S-P room 533.

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1 Introduction

1.1 Motivation

My motivation to research this particular topic derives from the belief that this topic is challenging from a personal perspective and that the importance of Service Parts Management and Aftermarket Logistics is continuously increasing in the last years. In many occasions, the profit that companies have from service parts equals or even surpasses the profit of all the other divisions of a company. Despite the increasing importance of Aftermarket logistics, the research in this particular area has not been fully developed yet. Furthermore, the research so far focuses in specific companies or industries without comparing and contrasting the practices of these companies or industries.

Understanding the principles that affect the aftermarket across different industries and shape the future of this important part of supply management is a very interesting and challenging target. Combining practices that are considered as "best" in different industries under a unified framework can lead to understanding the principles that shape these practices and to creating strategies for improvement for different companies across a variety of industries.

This project is a part of the Supply Chain 2020 Project which is a multi-year research project of the Center for Transportation and Logistics of the Massachusetts Institute of Technology. The goal of the project is to study pioneer critical success factors and concerns for future supply chains to the year 2020, and identify strategies that companies could use in order to prepare for the year 2020.The duration of the project is three years, and we are currently working

in the 2nd Phase, which includes finishing the Principles Research, developing Supply Chain Models and Macro Factors Scenarios.

The main issue of this thesis project, derived from the main research question, is the study of the supply chain in the aftermarket. The sub-questions that this project is intended to answer are the following:

- What roles do supply chain organizations play in the Aftermarket?
- What supply chain practices are used?
- What are the current practice trends?
- What are 'best' practices? And what are the underlying principles being leveraged?
- What macro factors have shaped the practices in the last 10-15 years? How and why?

1.2 Methodology and Data Collection

The methodology for this thesis is mainly based on studying the function of Aftermarket and Service Parts Logistics and identifying what is considered to be a "best practice" or a "best-in-class" company in the four different industries (Computers, Telecommunications, Automotive, and Aerospace). Since what is thought by each industry or person as "best-practice" can be very subjective, the main goal will be to identify the underlying principles that are common between the companies that are considered to be "best-in-class" or to have "best-practices". Because the research question to be answered is not strictly analytical but includes major conceptual elements, literature review and interviews are the main parts of the methodology and my approach to the questions.

Along with reviewing academic literature and business publications concerning the Aftermarket function, industry professionals that have experience across all the industries in

question provide their expert opinion. Finally, the research includes all the previous findings of the people involved in Phase I of the Supply Chain 2020 project from the previous and the current academic year (through review of previous theses, publications, and meetings).

1.3 Introduction

"The service parts business can be very profitable. Yet few companies even come close to tapping its full potential. For many, the aftermarket business is just an afterthought." (Aschkenase et. al, 2003)

Realizing the potential of the Aftermarket function of a company is still an issue for many companies. However, others have evolved their business in such a way where the Aftermarket is the key differentiator of the whole company. The aftermarket practices of companies such as Dell, Cisco and Saturn, which are typical examples of this evolution, are analyzed in the following chapters.

In order to realize the potential of the Aftermarket function it is necessary to understand how big this function in terms of sales, profits and revenues is. In 1997, $148 Billion were invested in service parts, only in the Fortune 500 companies (Patton, 1997). In 2003, it was estimated that the total spending for service parts was evaluated to exceed $700 Billion, an amount close to 8% of the U.S. Gross Domestic Product. (Poole, 2003)

Although the Service Parts or Aftermarket division of a company can be the most profitable division of the company, many times its importance is underestimated. Deloitte benchmarked the Aftermarket divisions of many of the leading global manufacturing companies, whose combined revenues exceeded $1.5 Trillion. The results showed that the benchmarked

companies on average generated 25% of their revenues from the Aftermarket. In terms of profitability, the same companies generated 46% of their profits from their aftermarket divisions, a percentage 75% higher than the total profitability of the companies. Despite these numbers, two out of three benchmarked companies grow their Aftermarket division in a slower or same rate as their total business. (Koudal, 2006)

	Share of service and parts business in overall sales	
Global industry	Average (percent)	Top 90th Percentile (percent)
Aerospace and defense	47%	More than 50%
Automotive and commercial vehicles	37%	More than 50%
Diversified manufacturing and industrial products	20%	More than 50%
High technology and telecommunications equipment	19%	More than 50%
Life sciences/medical devices	21%	More than 50%
All companies	26%	More than 50%

Table 1: Revenue Impact of Service and Parts Business by Global Industry. Source: Deloitte Research

Similar results are shown in a previous study. AMR research showed that although the Aftermarket divisions of many companies generate up to 25% in terms of revenue and 40-50% of the total annual profits, however the percentage of IT invested in the same division is significantly lower. (Poole, 2003)

Even among the biggest manufacturing companies, one can observe many differences in the way the aftermarket function is structured and operates and in the results it produces. Deloitte Research shows that only 19% of the companies researched had revenues from the aftermarket that exceeded the company's total revenues from other departments. (Koudal, 2006)

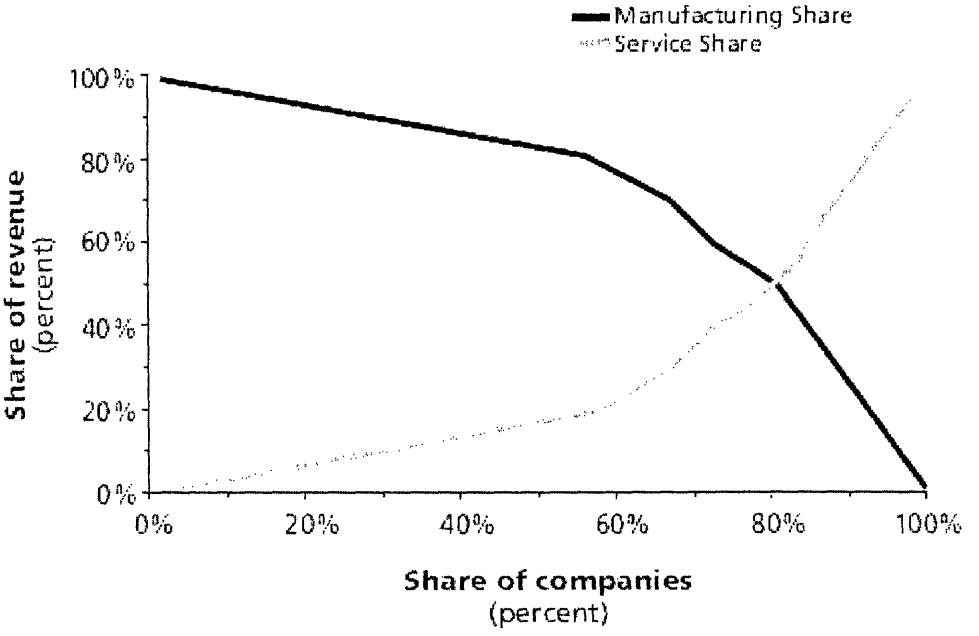


Figure 1: Catching up to the Service Revolution in Global Manufacturing.
Source: Deloitte Research

These substantial differences imply that some companies operate their aftermarket departments with more efficiency than others. These differences are even bigger across industries, where the same practice might be successful in one industry and unsuccessful in another. There are many factors that influence this diverse behavior, and will be examined in the following chapters.

After we define the main characteristics of the Aftermarket and present the methodology and the focus of the research in this first introductory chapter, we continue by reviewing the literature that has been published regarding the Aftermarket and Service Parts Management. This literature review is the basis of the research.

The next four chapters are devoted to each of the industries that this research focuses on, which are the Computers, the Telecommunication Network Equipment, the Automotive and the Aerospace industry respectively. In each industry four areas of the Aftermarket are researched, and "best practices" are identified through specific examples. The final chapter of this thesis is dedicated to comparing and contrasting the observations of the previous chapters, as well as identifying underlying principles among the industries and the best-in-class companies. A framework explaining the behavior of companies is presented.

1.4 Focus

Since this research concerns Aftermarket Products and Services, only industries which manufacture durable products are considered, because only products with a significant lifecycle is reasonable to have a post-sales market.

Four industries with durable products are involved in this research. These four industries were chosen because we believe that they are representative of the different aftermarket supply chains, and also because they are industries with durable products that are part of the focus of the overall Supply Chain 2020 Project. These four industries are the Computer Industry, the Telecommunications Equipment Industry, the Automotive Industry and the Aerospace Industry.

However, due to the limited time available for research and facing the danger of widening the research too much, the focus of the research was specified further more within each industry. Thus, in the Computer Industry our focus was Personal Computers, Laptops and Servers. In the Telecommunications Industry we focused on telecommunications network equipment. In the automotive industry the research focuses only in cars and not in other vehicles like buses or heavy machinery vehicles. Finally, the research in the aerospace industry includes only the Aftermarket Products and Services of Commercial Passenger Airlines and Manufacturers, excluding the Defense Industry.

1.5 Definitions

Before starting the cross-industry analysis of Aftermarket Products and Services it is necessary to define some of the main aspects of this analysis. The necessity for these definitions becomes more important because there are different unofficial definitions of terms that exist in the internet and specifically in non-academic and non-professional organizations that confuse any reader. The major confusion in the terminology is observed between the terms of reverse and aftermarket logistics, which in some cases are used as synonymous, when in fact these two terms although related, have many differences.

By reading the definitions stated below by different official logistics organizations and academic publications we understand that reverse logistics and aftermarket logistics are two terms used for different functions of supply chains. Although reverse logistics are part of aftermarket logistics and vice versa, the two functions are not completely identical. On the other hand, terms as aftermarket logistics, service parts logistics and spare parts logistics can be used as synonymous terms.

The definitions of terms are:

Aftermarket Logistics: Everything the company provides after the sale - spare parts replacement, professional services, help desks, warehousing, product recalls, and field technicians, among others that needs to be managed as an integrated whole. (Reverse Logistics Association, http://www.reverselogisticstrends.com/car-tnt-logistics-busdev.php

After-Sale Service: Services provided to the customer after products have been delivered. This can include repairs, maintenance and/or telephone support. (Vitasek, 2005)

Reverse Logistics– Definition 1: A supply chain that is dedicated to the reverse flow of products and materials for returns, repair, remanufacture, and/or recycling. (http://www.apics.org/ 10th edition.)

Reverse Logistics – Definition 2: A specialized segment of logistics focusing on the movement and management after the sale and after delivery to the customer. Includes product returns for repair and/or credit. (Vitasek, 2005)

Durable goods or products – Definition 1: In economics, a durable good or a hard good is a good which does not quickly wear out, or more specifically, it yields services or utility over time rather than being completely used up when used once. Most goods are therefore durable goods to a certain degree. Perfectly durable goods never wear out. (www.wikipedia.org)

Durable goods or products – Definition 2: A good that can continue to be used over an extended period of time (Deardorff's Glossary of International Economics, 2001)

Spares (Spare Parts): Components or parts, either consumable or repairable, from the associated bill of material used to maintain or repair machinery or equipment (The Chartered Institute of Logistics and Transport –UK)

Service Parts Revenue: The sum of the value of sales made to external customers and the transfer price valuation of sales within the company of repair or replacement parts and supplies, net of all discounts, coupons, allowances, rebates, and/or telephone support (Vitasek, 2005).

After reviewing the above-mentioned as well as other definition we decided to provide a definition of Aftermarket Logistics that will be used for the purposes of this research work. The definition is the following:

"Aftermarket Logistics includes all the services provided by a company after the actual sale of a durable product. This includes the management of services parts as well as other services provided by the seller: Warranty Management, Sale of Accessories and Upgrades, Repairs and Product Recalls, Help Desks, Online and Telephone Assistance, and Field Technicians. All these operations are managed as an integrated business unit".

2 Literature Review

Before starting the analysis of the aftermarket products and services across the four previously mentioned industries, a review of articles and studies published on the subject was necessary. Thus, a review of academic and non-academic publications was conducted. In the academic area, different books and articles covering different areas of the aftermarket were reviewed. In the non-academic publications, the review covered mainly articles in business magazines and white papers and studies from consulting firms.

In order to introduce the researcher to the area of service parts management, the work of Joseph Patton can prove very helpful. The books "Service Parts Management" (Patton, 1984) and "Service Parts Handbook" (Patton and Feldman, 1997) provide the reader with a thorough analysis of the service parts function, covering all aspects of service parts management from introductory definitions to areas such as service parts inventory management, forecasting, procurement, marketing and pricing methods. However, this work can only serve as an introduction to the field because technological advancements and new business methods and realities have made this work somewhat outdated.

The academic publications on the subject mainly focus in the area of inventory management for spare parts, compared to inventory management for regular products.

Caglar, Li and Simchi-Levi (2004) examine a two-echelon service parts inventory system of electronic machines with expensive parts that fail according to a Poisson process. By developing a continuous review, base stock policy almost optimal heuristic for this system the

authors achieve to minimize inventory costs, with the constraint of a specific response time for each depot. This approach depicts the problems faced by a computer mainframe manufacturer.

Furthermore, other approaches have been proposed for managing spare parts inventory in the high-tech industry (Ashayeri, Heuts, Jansen, 1996). Based on a case study of the Olivetti computer company, with repair facilities in two European Union countries, they use a simulation approach to address the problem of service parts inventory management. Their approach distinguishes items in repairable and non- repairable, focuses on a single echelon system and uses a continuous review policy. Their results lead to cost reduction, better service level and a well defined process for decision making.

Candas and Kutanoglou (2006) combine the problem of network design and inventory stocking. Since service has to be delivered in specific short time limits, the location of inventory and the stocking level of each parts in the different locations is critical. The authors propose a model that optimizes this combined problem.

Hammant et. al. (1999) focus in the development of supply chain networks in the automotive aftermarket sector, where they model and simulate the behavior of these networks with the use of a decision support system.

Several benchmarking studies for service parts logistics exist in academic publications. Morris Cohen and Vipul Agrawal , professors at the University of Pennsylvania have published several studies over the last 15 years. Although their focus was the computer industry, several companies from different industries were researched each time. The areas that were benchmarked were the parts distribution networks of companies as well as the control systems that each company used in these networks (IT systems, inventory management policies, communication systems, transportation modes). Specific performance metrics were introduced in

order to benchmark the performance of companies (Cohen, Zheng, Agrawal, 1996). As these benchmark studies evolve we observe changes such as improvement of overall service levels, minimization of response time to service, change of performance metrics to a more customer oriented focus. We also realize that better management of the aftermarket sector can lead to both improved customer service and lower inventory levels (Cohen, Agrawal, 1999). On the other hand, non-academic studies show that in many cases Key Performance Indicators (KPI's) are internally oriented rather than customer facing (Barkawi, 2002).

Besides academic literature on the aftermarket function, several non-academic professional studies and articles have been published, mainly by consulting firms and company divisions that operate in the aftermarket area. These publications tend to look at the aftermarket function from a more strategic and business-oriented point of view than the academic literature, where more specific problems are addressed many times with the use of extensive analysis.

Customer satisfaction is another factor that companies consider as one of the most important aspects when they apply solutions to improve their Service Parts Logistics. According to a study by AMR Research (2005), 95% of the manufacturing companies that are considered "best-in-class" estimate that improved customer satisfaction is one the three main factors that drive them to improve their Aftermarket Service Operations. Satisfactory service levels is one of the main factors that affect customers buy a durable product from the same company again, thus making the aftermarket function a potential differentiation factor for every company that produces durable products.

Companies try to overcome these obstacles and implement solutions in order to achieve greater profit margin from their service divisions and maximize the satisfaction of their customers. These solutions are mainly directed in the areas of implementing software solutions

and redesigning their supply chains. A number of different software solutions that exist are used by companies to improve their service levels. Despite this fact, about 50-60% of the companies use spreadsheets and Enterprise Resource Planning (ERP) solutions only. The AMR Research study analyzes the different services offered by a variety of Service Parts Planning (SPP) software providers. These providers showed a $105 million of revenue in 2004, with a 20% estimated growth for the following year (Ruggles, Suleski, & Samaraweera, June 2005). However, according to AMR Research (October 2005) the need for differentiation is forcing companies to invest in Service Parts Planning (SPP) applications. Some other reasons for this investment are the growth of slow-moving parts in the aftermarket because of increased product proliferation, and the pooling strategies that some companies use for their service parts management, along with increased customer needs.

Turning the service parts division of a company to a profit-generating machine has a lot of difficulties, which are mainly related with the lack of communication and underestimation of the potential of this operation. According to a study by Aberdeen Group, for 72% of all companies, difficulty in communication between the various departments (sales, marketing, service, and manufacturing) is the main reason of failure. The importance of people in the success of the aftermarket division and the necessity of investment in human capital in also stressed (Vigoroso, 2005).

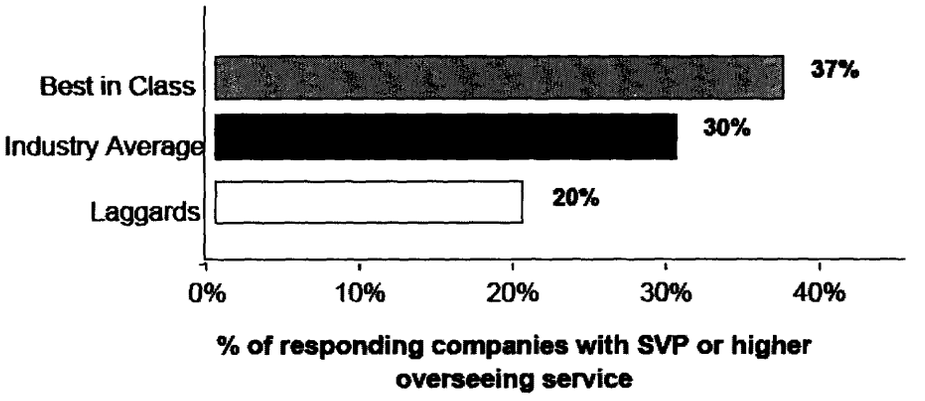
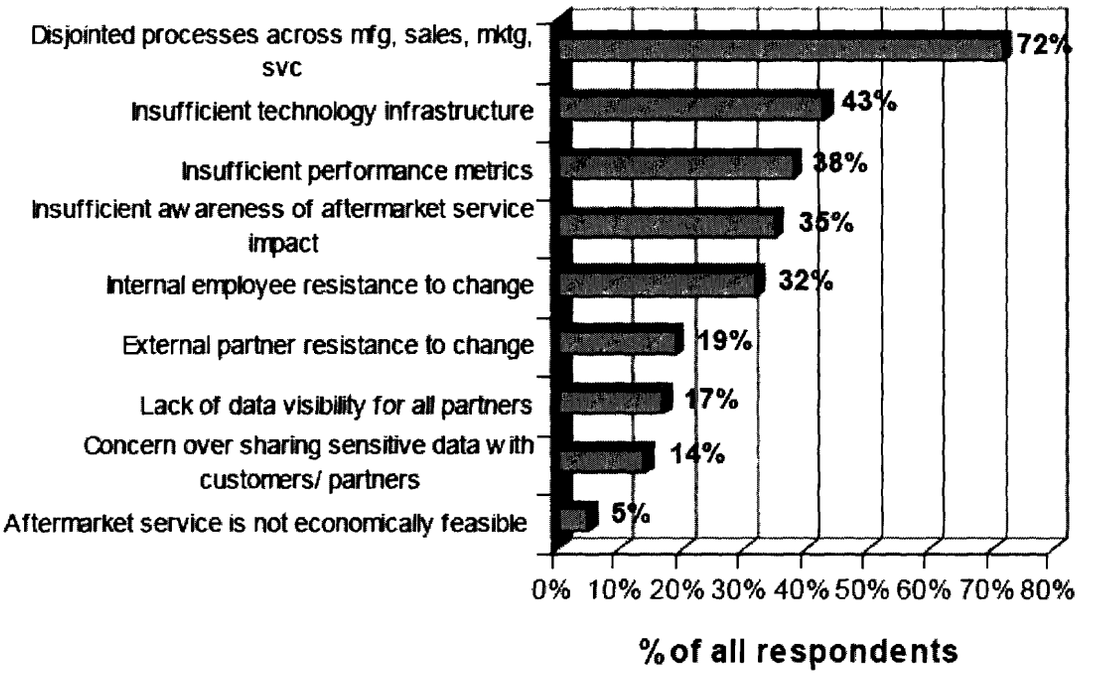


Figure 2: Companies with Senior VPs or higher overseeing Service. Source: Aberdeen Group, 2005



Source: Aberdeen*Group*, September 2005

Figure 3: Obstacles to Service Operations Profitability

Aschkenase et al. (2005) also stress out some of the previously mentioned strategies for improvement of the aftermarket division of a company, such as sophisticated inventory management, investment in human capital and use of specialized I.T. systems. Further, the

necessity of accurate transaction and product data to reduce mistakes in calculations is pointed out (proposing 95% and 98% accuracy levels respectively).

Bundschuh and Dezvane (2003) mention the fact that companies lose serious proportions of their profitability because of inaccurate pricing and poor design of service plans. An example of this problem is a building-equipment manufacturer, whose 11% of service contracts did not cover their marginal costs. Segmentation of customers according to the level of service they require and different pricing policies for different segments is the solution proposed.

Because service management is a difficult and complex problem, Cohen (2005) divides the decision making process into three periods: The budget planning period, the strategy planning period and the tactics planning period. In each of these distinct periods the decision maker faces different managerial tradeoffs and focuses on different objectives. The tradeoffs mentioned are between revenues, costs and service. A efficient frontier curve is introduced to show the relationship between levels of promised performance and investment in service.

MCA Solutions, a consulting firm specializing in service parts management and the aftermarket sector, in a white paper titled the "Top Ten Things Your CEO Should Know About Service" (MCA Solutions, 2005), connects service and spare parts management to product design and product innovation. Innovative companies involve their service personnel in the development of new products, in order to achieve top quality and efficient failure forecasting. Also, close collaboration exists between service engineers and product developers, using statistical failure data to improve product quality.

A final aspect of aftermarket logistics mentioned in the literature is warranty management. According to an Accenture white Paper *"Few companies today pay enough attention to their warranty management capabilities. The entire area of service management is*

mostly an afterthought and warranty management only an afterthought of an afterthought" (Sprague, 2005). Even though warranty claims account for $24 Billion annually, most companies do not pay attention to their warranty management processes. Some potential benefits for companies might be improved profitability and revenues through increased warranty sales, improvement in quality, increased customer satisfaction and loyalty and a decrease in warranty claims expenses by 25%.

3 The Computer Industry

3.1 Industry Overview

The Computer industry was revolutionized as an industry in the late 1970's – early 1980's with the introduction of the first personal computers into the world market. Until then, the computer market was dominated by IBM, which produced huge computers which were used only in big companies and other organizations in the government and educational sectors as computer mainframes. The introduction of the personal computer revolutionized the market, creating tremendous opportunities for companies that would operate in the field (Graham-Hackett, 2005). From that era of the first personal computers to today the computer hardware industry has transformed to a $228 billion market (2003), with many competitors and different smaller markets (Roy, 2005).

Standard and Poor's divides the computer hardware industry into three categories with different characteristics: The personal computers segment, which includes laptop and desktop computers, the server segment, which resemble PCs and are used in corporations and big organizations for large computations, and the workstation segment which "essentially, are high-end PCs with advanced graphics capabilities that are designed to handle data-intensive scientific and engineering applications". Personal Computers dominate the hardware industry, comprising

about 91% of the market's global revenues[1]. The server sector is divided into different subcategories, with different competitors in each category (See Appendix A).

For the purpose of this research we are going to use the above-mentioned description of the market in order to define the computer industry. Specifically, we are researching supply chain practices in the aftermarket sector of Personal Computers, Servers and Workstations. The main players in this industry are the Original Equipment Manufacturers (OEMs) of these systems, as well as companies that distribute and sell these products or provide service parts or aftermarket services. In order to examine the procurement of service parts, we are going to also include components and spare parts manufacturers.

The most important players in this market are the OEMs, which are companies that manufacture and assemble computers, servers and workstations. These companies usually outsource many of the components of the computers and use the same processors and other parts (for example Intel provides 90% of the microprocessors used in personal computers) for their systems. Sometimes the OEMs only assemble the computer using totally outsourced components. For example, companies like IBM, Gateway, Apple Computers, Sony Corp., Fujitsu Ltd. have used manufacturing companies to produce full lines of their products, and have introduced the concept of Electronic Manufacturing Services (EMS) companies (Graham-Hackett, 2005).

The major competitors in the PC sector are Dell, Hewlett-Packard and IBM-Lenovo, a company recently created by the acquisition of IBM PC division by the Chinese owned Lenovo in May 2005.These companies are often mentioned as tier-1 vendors. Other companies with

[1] Standard and Poor's Industry Surveys: Computers Hardware. www.standardandpoors.com

smaller market shares follow, which are classified as tier-2 vendors (see Figure 4). A large segment of the market is occupied by systems that are either assembled by the customers of small assemblers and retailers, and this section is called "white box" market. "White box" computers tend to have lower prices, but also fewer customizations and lower level of aftermarket support by the seller[2].

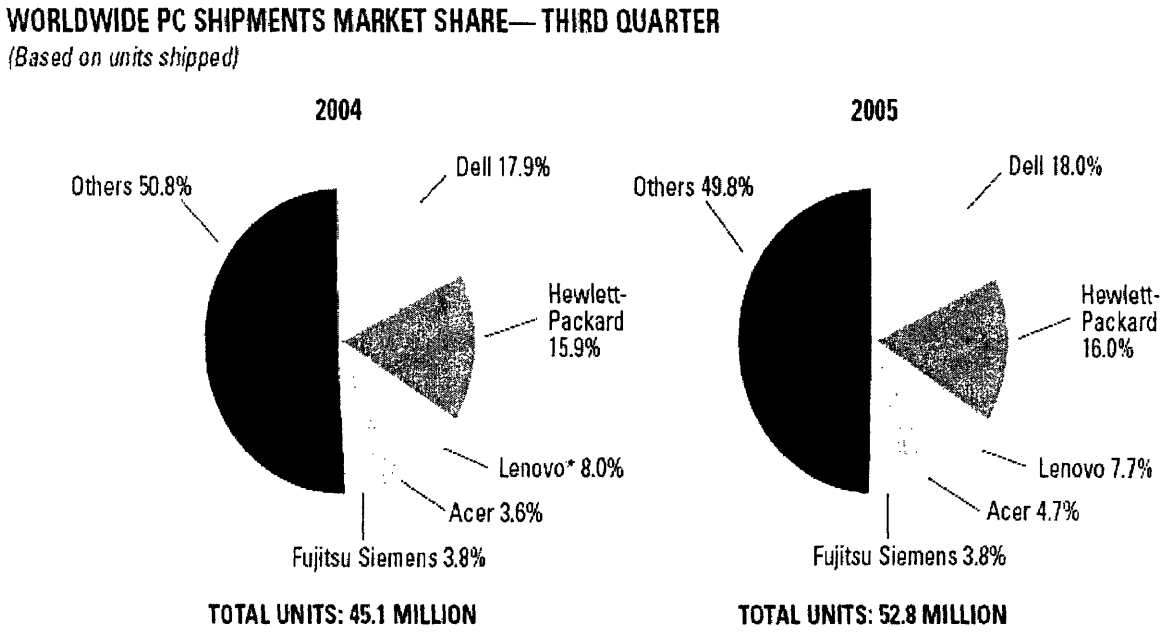


Figure 4: Global PC Market Shares Source: IDC and Standard and Poor's

In terms of growth, the PC market is showing more than 10% growth from 2003 until 2005, after the impacts of the crisis caused by economic recession and the "Internet bubble" in the year 2001 (see Figure 5). The top three vendors are showing very good growth, but Acer is growing faster than anyone else (see Figure 6).

[2] Standard and Poor's Industry Surveys: Computers Hardware. www.standardandpoors.com

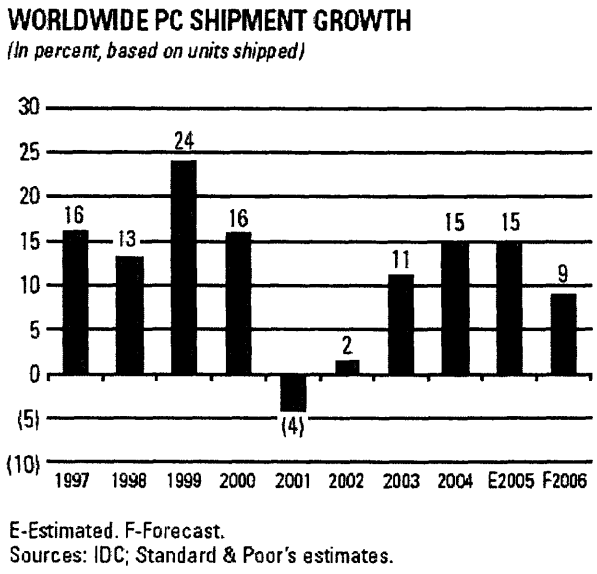


Figure 5: PC growth rates since 1997 Source: IDC & Standard and Poor's

This growth is mainly driven by the demand for portable computers (growth 39% in Europe) and systems for small and medium businesses. Also the growth rates in the market of Asia are driving the global growth of the market. Sales in Asia are expected to surpass US sales in the following years[3].

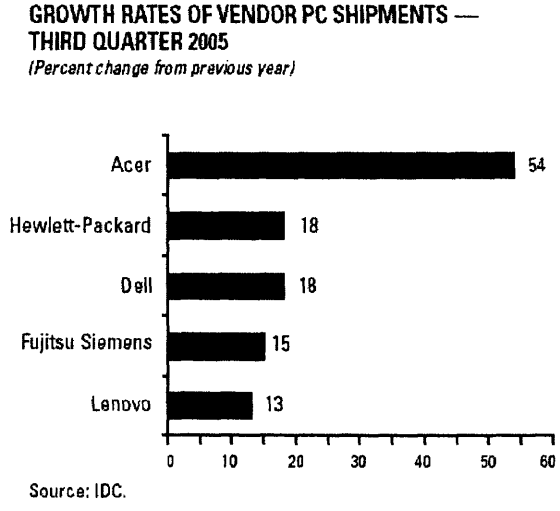


Figure 6: Company Growth Rates in the PC Sector. Source: IDC & Standard and Poor's

[3] Standard and Poor's Industry Surveys: Computers Hardware. www.standardandpoors.com

In the server sector, IBM dominates the market. The market is steadily growing in the last years, although it has faced serious drawbacks in 2000 and 2001.In the second quarter of 2005, the server sector grew 5.6% to $12.2 Billion. The second biggest competitor in the field is Hewlett Packard, with Sun Microsystems and Dell following. The server sector is not dominated by the existence of "white box" unbranded systems as the PCs. In terms of server sizes and sales, the volume server sector is gaining against the midrange and high-end sectors.

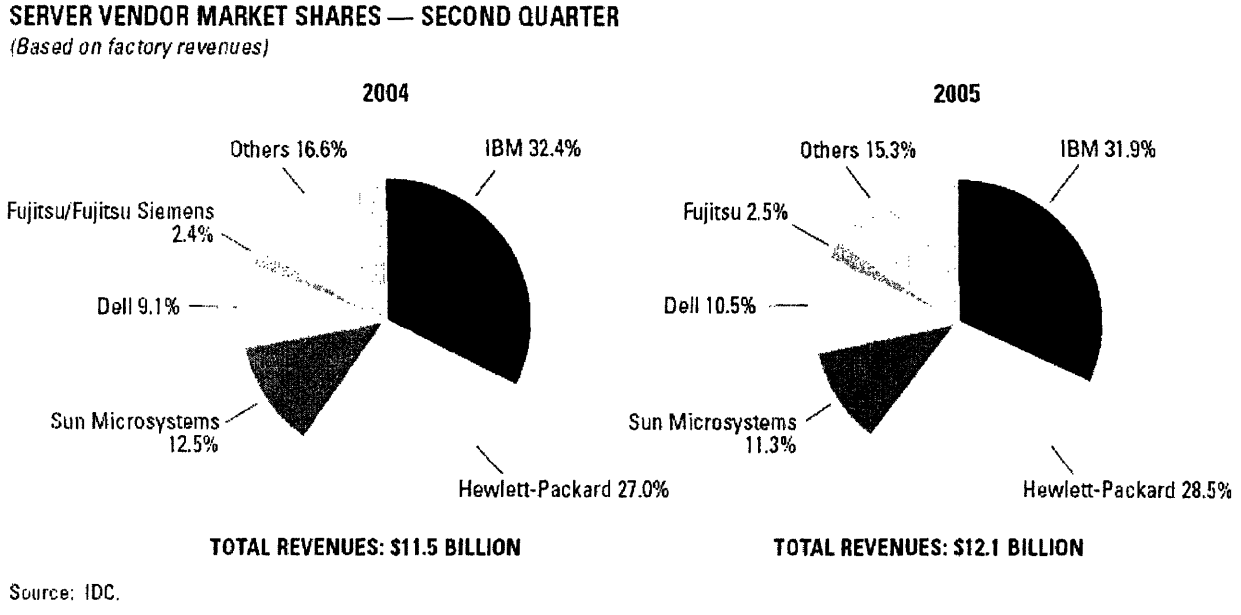


Figure 7: Server Companies Market Shares. Source: Standard & Poor's and IDC

Some of the major factors that affect the whole computer industry and specifically the aftermarket are technological advancements, extensive pricing competition, market consolidation and extensive outsourcing. First of all, the technological advancement of this industry is probably the most impressive in the whole global economy. Computing capabilities are rising, cost is deteriorating rapidly, and computers become much more powerful and smaller in size. This phenomenon has reduced the product lifecycle especially for PCs even to a period of a few months. This rapid development of new technologies and high supply for PCs has made sellers reduce prices significantly (see Figure 8). Also, another market trend is consolidation of

companies in order to withstand the competitive pressures. Thus, in 1992 the top ten companies globally had about half of the market in market share, a percentage which has been reallocated to the top five players in 2002. Some forecasts predict that in the near future the top five sellers will control 70% of the global market. As it is mentioned in a Standard & Poor's Survey, "only the fittest PC producers have survived"[4].

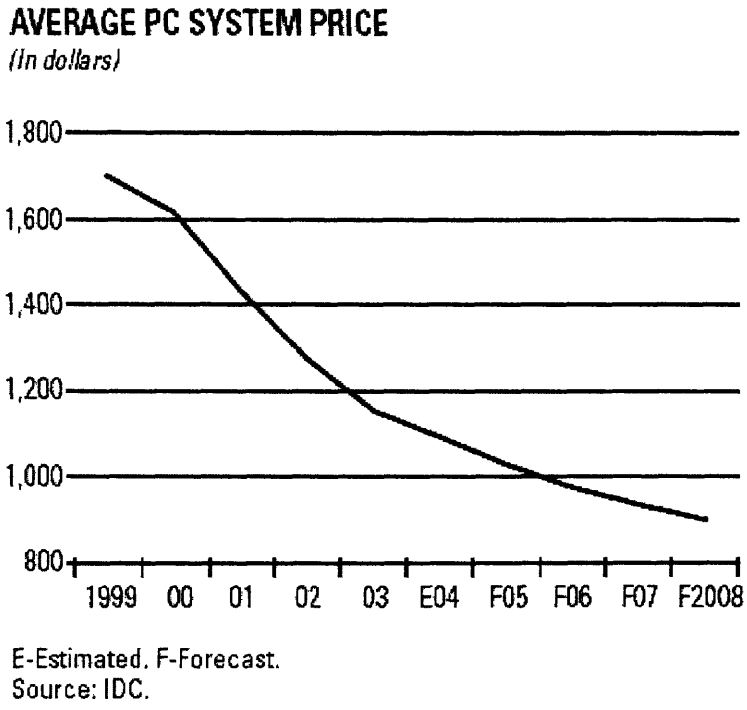


Figure 8: Average PC Price over the years. Source: Standard & Poor's and IDC

In the following pages the aftermarket sector of the computer industry is analyzed, and specifically four different functions of the aftermarket. Through examples and case studies best practices in procurement of service parts, structure of aftermarket supply chains, spare parts inventory and aftermarket customer service are analyzed. Previous work in the SC2020 project and personal interviews with industry experts are the main source of information.

[4] Standard and Poor's Industry Surveys: Computers Hardware. www.standardandpoors.com

3.2 Supply Chain Network Structure

3.2.1 General observations and examples

Different factors affect the structure of the aftermarket supply chain network in the computer industry. One of the main factors is the size of the company. Thus, bigger companies tend to have a 3-tier network, while smaller companies with fewer products or specific customers have a network with only one distribution center (Cohen and Agrawal, 1999).

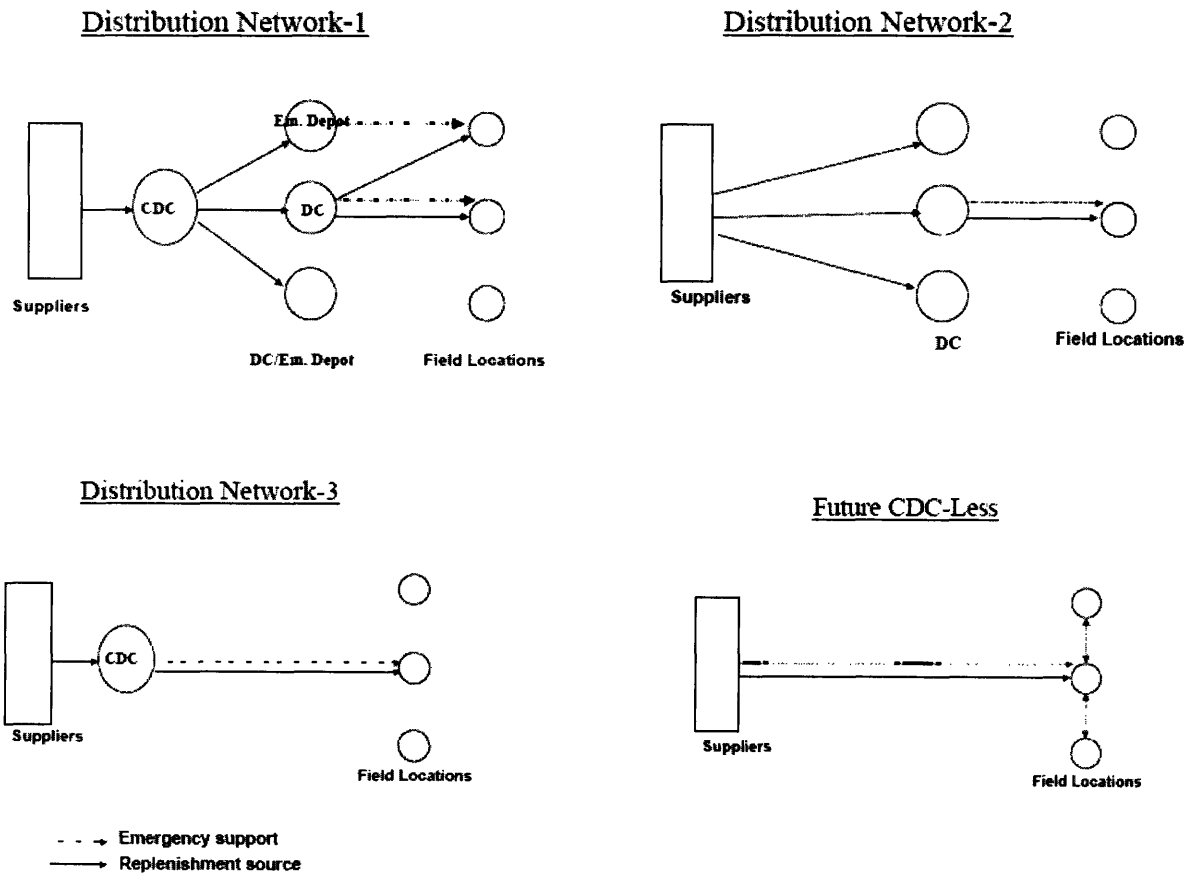


Figure 9: Alternate Distribution Network Designs in the Computer Aftermarket. Source: Cohen & Agrawal, 1999

Other important factors in a company's decision when designing its network for service are the density of customers and the criticality of the product served. Most PC manufacturers maintain a central DC and many inventory field locations. For example, Hewlett Packard has over 400 field locations in the U.S. while Sony Vaio, has only one central distribution center in the same region from where it dispatches parts to distributors and outsources repair to third party providers outside the distribution center. In the semiconductor industry where the customers are the OEMs and therefore they are located in few specific locations globally, the location of inventory is more centralized (Industry Expert, Interview, 2006) Toshiba is using an infrastructure of few repair malls, where all the components' manufacturers are located, in order to provide better service to its customers (Industry Expert, Interview, 2006). In 2004 IBM decided to change its aftermarket division's structure. Instead of segmenting by regional area, they segmented their divisions by business process. The result was one service provider in Europe for handling the logistics of all spare parts, instead of different service providers in each European country that the company operated in (Roy, 2005).

In the server and workstations sectors, inventory is located closer to the customer and therefore, more locations with inventory are created. This happens because on-site repair is usually necessary, and because of the increased criticality of the servers compared to personal computers (Industry Expert, Interview, 2006). In general, we can conclude that parts for personal computers tend to be more centralized, while servers and workstations tend to be more locally located (Cohen, Agrawal, 1999)

An emerging trend in the whole computer industry over the last decade is the increasing use of Third Party providers (3PLs) for different tasks of the aftermarket function (Cohen, Agrawal, 1999). Besides parts manufacturing, specialized 3PL companies are used in all

aftermarket tasks, creating a mixed system of 3PL and OEM owned facilities and services (Interviews with Industry Experts, 2006)

3.2.2 Dell's Aftermarket Structure

In all the duration of the research for this thesis, Dell was mentioned several times by different sources (academic publications, business magazines, interviews) as an example of company with a supreme supply chain network. This is the reason that a subchapter is devoted to the analysis of Dell's Aftermarket structure, as a case study.

Dell has stationed its main aftermarket operations depot for the U.S. in Memphis, TN. Dell is offering a variety of three types of aftermarket services to its customers (Roy, 2005). These are[5]:

a. ***Return to depot Operations <10% of the cases:*** Any customer can return any part back to the company within the warranty period. The servicing is done in the central depot in Memphis. The supplier or a partner 3PL repairs the component. But Dell oversees the operation to guarantee on-time delivery and repair.
b. ***Next Business Day onsite repair =90% of the cases***: Customers of this category receive service by the next business day. The company achieves a 99% fill rate in this service. To do so, Dell is forcing its suppliers to maintain service parts in the Supplier Logistics Center (SLC) which is located close to its shipping center. The supplier also operates the repair center. Dell's fulfillment center has 5 days of inventory whereas the Supplier Logistics Center holds 30 days of inventory.

[5] For more details, see appendix B

c. **Four hour rapid repair (remaining):** This operation serves the company's business customers. All eligible customers are served within a four hour timeframe. One hundred locations operate all over the U.S. with inventory to help this operation. Dell is using several factor (sales records, contracts, failure rates, criticality) to stock parts in these locations (Roy , 2005)

3.3 Service Parts Procurement

Procurement of service parts in the computers' industry has some distinct characteristics, which are related to the characteristic of the product. The spare parts for the computers, as all components of the product, are usually outsourced to third party manufacturers. Since there are only a few manufacturers (OEMs) and many third party companies that serve multiple OEMs many times parts are interchangeable (Industry Expert, Interview, 2005).

The short lifecycle of the products of this industry had both positive and negative impact on the complexity of service parts procurement. Poole (2003) categorizes computers as short lived assets, with up to two years of life. According to Dennis and Kambil (2003), *"Computer manufacturers introduce a new generation of products every four months. The resulting problems, supporting multiple generations, tracking part types, and ensuring parts and service availability to different regions are considerable"*. Obsolescence of unnecessary parts is the largest cost component, especially for personal computers (Cohen and Agrawal, 1999). To minimize these costs, companies like Dell force their supplier to carry spare parts inventory for them.

3.4 Inventory Management

The management of levels of inventory in each service location is one of the most important aspects for every company that wishes to maintain successful aftermarket operations. In all the industries in this research, inventory management is affected by three important factors: The size of the network, the range of the price of components and the product lifecycle. The major tradeoff for the OEMs is between customer expectations and cost (Industry Expert, Interview, 2006).

Inventory is handled differently in the personal computers and the servers and workstations sectors. In the Server and workstation sectors, there is a tendency for the OEMs to have agreements with their suppliers (Industry Expert, Interview ,2006) and with their customer's (Industry Expert, Interview, 2006), called Service Level Agreements (SLAs). With these agreements the supplier or the OEM agrees to provide a certain service level and to have a certain percentage of parts availability, otherwise it pays some form of penalty to its customers. For example, Intel has certain SLAs with its semiconductors suppliers where if the supplier does not have the parts available, it pays to Intel penalties up to $50,000 per minute (Industry Expert, Interview, 2006).

The distinction between slow moving and fast moving service parts exists in the computer industry. However, because the price for slow moving parts is not that high and because the lifecycle of computers is relatively short, the distinction is not as important as in other industries when a company is forecasting demand of these parts.

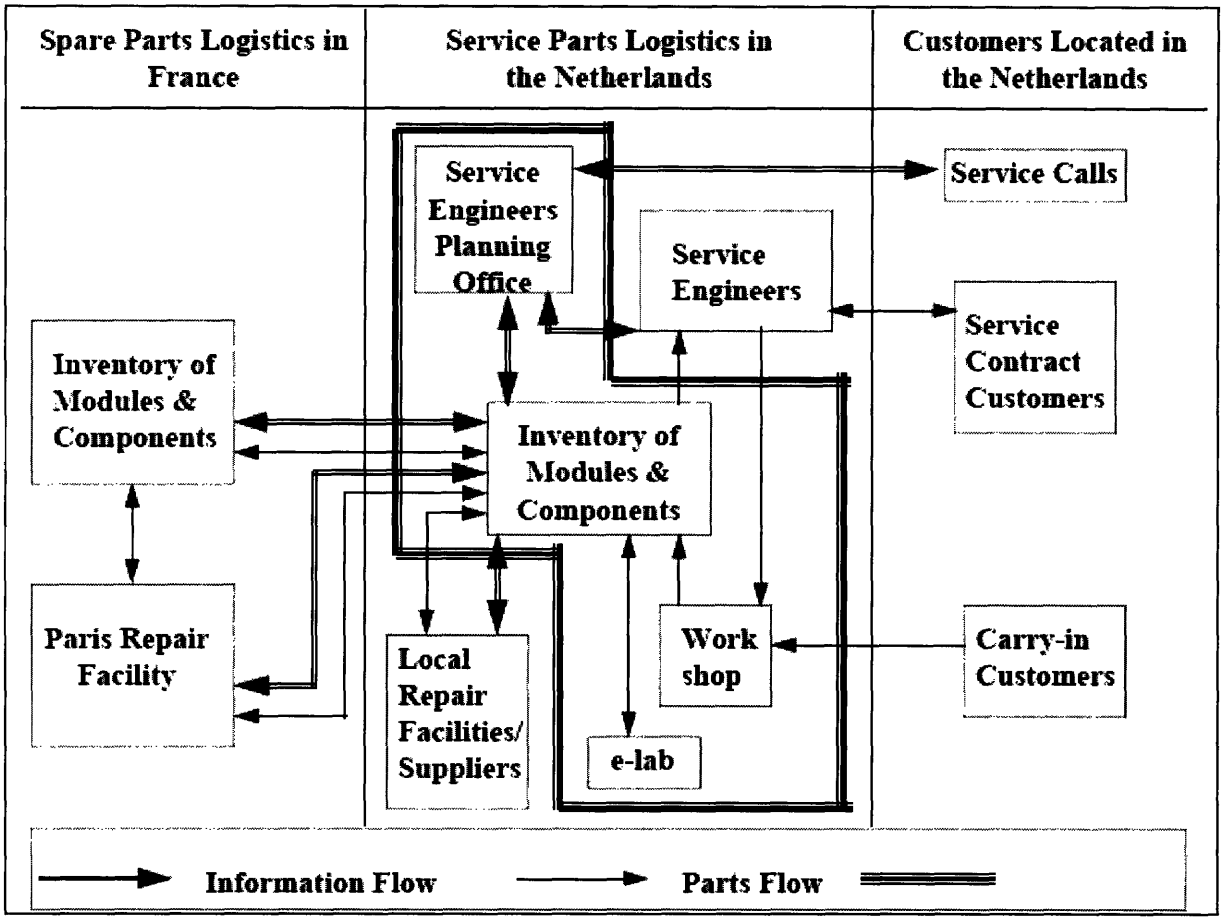


Figure 10: The logistics flow of service parts inventory. The 2-tier supply chain network of Olivetti in Europe. Source: Ashayeri et al.

Levels of inventory for spare parts are usually calculated with the use of complicated forecasting software. There are many different software solutions in the market, usually offered to companies as a package covering all needs of aftermarket operations. Companies like SAP offer software solutions to their customers especially customized for different players of the computers industry (OEM, EMS, Semiconductor Manufacturers, and Software Providers) and different sizes of operations (midsized or large enterprises)[6].

[6] www.sap.com

Most companies have been using known forecasting techniques for their inventory management. In 1999, in a benchmark analysis of the computer industry, Cohen et al state that "Almost all the companies use the ABC method for parts classification, min-max stock level controls and some type of forecasting method. EOQ is also used extensively".

The trend in inventory planning software is driving companies from optimizing inventory levels for parts in a specific location or mode to global and multimode optimization inventory software (Industry Expert, Interview, 2006) According to a study by AMR Research (June 2005) "high tech is also in the lead in consolidating service networks to create global planning environments by integrating to multiple Enterprise Resource Planning (ERP) Systems". The same authors (October 2005) give an example of an OEM that succeeded in reducing its service parts inventory level by $75 million by switching to a multi-echelon optimization model and by pooling its slow-moving parts in centralized locations. In the same study, multi-echelon optimization, pooling of inventory and multi-indentured optimization are identified as areas that companies have the opportunity to improve in the future.

3.5 Customer Service

In service parts management there are two distinct situations in terms of customer service. In the first scenario, the company (or a third party partner) services the product which the company sells, while in the second scenario, the company services a product that it owns. In the computer industry where the end customer is the consumer (either a person or a company) the company services a product that it sells (Industry Expert, Interview, 2006).

The expectation of the customer, especially in the servers and workstations sectors, is to have the machine up and running again in the minimum possible time. The response time that the

customer is willing to wait is decreasing as times goes by. Of course, there is a service level – cost tradeoff. (Industry Expert, Interview, 2006) Companies price their servicing in different ways to satisfy different customers. Dell's three-level service structure is a typical example (see Appendix B). Cohen and Agrawal categorize service packages in the almost the same way: Same day on site service, Next Day and 3-5 days service (1999).

In the server and workstation sector, immediate response (6 hours or less) is becoming more and more prevalent. In the personal computers sector, although response time usually is longer, a 24 hour response time is becoming the minimum for acceptable service (Cohen, Agrawal, 1999). In the personal computers sector the servicing of the product can be done in a repair shop and is not on site. Some companies in this sector provide their customers with loaners (computers they use while the servicing is done) or immediately replace the malfunctioning machine with a new one (Industry Expert, Interview, 2006). Usually this practice happens as a consequence of a warranty that the company provides to the customer. An example of a service repair cycle is depicted in Figure 11.

Many times in the case of personal computers the servicing is done in a retail shop, by the retailer's servicing department and not by the Original Equipment Manufacturer or the parts manufacturer (Industry Expert, Interview, 2006). This practice is especially used by big retailers (for example, BestBuy) who sell their own warranty plans as extensions or enhancements of the OEM's warranty plan and take the responsibility to service the product for a specific period in exchange for a fee. The service by the retailers openly competes with the OEMs by offering a wide variety of services (on site service, 24 hour – 7 days a week service, and others)[7].

[7] BestBuy's support Services, http://geeksquad.com

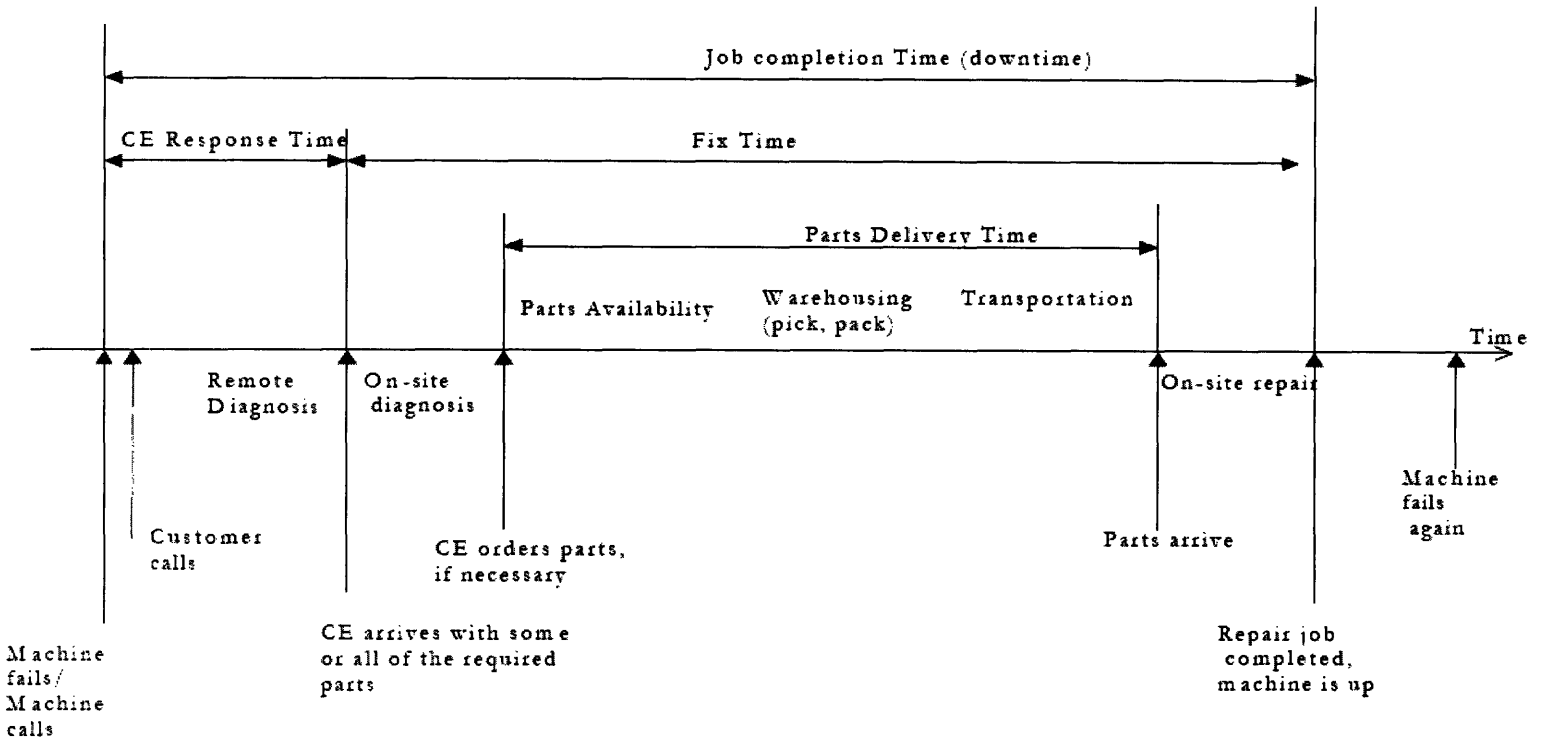


Figure 11: Field Service Repair Cycle. Source: Cohen and Agrawal, 1999

4 The Telecommunications Equipment Industry

4.1 Industry Overview

Defining the Telecommunications Equipment industry is a complex task by itself. In particular, deciding which parts of the industry to include and which to exclude is difficult. For this research, the main factor for this division has been whether each sector of the industry can support aftermarket services or not, and especially if the services that the companies provide include service parts management.

Standard and Poor's includes in the telecommunications industry all companies that offer services or sell products in the following areas: Broadband access, Optical, Private Branch Exchange, Routing, Switching, Wireless Handsets and Wireless Infrastructure[8]. According to Hoover's online database, our research for this industry includes Telecommunications Equipment, both wireless and wireline, as well as computer networking equipment, mainly switches and routers[9].

In general, we can see even from the start of the research, a close connection between the telecommunications and computers industries, a connection that we will identify also in the aftermarket sectors of these industries.

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[8] Standard and Poor's. Industry Surveys: Communications Equipment, 02/02/2006. www.standardandpoors.com
[9] Hoover's Online Database. Hoover's Industries. http://premium.hoovers.com/subscribe/ind/dir.xhtml

For this thesis, our main interest for research lies in companies that operate in routing, switching and telecommunications infrastructure. The industry overall is showing growth in the last years, after a serious fall in 2000 and 2001. The whole hardware industry for communications and data networking equipment is estimated by Standard and Poor's to be around $300 billion in revenues. This sector is dominated by companies that manufacture the equipment and that are located in various regions globally, Some of these companies which compete and operate in different market segments are: The French-based Alcatel, the Japanese Fujitsu and NEC, the U.S.-based Cisco, Motorola and Lucent, the Canadian Nortel, and finally the Europeans Nokia and Ericsson. These companies operate around the world, manufacturing a variety of products and have relationships with major telecommunications companies and governments around the world[10] .

SELECT VENDOR OPERATIONS

VENDOR	BROADBAND ACCESS	OPTICAL	PRIVATE BRANCH EXCHANGE	ROUTING	SWITCHING	WIRELESS HANDSETS	WIRELESS INFRASTRUCTURE
3Com			○		●		○
Alcatel	●	●	●	○	○	○	○
Avaya			●		○		○
Cisco	●	○	○	●	●		○
Ericsson						○	●
Huawei	○	○			○	○	
Juniper				●			
Lucent	○	●			○		
Motorola	○					●	●
NEC	○	○	○			○	○
Nokia						●	●
Nortel		●	●	●	●		○
Siemens	●	○				●	○

All vendors indicated with ○ or ● are participants in that industry. ●Denotes top three vendors in each industry area, based on 2004 market share data.

Table 2: Major Companies competing in different market segments in the Telecom industry. Source: Standard and Poor's, Company Reports, 2006

[10] Standard and Poor's. Industry Surveys: Communications Equipment, 02/02/2006. www.standardandpoors.com

The customers of the industry and especially the industry segments this research is interested in are mainly major enterprises and organizations with large networks and global operations. In the enterprise sector, we witness an increasing interest and investments in telecommunications equipment in the last years. The Telecommunications Industry Association expects the enterprise segment to be $122 billion in 2007. This gradual increase is mainly attributed to a network upgrade cycle which is happening in the last years. These cycles occur within the market in order for the enterprises to adapt to the emerging new technologies and to have up-to-date networks. The last cycle took place in the late 1990's because of the fear that computers and networks would not handle dates correctly after the year 2000 (Y2K problem). Since switches and routers have a lifecycle of four years on average and become obsolete and other similar components have a lifecycle of up to 10 years, the necessity for another upgrade cycle is obvious[11].

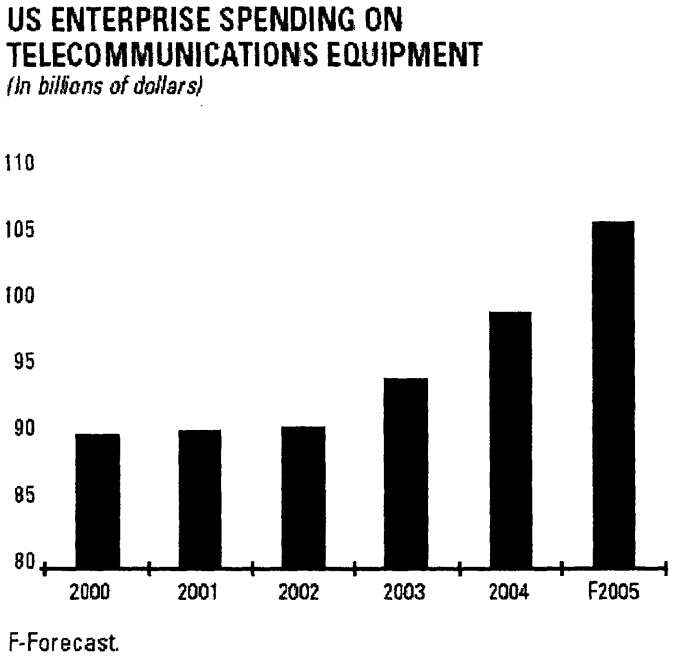

Figure 12: U.S. Enterprise spending on telecommunications equipment. Source: Standard and Poor's, TIA Online

[11] Standard and Poor's. Industry Surveys: Communications Equipment, 02/02/2006. www.standardandpoors.com

In the switching and routing sectors, Cisco is the company that dominates the market. Hoover's Online Database mentions that "The ruler of routers, the sultan of switches, Cisco Systems continues to dominate the market for equipment used to link networks and power the Internet". Although the company's customers are mainly enterprises, Cisco has products also for small businesses and consumers. To compete in an environment of increasing competition, Cisco has used more than 100 (see Appendix C) acquisitions (1993-2006) to enhance its products lines and specialize in the services it provides. Some major competitors in the switching and router sub-sectors are Extreme Networks, Juniper Networks and Nortel. Other competitors in the wider telecommunications industry are Alcatel and Motorola. The switchers and routers sector of the company account for 65% of its annual sales[12]. The Routers sector is divided into 7 different categories (Layer 1-7 switches) and the Switches sector is divided into (low-end, mid-range, high-end, multi-service wide area network switches, and broadband aggregation equipment), with the company facing different competitors in each segment (Standard and Poor's, 2006).

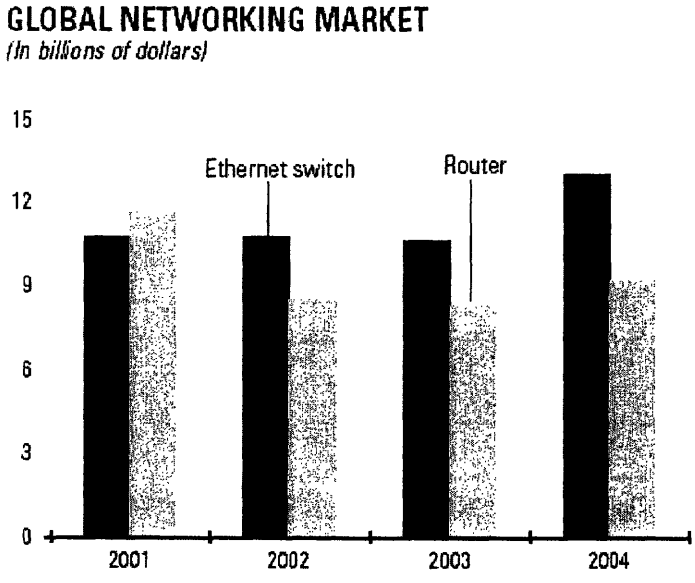

Figure 13: Global networking market. Source: Standard and Poor's, Dell'Oro Group, 2006

[12] Hoover's Online Database. Custom Report Builder. Cisco Systems, Inc. http://premium.hoovers.com/

In the wireline equipment segment Lucent is one the main competitors. Specializing in communications network infrastructure, Lucent offers a wide variety of products to its companies, with the help of its Bell Laboratories research and development unit. The company suffered a lot in the crisis of 2000 and 2001, and had to undergo a five year restructuring plan to survive. This affected all of the company's business units, including its aftermarket sector. One of the biggest companies in the industry, Alcatel, agreed to buy Lucent for $13.4 billion in April 2006[13].

The major trend in this industry, driven mainly by competition, is that all main competitors start to offer to their customers complete bundles of products, including voice, video and data services. According to a survey by Standard and Poor's "bundled service has become a critical success factor". Globally the communications infrastructure is becoming a series of interconnected networks supporting all the above mentioned capabilities. This phenomenon is becoming both a challenge and an opportunity for major companies. Companies that were not traditionally competing directly now start offering similar hybrid products, and the industry is experiencing a transformation phase. Some of the areas of this competition in the future will be Internet Telephony (Voice Over IP Protocol – VoIP), fiber-optic service for homes (FTTP), and Internet Protocol Television (IPTV)[14].

4.2 Supply Chain Network Structure

The structure of the aftermarket supply chain networks in this industry has many similarities to the structure of the previously analyzed computer aftermarket supply chain. The major characteristics of this supply chain depend on the type and complexity of each product, the

[13] Hoover's Online Database. Custom Report Builder. Lucent Technologies, Inc. http://premium.hoovers.com/
[14] Standard and Poor's. Industry Surveys: Communications Equipment, 02/02/2006. www.standardandpoors.com

price and the range of prices of each component, and the criticality of the product to the customer.

The number of the products that each company produces and the complexity and diversity of these products is the first major factor that affects the structure of its aftermarket network. For example Cisco produces a wide variety of products, from the gigantic CRS-1 router to small switches and products designed for homes and individual customers (Boasson, 2005)

The aftermarket for the telecommunications industry consists usually of a 3-tier network (Central or Global Distribution Center, Regional Distribution Center and Local Distribution Centers or Stocking Points). Fast moving parts are stocked many times on the customer's site, where the servicing is usually done. The stocking points usually serve the company's technicians, since they are the people responsible for the on-site servicing. (Industry Expert, Interview, 2006). Since the companies usually have to response within hours for premium service contracts, local stocking points usually serve customers within a 120 mile radius at a maximum, while service technicians also have parts (usually cheap fast movers) stocked on their vehicles, creating what is called "trunk" spare parts (Kass, 2004)

Despite the multiple local stocking points the network in this industry is relatively simple, since there are a few manufacturers and the major customers, especially enterprises are located in fewer places than, for example, the customers in the automotive industry or the personal computer sector of the computer industry (Industry Expert, Interview, 2006).

In this industry the criticality of the product to the customer is increased, compared to the computer industry. Although similar in characteristics, a malfunction of a network would cost the customer (enterprise or organization) even more than the cost of a problematic server or

workstation (Industry Expert, Interview, 2006). Thus, the aftermarket network is designed to be as close to the end user as possible to minimize these phenomena.

Of course, market conditions also play an important role in the design of each company's aftermarket. For example, Lucent had 16 repair centers in early 2001 but kept only four in 2003, due to restructuring of the company after the crisis that the market suffered a few years ago. (Boasson, 2005)

4.2.1 Cisco's Aftermarket Structure

Besides being a global leader in this industry, Cisco was mentioned by many interviewers and publications during my research as the company with the best aftermarket services in the telecommunications equipment industry. Therefore, a part of this chapter is devoted to the analysis of Cisco's aftermarket structure and the practices that the aftermarket division of the company uses.

Cisco's revenue from aftermarket services grew 12% in the second fiscal quarter of 2005, with the revenues adding up to $998 million. The aftermarket division represents 16% of the total revenues that the company has (Moad, 2005). Cisco's Global Products Services, as the aftermarket division of the company is called, manages a very complex supply chain, designed to provide excellent customer satisfaction. The network of the company consists of 3-5 echelons (usually a central depot, regional and local warehouses, and forward locations of inventory), depending on the region, with nearly 750 stocking locations. The division serves over 10 million service contracts, with thousands of transactions each day. These contracts are segmented according to different customer performance targets. The three major categories are (Cohen, 2005):

- **High Priority:** 2-4 response time guarantee
- **Medium priority:** 8-12 hour response time guarantee
- **Next Business Day**: 24 hour response time

The network of Cisco is more complex than an average network of the industry because of the size of the company and the variety of its products. Cisco has over 25,000 stock keeping units (SKUs), and 270 suppliers (Boasson, 2005). Cisco's aftermarket supports hundreds of products with more than 100,000 parts supported through its whole service supply chain. The company uses many echelons because many of the parts are expensive with infrequent demand, with global demand not exceeding 10 parts yearly (Cohen, 2005). Slow movers are pooled centrally, while other parts are more locally stored.

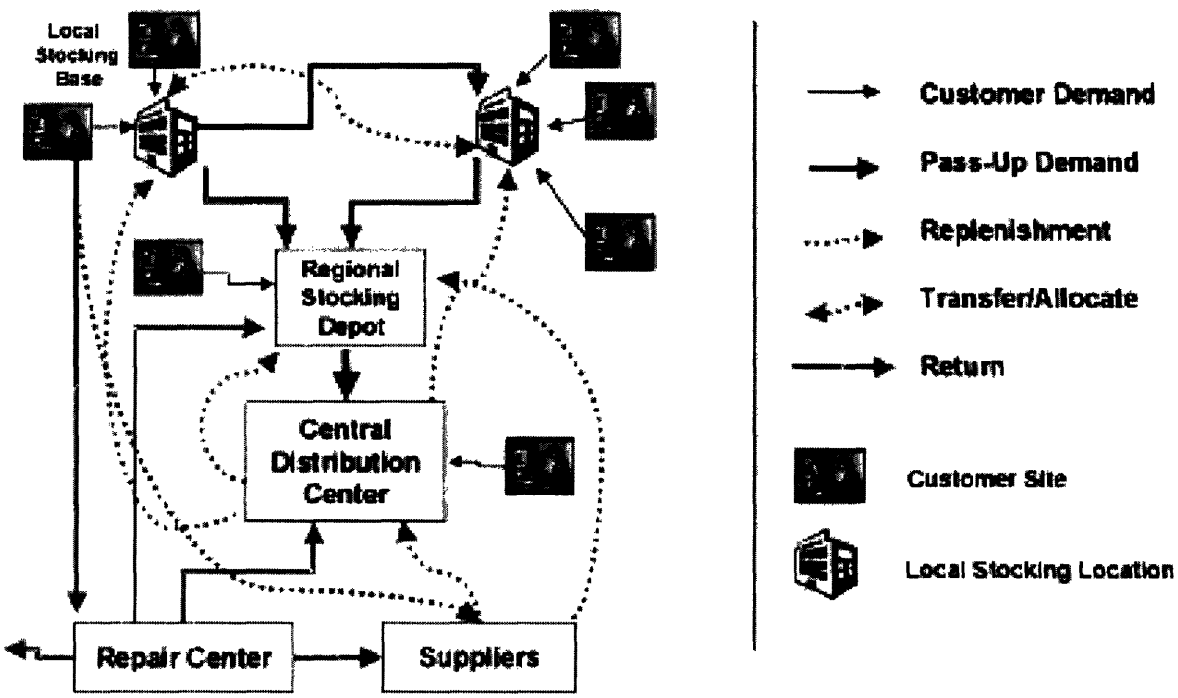

Figure 14: Cisco's Multi Echelon Service Supply Chain Material Flows. Source: MCA Solutions

Cisco's aftermarket operations, which are owned and operated partly by Cisco, and partly by distributors, third party logistics providers or repair providers, are depicted in Figure 14. In the span of the last five years, the company is moving towards massively outsourcing its operations. Manufacturing is outsourced 90% by revenue and 98% by volume, while the transportation aspect of the company is totally outsourced to 3PL. Overall, for every employee that the company has, there are six outside employees operating in different company divisions (Boasson, 2005).

4.3 Service Parts Procurement

In the telecommunications industry the procurement of spare parts has many similarities to the computer industry, but also has some distinct characteristics. One characteristic is that parts are not interchangeable between companies, as they are in the computer industry. However, this phenomenon gradually changes, since unbranded parts, especially from Asian markets, become available to customers (Industry Expert, Interview, 2006)

The lifecycle of products in the industry varies, depending on the type of the product and its complexity. Parts for telecommunications equipment can be characterized both as medium-lived assets (2-7 years) and long-lived assets (7+ years) (Poole, 2005).

Outsourcing is a clear trend in the telecommunications industry. Most companies use third party manufacturers for their parts supplies. As we mentioned above Cisco has over 270 suppliers, with 90 of them providing 90% of the business. Cisco uses third party manufacturers

for procuring 80% of its parts, while the other 20% is manufactured by the company (Boasson, 2005). Telecommunication Equipment Manufacturers support their products with service parts, after the end of life of each product, according to different policies that each company follows and offers to its customers. For example, Cisco provides all its customers with an end-of-life notice for all its products six months before the last day that the product can be ordered. After that deadline, the company provides 24 hours a day, 7 days a week service and spare parts to all its customers that have a signed service contract. The duration of this service for hardware is 5 years after the end –of-sale date[15]. Lucent has adopted a similar policy, notifying its customers 1 year before the end-of-sale date and providing spare parts for 5 years after the deadline[16]. These policies show that manufacturing companies maintain the supply of service parts for many years after the end-of-sale date.

4.4 Inventory Management

Service parts inventory management is another area in the telecommunications industry where someone can realize many similarities to the computer industry. The presence of strong Service Level Agreement contracts is dominating the market, and companies locate their inventory accordingly to satisfy these agreements (Industry Expert, Interview, 2006). The price of penalties paid by companies for not satisfying these agreements is higher than in the computer industry (Industry Expert, Interview, 2006)

[15] Cisco Systems, End-of-life Policy, http://www.cisco.com/en/US/products/products_end-of-life_policy.html
[16] Lucent Technologies, Maintenance Services End-of-Life Guidelines, http://www.lucent.com/knowledge/documentdetail/0,1983,inContentId+090094038002517a-inLocaleId+1,00.html

Although spare parts inventory is managed according to the component's price, the overall criticality of the product is increased compared to the computer industry. On the other hand, the distinction between fast movers and slow movers is more significant in this industry than in the computer industry. Therefore, fast moving spare parts are stored in near proximity to the customer, while slow moving parts are pooled in central locations to minimize both inventory costs and risk of stock-out incidents (Industry Expert, Interview, 2006).

To achieve managing their complex spare parts inventories, companies re investing in software solutions from specialized companies or totally outsource their inventory management and aftermarket services.

Again, the trend in inventory management software leads companies to global inventory optimization tools instead of local optimization tools (Industry Expert, Interview, 2006). Companies are using sophisticated integrated solutions to plan their inventory levels and manage their aftermarket divisions. SAP is offering specialized services to its customers, based on the needs and the specific requirements of the telecommunications equipment industry[17]. Another company with specialized software for the same industry is MCA Solutions. Cisco is using the Service Planning and Optimization (SPO) application of MCA Solutions to manage its inventory level at each stocking locations. By combining the capabilities of the SPO application with its ERP program Cisco allocates spare parts for each new customer (Moad, 2005).

The use of Service Parts Planning (SPP) software in general is increasing. According to a case study by AMR Research, a telecom company managed to rebalance its service parts inventory with the help of SPP software. By reallocating 8000 different parts the company

[17] www.sap.com

managed to close 160 stocking locations, reduce its planning staff by 50% and on the same time improve fill rates. For some other examples of implementations of service parts planning solutions, see Table 3.

Industry	Implementation	Solution Size		Benefits			Future Opportunities
		Parts	*Network*	*Inventory Reduction*	*Fill Rates*	*Other Benefits*	
Telecom Company A	6 months	10,000	34 locations	30% reduction	97% to 98%		Roll out tool to other business units
Telecom Company B	6 months	10,000	1,500 locations	25% reduction year 1, anticipating 25% in year 2	93%	Project paid for itself in 5 months	Multiechelon planning

Table 3: Service Parts Planning Examples. Source: AMR Research

Sometimes companies outsource the management of their inventory and their aftermarket operations to third party companies. A successful example of using such a 3PL company is Hitachi Data Systems US, which is using Choice Logistics for its aftermarket operations. Through this cooperation, Hitachi has managed to maintain 99% on time service and 99.9% inventory accuracy level (Hannon, 2005).

4.5 Customer Service

In the Telecommunications equipment industry, the servicing of products is usually done by the OEM or a third party partner of the OEM. In other words, the OEM company usually services products that it sells to customers. The end customer of this service is usually an enterprise or a big organization, and more specifically a professional employee of this organization that has high expectations of service (Industry Expert, Interview, 2006).

The expectations of the customer are to have the product functioning again in the least downtime. There is a significant trend to reduce the time of response to the least possible time, leading to response times as low as 2 hours in many cases (Industry Expert, Interview, 2006). As we mentioned before, the criticality of the product is an essential aspect of service, since machine downtime can cost a customer $100,000 or more per hour (Koudal, 2006). Since the equipment that needs repair is usually installed in the client's site, and thus difficult or impossible to transfer, the actual service procedure is done on site. Also, techniques of preventive maintenance where the servicing is done before the machine breaks down is usual in the industry, with machines sometimes designed to self-identify problems and automatically and remotely inform the customer service unit of the manufacturer (Industry Expert, Interview, 2006). As Sam Mikles , director of Spares Operations of Hitachi Data Systems explains *"When one of our machines has an error, typically either the engineer will diagnose what part is required or the machine will call home itself via its internal diagnostics for a part. The part request information is put into our CRM tool and it is automatically sent out to a 3PL which dispatches and delivers the part, typically to the customer site. The timing is key so the part and the engineer meet at the customer site so the engineer is not waiting"* (Hannon. 2005)

The presence of Service Level Agreements and the high competitive environment of the market is another for increased concern about customer service. The different pricing strategies for different service agreements are dominant. For example, in 2004 Cisco signed a lucrative service contract with Nippon Telegraph and Telephone East Corporation, with the obligation to provide service parts within a thirty day timeframe after the installation of new products and a guaranteed two hour timeframe for delivering service parts throughout the product's life (Moad, 2005).

Companies in the industry realize the importance of aftermarket services for increased customer satisfaction and adopt different methods to guarantee excellent customer service. Avaya, an important communications equipment provider, is using Accenture to train all the members involved in its aftermarket processes (technicians, sales personnel, customers) to better understand the functionality and servicing of new products (Dennis and Kambil, 2003) .

Finally, an emerging trend in the telecom industry is the fact that customers don't buy equipment, but service capability, and pay by the hours that a machine operates (Industry Expert, Interview, 2006). However, this "Power-By-The-Hour" technique will be analyzed in the aerospace industry chapter, because this is the industry that the technique was first implemented and is most widely used.

5 The Automotive Industry

5.1 Industry Overview

The automotive industry is probably the most complex industry that this thesis examines. For the scope of this thesis, as we mentioned in Chapter 1, we will define as automotive industry all the companies involved in the production, selling and maintenance of light vehicles, which include passenger cars, sport-utility vehicles (SUVs), crossover-utility vehicles (CUVs), hybrid vehicles and some categories of light trucks[18].

Actually, what we define as the automotive industry is by many reports and professionals mentioned as two separate industries, the automotive manufacturers and the automotive parts manufacturers. This division probably occurs because the automotive manufacturers are a large segment by themselves and secondly because the structure of the auto parts manufacturer market is pretty complex. However, for the purposes of this research this division of two different industries will not be made.

The different players are divided into categories, according to the type of product or service they offer. The major categories of the industry are the Car Manufacturing Companies, the Original Equipment Manufacturers (OEMs), the Replacement Parts Manufacturers, the Replacement Parts Distributors, and finally Rubber Fabricators and Car Dealers (Levy, Ferazani, 2005).

The most important players in this industry are the Auto Manufacturers, which are companies that are the final assemblers and producers of vehicles. The most U.S. originating companies are General Motors, Ford Motor and Daimler/Chrysler[19], which are known as the Big Three. Other important companies are the Asian Toyota, Nissan and Honda, and the European Volkswagen Group. Global sales for each of the major competitors are shown in Table 4, while more detailed numbers for the US market are depicted in Appendix D.

LEADING COMPANIES IN GLOBAL LIGHT VEHICLE SALES
(Ranked by 2004 total light vehicle sales)

	CARS THOUSANDS OF UNITS			LIGHT TRUCKS THOUSANDS OF UNITS			TOTAL LIGHT VEHICLE SALES THOUSANDS OF UNITS		
	2003	2004	F2005	2003	2004	F2005	2003	2004	F2005
General Motors	5,005	5,184	5,049	3,349	3,449	3,360	8,354	8,633	8,409
Toyota	4,880	5,335	5,379	1,891	2,135	2,267	6,770	7,470	7,646
Ford Motor	3,478	3,452	3,472	2,982	3,118	3,075	6,460	6,570	6,547
VW Group	4,666	4,722	4,696	222	284	331	4,888	5,007	5,026
Daimler/Chrysler	1,891	1,915	1,975	2,162	2,244	2,269	4,053	4,159	4,244
Nissan	2,140	2,160	2,219	793	1,042	1,160	2,934	3,202	3,379
Honda Motor	2,232	2,470	2,475	685	719	777	2,918	3,189	3,253
Hyundai	2,206	2,526	2,799	616	622	730	2,821	3,148	3,528
PSA Peugeot Citroen	2,697	2,673	2,821	419	446	449	3,116	3,118	3,270
Renault	1,981	2,024	2,078	325	373	382	2,306	2,397	2,460
Fiat Group	1,564	1,602	1,633	345	391	370	1,909	1,992	2,003
Suzuki	1,306	1,468	1,539	316	318	334	1,622	1,785	1,873

F-Forecast.
Source: Global Insight.

Table 4: Leading Companies in Global Light Vehicle Sales.
Source: Global Insight, Standard and Poor's

The Big Three are seeing their market shares globally shrinking, facing high competition especially from the Asian manufacturers. The more efficient and less costly production methods, especially of the Asian companies, along with the general economic conditions (high oil prices) are changing the market dramatically. Standard and Poor's mentions that according to a Harbor

[18] Industry Surveys, Autos and Auto Parts, http://www.standardandpoors.com
[19] In 1998 Daimler-Benz AG merged with Chrysler Corp. , and from then either Daimler/Chrysler or its US part, Chrysler, can be referred to as part of the Big Three.

Consulting Inc. report GM lost on average $1227 for every vehicle sold in the US for the first half of 2005, Ford lost $139, Chrysler made a small profit of $186; while for example, the Japanese competitor Toyota earned on average $1488 per car sold. To compete with their Asian competitors, U.S. manufacturers are trying to restructure their companies. General Motors is undertaking a restructuring plan which involved closing many facilities in the U.S. and intensive layoffs, while Daimler/Chrysler changed its CEO and announced plans (2005-2006) for 8,500 job cuts through mutual termination agreements[20].

In terms of geographic segmentation, all major companies sell their cars all over the world, with major markets in the U.S., Europe and Asia. The U.S. market remains the biggest, with Europe following. Although the Asian market is third, the potential of growth of sales, especially in China, is forcing companies to turn their attention to the Chinese market. In terms of production of cars, the Asiatic region is the biggest, mainly because of low production costs (Standard and Poor's, 2005). The trend of transferring production in Asia is shown in Table 5.

LIGHT VEHICLE PRODUCTION BY REGION

(In thousands of vehicles)

	2000	2001	2002	2003	P2004
North America	17,150	17,473	16,369	16,243	16,265
South America	1,978	2,006	1,901	2,037	2,532
European Union	16,648	16,705	16,444	17,973	18,332
Other Europe	2,567	2,465	2,512	2,027	2,499
Asia & Oceania	17,550	17,082	18,110	21,972	23,951
Africa	316	380	364	328	378
Total	56,209	56,112	55,700	60,710	64,072

P-Preliminary.
Source: International Organization of Motor Vehicle Manufacturers.

Table 5: Regional Light Vehicle Sales. Source: Standard and Poor's , International Organization of Motor Vehicle Manufacturers

[20] Industry Surveys, Autos and Auto Parts, http://www.standardandpoors.com

Another important category of companies involved in the automotive industry are the Original Equipment Manufacturers, which are companies that manufacture parts and large components that the Car Manufacturers use to make the final assembly of the vehicle. Smaller companies supply the OEMs with smaller and simpler components. The parts manufacturers are categorized as tier-1, tier-2, and tier-3 suppliers according to how complex are the auto parts they produce. Tier-1 OEMs are closely connected to the car manufacturers, while they have subcontracts to multiple tier-2 or tier-3 suppliers. All these different levels of manufacturers are closely linked, since a disturbance in the demand for cars drops the demand for all tiers of parts. But in many cases the parts manufacturers also have significant power, especially when they are the only supplier of a bigger company. This phenomenon is mainly found in the relationship between tier-1 OEMs and car manufacturers, where the tier-1 supplier has a lot of power over the car manufacturer's production line[21].

Among the largest parts manufacturers are Dana Corporation, Delphi Corporation, Johnson Controls Inc., Tenneco Automotive Inc., and TRW. In the replacement parts manufacturing segment some of the bigger players are ArvinMeritor Inc., Dana Corporation, and Federal-Mogul Corporation (Standard and Poor's, 2005). The financial problems of the Big Three have seriously affected companies that provide the top three US car manufacturers with parts. From September 2004 to March 2006 ten of these companies filed for Chapter 11 as a consequence of this situation. These companies are Citation Corp, INTERMET, Amcast Industrial, Oxford Automotive, Tower Automotive, Meridian Automotive Systems, Collins & Aikman, Universal Automotive Delphi Corporation, and Dana Corporation. Although most of these companies emerged and survived closing, they suffered severe financial problems[22].

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[21] Industry Surveys, Autos and Auto Parts, http://www.standardandpoors.com
[22] Hoover's Online Database. Auto Parts Manufacturing. http://premium.hoovers.com/

Finally, important players in the automotive industry are also the replacements parts distributors, with Genuine Parts Co. being the largest independent distributor in the US (Standard and Poor's), and the car dealers. The dealers are the main sellers of vehicles to the end customer, and they often offer maintenance and other services. In 2004, the dealers in the US sold 16.86 million new cars (for details, see Table 6) (NADA Data, 2005).

Average dealership profile

	1999	2000	2001	2002	2003	2004	% change 2003–2004
Total dealership sales	$27,260,123	$29,360,978	$31,670,046	$31,275,581	$32,296,859	$33,009,335	2.2%
Total dealership gross	$ 3,443,159	$ 3,734,466	$ 4,154,469	$ 4,175,456	$ 4,315,664	$ 4,363,870	1.1%
As % of total sales	12.6%	12.7%	13.1%	13.4%	13.4%	13.2%	
Total dealership expense	$ 2,944,441	$ 3,278,542	$ 3,535,496	$ 3,576,246	$ 3,751,511	$ 3,804,184	1.4%
As % of total sales	10.8%	11.2%	11.2%	11.4%	11.6%	11.5%	
Net profit before taxes	$ 498,719	$ 455,924	$ 618,974	$ 615,673	$ 564,143	$ 559,686	-0.8%
As % of total sales	1.8%	1.6%	2.0%	1.9%	1.7%	1.7%	
Net pretax profit in constant 1982 dollars	$ 288,874	$ 255,498	$ 337,272	$ 339,027	$ 306,600	$ 304,177	-0.8%
New-vehicle department sales	$16,339,787	$17,638,914	$18,808,644	$18,651,091	$19,359,130	$20,116,264	3.9%
As % of total sales	59.9%	60.1%	59.4%	59.6%	59.9%	60.9%	
Used-vehicle department sales	$ 7,879,371	$ 8,388,678	$ 9,187,234	$ 8,942,973	$ 9,142,647	$ 9,030,534	-0.6%
As % of total sales	28.9%	28.6%	29.0%	28.6%	28.3%	27.5%	
Service and parts sales	$ 3,040,966	$ 3,333,386	$ 3,674,168	$ 3,681,518	$ 3,795,081	$ 3,802,537	0.2%
As % of total sales	11.2%	11.4%	11.6%	11.8%	11.8%	11.5%	
New-vehicle average selling price	$ 24,445	$ 24,923	$ 25,797	$ 26,163	$ 27,565	$ 28,060	1.8%
Used-vehicle average selling price	$ 13,236	$ 13,648	$ 13,930	$ 13,840	$ 13,473	$ 14,247	5.7%
Average net worth (as of 12/31)	$ 1,702,112	$ 1,876,231	$ 2,016,200	$ 2,230,699	$ 2,243,589	$ 2,613,063	16.5%
Net profit as % of net worth	29.3%	24.3%	30.7%	27.6%	25.1%	24.3%	

Table 6: Average US dealership profile. Source: NADA Data, NADA analysis division, 2005

The aftermarket is an important factor in dealer profits and revenues also. Since the gross profit margin for selling a new car is constantly dropping from 1998 to 2004 (Figure 15), the aftermarket services are driving the profitability of the dealers. The combined aftermarket income of the US dealers in 2004 was 26.2% rising 1% from the previous year (Figure 16). This income includes service contracts and financial-insurance services that the dealers offer (NADA DATA 2005).

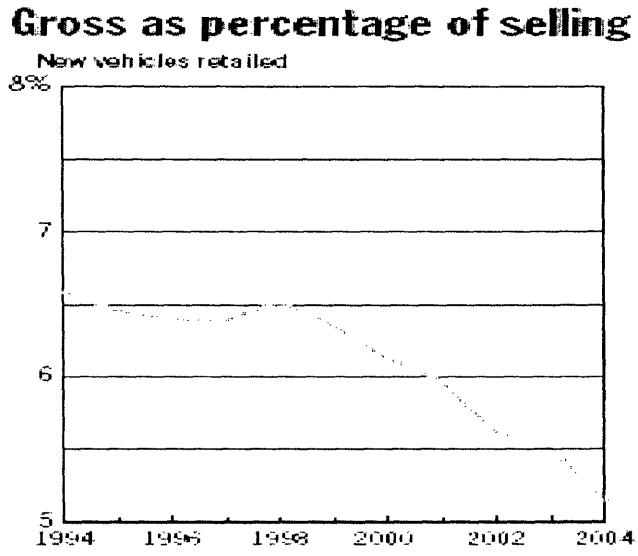

Figure 15: Gross Profit as percentage of selling price for new cars sold, US.
Source: NADA DATA 2005, NADA analysis divisions

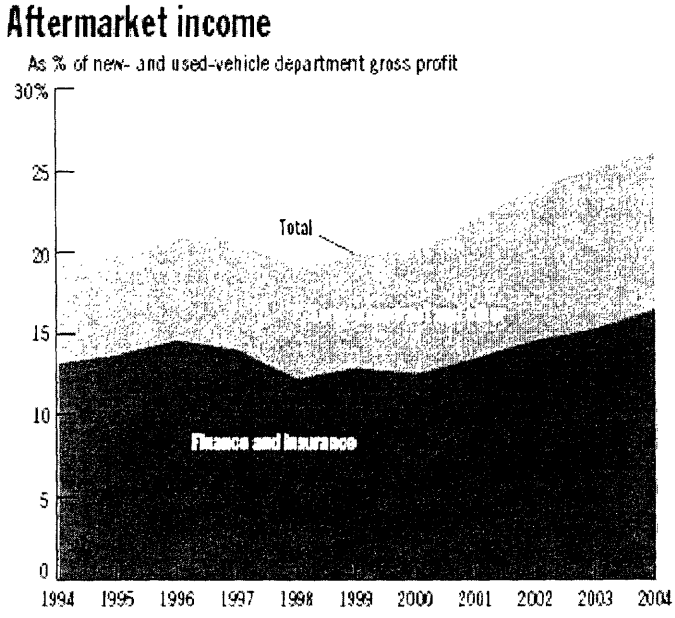

Figure 16: US Dealer's Aftermarket Income, 2005.
Source: NADA DATA 2005, NADA analysis divisions

In terms of market trends, the rising gas prices are affecting both the demand for cars and the future structure of the automotive market. After years of increase in demand, the demand for SUVs has started to decrease, and there is an increasing demand trend especially in the US market for more fuel efficient, more environmentally friendly cars. In terms of the automotive

aftermarket, two contrasting trends are important. Initially, the demand for aftermarket services increases since the average age of cars is increasing (Figure 17), thus creating more demand for aftermarket services. However, the increased competition in the market and the better quality techniques used for production has led car manufacturers to improve the total quality of the cars they sell, thus creating less demand for spare parts, since the failure rates of parts is decreasing (Standard and Poor's , 2005)

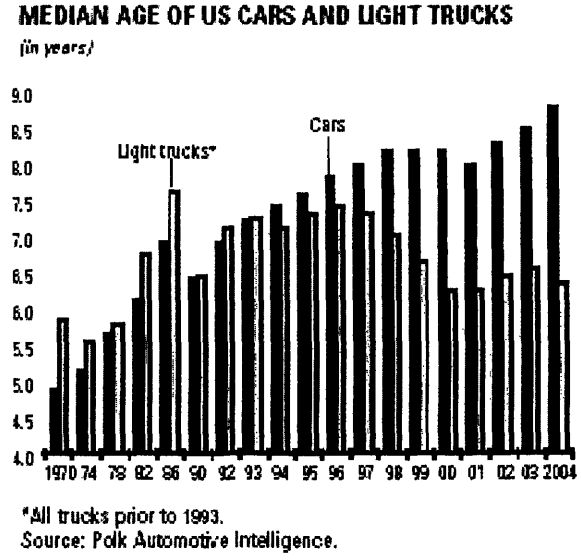

Figure 17: Median Age of US Cars. Source: Standard and Poor's, Polk Automotive Intelligence

A very important segment of the automotive industry, which could be also thought as a separate industry by itself, is the recycling segment. Automobiles are the most recycled consumer products globally nowadays, with 95% of retired cars sent for recycling instead of only 10% of consumer electronics. The automotive recycling industry is the 16th largest industry in the US, with annual revenues of $25 billion and 7,000 operations across the US. All manufacturing companies use vendors to recycle their vehicles, commit their suppliers to use recycled raw material in the production of their products, and manage to realize savings in both new and replacement parts manufacturing. Also companies using recycling policies are thought

more as having environmentally friendly policies. For example, it was calculated that 85 million gallons of oil would be needed to manufacture new car parts, if companies in the US did not use recycling policies. This fact shows the benefits for both the manufacturer and the environment from recycling[23].

5.2 Supply Chain Network Structure

The structure of the supply chain networks in the automotive industry has many similarities and some differences from the others industries that we previously examined. One difference is that different channels exist, mainly because there are different companies that provide servicing for cars (independent dealers, independent service providers, official company dealers and others) (Industry Expert, Interview, 2006).

The main structure of the network is similar to the other industries. Thus companies usually have a 2 or 3-tier network for their spare parts (global, regional, and local). Usually the dealer who is selling the car is also providing the servicing (Haesslein, Interview, 2006).

One dealer could be served by 2 different DCs, and a DC serves more than one dealer. A many-to-many relationship between dealers and Distribution Centers exists. Generally, fast-moving parts are more locally centralized, while slow-moving parts are pooled centrally. A certain part or component may change its status through the product's lifecycle. As demand for a product declines and the product reaches the end of its life, parts tend to be more centralized (Industry Expert, Interview, 2006)

[23] Auto Alliance - http://autoalliance.org/archives/RECYCLE_17.pdf

An emerging trend in the automotive aftermarket is that many companies try to reduce the number of layers in their network and increase the collaboration between dealers and other customers, in order to lower their costs and (Industry Expert Interview, 2006)

5.2.1 Saturn's Aftermarket Structure

During the research about the automotive aftermarket and automotive companies that excel in the aftermarket function, Saturn is a company that was mentioned both in the literature and during the interviews with the industry experts as an example. This is the reason that in this subchapter the aftermarket is devoted to analyzing the aftermarket policy of Saturn, based mainly on the work of Cohen et al (2000) "Saturn's Supply Chain Innovation: High Value in the After-Sales Service".

The major aspect of Saturn's strategy was the very early implementation of a strategy very similar to Vendor Managed Inventory (VMI), called Jointly Managed Inventory. With this strategy Saturn was sharing the risk of carrying inventory with its dealers. This policy allowed Saturn to rank first both in Parts Availability (Figure 18) and in Customer Loyalty (Figure 19), although it had the highest spare parts inventory turns in the market (Cohen et al, 2000).

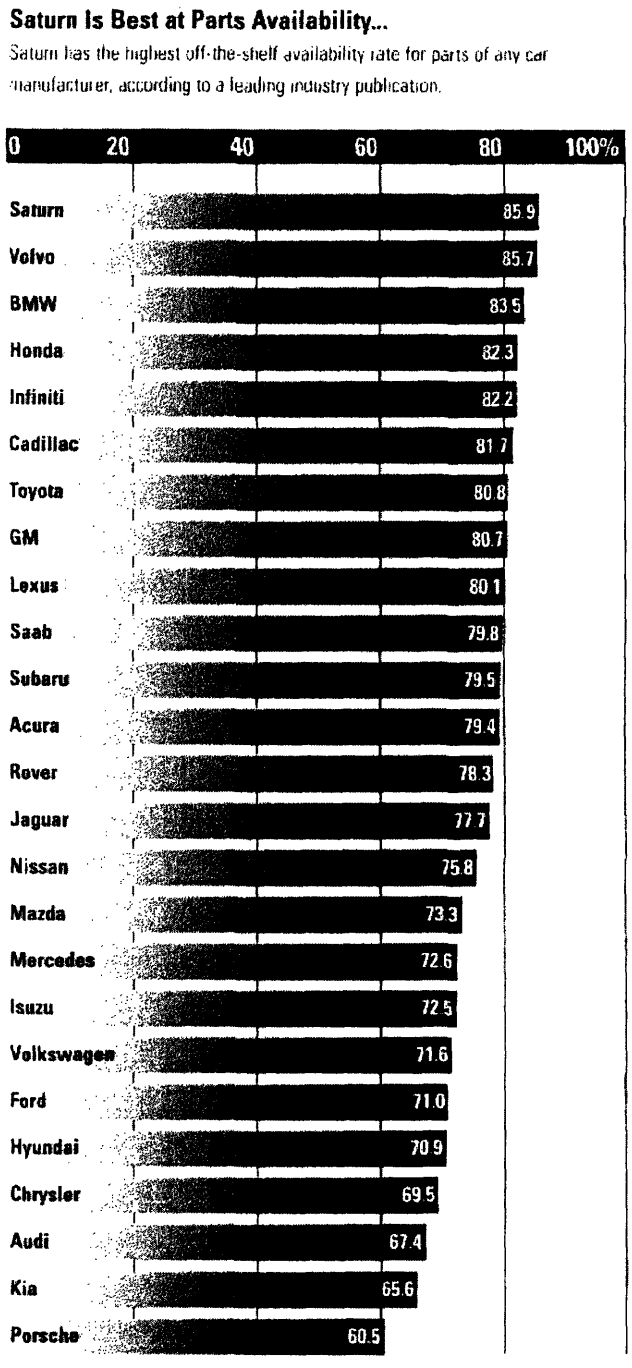

Figure 18: Off-the-self spare parts availability. Source: Parts Monitor, Cohen et al, 2000

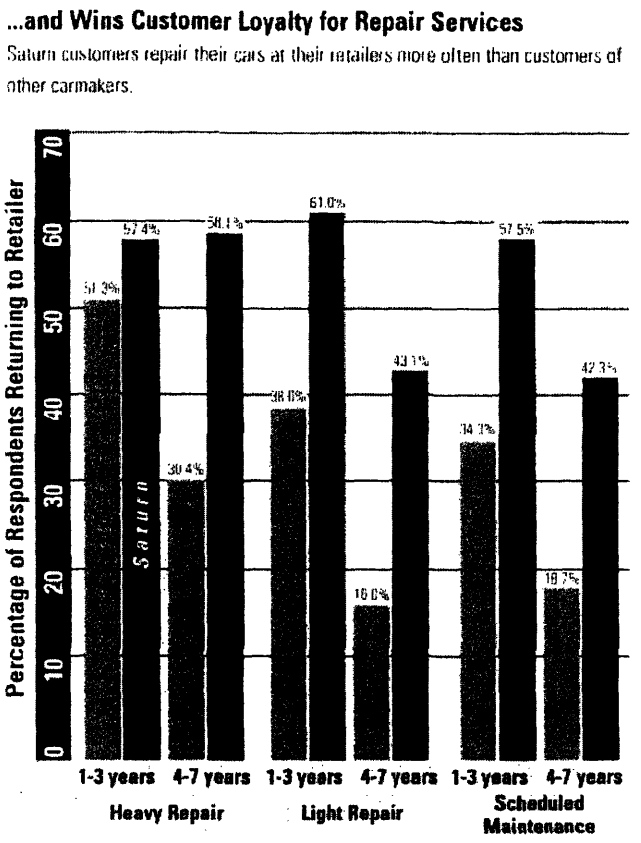

Figure 19: Saturn's Customer Loyalty. Source: Parts Monitor, Cohen et al, 2000

Since Saturn is a relatively new company, they designed an integrated system for their aftermarket supply chain from the beginning. Their strategy was to provide the customer with lifetime service at an excellent level, with reasonable prices. The network that was created included one global inventory stocking position, close to the company's main manufacturing plant in Tennessee. Also retailers stocked an amount of parts, especially fast movers. In order to avoid competition between dealers, the company gave to each dealer exclusive selling rights for each region, without any overlapping with any other official Saturn Dealer (Cohen et al, 2000).

The replenishment procedure was handled by a "pull" system. When a part was requested by a client, the system checked if the part was available at the dealer, and then if it wasn't the system would try to locate the nearest place that the part was available in other Saturn dealers. Only if the part was not available by any dealer with proximity to the request, the Central DC would ship the component. The system calculated inventories daily, and made proposals of

restocking to the dealer. If a part was not sold within a period of some months, Saturn would buy the part back (Cohen et al, 2000).

5.3 Service Parts Procurement

Procurement for service parts in the automotive industry is relatively more complex than in the computers and the telecommunications industry. One main reason for this increase in complexity is the longer lifetime of a car compared to the lifetime of a computer or a telecommunications network.

In the automotive industry, the lifetime of a car before its end-of-sale date is around 5 years, and the companies usually support their models another 15 years after its end-of-sale date (Industry Expert, Interview, 2006).Certain parts are interchangeable between different models and companies, but most parts come directly from the car manufacturer and are not interchangeable (Industry Expert, Interview, 2006).

Usually the manufacturer signs an initial contract with the supplier that covers procurement for some years of production. After the product's end-of-sale date different strategies are used. Many times the car manufacturer informs the dealers and the other companies responsible for servicing for a last-time-buy date, where the dealer or the service provider can order parts for an old vehicle one final time before the manufacturer stops providing parts. Another practice that is sometimes used after the product's end-of-life is that the manufacturers gives slow-moving inventory to small third party companies for free, in order to both keep servicing older customers and write off taxes and inventory. In case one of these parts is sold, the manufacturer receives a small premium (Industry Expert, Interview, 2006).

Another situation that exists mainly in the automotive industry, and is not usual in the aftermarket of other industries, is the existence of third party junkyards that are used as spare parts stocking locations. Parts from cars that are obsolete or semi-destroyed are used to service other vehicles of the same model. This situation is more common in the case of cars that have reached their end-of-sale date and especially for refurbishing (for example, engine or driving shaft) (Industry Expert, Interview, 2006)

5.4 Inventory Management

Service Parts Inventory Management is a very important aspect for companies in the automotive industry. The complexity of the product increases, and automobiles have more parts than, for example, a personal computer. Also, the range of the prices for the parts is wider in this industry. The existence of dealers, who until recently were using their judgment or rules of thumb to manage their inventory, is essential. The trends in inventory management in this industry which surfaced in most of the interviews with the industry experts, as well as in many pieces of literature, are the will of the manufacturing companies to move towards Vendor Managed Inventory Systems or at least systems with the characteristics of VMI; as well as global optimization of parts instead of local.

One very interesting evolution in the inventory management techniques for the automotive aftermarket is the move towards Vendor Managed Inventory (VMI). Companies are shifting to VMI, especially for managing fast-moving spare parts (Industry Expert, Interview, 2006). General Motors is one of the companies that is planning to implement a system with the characteristics of VMI. Specifically, the company plans that 8000 of its dealers in the U.S. and Canada will be using a system called Retail Inventory Management (RIM) for their restocking

calculations by the end of 2007. The system will calculate what quantity of what part to stock and will recommend it to the dealer. This will help both the dealers and GM, and will realize savings for both parties. General Motors gives as a guarantee the promise that if a part is not sold within 12 months, the part will be returned to GM (Tibodeau, 2006).

Subaru New England implemented a similar program of dealer inventory management, which allowed the company to impressively improve its fill rates from around 70% to 98% and reduce its spare parts inventory from $14 million to $6 million. To support this new system, Subaru New England promised its dealers that if a part didn't sell within 6 months, the part would be delivered back to the company. With this new system the dealers realized many benefits, with their spare parts availability increasing and their inventory levels reduced by half (Harrington, 2005).

Besides the implementation of Vendor Managed Inventory, the automotive aftermarket supply chain is moving towards the use of integrated software solutions that would help companies optimize their inventory policies on a global level and generally cover all aspects of service parts management (Industry Expert, Interview, 2006). Companies like SAP are offering dedicated solutions for automotive companies that handle all aspects of spare parts management[24]. Ford, one of the biggest global players in the automotive industry and member of the Big Three, had formed an alliance with SAP and Cat Logistics to create an integrated service parts management system. Being a company with 600,000 parts in inventory, 5,000 suppliers and 15,000 dealers worldwide, Ford needed a state-of-the-art software solution to manage its spare parts inventory. Using Cat Logistics as a strategic partner and SAP as a software developer, Ford wants to implement the experience of Caterpillar in creating and

managing an excellent service parts supply chain and the expertise of SAP to optimize its inventory levels globally, as well as have full visibility of its aftermarket supply chain. The main goals of this project are a 40% reduction of inventory levels in a period of six years and increased fill rates from 93% to 98% in the US and from 93.6% to 96.8% in Europe (Bowman, 2004).

The importance that a company pays to its aftermarket is also directly related to the installed base of the products it has sold in a region. As Moad (2005) describes, after KIA Motors US reached one million sold vehicles, the company implemented a restructuring of its aftermarket services. The reason for this restructuring was that the increase of the installed base made independent parts manufacturers and service providers target KIA's cars for servicing. KIA replaced its older homemade forecasting software with a full forecasting and service parts managing tool from i2 Technologies, and realized savings in inventory costs, improvement of fill rates, and decrease of shipping costs.

5.5 Customer Service

The objective of a dealer when servicing a customer is to retain the customer's loyalty, so that the customer will buy the same brand of car again. However, since dealers are an independent channel, most of the times more attention is paid to the selling of a new car and they think of servicing as a secondary task (Industry Expert, Interview, 2006).

In the automotive industry the dealers service the products they sell, which are cars. Of course, as it is mentioned above, the servicing is also done by independent service providers.

[24] www.sap.com, SAP for Automotive

Although the customers are demanding, and the acceptable time they are willing to wait is decreasing, the time a customer considers acceptable is relatively longer than in the other industries we examined. One of the reasons for this delay is that the dealers, who are providing the service operations for many decades, have in a way trained the customer to wait longer than he or she should for servicing a car. Since service is defined by how you set and meet expectations, dealers have set the expectations lower and the customers are in a way trained in these conditions. However, car manufacturing companies intervened and tried to improve the servicing operations (Industry Expert, Interview, 2006).

Generally there is segmentation in customer expectations, depending on the type of service they require and on the severity of the damage the vehicle has. If the customer is taking its vehicle to the service provider for preventive or scheduled maintenance, expectations for service are high and customers are usually demanding same-day service. The customer has the same demand for same-day service if the vehicle has small damage. On the other hand, if the damage is more serious, the customer will wait overnight or even more, depending on the severity of the damage. In general, overnight service is becoming less acceptable, especially for scheduled or small maintenance operations (Industry Expert, Interview, 2006).

Another situation that exists in the automotive industry is price segmentation according to the level of service provided. Companies that offer better servicing, with lower response time and the existence of loaner, tend to value their services higher than regular servicing (Industry Expert, Interview, 2006).

6 The Aerospace Industry

6.1 Industry Overview

Usually when we refer to the term "aerospace industry" we refer to the companies which produce parts and systems for air and space transportation. The "aerospace industry is divided into three different sectors (aerostructures, engines and equipment) and three different product segments (aircraft, missiles and space)" (Tiwari, 2005).

However, as it is mentioned in Chapter 1, this thesis focuses only on the aftermarket supply chain of aircrafts, and especially commercial aircrafts. Companies that are researched are Commercial Aircraft Manufacturers, Commercial Aircraft Parts Manufacturers and Distributors, and finally Commercial Airline Carriers (for specific umbers, see Table 7).

In the segment of Commercial Aircraft Manufacturers two companies, the U.S. Boeing and the European Airbus dominate the market in large commercial aircraft manufacturing. Although Boeing used to dominate the market until the start of the decade, Airbus, using an aggressive pricing policy, managed to surpass its main competitor both in the field of aircraft orders and actual deliveries.

After facing a serious crisis after the terrorist attacks of September 11th, 2001 both companies are now in a steady growth phase, both facing record sales and orders for the year 2005.

Industry Group	1989		1999	
	Value of Shipments	Employment (in thousands)	Value of Shipments	Employment (in thousands)
Aircraft mfg.	43,338.9	277.5	73,961.0	200.2
Aircraft engine & engine parts mfg.	21,565.8	132.0	24,290.6	83.2
Other aircraft & auxiliary equipment mfg.	19,074.9	192.9	22,429.5	132.6
Aircraft and parts (Subtotal)	**83,979.6**	**602.4**	**120,681.1**	**416.0**
Guided missiles, space vehicles & parts (Subtotal)	**29,497.7**	**221.0**	**18,981.4**	**73.9**
AEROSPACE PRODUCTS & PARTS MFG. – TOTAL	**113,477.3**	**823.4**	**139,662.4**	**489.9**

Table 7– Composition of aerospace industry 1989 and 1999- Increase in Civil Aerospace relative to Defense, and decrease in employee base. (All dollar figures are given in millions of current dollars) Source: Tiwari, 2005

The current market leader, Airbus, received 1055 aircraft orders while Boeing received 1002 orders. Actually, Airbus, which is a joint venture of EADS and BAE Systems and has 55,000 employees worldwide, is delivering more aircraft than Boeing since 2003, before surpassing its main competitor in orders also.

To face the increasing competition and in order to respond to the increasing needs of the market for fuel efficiency and lower costs, both companies have scheduled the launch of new aircraft in the next years. Airbus is planning to create the largest passenger aircraft in the world, the A380, capable of carrying 550-800 passengers. The aircraft, which flew its first voyage in 2005, is scheduled to start regular flights in 2007. Airbus is also planning to create the A350, a

mid-sized aircraft by the year 2010. The A350 is planned to directly compete with Boeing's 787 Dreamliner, which is scheduled for launch in 2008[25].

Besides these two main aircraft manufacturers, other companies in the area mainly compete in the production of smaller aircrafts. Companies such as Bombardier, the world's biggest regional jet (less than 100 seats) manufacturer, and Embraer compete with the two giants in mainly niche markets. Finally, the business jet segment is the third and last part of the commercial aircraft industry, where companies such as General Dynamics and Textron compete with Bombardier and Embraer (Cizmeci, 2005).

Most of the above-mentioned aircraft manufacturers are supplied by a wide number of supplier companies worldwide which are categorized into different tiers or levels. The first tier supplier companies such as General Electric Aircraft Engines (GEAE), Rolls-Royce and Honeywell produce large parts of the aircraft such as engines or avionics systems. Furthermore, suppliers that are categorized as tier 2 and tier 3 suppliers produce smaller and more commoditized parts and products. These companies, such as L-3Communications, Parker-Hannifin or Harris serve clients in multiple industries (for example the automotive industry) (Tiwari, 2005).

Finally, companies that distribute parts or systems for aircrafts and companies that provide maintenance as third-party companies finalize the structure of the aerospace industry (Hoover's , 2005).

Another major characteristic of the aerospace industry are the Passenger Airline Companies (for major players see Table 8). These companies are the actual clients in the aftermarket, because they are the ones that operate the final product, which is the aircraft.

[25] Hoover's Online Database - http://premium.hoovers.com/subscribe/ind/factsheet.xhtml?HICID=1519

Airlines (Ranked By Revenue Passenger Miles)	2004-5 Sales (millions)	2004-5 Net Income	2004-5 Employees
1.AMR Corp.	$20,712.0	($861.0)	92100
2.UAL	$16,391.0	($1,721.0)	61000
3.Air France-KLM	$24,721.0	$455.0	102077
4.Delta Air	$15,002.0	($5,198.0)	69150
5.Northwest Airlines	$11,279.0	($862.0)	39342
6.British Airways	$14,765.0	$474.0	49490
7.Lufthansa	$23,140.3	$551.1	90673
8.Japan Airlines	$19,803.6	$279.8	53962
9.Southwest Airlines	$7,584.0	$548.0	30974
10.Continental Airlines	$11,208.0	($68.0)	42200

Source: Hoover's Online Database, 2006

Table 8: Key Figures for Passenger Airline Companies

The Passenger Airline market is an unsteady market, with high competition and great sensitivity to fluctuations in the global economy. The terrorist attacks of September 11th seriously affected the market, and only four years after the attacks, in 2004, passenger traffic recovered and surpassed the numbers prior to 9/11. Despite the general recovery of the market, high fuel prices, intense price competition, high operating costs and events like the Katrina Hurricane in 2005 have forced many U.S. companies to file for bankruptcy (U.S. Airways, UAL, Delta Airlines, and Northwest Airlines)[26]. However, the global forecasts for air travel are positive, driven mainly by a major increase in the demand for air travel in Asia. Global passenger traffic is expected to increase on average 5.3% per annum for the years 2004-2023[27]. This forecast leads to increased demand for aircraft, as well as an increase in the importance of the aerospace aftermarket sector, since competition will increase and fully operating airplanes will be critical to the survival of any company (for profitability of specific divisions, see Table 9).

[26] Hoover's Online Database - http://premium.hoovers.com/subscribe/ind/overview.xhtml?HICID=1600
[27] Airbus : Global Market Forecast 2004-2023 – www.airbus.com

AEROSPACE & DEFENSE INDUSTRY SEGMENT OPERATING PROFIT MARGINS
(In percent)

	2000	2001	2002	2003	2004	5-YEAR AVERAGE
Large commercial aircraft	7.9	7.8	8.5	5.9	6.5	7.3
Business & regional aircraft	14.8	7.9	13.3	10.6	7.2	10.7
Maintenance, repair, & overhaul	14.6	12.8	5.4	5.9	5.5	8.8
Jet engines	14.8	14.2	12.8	11.8	12.5	13.2
Military weapons	8.1	8.4	8.6	7.4	8.3	8.2
Rocket launch & satellite making	0.5	0.3	2.2	(5.9)	(6.2)	(1.8)

Source: Company reports.

Table 9: Aerospace and Defense Industry Segment Operating Profit Margins. Source: Standard and Poor's, Company Reports, 2005

6.2 Supply Chain Network Structure

The structure of the aftermarket supply chain in the aerospace industry is probably the most complex of all the industries that are examined in this thesis. The reason for this complexity is the nature of the product, the airplane. Since airplanes fly all over the world, it is necessary for parts to be stocked in many locations globally. All airports have a spare parts inventory, and billions of dollars are invested in spare parts inventory. Of course this fact creates a lot of synergistic opportunities, which will be analyzed later (Industry Expert, Interview, 2006).

Every player in the aerospace aftermarket has different strategies and different designs for its aftermarket network. Since the servicing of an airplane is done either by the OEM, a 3PL company or the airline, different channels exist.

Usually the service provider maintains a global DC for stocking the parts that are expensive and extremely slow moving. Different facilities around the world are capable of providing smaller or more intensive servicing. There is usually a global hub and regional hubs

for airlines, which many times do their own servicing, either directly or by subsidiary companies. For example, Lufthansa and Delta are doing their own servicing (Industry Expert, Interview, 2006). Companies like KLM and Lufthansa offer their expertise to other companies. They provide servicing to smaller airlines. For example, Lufthansa has a network of 25 subsidiaries and affiliates and offers aftermarket services to 500 smaller carriers[28], while KLM is providing maintenance services to Philippine Airlines and TNT Airlines.[29]

Besides the airlines and 3PLs, the Original Equipment Manufacturers offer their own maintenance services, many times competing with their own customers. The OEMs have their own aftermarket. For example, one of the two most important players in the industry, Boeing, has a network of service hubs and centers globally to service its customers. The company has 6 major component repair centers around the globe: Four are located in the U.S. (Seattle, Arkansas, Wichita, Long Beach) , one in Europe (Amsterdam) and one in Australia. Also, Boeing opened a Commercial Airplanes Operations Center to provide 24 hour a day, 7 days a week immediate response service to its customers. A group of 200 field service representatives is located in 65 countries around the world, with close proximity to the customers. Spare parts are stocked in eight Global Distribution Centers worldwide[30].

Different facilities offer minor or major overhaul capabilities, and A, B, C, or D level checks according to regulations, which play a critical role in the aerospace aftermarket (Industry Expert, Interview, 2006).

[28] Lufthansa Technik AG, http://konzern.lufthansa.com/en/html/ueber_uns/geschaeftsfelder/technik/index.html
[29] KLM Enginnering and Maintenance, http://www.klm.com/engineeringmaintenance/site/en/index.html
[30] BOEING, Commercial Aviation Services. http://www.boeing.com/commercial/spares/index.html

Because of the criticality of the product of this industry, and since an airplane that cannot fly costs thousands of dollars for every minute that does not operate, certain parts are located in many locations around the world, and many times even on board the aircraft. These parts are usually handled via consignment contracts with the airlines. (Dennis, Kambil, 2003).

6.3 Service Parts Procurement

The aerospace industry's products have the longest lifecycle from all the industries that are examined in this research. Airplanes usually operate for more than 20 years, with sometimes reaching as long as 50 years of life. Also specific parts of the airplanes have a long lifecycle. For example, Poole (2003) characterizes aircraft engines as long-lived products, with lives of more than 7 years. Because of the long lifetime, companies need to provide service parts for many decades after the product is introduced to the market.

The complexity of service parts procurement increases because of the increased number of parts that an airplane consists of. For example, Boeing has over 500,000 different types of spare parts and over 6,500,000 different spare parts in its aftermarket to support all its airplanes[31].

Spare parts for airplanes are not interchangeable between the OEMs. However they are interchangeable between companies. Since almost all companies have purchased their fleets from the same companies, which are usually Boeing or Airbus, and since airplanes fly all over the world, it not unusual for airlines to loan parts to each other, especially when an aircraft breaks

[31] BOEING, Commercial Aviation Services. http://www.boeing.com/commercial/spares/index.html

down in an airport which is mainly operated by another company, and thus has parts in stock (Industry expert, interview, 2006).

6.4 Inventory Management

The characteristics of the product in this industry, the huge price range of parts, very long lifecycles, high penalty of downtime, and an industry which is highly regulated makes inventory management "one of the most interesting service parts management challenges", as one industry expert mentioned during one of the interviews for the thesis (2006).

Similar to the other industries that we previously viewed, aerospace aftermarket inventory management mainly relies on the existence of sophisticated software solutions. Many companies offer different software solutions especially designed to meet the challenges of the industry. SAP offers a complete dedicated software solution for aerospace companies Stressing the need for a move towards preventive inventory management, where the company anticipates demand through past data and forecasting techniques, SAP is mainly focusing in the Maintenance, Repair and Overhaul Segment of the aerospace market[32].

Many companies are turning to Service Parts Planning (SPP) solutions. SPP vendors include inventory optimization capabilities, which are used by Aerospace and Defense companies. In a survey called "Service Parts Planning Vendor Landscape: Service Level and Inventory Investment Tradeoff" AMR Research analyzes the factors that cause complexity in this industry's inventory management. It is specifically mentioned that *"The most difficult service problems to solve are in the A&D industry, where Performance-Based Logistics (PBL) contracts require commitment to a target level of system availability and place inventory*

burdens on the contract suppliers. Forecasting becomes difficult when assets move around and failure is driven by multiple causal factors" (Ruggles, Suleski, Samaraweera, 2005)

The solutions provided in the earlier years by different software providers were segmented and targeting specific areas of the aerospace aftermarket (see Figure 20). The trend is moving to more integrated software solutions

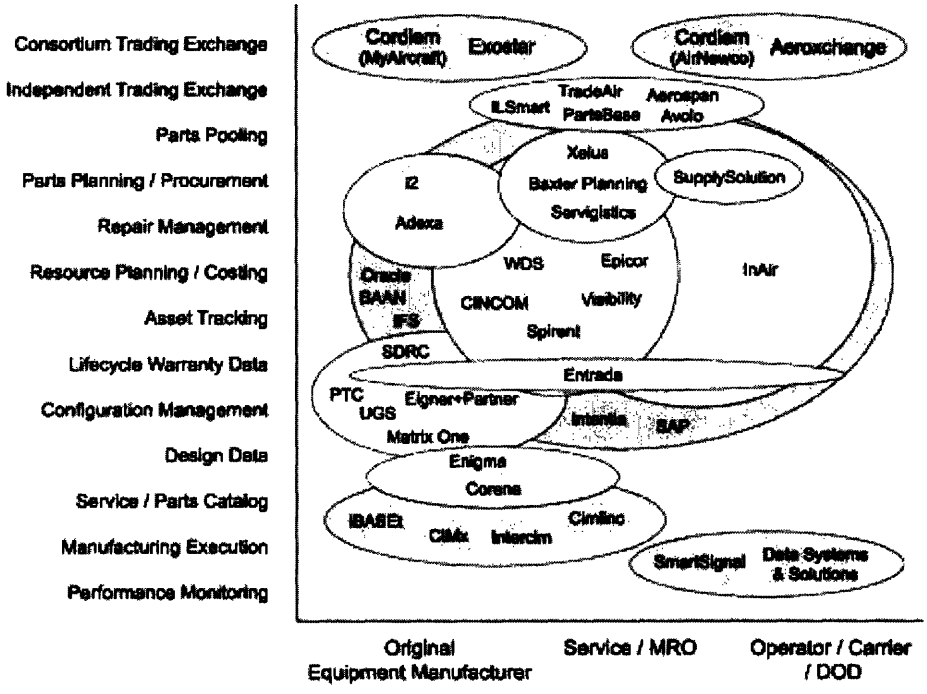

Figure 20: Application Landscape for Repair Services. Source: AMR, 2001

One of the tradeoffs that exists in the aerospace industry, more than in the previously examined industries, is the one between stocking individual parts versus stocking assemblies of parts. Since the complexity of an airplane is huge, there are many levels of subassemblies in which a part can be stocked. For example, a company could stock individual parts or a whole

[32] SAP for Aerospace and Defense in the MRO Industry, www.sap.com

engine. Through the use of software solutions and forecasting tools, each company optimizes this mix of stocked parts. (Industry Expert, Interview, 2006)

6.5 Customer Service

Customer Service in the aerospace aftermarket is a critical factor in the success of any company in the industry. Although customer service is important for all the industries that are examined is this thesis, certain characteristics of this industry increase the importance of customer service and differentiate the practices used by the service providers.

One main difference in the aerospace industry is that the customer is not the passenger, but it is the product itself, the airplane. Companies that operate the airplanes service a product they own, and at the same time OEMs service a product they sell (Industry Expert, Interview, 2006).

The criticality of the product is immense in this case. Every minute of downtime is a tremendous loss of revenues for the passenger airline. This makes service management very important (Industry Expert, Interview, 2006).

However, profit loss is not the only parameter in the aerospace industry. Another critical factor is safety. The management of service parts and the service procedure as a whole is highly regulated and monitored by organizations such as the Federal Aviation Administration (FAA) and the Joint Aviation Administration (JAA). Data about repairs are collected, parts are tracked and, in general large amounts of information are necessary. In terms of customer expectations, customers, although sometimes dissatisfied, are willing to wait for some time if safety reasons are mentioned

The trend of customer service in this industry is a move towards Performance Based Service and Service Level Agreements (SLAs). With these agreements the service provider guarantees availability of spare parts, reliability and quality of service with specific target levels. The most interesting and known agreement is "Power-by-the-Hour ©" by Rolls-Royce. The companies that choose this method of servicing pay Rolls-Royce based on the hours that the companies' engines are operational and running, with Rolls-Royce being responsible for every aspect of aftermarket services. It is up to Rolls-Royce to improve the quality of the engine and of the servicing to ensure that the product will be operational as many hours as possible (Koudal, 2006).

7 Conclusions

7.1 Comparison of practices

In the four previous chapters we analyzed the market structure and the aftermarket practices used in the Computer, Telecommunications Equipment, Automotive and Aerospace industries. Many examples of companies using innovative ideas and "best practices" were described. However, the concept of a "best practice" in each industry had unique characteristics, which cannot be applied to every case and every company across industries.

In the following pages the thesis focuses on comparing and contrasting the aftermarket practices used in the four industries, identifying underlying principles among these industries and realizing some macro-factors that have shaped and will in the future affect the four industries. The final subchapter proposes some further research steps in the same area, which this thesis did not cover mainly because of time limitations.

7.1.1 Creating a Comparison Framework

In order to proceed with the comparison of aftermarket supply chain practices in the four above mentioned industries, the creation of a comparison framework is necessary in order to be able to compare and contrast common aspects of the aftermarket supply chains of these industries. Based on the review of academic and professional literature, as well as on the opinions of the industry experts who were interviewed, a comparison framework with three

different categories was created. These three categories are Product Complexity, Criticality of Product to the Customer, and Criticality of the Aftermarket Function to the Company. Each of these categories has a variety of factors that affect them. For this comparison, in order to categorize each of the industries by each category we will use three distinct levels: Low, Medium, and High. These levels are viewed relatively to the other three industries each time.

For the category of Product Complexity, the dimensions or factors for comparison are: The Number of Parts in Each Product, the Range of Price for Service Parts, the Cost of Service Parts, the possibility of Interchangeability between Parts, the Product Lifecycle, the Dispersion of the Customer Base (whether clients are located in few areas or are spread around the globe), and the Number of Customers.

For the category of criticality of Product to the Customer the main factor that affects it is, as Cohen (2000) mentions "the cost to the customer if the product fails to function properly" or Penalty for Downtime. Another factor is the Safety vs. Wait Time dimension, which means the level of willingness that the customers show in waiting for a service part if safety aspects are involved.

For the category of Criticality of the Aftermarket Division to the Company the dimensions or factors are: Profitability of the Aftermarket Division Compared to other Divisions of the Same Company and Relative Profitability of the Aftermarket Division across Industries.

In the following subchapters similarities and differences in all these fields are identified, and conclusions are made. These comparisons are based on the findings of the application of the framework. In Table 10 we can see the results of the Comparison framework for the four industries in an organized way.

Category	Dimensions	INDUSTRIES Computer	Telecom	Automotive	Aerospace
Product Complexity	Durability	Yes	Yes	Yes	Yes
	Number of Parts	Low	Low/Medium	Medium	High
	Price Range	Low	Low	Medium	High
	Part Cost	Low	Low	Medium	High
	Interchangeability	High	Low	Medium	Medium
	Product Lifecycle	Low/Medium	Low/Medium	Medium/High	High
	Dispersion of Customers	High	Medium/High	High	High
	Number of Customers	Medium/High	Medium	High	Medium
Criticality to Customer	Penalty for Downtime	Low/Medium	Medium/High	Low/Medium	High
	Safety vs. Wait Time	Low	Low	Medium	High
Criticality of Aftermarket	Aftermarket Profitability/ General Profitability	High	High	High	High
	Relative Profitability	Low	Low	Medium/High	High

Table 10: Aftermarket Comparison Framework

7.1.2 Similarities Across Industries

The first major similarity that we encountered in this research is, of course, the fact that all industries sell durable products, and thus have aftermarket operations.

In terms of the complexity of each product, the main similarities that exist are between products in the computer and telecommunications equipment industries. As it is mentioned in Chapters 3 and 4, the telecommunications equipment and the computer industry have similar products, and in many cases similar aftermarket supply chains. The similarities exist mainly between networking equipment and servers. For example, the penalty for downtime of Servers is similar to the penalty paid for Network Equipment.

In terms of the structure of aftermarket networks, one major similarity that we notice is the dispersed and multi-tiered networks that exist in all industries, although the vast differences in product complexity among the industries. The reason for this similarity is mainly the number of customers and the dispersion of these customers around the globe for all the four industries. Also the factors calculated to allocate spare parts among stocking points in the different locations have many similarities among the industries. Slow-movers are centralized, while fast-movers are stocked locally. The increasing trend of reduction of response time is common in all industries, besides the fact that the actual response time varies and moves the stocking of parts closer to the customer.

In the area of procurement, the main similarities are in the way companies handle parts after the end-of-sale, and the offers for last-time-buy that exist in most industries. However, the differences in this area outnumber the similarities.

In the area of inventory management, the increasing trend is the extensive use of software solutions to globally optimize inventory. This similarity is mainly attributed to the technology advancement macro-factor that is analyzed in a following subchapter and has affected the supply chains of all industries. Another reason for this trend is the fact that despite the differences in product complexity the combination of all the characteristics that are mentioned in the framework makes the management of inventory a more or less complex problem for the aftermarket departments of all industries. The criticality of the product does not seem to affect inventory management or the way that parts are stocked throughout the supply chain. As it is explained above, the location and quantities of parts stocked are calculated by complex software applications based on factors such as the price of the part, the demand for the part and the dispersion of the installed base of products.

The location of parts is affected by the criticality of the product, but this location is always combined with differences in shipping methods depending on the criticality and the demand of the customer. Although fast-moving parts are located near to the customer in order to meet the customer's demands, slow-moving parts are centralized even for critical parts. The common method by which most companies in the four industries deal with a customer in need of a critical slow-moving part is by combining methods of expedited shipping (air if necessary) with the temporary replacement of the part or the whole product with a loaner, if that is possible. As we already mentioned, the main similarity in customer service among the industries is the fact that acceptable response time is decreasing. Customers seem to pay more attention to quick response and have increased concern about downtime in all industries. The attempts of the companies of all industries to respond to these increasing needs lead us to another similarity,

which is the different pricing strategies and different service levels that companies use to capture all potential customers and maximize their profits.

7.1.3 Differences Across Industries

As we can observe in Table 10, the differences in the product complexity across industries are significant. Although we can identify similarities in pairs of industries, the overall view shows a diverse mix of products that has aftermarket operations.

In the structure of aftermarket supply chain networks, the main difference among industries is what percentage of parts is stocked where. Although the general principles are the same, the actual percentage of parts centralized or localized is different in each industry, mainly because of the differences or product complexity across the four industries. Another important factor is the presence of regulations in each industry. For example, the FAA and JAA regulations in the aerospace industry allow specific maintenance operations to be conducted in specific airports, thus affecting the structure of the aftermarket supply chain.

Another difference between the aftermarkets of the four industries is the importance of reverse logistics in each industry. This factor is mainly influenced by the complexity of the product, and especially by the tradeoff between the cost for servicing versus the cost of replacing. In industries like the computer industry and the telecommunications industry, the cost of replacement is usually low and many times replacement is preferred instead of returning the product to service. Also many times, in the case of PCs, the customer returns the product to the service center and the importance of reverse parts-based logistics is generally decreasing. Another reason for this low importance of reverse logistics is that for installed items, such as telecommunications networks, the servicing has to be conducted on site, because the installed

network cannot be moved. Thus in these industries reverse logistics are mainly associated with third party companies providing recycling services.

The importance of reverse logistics increase in the automotive industry, where many times servicing is much cheaper than replacing a part, especially for expensive parts. Repairable parts are shipped to repair centers to be refurbished, and a whole network of dealers, mostly independent, providing refurbished parts exists. Also recycling is important in this industry, comprising a $25 billion market annually[33]. Repairable items also exist in the aerospace industry, but here reverse logistics is a complicated issue, since in some cases a whole aircraft needs to return to a service site. Companies like Boeing offer special services to their customers regarding the safe recovery and transport of damaged airplanes[34].

In terms of service parts procurement, the differences are many across the four industries. The main reason for this is the variety of number of parts, lifecycle, and interchangeability among the products of the four industries. The levels of supplier tiers are increased in industries where the product is more complex, such as the aerospace and the automotive industries. In those industries, three and many times four-tiered supplier networks exist, while in the computer and telecommunications equipment industries a 2-tier network is more usual.

In the area of inventory management, one difference is the amount to which trends like global optimization of parts had penetrated each industry. For example, as AMR Research (2005) mentions in the Service Parts Planning area, the optimization functionality has been implemented mainly in the High Tech and Aerospace industries, Types of agreements such as SLAs and PBLs also have different levels of penetration in the four industries. For example the

[33] http://www.autoalliance.org/archives/archive.php?id=215&cat=Recycling%20Vehicles

"Power-by-the-hour" technique is only found in the aerospace industry and in small parts of the telecom industry.

In the area of customer service, despite the general trend of the reduction of acceptable response time, there are several differences in the four industries. Important roles in these differences are played by two dimensions; the Criticality to the Customer Category as seen in Table 10, and the fact that in the aerospace mainly, but also in the automotive industry, customers are willing to wait a little longer to ensure safe traveling.

7.2 Underlying Principles Across Industries

After observing the similarities and differences in the structure of aftermarket supply chain networks and in the practices used in each of these industries, we need to understand some underlying principles that exist in companies that are considered to provide excellent aftermarket services in these four industries, but have different strategies and tactics. These underlying principles were realized with the help of the literature review and especially white papers from different companies, the interviews with the industry experts and the comparison of practices across the industries.

The first principle for a company which wishes to succeed in aftermarket logistics is the realization of the potential of the aftermarket and the incorporation of this realization into its business strategy and model. Although this realization may seem over simplistic and might be taken for granted in many occasions, it is actually one of the most important steps. As an example we can say that according to a benchmarking report from Aberdeen Group (2005) 37%

[34] www.boeing.com

of Best-in-class companies have a Senior Vice President or Higher overseeing service, while only 20% of the laggards have the same structure.

Another important principle is the alignment of customer needs and the design of the aftermarket service. Despite the differences or similarities in the four industries, companies that excel in their aftermarket operations design and operate their aftermarket supply chain in such a way that serves the needs of their customers and the specific needs of the industry. Supply chain network structure, customer service and inventory management are designed and operated in such a way to provide almost total parts availability, quick response and minimization of downtime, and anything else that might make the customer happy.

The third underlying principle is the alignment of service and profitability. Companies that have excellent aftermarket supply chains are also usually the most profitable ones. Different pricing strategies for different types of customers in order to maximize profit and satisfy customers at the same time is a typical principle found in the servicing strategies of such companies.

Finally, the companies that excel in the aftermarket are usually innovative companies. Companies that are on the edge of technology, that use modern IT systems for all their supply chain functions usually also use the most innovative software solutions for service parts management, a necessary factor for a company's success in the area.

7.3 Macro-factors

All across the four industries products, supply chains and especially the aftermarket sector have been affected in the last 10-15 years by different macro-factors, which have shaped

the structure of the market, their supply chains and their aftermarket operations. Some of these macro-factors can potentially influence the future of these supply chains and of Aftermarket Logistics in general in the years to come.

The major macro-factor that has changed the whole face of all these four industries is undoubtedly the technological advancements. Two decades ago these four industries were completely different. The products have changed not only in shape or design, but in their core characteristics. The computer and telecommunications equipment industries were almost non existent, whereas automotive and aerospace had products that were less safe, less environmentally friendly and cost more.

Developments in design, and the collaboration between different divisions of companies such as the sales, design, supply chain, and service divisions has led to better design of products to serve all the needs of the companies. The standardization of parts, especially between products of the same company, but also the use of standardized parts by OEMs (for example, Intel's Central Processing Units – CPUs for computers) is a factor very important for the future of the four industries under examination. This standardization of parts is affecting and will continue to affect the profitability of companies, since it helps them improve their supply chains, simplify their production, and increase the resilience of their company as a whole. Unstable demand is handled easier since production is easier to shift between products of the same company. Of course, this factor also affects the aftermarket operations, since fewer parts are needed for servicing, and since companies use the same parts for many of their products, parts can be stocked more locally, leading to increased fill rates and better quality of service in general.

In all the industries the supply chains were dominated by old practices, where the use of rules of thumb or practices that were adopted decades ago were dominant. As for the aftermarket division of these industries, in the best case scenario some profit was made without serious efforts to improve.

The advancement of technology in general, and especially the development of the computer, transformed the markets, the supply chains and the aftermarket divisions. More products were introduced, and volumes in the computer and telecommunications equipment industry increased exponentially. Although this added complexity to supply chain management practices, the advantages of technology by far surpassed the disadvantages. Communication became easier and delays in communications were eliminated. Sophisticated software replaced rules of thumb and old procedures in inventory management. The revolution that the Internet brought to communications simplified procurement procedures and customer support. In general, aftermarket logistics and supply chain management in general entered a new era.

Another macro-factor that influences the structure of markets from time to time is the price of fuel. The increasing price of oil in the last years is generating speculations over the future structure of supply chains. Rises in fuel prices are forcing the automotive and aerospace industries to design more fuel efficient, environmental friendly vehicles. Especially in the automotive industry, demand is shifting towards smaller, less fuel consuming cars.

In case of a continuous increase in the price of oil, the possibility of change in the structure of supply chain networks is there. Since transportation costs will rise, the tradeoff between inventory pooling and the cost of transport might change, and shift the stocking of

inventory closer to the end user to lower total costs. This scenario applies to the aftermarket divisions of all industries, as well as to the traditional forward logistics supply chains.

Finally, a macro-factor that has already started to affect industries in a variety of ways is the general issue of the destruction of the environment. The worrying effects of the destruction of the environment have increased public concern over environmental issues, and governments have started taking action in different ways. Starting from the European Union and continuing to the US, in states like California, a series of laws known as "Green Laws" have started to dictate ways in which products are designed and handled to be more environmental friendly. Car manufacturers are forced to reduce car emissions, and be responsible for recycling products. Similar laws are forcing aerospace manufacturers to reduce emissions and noise, and computer manufacturers to recycle products. Without doubt, the environmental issues are affecting all the industries under examination, and will continue to affect them in the future.

7.4 Recommendations for further research

The time restrictions of this project, as well as the necessity for this research to comply with the general research of the SC2020 project has forced some limitations on this thesis. However based on the work and the analysis of this work, I would recommend two areas for research by future researchers.

The first area where more research in the future would be meaningful is the research of aftermarket supply chain practices in specific segments of these four industries. For example, the highly regulated and highly influenced by politics area of the Defense Aerospace Industry is an area which this thesis does not cover and which future research could provide interesting results.

A second segment of the aerospace industry which is very interesting and challenging for any researcher is the space industry, and especially its aftermarket. The space aftermarket is an area which has not yet been, to my knowledge, analyzed in terms or practices used and aftermarket structure. The unique characteristics of spaceships and spaceship spare parts are creating a unique aftermarket. The complexity of the product is immense, the installed base of products is minimum (maybe even one spaceship) the parts must be located on board the product, the crew must be trained to provide service, the price range is vast and of course the criticality is the highest possible, since a malfunction while on a mission could lead to fatal incidents, loss of billions of dollars, and setbacks in scientific research that could take years to overcome. All these characteristics show that the research of the space aftermarket could be both interesting and challenging.

The second area where future research could find interesting topics is in the combination of this research with a Systems Dynamics application or model. System Dynamics, a modeling methodology and tool created by Jay W. Forrester at the Massachusetts Institute of Technology, could be used to model the structure of the aftermarket in various industries. Combining the findings of the SC2020 project with the work of the System Dynamics Group at MIT would be a very interesting topic for future research.

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A Appendix A: Server Companies' Market Shares Categorized by Server Size

Table 11: Market Shares for Volume Servers

WORLDWIDE VOLUME SERVER MARKET SHARE

(Based on factory shipments, in millions of dollars)

	REVENUES			MARKET SHARE (%)	
	2003	2004	% CHG.	2003	2004
Hewlett-Packard	6,405	7,469	16.6	32.1	31.9
Dell	4,135	4,727	14.3	20.7	20.2
IBM	3,260	4,056	24.4	16.4	17.3
Sun Microsystems	1,554	2,068	33.1	7.8	8.8
Fujitsu Siemens	579	605	4.5	2.9	2.6
NEC	362	408	12.7	1.8	1.7
Fujitsu	370	387	4.6	1.9	1.7
Acer	167	169	1.2	0.8	0.7
Apple	67	165	146.3	0.3	0.7
Hitachi Ltd.	143	155	8.4	0.7	0.7
Rackable Systems	24	115	379.2	0.1	0.5
Toshiba	100	94	(6.0)	0.5	0.4
Lenovo	52	61	17.3	0.3	0.3
Groupe Bull	50	58	16.0	0.3	0.2
Maxdata	47	52	10.6	0.2	0.2
Other	2,623	2,850	8.7	13.2	12.2
Total	19,937	23,440	17.6	100.0	100.0

Note: Totals may not add due to rounding.
Source: IDC

Table 12 Market Shares for Midrange Servers

WORLDWIDE MIDRANGE SERVER MARKET SHARE

(Based on factory shipments, in millions of dollars)

	REVENUES			MARKET SHARE (%)	
	2003	2004	% CHG.	2003	2004
IBM	5,176	5,111	(1.2)	37.6	40.6
Hewlett-Packard	4,048	3,580	(11.6)	29.4	28.4
Sun Microsystems	2,770	2,171	(21.6)	20.1	17.2
Fujitsu	554	657	18.6	4.0	5.2
Unisys	228	235	3.1	1.7	1.9
Fujitsu/Fujitsu Siemens	201	204	1.5	1.5	1.6
Groupe Bull	149	150	0.7	1.1	1.2
NEC	167	113	(32.3)	1.2	0.9
SGI	137	106	(22.6)	1.0	0.8
Hitachi Ltd.	110	85	(22.7)	0.8	0.7
Stratus Computer	70	78	11.4	0.5	0.6
Mitsubishi	35	42	20.0	0.3	0.3
NCR	29	30	3.4	0.2	0.2
NEC	19	8	(57.9)	0.1	0.1
Dell	37	7	(81.1)	0.3	0.1
Other	20	17	(15.0)	0.1	0.1
Total	13,749	12,594	(8.4)	100.0	100.0

Note: Totals may not add due to rounding.
Source: IDC

Table 13: Market Shares for High End Servers

HIGH-END SERVER REVENUES

(Based on factory shipments, in millions of dollars)

	REVENUES			MARKET SHARE (%)	
	2003	2004	% CHG.	2003	2004
IBM	6,359	6,968	9.6	51.1	55.2
Hewlett-Packard	2,043	1,906	(6.7)	16.4	15.1
Sun Microsystems	1,045	929	(11.1)	8.4	7.4
Fujitsu	677	595	(12.1)	5.4	4.7
Fujitsu Siemens	442	423	(4.3)	3.6	3.4
NEC	346	423	22.3	2.8	3.4
Hitachi Ltd.	555	417	(24.9)	4.5	3.3
Unisys	333	358	7.5	2.7	2.8
NCR	172	241	40.1	1.4	1.9
SGI	99	173	74.7	0.8	1.4
Groupe Bull	174	115	(33.9)	1.4	0.9
Cray Inc.	91	40	(56.0)	0.7	0.3
NEC	95	26	(72.6)	0.8	0.2
Stratus Computer	10	12	20.0	0.1	0.1
Total	12,439	12,626	1.5	100.0	100.0

Note: Totals may not add due to rounding.
Source: IDC

B Appendix B: Dell's Aftermarket Services

Source: Shaunak Roy, 2005

Dell's Return to Depot (After market) Operation

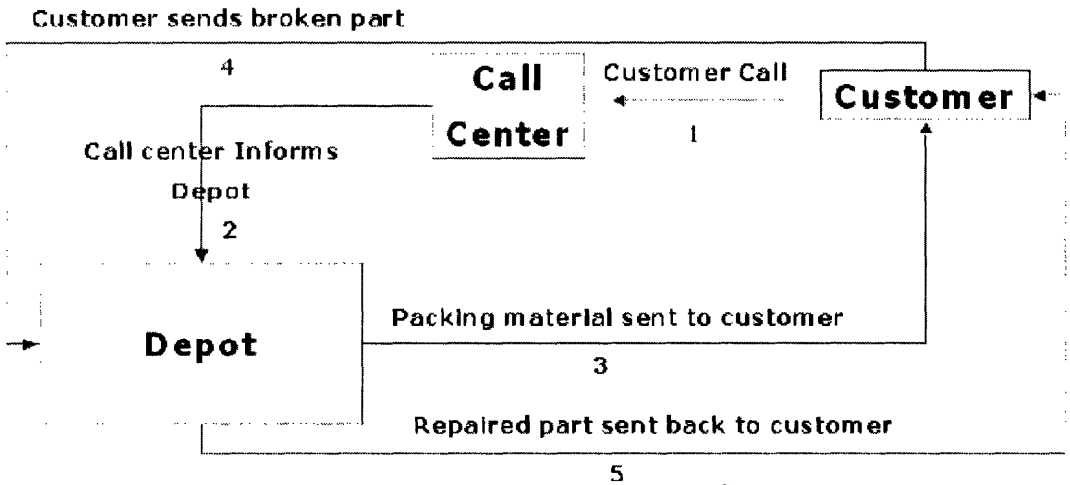

Figure 21: Dell's Return to Depot Operation

Process flow for return to depot operation is as follows (Roy, 2005)

A. Customer calls the call center

B. Call is processed, validity checked, and information is sent to the depot

C. Depot dispatches the packing material the next day to the customer

D. Customer packs a broken part into the pack and sends back to the Depot

E. Depot gets the defective part in the morning, repairs it during the day and ships it out back to the customer by night

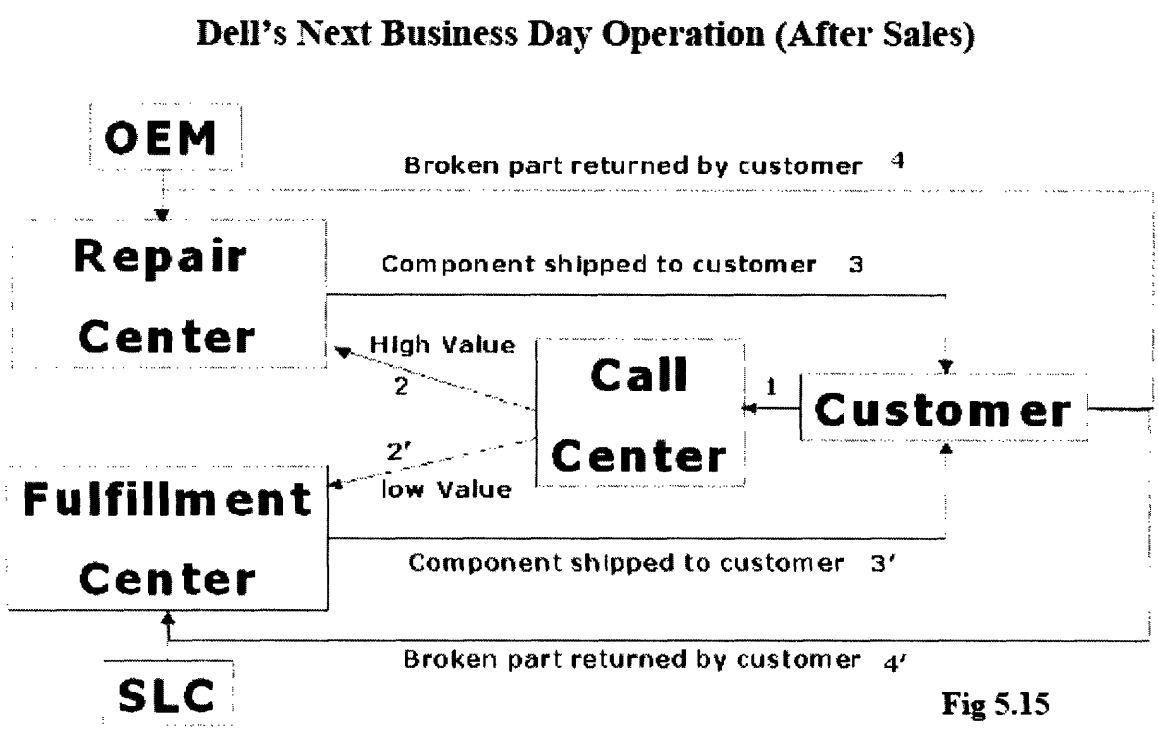

Figure 22: Dell's Next Business Day Operation

The process flow for next business day operation is as follows (Roy, 2005)
A. Customer calls up the call center to report hardware issues.

B. The tech support team analyzes the problem and arranges a time and date for repair.

C. The information is then sent to the fulfillment center that manages both the service parts and the field technician teams.

D. If the customer places his/her complaint by 5:00 PM local time, the replacement part is shipped for the next day delivery from the fulfillment center. There is a standard metric that measures what percent of orders that were shipped by the next day. In case there is any delay, there are metrics that measure if the delay was because of a fulfillment /warehouse issue.

E. If it is a customer replaceable unit (50% cases), then the material is shipped directly to the customer. Otherwise, it is shipped to the field technician. The field technician either picks up the material from the airport or gets it shipped directly to him/her.

F. The field technician visits the customer site if onsite help is required and then returns the defective part to the fulfillment center. For customer replaceable parts, which represent nearly 50% of the cases, the customer himself/herself has to return the broken part.

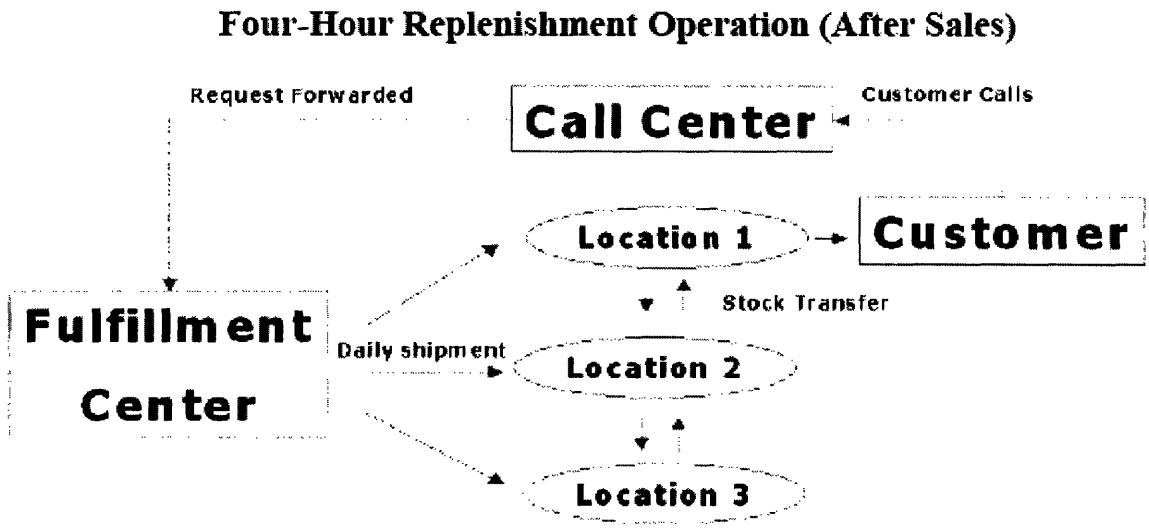

Figure 23: Dell's Four Hour Replacement Operation

Process flow for the four-hour replacement operation is as follows (Roy, 2005):

A. Customer eligible for 'four-hour service' calls up and reports problem at the call center

B. The availability of the required part is checked at the closest 'four-hour stock location'. If stock not available, the closest stocking location is searched where inventory is available

C. The component is shipped from the stocking location directly to the customer. A Dell representative also attends the customer if required.

D. The enterprise command center monitors the movement of these parts / stock outs etc on a real time basis. Inventory is shipped from the central fulfillment center as well as among the various stocking locations based on requirements.

C Appendix C: Cisco's Acquisitions 1993-2006

•SyPixx Networks (April 2006, video surveillance networking)
•Scientific–Atlanta (February 2006, set–top boxes)
• Intellishield Alert Manager assets (November 2005, network security service)
• Digital Fairway (November 2005, IP telephony provisioning)
• Nemo Systems (October 2005, network memory chip development)
• Sheer Networks (September 2005, network service management software)
• Kiss Technology (September 2005, consumer electronics for home networks)
• NetSift (July 2005, packet processing)
• M. I. Secure (June 2005, virtual private network security)
• FineGround Networks (June 2005, application acceleration appliances)
• Vihana (May 2005, semiconductor design)
• Sipura Technology (May 2005, consumer VoIP equipment)
• Topspin Communications (May 2005, server switches)
• Airespace (March 2005, wireless networking equipment)
• BCN Systems (December 2004, network routing software)
• Jahi Networks (December 2004, network management appliances)
• NetSolve (December 2004, remote network monitoring)
• Perfigo (December 2004, network access control)
• dynamicsoft (October 2004, IP networking protocol)
• P–Cube (October 2004, network monitoring software)
• Parc Technologies (August 2004, routing optimization software)
• Actona Technologies (August 2004, file service software)
• Procket Networks (August 2004, routers)
• Riverhead Networks (April 2004, network security)
• Twingo Systems (April 2004, virtual private network security)
• Andiamo Systems (February 2004, storage networking switches)
• Latitude Communications (January 2004, conferencing systems)
• Linksys (June 2003, consumer networking equipment)
• SignalWorks (May 2003, IP telephony software)
• Okena (April 2003, network security software)
• Psionic Software (December 2002, network intrusion detection)
• AYR Networks (October 2002, networking service and routing software)
• Navarro Networks (June 2002, ASIC components)
• Hammerhead Networks (June 2002, service delivery software)
• Allegro Systems Inc. (September 2001, virtual private network acceleration)
• AuroraNetics (August 2001, chips for fiber–optic routing)
• ExiO Communications (February 2001, wireless telephony)
• Radiata (February 2001, chipsets for wireless networks)
• Active Voice (February 2001, Internet Protocol–based messaging)
• CAIS Software Solutions (December 2000, Internet service management software)
• PixStream (December 2000, digital media management systems)
• Vovida Networks (November 2000, voice over Internet Protocol software)
• IPCell Technologies (November 2000, voice and data access integration software)
• IPmobile (September 2000, wireless networking software)
• NuSpeed Internet Systems (September 2000, storage–area network/Internet Protocol integration)
• Komodo Technology (September 2000, voice over Internet Protocol devices)
• Netiverse (September 2000, content acceleration technology)
• HyNEX (September 2000, asynchronous transfer mode access devices)
• Qeyton Systems (June 2000, optical networking)
• ArrowPoint Communications (June 2000, content networking technology)
• Seagull (July 2000, silicon for terabit routers)
• PentaCom (June 2000, metro Internet Protocol networks)
• infoGear Technology (June 2000, information appliance software)
• SightPath (May 2000, content delivery networks)
• JetCell (May 2000, wireless telephony)

- Atlantech Technologies (May 2000, network element management software)
- Aironet Wireless Communications (March 2000, wireless local–area network products)
- Growth Networks (March 2000, Internet switching fabrics)
- Altiga Networks (March 2000, virtual private networks)
- Compatible Systems (March 2000, virtual private networks)
- Pirelli Optical Systems (February 2000, optical networking)
- Internet Engineering Group (January 2000, optical networking software)
- Worldwide Data Systems (January 2000, consulting and engineering services)
- V–Bits (December 1999, digital video processing systems)
- Tasmania Network Systems (November 1999, network caching software)
- WebLine Communications (November 1999, customer interaction software)
- Cerent (November 1999, optical networking)
- Calista (November 1999, Internet Protocol telephony)
- Cocom A/S (October 1999, cable modems)
- Monterey Networks (October 1999, optical networking)
- MaxComm Technologies (September 1999, digital subscriber line technology)
- StratumOne Communications (September 1999, optical networking semiconductors)
- TransMedia Communications (September 1999, media gateway technology)
- Amteva Technologies (June 1999, Internet Protocol–based communications software)
- GeoTel Communications (June 1999, call routing software)
- Sentient Networks (June 1999, circuit emulation)
- Fibex Systems (June 1999, integrated access digital loop carrier)
- PipeLinks (March 1999, routers)
- Selsius Systems (November 1998, Internet Protocol telephony)
- Clarity Wireless (November 1998, wireless networking)
- Summa Four (November 1998, programmable switches)
- American Internet (October 1998, Internet Protocol address management software)
- CLASS Data Systems (June 1998, policy–based networking)
- WheelGroup (May 1998, network security)
- Precept Software (April 1998, Internet Protocol networking software)
- NetSpeed (April 1998, digital subscriber line products)
- LightSpeed International (February 1998, signaling controllers)
- Dagaz (Integrated Network Corporation) (September 1997, digital subscriber line multiplexers)
- Ardent Communications (August 1997, combined communication support)
- Global Internet Software Group (August 1997, firewalls)
- SkyStone Systems (August 1997, optical networking)
- Telesend (August 1997, network access)
- Metaplex (December 1996, enterprise networking migration)
- Netsys Technologies (November 1996, network infrastructure analysis software)
- Telebit's MICA Technologies (October 1996, access servers)
- Granite Systems (September 1996, Ethernet switching)
- Nashoba Networks (September 1996, token ring switching)
- Stratacom (July 1996, wide–area network switching)
- TGV Software (March 1996, enterprise networking software)
- Internet Junction (February 1996, Internet gateway software)
- Network Translation (December 1995, network address translation and firewalls)
- Grand Junction Networks (November 1995, Ethernet switching)
- Combinet (October 1995, remote access networking)
- LightStream (January 1995, asynchronous transfer mode switching)
- Kalpana (December 1994, local–area network switching)
- Newport Systems Solutions (August 1994, routing software)
- Crescendo Communications (September 1993, local–area network networking)

Source: ***Hoover's Online Database***
Custom Report Builder
Cisco Systems Inc., 2006

D Appendix D: US New Light Vehicle Market Shares

MARKET SHARES OF US DEALER NEW LIGHT VEHICLE SALES
(Calendar year)

	THOUSANDS OF UNITS				% OF TOTAL			
	2001	2002	2003	2004	2001	2002	2003	2004
PASSENGER CARS								
US MANUFACTURERS								
General Motors Corp.	2,272.5	2,099.2	1,958.6	1,875.6	27.0	25.5	25.7	25.0
Chevrolet	830.0	746.6	709.5	909.2	9.9	9.2	10.5	12.1
Pontiac	458.7	441.2	408.7	420.0	5.4	5.4	5.4	5.6
Oldsmobile	173.7	118.2	103.1	20.4	2.1	1.5	1.4	0.3
Buick	373.9	370.5	259.3	223.3	4.4	4.6	3.4	3.0
Cadillac	140.3	150.1	151.3	141.9	1.7	1.9	2.0	1.9
Saturn	260.3	204.8	189.2	123.5	3.1	2.5	2.5	1.6
Saab	37.6	37.9	47.9	38.2	0.4	0.5	0.6	0.5
Ford Motor Co.	1,485.2	1,325.7	1,169.4	1,018.3	17.6	16.4	15.4	13.6
Ford Division	978.1	894.9	782.3	684.8	11.6	10.7	10.4	9.1
Lincoln-Mercury	371.2	313.1	240.6	204.0	4.4	3.9	3.2	2.7
Jaguar	44.5	61.2	54.7	45.9	0.5	0.8	0.7	0.6
Volvo	101.4	86.5	81.7	83.8	1.2	1.1	1.1	1.1
DaimlerChrysler Corp.*	558.0	527.1	456.7	474.1	6.6	6.5	6.0	6.3
Chrysler/Plymouth/Jeep/Eagle	229.0	178.8	158.1	252.2	2.7	2.2	2.1	3.4
Dodge	329.1	348.2	298.6	221.9	3.9	4.3	3.9	3.0
Total, Big Three	4,325.7	3,922.0	3,585.1	3,368.0	51.4	48.4	47.1	44.9
JAPANESE MANUFACTURERS	2,819.3	2,879.4	2,785.8	2,946.7	33.5	35.5	36.6	39.3
Honda Motor	899.9	838.6	820.1	843.3	10.7	10.3	10.8	11.2
Mazda	168.0	158.6	163.7	187.7	2.0	2.0	2.2	2.5
Mitsubishi	236.5	259.7	161.5	108.8	2.8	3.2	2.1	1.5
Nissan	414.6	490.7	505.4	536.8	4.9	6.1	6.6	7.2
Subaru	130.9	123.6	116.4	121.7	1.6	1.5	1.5	1.6
Suzuki	15.6	22.5	22.5	47.1	0.2	0.3	0.3	0.6
Toyota	955.7	985.8	996.0	1,101.2	11.3	12.2	13.1	14.7
OTHER FOREIGN MANUFACTURERS	1,277.8	1,301.9	1,239.7	1,191.3	15.2	16.1	16.3	15.9
BMW	172.5	213.9	236.2	226.3	2.0	2.6	3.1	3.0
Hyundai	290.2	296.8	298.9	300.1	3.4	3.7	3.9	4.0
Kia	156.3	150.4	140.4	155.9	1.9	1.9	1.8	2.1
Mercedes	160.3	170.4	186.8	194.1	1.9	2.1	2.5	2.6
Volkswagen	427.0	411.2	362.1	301.5	5.1	5.1	4.8	4.0
Others	71.3	59.2	15.5	13.4	0.8	0.7	0.2	0.2
Total domestic-built	6,325.0	5,877.6	5,527.4	5,358.9	75.1	72.5	72.6	71.4
Total imported	2,097.6	2,225.6	2,083.1	2,149.1	24.9	27.5	27.4	28.6
Total car sales	8,422.6	8,103.2	7,610.5	7,505.9	100.0	100.0	100.0	100.0
LIGHT TRUCKS								
US MANUFACTURERS								
General Motors Corp.	2,580.1	2,746.0	2,757.0	2,781.9	29.7	31.5	30.5	29.7
Chevrolet	1,843.8	1,883.1	1,843.4	1,839.8	21.2	21.6	20.4	19.7
GMC/Pontiac	611.5	619.7	631.3	637.2	7.0	7.1	7.0	6.8
Saturn	0.4	75.5	81.9	88.5	0.0	0.9	0.9	0.9
Other divisions	124.4	167.8	200.3	216.4	1.4	1.9	2.2	2.3
Ford Motor Co.	2,420.7	2,251.2	2,267.8	2,252.8	27.8	25.8	25.1	24.1
DaimlerChrysler Corp.*	1,715.2	1,678.4	1,670.8	1,731.8	19.7	19.3	18.5	18.5
Chrysler/Plymouth/Jeep	788.5	761.8	748.1	763.9	9.1	8.7	8.3	8.2
Dodge	926.7	916.6	924.7	968.0	10.7	10.5	10.2	10.3
Total, Big Three	6,715.9	6,675.6	6,695.6	6,766.5	77.2	76.6	74.2	72.3
FOREIGN MANUFACTURERS	1,983.8	2,037.5	2,333.0	2,594.1	22.8	23.4	25.8	27.7
Honda	387.8	409.2	529.7	551.1	3.5	4.7	5.9	5.9
Hyundai	68.0	78.3	101.3	118.5	0.8	0.9	1.1	1.3
Isuzu	84.1	57.5	34.8	31.9	1.0	0.7	0.4	0.3
Kia	67.4	87.0	97.0	114.1	0.8	1.0	1.1	1.2
Mazda	103.6	99.7	95.2	78.2	1.2	1.1	1.1	0.8
Mitsubishi	87.2	86.3	96.0	53.3	1.0	1.0	1.1	0.6
Nissan	289.0	249.2	288.4	448.5	3.3	2.9	3.2	4.8
Subaru	55.0	58.4	70.5	65.7	0.6	0.6	0.8	0.7
Suzuki	40.1	45.4	35.9	28.8	0.5	0.5	0.4	0.3
Toyota	785.5	770.3	870.3	958.8	9.0	8.9	9.6	10.2
Others	99.0	98.4	113.0	147.9	1.1	1.1	1.3	1.6
Total domestic-built	7,718.5	7,646.8	7,801.4	7,801.6	88.7	87.8	86.4	83.3
Total imported	981.3	1,066.4	1,227.2	1,227.1	11.3	12.2	13.6	13.1
Total light truck sales	8,699.7	8,713.0	9,028.6	9,360.6	100.0	100.0	100.0	100.0
Total domestic-built cars & trucks	14,043.5	13,524.4	13,328.8	13,158.5	82.0	80.4	80.1	78.6
Total imported cars & trucks	3,078.9	3,292.0	3,310.2	3,376.2	18.0	19.6	19.9	20.4
TOTAL MOTOR VEHICLE SALES	17,122.4	16,816.4	16,639.1	16,534.7	100.0	100.0	100.0	100.0

Note: Totals may not add due to rounding. *Chrysler division only of DaimlerChrysler.
Source: *Ward's Automotive Reports.*

Table 14: US Light Vehicle Market Shares.
Source: Standard and Poor's, Ward's Automotive Reports