The Dynamics of Supply Chains in the Automotive Industry

by

Niklas Braese

B.S., Information Sciences and Technology (2003)
The Pennsylvania State University

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 2005

Signature of Author .....
Engineering Systems Division
May 6, 2005

Certified by .....
Dr. Lawrence Lapide
Research Director, MIT Center for Transportation and Logistics
Thesis Supervisor

Accepted by .....
Yossi Sheffi
Professor of Civil and Environmental Engineering
Professor of Engineering Systems
Director, MIT Center for Transportation and Logistics

The Dynamics of Supply Chains in the Automotive Industry

by

Niklas Braese

Submitted to the Engineering Systems Division
on May 6, 2005 in Partial Fulfillment of the
Requirements for the Degree of Master of Engineering in
Logistics

Abstract

This thesis looks at how supply chains in the automotive industry operate from the perspective of the manufacturers. The study includes the industry structure, the top players in the industry, factors that drive the industry, and supply chain challenges for companies in the industry. It was found that consideration to the just-in-time production system takes precedence in business decisions, and the build-to-order model still needs work in terms of lead time reductions. The thesis includes a case study of General Motors and how key business processes support one of their supply chains.

Thesis Supervisor: Dr. Lawrence Lapide
Title: Research Director, MIT Center for Transportation and Logistics

Acknowledgements

First of all I would like to thank my contacts at General Motors for all the effort they put in for the interviews, as well as reviewing the information that I collected. They provided the bulk of my research, and it would not have been possible without them. I would also like to thank CSC Consulting, i2 Technologies, and UPS Consulting for taking an hour of their time to provide insights on the state of the industry and to direct me to further research. Finally I would like to thank my thesis advisor and the executive director of the MLOG program at MIT for being involved with their students, and my friends and family for supporting me throughout my research.

Table of Contents

Abstract **2**

Acknowledgements **3**

Table of Contents **4**

List of Tables **5**

List of Figures **5**

1 Introduction **6**
1.1 Motivation 7
1.2 Approach 8

2 Literature Review **9**

3 The Automotive Industry **13**
3.1 Industry Structure 13
3.2 Consumer Segments and Sales Channels 18
3.3 Top 5 Players 20
3.4 Industry Drivers 21
3.5 Industry Responses 26
3.6 Supply Chain Challenges 29

4 General Motors' Position in the Industry **33**
4.1 GM's Recent Strategic Choices 33
4.2 Historical company revenues, net incomes, and employees 35
4.3 Business Units and their Products and Services 36
4.4 Sales Channels 39
4.5 GM's position relative to their top competitors over time 39

5 General Motors' 360 Platform Supply Chain **40**
5.1 The Supply Chain for the 360 Platform 40
5.2 Order Management 41
5.3 Supply-Side Business Processes 42
5.4 Inbound Transportation 48
5.5 Inside Business Processes 48
5.6 Outbound Transportation 50
5.7 Customer-Side Business Processes 51
5.8 Accessories 52

6 The Supply Chain Framework for the 360 Platform **54**
6.1 Business Strategy, Operating Models, and Operational Objectives 55
6.2 Tailored Business Processes 57
6.3 Tying it all together 60

Bibliography **63**

List of Tables

Table 1 Light Vehicle Production by Region 12
Table 2 U.S. Sales by Vehicle Type in 2003 15
Table 3 U.S. Aftermarket 18
Table 4 Global Light Vehicle Sales in 2003 20
Table 5 Model Proliferation 24
Table 6 Examples of Platform Sharing in 1999 28
Table 7 List of GM Acquisitions, Joint-ventures, and Expansions 34
Table 8 List of GM Divestitures 34
Table 9 Market Share By Region 38

List of Figures

Figure 1 Industry Supply Chain Structure 14
Figure 2 U.S. Passenger Car vs. Light Truck Sales 16
Figure 3 Share of Total Dealership Sales Dollars 17
Figure 4 Sample Customer Segmentation 19
Figure 5 Total Company Revenue Growth for the Top 5 Players 21
Figure 6 Vehicles Sold Entirely over the Internet in 2003 25
Figure 7 GM Total Company Revenues from 1994 to 2003 35
Figure 8 GM Total Company Net Income from 1994 to 2003 35
Figure 9 GM Total Company Employees from 1994 to 2003 36
Figure 10 GM Net Income by Business Unit 37
Figure 11 GM Revenues by Business Unit 37
Figure 12 Supply Chain for the 360 Platform 41
Figure 13 Order Management 42
Figure 14 Accessories Supply Chain 52
Figure 15 Strategic Framework 54
Figure 16 GM's Framework 55
Figure 17 Illustrative Operational Objectives 56

1 Introduction

This thesis analyzes supply chains in the automotive industry and determines trends, strategies, and best practices that companies have adopted over recent years due to a changing business environment. This environment entails changing government regulations, the entrance of new competitors, and other factors both within and beyond the control of the competing companies. Further, the thesis assesses the whole spectrum of supply chains, from raw materials to dealerships, but focuses on the automotive assembly manufacturers. This is the point in the supply chain where the most coordination is required in order to handle the complex coming together of hundreds of suppliers and thousands of parts at just the right time for vehicle assembly.

This thesis starts by discussing supply chains on an industry level. It clarifies the general structure, names and discusses the top competitors in the field, identifies factors that drive strategic choices, and determines the responses companies have taken to deal with those factors. Finally it lists some of the challenges that companies are facing in regard to their supply chains.

The next section covers how General Motors positions itself in the industry, pointing out the highlights of strategic choices that GM has made in recent years, analyzing its performance based on revenues, net incomes, and employee levels, and providing a description of the company structure in terms of its business units. Lastly it covers sales channels and how General Motors has fared against its competitors since 1998.

The last part of the thesis takes a look at General Motors' supply chain for the 360 platform, which is used to make Trailblazers, extended Trailblazers, and Trailblazers with sunroofs for the 1500, 2500, and 3500 weight classes. It describes the supply-side, inside, and customer-side business processes, and the framework and structure of the supply chain. It ends by showing how the industry level strategies and operating models fit with the priorities of the supply chain for the 360 platform.

1.1 Motivation

The motivation for the thesis stems from the Supply Chain 2020 initiative, one of the current research efforts by the Center for Transportation and Logistics at the Massachusetts Institute of Technology.

The premise of this initiative is that corporations generally have short-term plans for adapting their current supply chains to fit their needs, while few corporations, if any at all, are able to develop long-term plans, for the next fifteen years. There are two phases in the Supply Chain 2020 initiative. The first phase entails researching different industries and companies to identify and understand their supply chains and the best practices, strategies, and external forces that drive them. The second phase builds on this information by analyzing the data, hypothesizing on future best practices, strategies, and external forces, and then modeling and simulating the structures of supply chains in the year 2020.

This thesis is involved with the first phase of the Supply Chain 2020 initiative. The purpose is to determine the key aspects of supply chains in the automotive manufacturing industry so as to provide the relevant and necessary information for phase two of Supply Chain 2020.

1.2 Approach

This thesis looks at two levels of information, the industry and a specific supply chain. The industry level analysis identifies the general characteristics of supply chains, the competitive landscape, and evolving trends. The case study on General Motors gives an example of an actual supply chain, and the operations and business processes needed to support it. Finally it ties the research together by illustrating how the strategies and operating models of the industry level analysis apply to the General Motors case study.

The relevant literature about the automotive industry and interviews provide the industry data required for this research. The literature provides background information about the structure of supply chains in the industry, factors that influence supply chains, and strategies that the players in the industry have developed to stay competitive. The interviews fall into two categories, industry expert interviews and interviews with General Motors managers for a case study.

The industry expert interviews were with UPS Supply Chain Consulting, CSC Consulting, and i2 Technologies. They give first-hand insights on current views and trends in the automotive industry. The interviews were with General Motors experts and provided details about their supply chain for the 360 platform, as well as the supply-side, customer-side, and inside business processes.

2 Literature Review

Historically supply chains in the automotive industry have undergone three phases over the last century. The era of craftsmanship production roughly began in the end of the 19th century. Production at this point required highly skilled workers and a lot of time. Automakers generally had many suppliers, and coordination across the supply chain was poor. The problem with this system was that few cars could be produced by any one automaker, and vehicles tended to be quite expensive (Womack, Jones, & Roos, 1990).

Shortly afterwards, in the early 20th century, the concept of mass-production was developed by Henry Ford. His original idea was to make all of the parts in his cars interchangeable and easy to assemble. Next mass-production strove for shorter vehicle manufacturing times. One of the most noted inventions for this is the assembly line, which minimized the amount of time workers would have to waste by walking between stations. The result of mass-production was that manufacturers wanted to build as many cars as possible, and defects had to be dealt with in a separate rework area. To keep the line going at all times required high inventory levels, many workers, and a lot of rework (Womack et al., 1990).

Lean production came about in the mid 20th century, largely from practices developed at Toyota, and other automakers today have adopted the concept to varying degrees. It is about teamwork within the manufacturing plant, coordination along the supply chain, and the elimination of waste in the pursuit of perfection. Teamwork in the manufacturing plant is essential because it allows workers to get a better insight as to the whole assembly process, gives

them the opportunity to learn a greater variety of skills, and allows them to contribute to make product development more effective. Additionally, if any defects are found or a worker has a problem, the rest of the team can help to fix the problem. Coordination along the supply chain is necessary in order to reduce inventory levels using a Just-In-Time (JIT) system. This is true for both suppliers and customers, because in lean production the supply chain shifts to a pull from a push system. The elimination of waste is what gives lean producers the continuous ability to improve. Less defects mean less rework. Lower inventory levels mean less invested capital and greater flexibility in the case of disruptions such as receiving a load of defective parts (Womack et al., 1990).

One of the current trends in the automotive industry is the move to more modular production. In context to the automotive industry, this means building larger subassemblies of the vehicles before the assembly stage. Two examples of this are 1st tier suppliers building an entire instrument panel or vehicle interior. Modularity has three levels, modularity in design, modularity in manufacturing, and modularity in organization (Camuffo, 2000). While this change is likely to reduce costs and improve flexibility, there are also other implications that need to be considered with the introduction of modularity.

Modularity in design is about developing a system that is composed of a set of sub-systems, or modules. Each of these modules is independent from each other. This requires that each module have an interface that can directly work with other modules. Also, there has to be an evaluative system to assess the design specifications of the module and to determine product flaws (Camuffo, 2000).

Modularity in manufacturing entails developing methods to simplify production and assembly processes. This can be done by creating teams that work on sets of tasks independently

of one another. This includes testing and sub-assembly of modules, and outsourcing some of the design and assembly tasks to suppliers (Camuffo, 2000).

Finally, modularity in organization is about flexibility. The key here is to be able to adjust machinery in a timely and cost effective manner to change production output to accommodate changing consumer demands. This requires careful planning and standardization of layout, equipment, and technology. Essentially, each assembly team within a manufacturing plant is an "organizational module" which develops a single module. Ideally, this makes it easier to spread organizational structure across all of the manufacturing plants within an organization (Camuffo, 2000).

The introduction of modularity into the automotive industry is forcing a change in the supply chain. Auto manufacturers are now looking to consolidate their suppliers in an effort to reduce complexity along their supply chain, and to improve efficiency (Cole and Baron, 2003). Improved efficiency can be gained in this way by having better collaboration with suppliers and involving them in the product development process. This is important because suppliers may have better knowledge in how certain modules ought to be designed, both for functionality and manufacturability. In turn, this means that suppliers will need to broaden their expertise to build those entire modules, not just parts. Some of the smaller suppliers will not have the capacity to adapt to this new standard, and therefore will either have to drop down to a 2^{nd} tier supplier, or go out of business (Doran, 2003).

One of the major considerations automakers have to be concerned with today is globalization. China especially has proven to be a market with significant growth potential. Many of the auto manufacturers have already begun to invest in plants and increased production in an effort to exploit this opportunity (Table 1). Competition in these markets is likely to

continue to increase (Standard & Poor's, 2004). It is estimated that about 12% of the world's population own a vehicle, and that global industry growth is at 20% every decade. The majority of this growth will come from emerging markets, primarily China, India, Russia, and Brazil (Howell & Hsu, 2002).

Table 1

Light Vehicle Production by Region (in thousands)

	1999	2000	2001	2002
North America	17,037	17,150	17,473	16,369
South America	1,598	1,978	2,006	1,901
European Union	16,475	16,648	16,705	16,444
Other Europe	2,473	2,567	2,465	2,512
Asia & Oceania	16,305	17,550	17,082	18,110
Africa	301	316	380	364

Source: Standard & Poor's, 2004

Early in the history of General Motors Alfred Sloan adopted the company strategy of developing a car for every "purse and purpose" (Womack et al., 1990). In the 1970's and 1980's GM had to change their view as government regulations about safety and emissions became more strict. General Motors started investing in more research and development to meet the higher standards. Also, GM started to realize that the threat of Japanese competitors was more pronounced than they had initially gauged it. As a result GM focused its R&D on cost savings and quality improvement technologies as well. In the 1990's GM managed to be relatively up-to-speed in these matters (Howell, 2003). Now that the company has implemented lean technologies, they are weighed down with the remainder of their investments during the mass-production period. GM has very high fixed costs and a lot of capital invested in assets. This forces General Motors to maximize economies of scale in order to get the best utilization out of their assets. At the same time this hinders their flexibility (Shilling, 2005).

3 The Automotive Industry

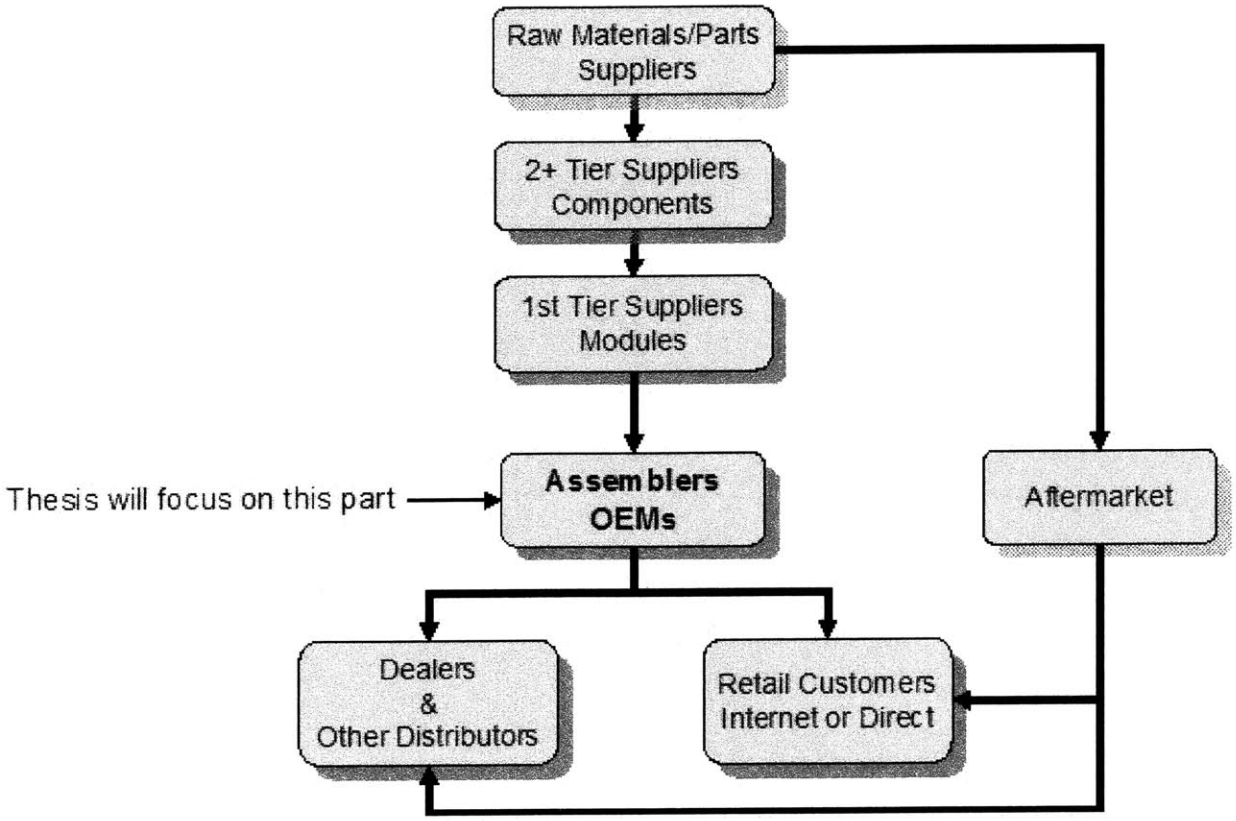
This section surveys the automotive industry to determine its supply chain structure from the manufacturer's point of view. It starts by describing the upstream suppliers, then moves downstream first to the manufacturers, and then finishes with distributors and dealers. It also covers the method in which the manufacturers' marketing departments generally segment their customers, as well as the sales channels for vehicle sales. Next this section compares the top five industry leaders by revenues, net incomes, and operating margins. In addition it covers the drivers of the automobile manufacturing industry including economies of scale, globalization, competition, changing consumer demands, regulatory requirements, and technology, as well as the manufacturers' respective responses. The section ends discussing the current supply chain challenges in automobile manufacturing such as Build-to-Order and modularity.

3.1 Industry Structure

The automotive industry is divided into the upstream suppliers, the Original Equipment Manufacturers (OEMs), and the downstream dealers and distributors (Figure 1). Another part that is not within the automotive vehicle manufacturing supply chain, yet is related, is the aftermarket.

In literature the suppliers are generally tiered from the manufacturer's perspective. This means that if a supplier directly delivers product to the manufacturer, they are a 1st tier supplier. First tier suppliers are the closest to the OEMs in the supply chain, and provide larger modules

Figure 1: Industry Supply Chain Structure



Source: Standard & Poor's Market Insight

and parts for the final assembly. The 2nd and 3rd tier usually source the raw materials and supply the components and smaller modules to the 1st Tier. Generally there are many more tiers of parts suppliers, relative to a manufacturer, although these are not indicated in Figure 1. Beyond those tiers are the raw materials suppliers. The number of 2nd and 3rd tier suppliers is often in the thousands, while a manufacturer might only have tens to hundreds of 1st tier suppliers (Standard & Poor's, 2004).

The 1st tier suppliers are becoming increasingly important as design is pushed up the supply chains by the OEMs. They are starting to build whole sections of vehicles in the form of

modules. This means that suppliers have to adapt by gaining new expertise. At the same time they are being pressured by OEMs for price reductions. This puts them in a bad situation, as they also have to deal with rising raw material costs, and it is difficult to improve efficiency to maintain the margin (i2 Interview).

The OEMs market the vehicles, complete the final assembly of modules and components, and usually ship the cars and trucks to the distributors via rail. According to U.S. figures, in 2003 the automotive manufacturing segment was a $542 billion dollar industry, which grew by about 7.4% from 2002. It employed almost 1.9 million people in 2002. Manufacturing is divided up into several categories of vehicles, which are passenger cars, light, medium, and heavy trucks. The different weight classes and their respective sales according to U.S. retail figures can be seen in Table 2.

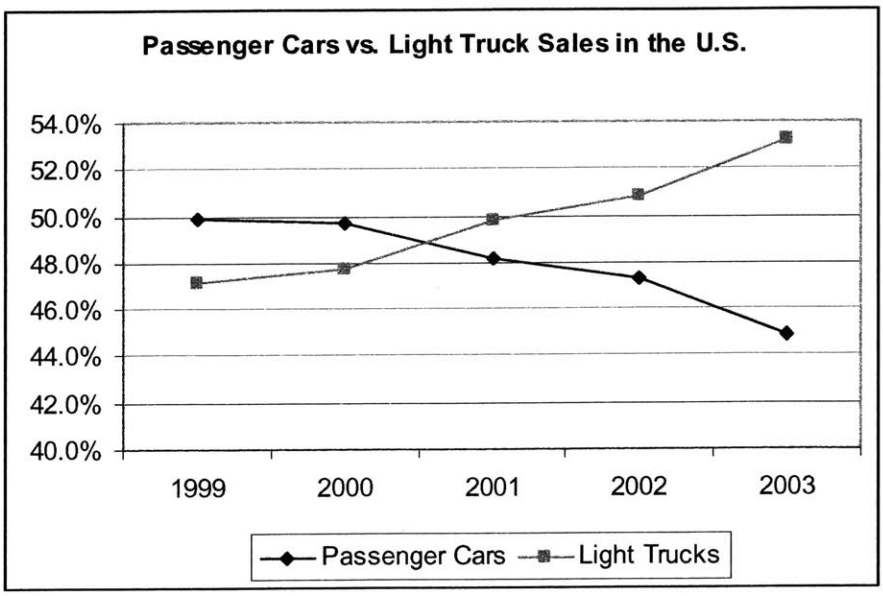
Table 2

U.S. Sales by Vehicle Type in 2003		
	Units	% of Total
Passenger Cars	7,610,468	44.9%
Light Trucks, total	9,028,572	53.2%
Medium-Duty Trucks, total	186,425	1.1%
Heavy-Duty Trucks, total	141,964	0.8%
Total US Sales	16,967,429	100.0%

Source: Standard & Poor's Market Insight

From here it can be noted that passenger cars and light trucks accounted for about 98% of all motor vehicle sales in the U.S. in 2003. It can also be seen that light trucks are outselling passenger cars. This trend only recently came about, and is likely to continue, barring significant shifts in the availability and price of gasoline. Figure 2 depicts the progression of the growth of truck sales over five years in the U.S.

Figure 2



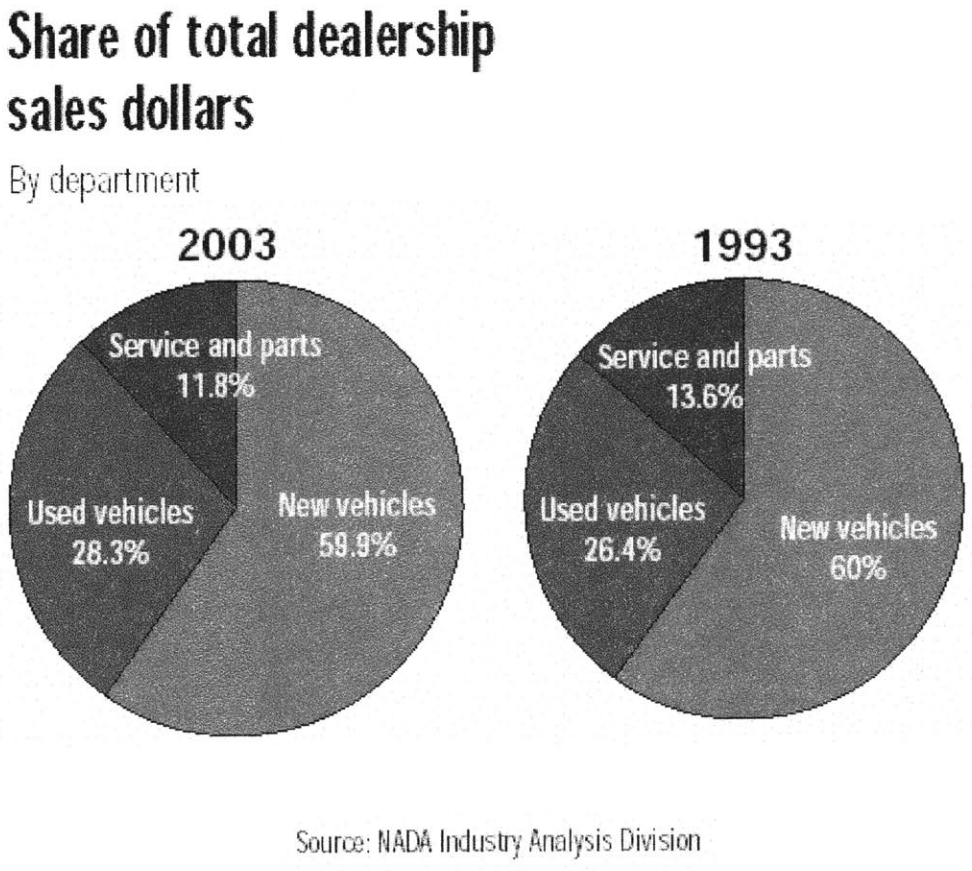
Source: Standard & Poor's Market Insight

Specifically, the sales of light trucks with weights of up to 10,000 lbs. are responsible for the increase of overall truck sales. The medium and heavy-duty trucks have actually been continuously performing worse over the last few years, but the number of trucks sold in these categories is so low that it does not affect the overall performance of truck sales (Standard & Poor's, 2004).

In 2003 automotive retail was a $699.2 billion dollar industry. The National Automobile Dealers Association represents a large portion of the industry and is composed of over 19,500 dealers with over 43,000 dealerships globally. Over the last 20 years there has been some consolidation among the dealers. In 1983 there were about 24,725 dealers. By 2004 this number had gone down to 21,650, a decrease of about 12.44% (Taylor, 2004). In automotive retail the dealers receive the vehicles by truck either directly from the manufacturing plant, or from a vehicle distribution center. The dealers generate revenue from the sale of new cars, used cars, and service parts (Figure 3). An important distinction here is that service parts and accessories

have different and separate supply chains, yet are still sold at dealerships. Parts in the aftermarket may come from components suppliers as well as the OEMs to the repair, maintenance, and customization shops.

Figure 3



The aftermarket is involved with all purchases that are related to the vehicle for repair, maintenance, or customization after the original sale. In 2003 it was a $244 billion dollar industry that employed about 4.6 million people. The aftermarket is comprised of the automotive aftermarket, which focuses on light vehicles, and the heavy-duty aftermarket, which focuses on medium and heavy weight trucks (AAIA website). The revenue split is displayed in Table 3.

Table 3

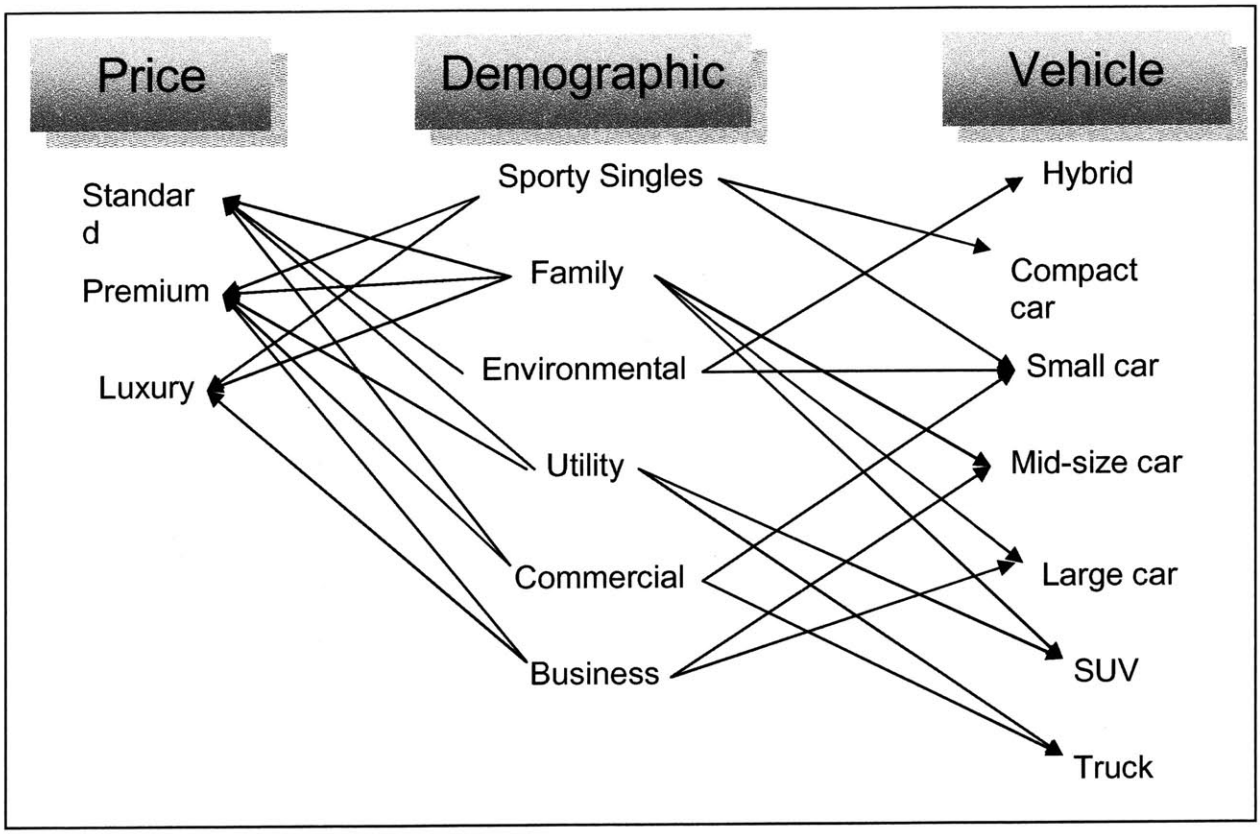
U.S. Aftermarket (Retail dollars in millions)	
	2003
Over-the-counter purchases	**$34,193**
Tires	**$17,100**
Service Repair	**$131,177**
Labor	$59,039
Parts, chemicals	$72,147
Automotive Aftermarket	**$182,470**
Heavy Duty Aftermarket	**$62,100**
Total Motor Vehicle Aftermarket	**$244,570**

Source: Automotive Aftermarket Industry Association (AAIA) www.aaia.org

3.2 Consumer Segments and Sales Channels

The segmentation of consumers is arbitrary and dependent on the marketing department of a company, but the same general categories exist across all of the manufacturers. These categories are price class, vehicle type, and demographic. For any given vehicle the manufacturers then decide on a combination of options within these categories. The first step in the process is generally to identify a consumer demographic that the company wants to address. From there the marketing department can determine the most suitable vehicle types and price classes for the most effective sales strategy. Figure 4, while not extensive, gives some possible consumer segmentation options. For example, a person in the "Sporty Singles" category would most likely be interested in buying a fast sports car. These cars tend to be smaller and more expensive. On the other hand an environmentalist would be concerned about the gas-mileage, and therefore might choose a hybrid.

Figure 4: Sample Customer Segmentation



There are only a few sales channels that serve these customer segments. The vast majority of sales are through dealerships. Then there are some direct sales through e-commerce sites, which are mostly hosted by dealers as well. Finally there are fleet sales, which are for rental car companies and the like. These sales are often through national sales companies (Holweg & Pil, 2004).

The dealers are given some incentives to carry the inventory. Generally the automotive manufacturers have their own financial services divisions, which provide leases to the dealers that compete with financing options that banks provide. The purpose of these leases is twofold. First, the automotive manufacturers are interested in capturing as much market share as possible. Making vehicles more affordable gives dealers a reason to buy more vehicles. The second

purpose is that most manufacturers are interested in maintaining economies of scale and a stable production output. By providing price incentives with leases, they are able to push vehicles out to the dealers with less resistance (Cocheo, 1986).

3.3 Top 5 Players

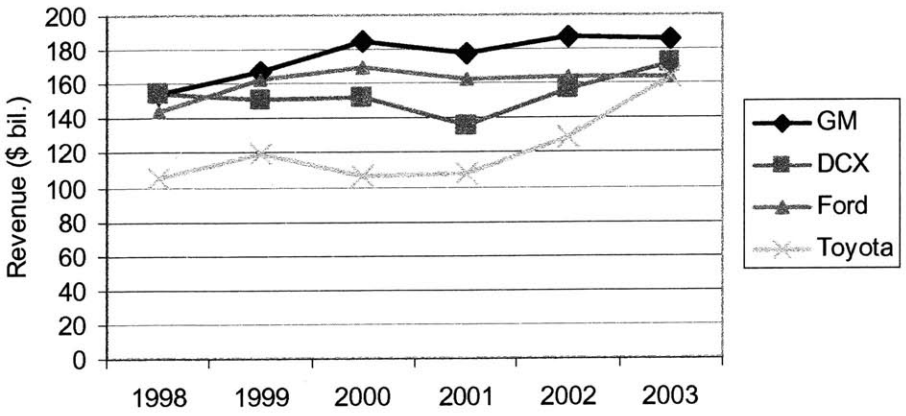
The top five leaders of the automotive manufacturing industry in terms of revenue are General Motors, DaimlerChrysler, Ford, Toyota, and Volkswagen. General Motors has been in the lead for a long time now, but the entrance of Japanese manufacturers has cost them a significant amount of market share and revenues. In Figure 5 are the revenues of the top five companies from 1998 to 2003. Here we can see that GM and Ford have made a slight gain, while DaimlerChrysler (DCX) and especially Toyota have been catching up rapidly. Volkswagen is a competitor, but still has less revenue than the next closest industry leader by about $55 billion (Hoover's Inc., 2004). In terms of global vehicle sales in 2003 the distribution is a little bit different. General Motors is still in the lead, but DaimlerChrysler has dropped to fifth place (Table 4).

Table 4: Global Light Vehicle Sales in 2003 (in thousands)

	Light Vehicles
General Motors	8,286
Ford	6,769
Toyota	6,465
VW Group	4,871
DaimlerChrysler	4,000

Source: originally from Global Insight, referenced from Standard & Poor's

Figure 5: Total Company Revenue Growth for the Top 5 Players



Source: Hoover's Online

3.4 Industry Drivers

This section covers the different factors that influence the choices companies make regarding their supply chains. This includes both factors that they can directly control, as well as factors that are beyond their business scope. The factors covered are economies of scale, globalization, competition, changing consumer demands, regulatory requirements, and technology innovations.

3.4.1 Economies of Scale

The manufacture of cars involves thousands of parts that are assembled in a highly complex system. This means that the cost of the assembly machinery is very high, and needs to be utilized to maximum capacity. In the automotive industry the benefits of the economies of scale are very significant, therefore OEMs like to keep a stable plant utilization of about 80-90% of total capacity at any given time. Naturally this has a direct impact on many other parts of the supply chain. Suppliers have a relatively stable demand to work with when supplying the OEMs,

and dealers are often left to accommodate variations in demand which results in lots of extra inventory. As a result price incentives are needed to push the dealer inventory (i2 Interview).

3.4.2 Globalization

In the automotive industry foreign growing markets are a good source for new revenues. These markets have different dynamics because it usually is more profitable to have a high production output to get the product to as many new customers as possible. In mature markets variety and product differentiation tend to be more important.

Over the last few years, as China has developed, a huge opportunity for revenues has opened up in the automotive industry. China has the largest population of any given country, as well as a small percentage of vehicles owners. This means that investments to improve the Chinese infrastructure are welcomed, and likely to yield significant profits and growth (Standard & Poor's, 2004). These profits have been coming both from commercial sales as well as general consumer sales. The downside is that because labor is cheap and the country is still developing, the average consumer does not have a lot of funds to buy vehicles with.

Some of the disadvantages of working in a foreign country are that manufacturers like to have their suppliers nearby, and that many countries will only allow manufacturers to enter the market through joint-ventures. This means that either the suppliers will have to open up organizations in foreign countries, or there will be long lead times for parts supply. Long lead times are often not a good option because gaining as much market share as possible and saturating the market are key strategies in developing countries. Therefore OEMs often ask the suppliers to open up operations in those developing countries. Joint-ventures on the other hand have been viewed with mixed opinions. In some cases these have worked out well in the past, in

others not so well. Other markets that are opening up and being targeted by the automotive industry are India and Brazil (Howell & Hsu, 2002).

3.4.3 Competition

For a long time the U.S. was ruled by the Big 3, General Motors, Ford, and Chrysler. With the entrance of the Japanese and European auto manufacturers in the late 1950's the Big 3 had to modify their operations to fight for their market share. Competition drives this industry to optimize their design, supply, manufacturing, and distribution systems in order to lower costs. This is the reason why essentially every OEM adopted lean manufacturing when Toyota entered the market and demonstrated high net incomes. The threat of the Japanese manufacturers forced everyone else to improve their efficiency. Because a change such as adopting lean manufacturing takes many years, the Japanese manufacturers have been able to gain considerable market share while the others have been fighting to bring their processes up to speed (Womack et al., 1990).

3.4.4 Changing Consumer Demands

In the mature markets, such as the U.S., consumers have been showing increased demand for more variety in vehicles. They are interested in having more unique cars with many options for both the look of the car as well as the functional aspects such as power locks and steering. This along with fragmentation of the market has driven lower volume sales per model. Economies of scope are starting to become more important, while economies of scale are declining. In order to accommodate model proliferation the asset base of the supply chains has to become more flexible (i2 Interview). The increase in the number of models is indicated in Table 5, which shows that in 1990 the industry offered about 950 models, compared to about 1,314

models in 2002. In order to keep up with this trend and offer more vehicles models, the manufacturers will need to become more flexible in their manufacturing.

Table 5: Model Proliferation in the U.S.

	1995	2001	2002
Models	950	1,165	1,314

Source: Advertising Age, 2002

3.4.5 Regulatory Requirements

Government regulatory laws differ for each country, and tend to become stricter with time. This can been seen with the increase of green laws to control emission standards and for recycling of vehicles. While many of these can be found in Europe, the U.S. has also begun to change their policies, especially in California. At the same time auto manufacturers need to consider safety requirements for accidents. The key for OEMs is to find cost-efficient solutions that adhere to and satisfy the regulatory requirements (Standard & Poor's, 2004).

3.4.6 Technology

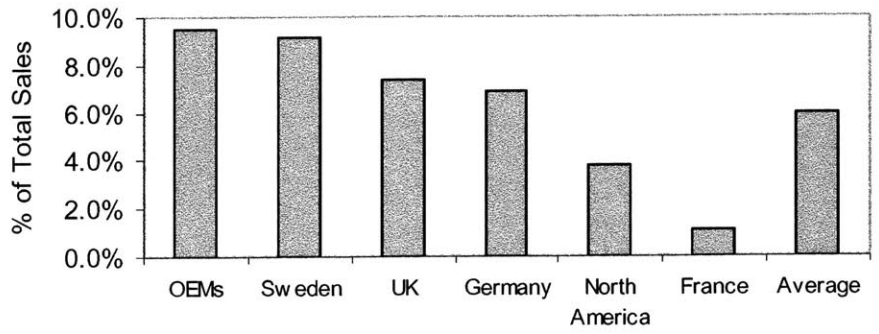
A few years ago manufacturers used to make highly detailed clay models of cars in the design process. As technology improved, computers have provided a means for the virtual design of cars, which is used along with standard clay models. New technology has also been used in the actual manufacturing process, and can help to facilitate communication among the different partners in the supply chain. All of these help to speed up time-to-market for a given product.

The composition of vehicles has also been changing. Steel and gasoline costs have been rising, and therefore auto manufacturers started using more aluminum and plastics because they are cheaper, and because they make the vehicles weigh less, which makes them more fuel

efficient. The downside to these changes in vehicle composition is that lighter materials increase the risk of injury in accidents. The benefit comes from being able to design a vehicle that uses aluminum and plastics and still retains the necessary measure of safety (Dickinson & Buckley, 1997). Another aspect of composition that has been changing is the amount of electronics in a car. With new technologies coming in, everything from automatic wipers to navigation systems, the electronics of a vehicle are becoming as important as the rest of the car. This applies more heavily with luxury versions of vehicles, which are expected to have all sorts of options that make the consumer experience more enjoyable (Fine, 1998).

Another technology that has provided opportunities is the Internet. One of the first reactions of the manufacturers was that the Internet could be used to develop a direct sales channel to the consumers. When they attempted to implement the channel the distributors strongly protested, not wanting to lose sales. The result was that for the most part the manufacturers gave up direct sales, and the dealers developed their own e-commerce vehicle sales websites.

Figure 6: Vehicles Sold Entirely Over the Internet by Dealers and OEMs in North America and Select European Countries in 2003



Original Source: Cap Gemini Ernst & Young, October 2003
Modified from: eMarketer.com

Initially the idea of selling vehicles over the Internet did not take off. One of the problems was that consumers did not trust the Internet yet, and were unwilling to make such a large transaction using their credit card or other means. Another problem was that consumers are interested in seeing, touching, and sometimes driving the car before buying it. Clearly the Internet does not allow for this (Urban & Hoffer, 2003). By now, Internet sales of cars have become more prominent (Figure 6).

3.5 Industry Responses

As a result of the factors that drive the automotive industry, manufacturers have adopted a number of strategies to keep their competitive edge. These strategies include everything along the supply chain, from the interactions between the suppliers, OEMs, and distributors, to design and manufacturing processes, and taking advantage of new opportunities.

3.5.1 Design and Development Changes

As a result of improvements in technology, manufacturers have cut down on the time it takes to design a vehicle. The design time of a car used to take up to 5 years, by now it has been reduced to two or three years. This time will need to be further reduced to accommodate the rapidly changing consumer tastes and government safety regulations and green laws.

Using 3-D visualization in manufacturing not only helps to reduce development cycle times, but also to analyze manufacturability of parts while in the design phase of the car. This is a significant improvement over the past, where it was essential to develop several prototype models to determine functionality, safety, and style. Nowadays the use of such technology can determine these factors, which helps to reduce design costs by about 75% because only one or

two prototypes have to be built. The more analysis that can be done virtually, rather than with prototypes, the faster the product can be brought to market (Waurzyniak, 1999).

3.5.2 Investments in Emerging Markets

The potential benefits of foreign markets are significant. As a result auto manufacturers have invested large sums into joint ventures in China. They chose this method over exporting because of the high tariffs and taxes, lead times, different consumer tastes and needs, and Chinese laws. Long lead times are not an option, as manufacturers do not want to not give up market share to competitors. Therefore it is most economical to avoid the duties and lead times of importing into foreign markets, and to produce locally (Standard & Poor's, 2004).

3.5.3 Platform Sharing

Another method of improving the production process and to cater to the large variety of consumer tastes while not giving up manufacturability is platform sharing. Platform sharing is when several vehicle models have the same base of a vehicle, which can include anything that is not essential in determining the stylistic aspects (Automotive News, 2000). The benefit of platform sharing is that parts can be shared across models, demand for shared parts can be aggregated, and overall manufacturing efficiency improves because of decreased parts proliferation. Another issue that platform sharing addresses is the loss of economies of scale due to a drop in sales per vehicle. This trend is inherent with vehicle model proliferation to satisfy rapidly changing demands. In platform sharing the parts are required for several different model types, and therefore economies of scale can be partially re-established. Examples of platform sharing are shown in Table 6.

Table 6: Examples of Platform Sharing in 1999

Automaker	Vehicles
Toyota	Avalon, Camry, Camry Solara, Sienna
General Motors	Buick Century & Regal, Chevrolet Impala, Lumina & Monte Carlo, Oldsmobile Intrigue, Pontiac Grand Prix
Volkswagen	Golf/GTI, Jetta, New Beetle
Ford	F Series, Super Duty, Expedition, Excursion, Navigator

Source: Automotive News, 2000

3.5.4 Stabilizing Production Output

It has been a constant struggle for auto manufacturers to match their demand to supply. They want to keep their production output stable at a high plant capacity utilization for economies of scale. The result is that they have to aggressively fight for market share. Usually this is through price incentives, and forcing the dealers to have high inventories. The natural consequence of price incentives is that margins are reduced. Even though the OEMs generally have more power and are used to having their way, now dealerships are starting to fight the OEMs on this matter. They are doing this by starting to develop policies on the amount of inventory that they are willing to carry (i2 Interview).

Auto manufacturers make up for this by shifting the pressure up the supply chain by asking for price concessions from their suppliers. This puts suppliers in a very tight spot, as they already have increased costs due to rising costs of raw materials such as steel and oil. Yet they are not in a position where they can aggressively fight against the price concessions because the OEMs have the brand recognition and loyalty in the supply chain. Suppliers now are starting to

see the benefits of working with each other. An example of this is that they sell fuel cell technologies and engines to each other (UPS interview).

3.6 Supply Chain Challenges

This section introduces the different supply chain challenges that the industry is currently facing. The issues addressed are the concepts and difficulties of Build-to-Order and shifting into a modular structure.

3.6.1 Build-to-Order

Build-to-Order in this industry is when an OEM only builds and sells a vehicle because a specific customer has demanded it. While the concept has been around for several years, it has been exceedingly difficult to implement. There have been many attempts, but for the most part OEMs tend to pre-produce the most common combinations of specifications. Instead OEMs offer bundles of equipment. They take some of the more popular specifications, mix them with unpopular options, and then reduce the total price. In this way they can sell extra content (UPS Interview).

Currently the structure of the industry is that an OEM will make a forecast several months in advance of anticipated sales, and then will plan and produce accordingly. During the course of production they may modify their forecast based off updated vehicle sales information. If they make changes too late or too often, this puts significant pressure on their suppliers and makes them have high safety stocks in order to ensure their on-time delivery standards. The suppliers will then try to find a way to charge their extra costs back to the OEMs (CSC Consulting Interview). If the result of a change to the production is considerably different than

the actual demand, due to inflexibility there is either a shortage or an oversupply. In the case of today's industry, there is an oversupply which the OEMs push to the dealers, who have to carry a lot of expensive inventory. The only way to make sales is to offer massive incentives. This can be seen as in the case of General Motors compared to Toyota. In October of 2002 General Motors gave incentives of about $3,855 for a given vehicle, while Toyota only offered $729 on average (Automotive News, October 28, 2002).

One of the reasons why Build-to-Order has not taken off in the automotive industry is that it does not directly affect consumer buying preferences (CSC Consulting Interview). Also, it is extremely hard for an OEM to move away from forecast based production. The reason is that once a forecast based model is set up, a manufacturer will focus on maximizing profit by reducing costs on the shop floor. Increasing the production efficiency then makes it even more attractive to exploit the economies of scale. As more vehicles are pushed to the customers, higher incentives need to be given to make a sale. This in turn cuts into the margins of the producers, in which case they need to find ways to reduce costs again. The result is a vicious cycle. If a specific order were to be made, it would take a long time to be fulfilled because it would be difficult to conveniently schedule the production (Holweg & Pil).

3.6.2 Modularity

Creating a modular design in the supply chain has some implications on the relationships between the echelons. First of all it forces tighter relationships between suppliers and manufacturers, as it is typically done in a lean enterprise. OEMs have to work with 1st tier suppliers to design parts for practicality, manufacturability, and style. The only way to achieve tighter coupling is to consolidate the suppliers by focusing on the critical ones. This is exactly

what has been happening in the automotive industry. For example, a typical car requires parts from about 200 1st tier suppliers. The Smart car, a vehicle produced by Swatch and Mercedes, is heavily modular and only uses about 25 1st tier suppliers (Doran, 2003). Currently most automotive manufacturers are not at this level of integration, and still have several hundred 1st Tier suppliers.

For the Big-3 it may not be entirely feasible to achieve the tightly-coupled collaboration with suppliers that a lean enterprise such as Toyota has. This is because these companies have a hard time quickly changing their processes as needed. Instead a loosely-coupled Keiretsu may provide the necessary means for domestic OEMs to stay competitive. The premise of this concept is that the change is driven from the bottom up to the operating models through IT systems. This is a feasible solution that will likely compete with tightly-coupled supplier collaboration due to having the advantages of speed to implement and low cost. The downside is that it will not be as effective (CSC Consulting interview).

The shift of design up the supply chain has been increasing, and may even get to a point where 1st tier suppliers develop entire vehicles. In this case the role of OEMs will then be focused on marketing and design. Since the OEMs still own the brand name, they will have significant influence in the supply chain (UPS Interview).

3.6.3 Identifying Core Competencies

In order to stay competitive, automotive manufacturers have been identifying their core competencies and making appropriate make vs. buy decisions. The general trend has been that powertrains, which are engines and transmissions, are developed in-house. The reason is that consumers associate brands with not only the exterior vehicle design, but the power and type of

the engine as well. This is particularly true for sports cars and light trucks. Most auto manufacturers outsource most of the other parts (GM interview).

Another aspect to this is that automotive manufacturers have started to realize that they need to focus on the actual marketing, design, and manufacture of vehicles. This can be seen with the Visteon and Delphi spin offs from Ford and General Motors respectively. Both of the spin offs happened for similar reasons. First, the automotive manufacturers believed that the parts suppliers could benefit significantly by supplying to the overall market. The automotive manufacturers wanted to take advantage of sourcing cheaper parts from suppliers that had lower labor costs. While both manufacturers still are supplied parts by Visteon and Delphi, they can now concentrate on their strengths (Muller, 2000) (Detroit Free Press, 1999 May) (Detroit Free Press, 1999 April).

4 General Motors' Position in the Industry

This chapter describes General Motors as a company and how it is faring against other automotive manufacturers in the industry. It covers some of the strategic choices GM has made, as well as its revenues, net incomes, and employees over the past few years. Then it will go into the different business units, and the products and services that they offer. In the end it discusses the sales channels and GM's position relative to its competitors over time.

4.1 GM's Recent Strategic Choices

Historically General Motors has had a strategy of acquisition and expansion to broaden their product lines and services. This can be seen through a variety of joint-ventures, expansions, and acquisitions that they have been involved with in the 1980's and early 1990's. GM decided to become involved in all kinds of industries, including defense, electronics, aircraft, and electro-motive (Table 7).

In the late 1990's and 2000's General Motors seems to have changed its strategy somewhat, deciding to sell parts of its business and concentrate on automotive manufacturing, and peripheral products and services (Table 8). This is illustrated when GM got involved with OnStar and XM Satellite radio. The most notable recent event is the Delphi spin-off in 1999. Delphi was a GM owned industry leader in automotive parts supply. One of the reasons for the spin-off is that labor wages at Delphi were extremely high, and GM could potentially benefit

from lower cost suppliers in the market. For Delphi this opened up opportunities to pursue more business from other automotive manufacturers helping to potentially use economies of scale to lower costs.

Table 7: List of acqusitions, joint-ventures, and expansions

- 1983 - GM forms a joint-venture with Toyota, the New United Motor Manufacturing, Inc. (NUMMI)
- 1984 - Acquired Electronic Data Systems (EDS)
- 1985 - Acquired Hughes Aircraft Company
- 1986 - GM Europe is established
- 1986 - Acquired Group Lotus
- 1986 - GM and Volvo joint-venture in the U.S.
- 1988 - GM and Toyota joint-venture in Australia
- 1988 - Allison Transmission is created
- 1989 - GM buys 50% of Saab Automobile AB
- 1992 - GM and Jinbei Automotive Company Ltd. joint-venture in China

Source : www.gm.com

**List only covers the major events, it is not complete*

Table 8: List of Company Divestitures

- 1996 - EDS is officially split off from GM
- 1999 - Delphi spin-off
- 2003 - Split-off between GM and Hughes Electronics
- 2003 – Sale of GM's defense unit
- 2005 - GM announces its intention to sell GM Electro-Motive

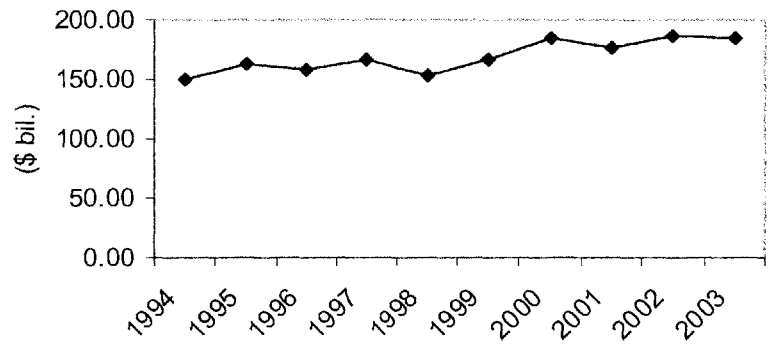
Source : www.gm.com

**List only covers the major events, it is not complete*

4.2 Historical company revenues, net incomes, and employees

From 1994 to 2003 General Motors has had slightly fluctuating revenues, with an overall positive trend leading to a total increase of about $30 billion dollars (Figure 7). This shows that even though GM has been losing market share over the last few years, they have managed to capitalize on their opportunities in foreign markets and in fleet sales (Hoover's Inc., 2004).

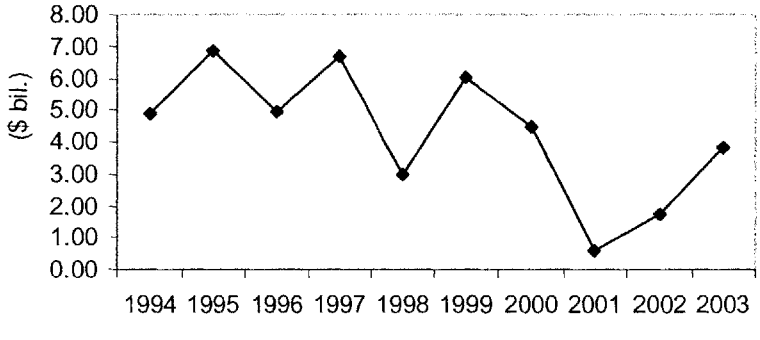
Figure 7: General Motors Total Company Revenue



Source: Hoover's Online

Looking at the net income we can see that there are significant fluctuations (Figure 8). The final major fluctuation in 2001 and 2002 is partially due to General Motors focusing a lot of attention on their healthcare and retiree benefits program. In 2004 the company was finally able to get up to speed and pay back billions of dollars for its debts in this matter (Hoover's Inc., 2004).

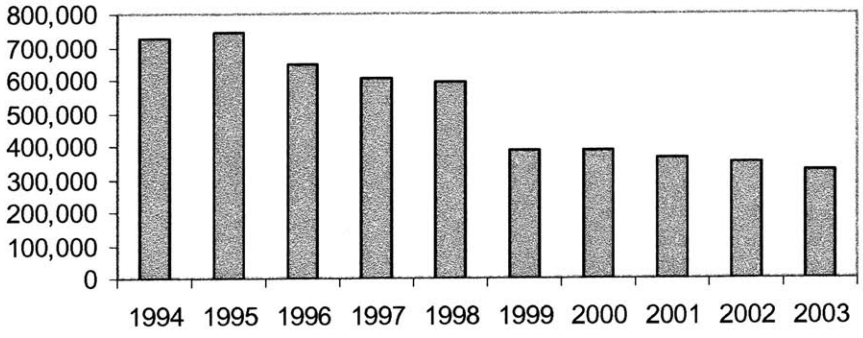
Figure 8: General Motors Total Company Net Income



Source: Hoover's Online

When it comes to employees, General Motors has been drastically reducing the size of its operations (Figure 9). Over a ten year span the company cut about 400,000 jobs worldwide. Part of the reason for this was a move towards implementing lean manufacturing for higher efficiency. Other reasons for this were spinning off Delphi in 1999, concentrating more on the automotive manufacturing business and outsourcing of parts that are not core competencies. Modularity also plays a role because the more design is shifted upward the supply chain, the less employees General Motors needs to build and assemble those parts.

Figure 9: General Motors Total Company Employees



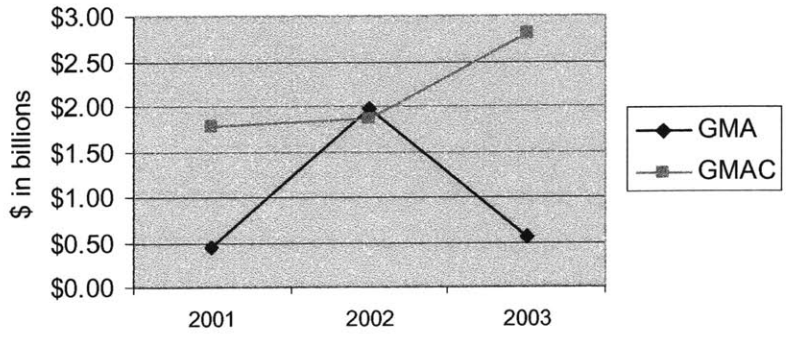
Source: Hoover's Online

4.3 Business Units and their Products and Services

General Motors has seven major business units. The largest one is General Motors Automotive (GMA), which consists of GM North America (GMNA), GM Europe (GME), GM Latin America / Africa / Mid-East (GMLAAM), and GM Asia Pacific (GMAP). Then there is the General Motors Acceptance Corporation (GMAC), which is a financial services division that supports GMA. The other business units mostly support GMA, and are GM Service Parts and Operations, GM Powertrain, OnStar, XM Satellite Radio, and GM Electro-Motive. In early 2005 GM announced that it would sell GM Electro-Motive to Greenbriar Equity Group LLC and

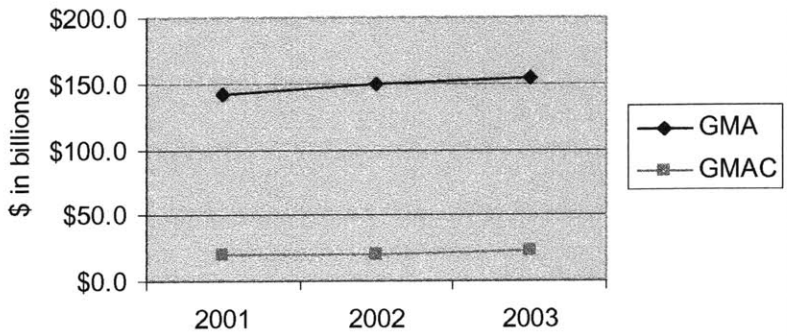
Berkshire Partners. This thesis mostly focuses on the GMA and GMAC business units. A breakdown of net incomes and revenues over time for these units can be seen in Figures 10 & 11 respectively (Hoover's Inc., 2004).

Figure 10: GM Net Income by Business Unit



Sources: GMAC 10-K Report, GM 2003 Annual Report

Figure 11: GM Revenues by Business Unit



Sources: GMAC 10-K Report, GM 2003 Annual Report

4.3.1 General Motors Automotive (GMA)

General Motors Automotive is the main business unit of the company. It is the unit that is responsible for the design, development, manufacture, and marketing of vehicles. It has revenues

of about $154.5 billion, and a global market share of 14.7% (Table 9). The different brands it offers are Buick, Cadillac, Chevrolet, GMC, Holden, Hummer, Opel, Pontiac, Saab, Saturn and

Table 9: Market Share By Region

	2001	2002	2003
GMNA	27.6%	27.9%	27.4%
GME	9.1%	9.1%	9.4%
GMLAAM	16.6%	15.7%	16.0%
GMAP	4.0%	4.6%	4.9%

Source: GM Annual Report 2003

Vauxhall. It is also involved with a number of joint-ventures. Overall General Motors Automotive manufactures in 32 countries, and in 2004 sold about 9 million cars and trucks to 200 countries. It also invested $5.7 billion in research and development in 2003 (GM Annual Report 2003).

4.3.2 General Motors Acceptance Corporation (GMAC)

This business unit offers all kinds of financial services to dealers and GM customers. This includes automotive financing, commercial finance, insurance and mortgage products, and real estate services throughout 41 countries.

GMAC grew significantly in 2003, sporting revenues of about $22 billion and a net income of almost $2.8 billion. This means that the financial services business unit was actually responsible for the majority of the overall company net income. The majority of their sales is from financing, which made up about 58% of the total (GM Annual Report 2003).

4.4 Sales Channels

The two main sales channels for General Motors are dealerships and fleet sales. Fleet sales make up about 26% of GM's total sales, and have been rising over the last few years. This has helped to offset the loss of market share for the dealership sales. As to dealerships, there are 7,700 retail outlets in North America, 800 in Canada, 260 in Mexico, and 15,500 overseas (GM Annual Report 2003).

4.5 GM's position relative to their top competitors over time

GM's business strategy is to have as much market share as possible. With the entrance of foreign competitors who have more efficient production this has become exceedingly difficult in the U.S. As stated before, GM has been trying to use fleet sales to balance the loss in overall market share. Therefore Toyota and DaimlerChrysler have gotten more dealership sales and higher revenues. The trend has not been looking too positive for General Motors, but at this point they are still in the lead.

GM's competitors have a variety of strategies. Toyota's goal seems to be flexibility and efficiency, which has helped them retain high net incomes. Volkswagen focuses on the production of passenger cars, not so much light trucks. This may be due to the fact that in Europe more compact cars with high fuel efficiency tend to be favored (Hoover's Inc., 2004).

5 General Motors' 360 Platform Supply Chain

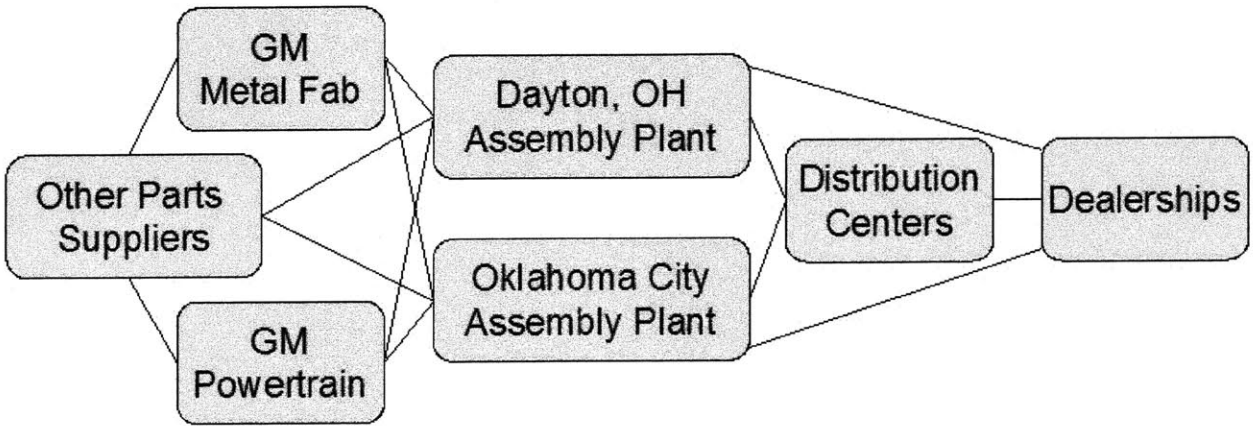
This section looks at the inner workings for one of General Motors' specific supply chains. All of the data for chapters 5 and 6 was collected in a series of interviews with several General Motors managers. Due to the nature of the company's operations, it is difficult to assess a supply chain for a specific brand or even model. It is much more practical to identify a supply chain for a plant or platform. This thesis analyzes the supply chain for the 360 platform. This platform is used to build standard Trailblazers, extended Trailblazers, and Trailblazers with sunroofs. Additionally there are three weight classes for each of those versions, which are the light-weight 1500 series, the medium-weight 2500 series, and the heavy-weight 3500 series. This section covers the general structure, how orders are received and managed, the supply-side, inside, and customer-side business processes, transportation, and finally how accessories fit into this supply chain.

5.1 The Supply Chain for the 360 Platform

The supply chain for the 360 platform was chosen to research because this line of vehicles has many options and accessories, and therefore has many combinations of possible orders, making it complex. The major parts of the supply chain are the suppliers, the assembly plants, and the distribution centers and dealerships (Figure 12).

On the upstream side of the assembly plants General Motors has its own metal fabrication and powertrain manufacturing operations. All the other 2000+ parts and modules are sourced from about 200-300 Tier 1 suppliers.

Figure 12: Supply Chain for the 360 Platform

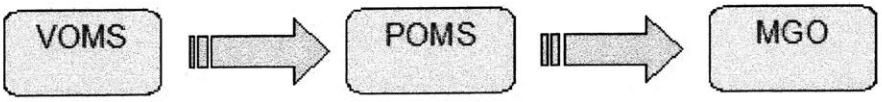


For the 360 Platform, General Motors has two assembly plants, which are located in Dayton, Ohio, and Oklahoma City, Oklahoma. When a vehicle is built, it is then sent on to the dealers. The mode of transportation and whether it is sent to a distribution center is determined by the distance from the plant to the dealer. The majority of the vehicles produced on the 360 platform are sent first by rail to vehicle distribution centers, and then by truck to the dealerships. The rest of the vehicles are shipped directly by truck.

5.2 Order Management

Order management involves three key information systems, the Vehicle Ordering and Management System (VOMS), Production Order and Material Scheduling (POMS), and Materials Global Organization (MGO) (Figure 13).

Figure 13: Order Management



VOMS is the customer side information system. Here the dealers can enter orders, check the status, and see the shipment date. They can also modify their orders. This is done through a web interface, and the order is then sent to POMS.

POMS receives the information for all of the orders, and then organizes and schedules production. It first determines the location of production by choosing one of the plants, and then lays out a weekly schedule in which the vehicles are built. The schedule is determined 20 weeks in advance.

When POMS has determined the plant and sequence, the MGO breaks down each order to the part level and sends out the appropriate order signals to the suppliers. It works very much like a Material Requirements Planning (MRP) system.

5.3 Supply-Side Business Processes

The supply-side business processes are the different ways in which General Motors works with their suppliers. This section looks at how the company chooses their suppliers, segments and manages them, and how collaborative product development is done. It also discusses risk management, purchasing, and warehouse management.

5.3.1 Supplier Selection & Segmentation

The Global Purchasing Organization at General Motors chooses suppliers and looks at four major criteria in the process. These criteria are directly related to their needs in having a just-in-time supply process to their assembly of vehicles. The criteria are quality, service, technology, and price. The most important piece is that the supplier has to be able to work with GM's quality expectations. This is because if a load of parts comes in and they have a defect, the assembler's production line may have to stop and wait until replacement parts come in. This has a significant impact on GM's operation, and it may not be possible to deliver the finished vehicles to the dealers on time. Service refers to the ability of the supplier to reliably and frequently deliver the parts when they are needed. Variability in the lead times for supplying parts is not desirable. The third part is about whether or not the supplier has the technical infrastructure and aptitude to work with GM. Finally, the fourth component is to determine a low price supplier.

When the Global Purchasing Organization has chosen a supplier or approved a part, the Supply Chain, Quality, and Engineering departments make an assessment. If all of the departments approve, business with the supplier will be established or the part will be built. It takes all four departments to make final purchasing decisions, which is a significant improvement from past business.

Supplier segmentation is done by commodity type. Since there are 2000+ parts that are sourced, it is most beneficial to create categories, such as stamping suppliers. Within each of these commodity type categories the suppliers are further segmented into their ability to meet the same four qualities that are used for supplier selection.

5.3.2 Supplier Management

General Motors uses two methods to manage their suppliers: metrics and their Advanced Quality Planning Process (APQP). These metrics include quality performance, whether they meet material required dates, part availability, and the type of freight they use for shipping. The APQP first gives the supplier the right to make the indicated part according to General Motors' specifications. Second, it gives the supplier the right to actually produce the part at a pre-determined rate or number. Essentially the APQP states the terms of the relationship with the supplier.

5.3.3 Collaborative New Product Development

For collaborative new product development General Motors has close ties to their suppliers. Often General Motors will host a team of their suppliers' employees to work with them on product development. Over the course of several months the inter-company teams will then design parts for both manufacturability and efficiency.

5.3.4 Risk Management

The Advanced Planning Quality Process is a major component of risk management with suppliers. It provides all of the rules that the supplier has to adhere to when they receive an order. The other aspect to risk management is determining the supplier-to-dock and dock-to-operator integration level. Supplier-to-dock encompasses all of the steps it takes for the supplier to get the part to General Motors' dock door. Dock-to-Operator involves all of the steps needed to bring the part from the dock door to the employee who will assemble it into the vehicle. The integration level is determined by how well the supplier conforms to making their operation as

stable as possible so as to provide regular deliveries with little fluctuations in lead time. A new program that GM is planning on implementing is to launch regular readiness reviews with suppliers.

5.3.5 Purchasing

All of the purchasing is done through GM's Global Purchasing Organization. When an order for a part is made, GM provides a short-term and a long-term forecast. The short-term forecast spans 20 weeks and is detailed for each individual vehicle, the components, and the service parts that go along with it. It provides the supplier with four weeks for material authorization, which is the process of sourcing raw materials for the needed parts from the supplier's suppliers. Also included are two weeks for fabrication of the parts. This leaves the suppliers with some of the risk of schedule fluctuations, especially after the initial two weeks. The long-term forecast spans one year and gives general vehicle sales numbers. These are used by suppliers for capacity planning.

The basis for purchasing decisions is the corporate vision, and is made at the strategy board level. The corporate vision is to be the "world leader in transportation and automotive services." This is how General Motors decided that to build powertrains in house as one of their core competencies. It is one of the parts that distinguish them from their competitors. On the individual part level, sourcing decisions are made by a business case study of the supplier, looking at the fixed and variable costs. If the supplier passes, the Supply Chain, Engineering, and Quality departments judge the supplier based on their own criteria. Overall, General Motors is interested in having a common bill-of-process setup for all of their plants. This means that they

use the same suppliers and same processes, if possible, which gives them more flexibility in their supply chain.

The procurement process is very integrated with replenishment policies. The reason is that the purchasing process uses global parameters, terms, and conditions in their running contracts with suppliers. On a day-to-day basis GM uses Electronic Data Interchange (EDI) in their replenishment processes. When a supplier receives an order, they send an Automatic Shipping Notice (ASN). There are also signals that are sent on pickup and delivery of the parts. This electronic automation of information is very important, as a given plant may receive over 600 orders a day, and is therefore very complex to run.

Procurement adheres to time and quality standards by keeping performance records of their suppliers. This is done with their Problem Report and Resolution (PRR) system. From here General Motors can monitor any failures in quality, the amount of time it took the supplier to fix the problem, and who was at fault. This system is then used to decide on future business with suppliers. For new suppliers GM will try to find similar reports from other sources.

There are two quality processes that are responsible for supporting procurement processes. The first is for advanced quality processes, which develops contracts with suppliers three to five years in advance. This covers products which are not yet in production, and makes sure that suppliers are capable of delivering a high quality product to the right place at the right time. When a contract is developed, an agreement is bundled in with it stating that the supplier will provide the appropriate service parts for several years after the current production run. Current quality processes improve the quality level of parts that are currently in production, and makes sure that the parts are sourced at the most competitive market price level. Auctions are

primarily used for those parts where there are many suppliers with the same quality and service level, and the only differentiator is price. This usually involves simpler parts that the final consumer may never directly interact with.

One of the key challenges of product portfolio management is being responsive to the market. There are a lot of things in the supply chain that are not flexible enough that allow GM to shift to those changing demands. Therefore it is General Motors' goal to build flexibility into the supply chain. This is true on a global basis, not just domestically. The company has been becoming more flexible in the plants with their production processes, by being able to develop more architectures in each plant. The supply base has also become more flexible. This has come in the form of more tooling for suppliers to make a larger selection of parts without an impact on cost.

5.3.6 Warehouse Management

Typically General Motors prefers for suppliers to hold and manage their own inventories. Then they like to draw from those inventories whenever needed. In the case of suppliers that are offshore and larger suppliers that do not want to hold all of the inventory, General Motors leaves the warehouse management to their joint-venture with CNF called Vector SCM. Vector SCM serves the role of a fourth party logistics provider (4PL) and was founded in 2000 with the purpose of developing faster, more reliable logistics processes which could cut inventory costs. It handles the majority of GM's logistics processes by managing the thousands of logistics service providers. Vector SCM does not actually provide logistic services, they only manage the providers and warehouses.

5.4 Inbound Transportation

The key considerations for inbound transportation are highly dependent on GM's Just-In-Time (JIT) production, and are first a high service level, then cost. The company is mostly worried about preventing anything that could stop the production line, which for inbound transportation requires the availability of power, crew, and equipment. The modes of transportation are dependent on the location of the supplier. Generally offshore suppliers send their parts via ocean shipments, but air is used if the parts are small and very expensive or if a shipment needs to be expedited. Domestically mostly trucks are used, and rail to a smaller degree.

5.5 Inside Business Processes

The inside business-processes cover all the different things that General Motors has to manage within their own organization. The topics in this section are inventory segmentation & management, production management, and supply chain responsiveness to order modifications.

5.5.1 Inventory Segmentation & Management

General Motors as a company generally does not segment its inventory. The reason is that if any part is not at the plant when it is needed, the vehicle can not be built. Therefore all those parts are equally critical. The assembly plants work on Just-In-Time (JIT) processes, and therefore General Motors holds very little inventory and has no need to segment it.

There are some occasions in which the company holds inventory. One of these is that General Motors holds some buffer inventory for parts from offshore suppliers. The purpose for this is to make sure that if there is a complication General Motors will not need to shut down the

assembly plants. The other situation in which General Motors will hold inventory is for the large-scale part suppliers, such as Delphi, that are not interested in holding all the inventory until GM wants to pull from their warehouse. When General Motors does hold inventory, they let Vector SCM, their joint-venture with CNF, manage it.

5.5.2 Production Management

In production management General Motors is primarily interested in three metrics. First of all they want to know whether or not the scheduled number of vehicles were produced on a given day. Second, they want to know if all of the vehicles that were built had the correct specifications. Third, they want to know the number of vehicles that came off the assembly line and went directly to the dealerships with no rework.

A lot of the production management has come from lean production principles. In the 1990's General Motors invested significant resources to become lean, and has since made large improvements. They have effectively adopted Just-In-Time practices, and have been improving in supplier relations. Also they have improved their quality processes, and they require less fixed assets for more efficient assembly.

Production planning has two major aspects to it, scheduling and sequencing of vehicles. After the initial 20 week schedule that POMS develops, there is a hard schedule set on a weekly basis. At this point the vehicles that are scheduled are guaranteed to be built. Within each plant the sequencing is done on a daily basis, about 3-5 days ahead of the production time. This sequence can then be used to determine the approximate assembly and delivery time. There are also manual re-sequencers on the assembly line. These re-sequencers take a look at the current day's operations, and if it looks like the replenishment of an option or so will come in an hour

late, they will re-sequence the vehicles so as to keep the production process flowing as smoothly and continuously as possible.

5.5.3 Responsiveness to Order Modifications

The level of responsiveness in the production system depends on the type of modification that is requested. If it is a major modification, such as changing the weight-class on an order of vehicles, that has to be done very early in the 20 week schedule. On the other hand, if the modification involves a change in the option packages, the system is very responsive. Such changes can be made up to the week before production.

5.6 Outbound Transportation

For outbound transportation the key consideration is to reduce the variability of delivery times. The reason for this is that the rail carriers are limited in their ability to provide the service that General Motors would like. The rail carriers have special multi-level platforms to transport vehicles. These multi-level platforms can not be used for anything else. Therefore the rail carriers send them back and forth between all the auto manufacturers as they are needed. This means that it is difficult to correctly allocate the locations of the multi-level platforms at any given time. If the platforms aren't where they are needed, General Motors is unable to send their vehicles to the dealers. Therefore General Motors' concern for outbound transportation is equipment availability.

5.7 *Customer-Side Business Processes*

The customer-side business processes entail the parts of General Motors' business that are involved with dealership interactions. Here the thesis analyzes order quoting and promising, and how different types of returns are managed.

5.7.1 Order Quoting & Promising

Order quoting has three parts to it. The first part is the standard vehicle model price. This is the base price for a given vehicle without the options. Then there is an additional fee based on the options that the order includes. Finally there is a freight charge. This charge is equalized throughout the country, meaning that no matter where the dealer is located the freight charge is always the same.

The initial delivery date promise of the order is calculated by taking the estimated production week and adding the transit time to the dealer. Within one week of the order a dealer can use the Vehicle Order Management System (VOMS) to see a final shipment date, which can be determined by the sequence number of the order on the production day. The sequence number can tell approximately when the actual order will be completed and shipped.

5.7.2 Returns Management

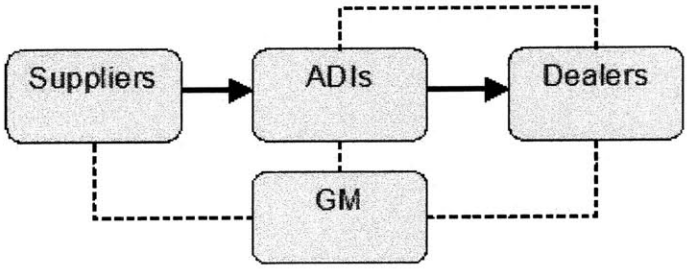
For returns management there are three possible scenarios. The first scenario is that the warranty for a part is still good, in which case the dealer will order the part and General Motors will send it. The second scenario is if the warranty is over, the part has to be ordered through GM's Service Parts Operations (SPO), who will then have the part sent directly to the dealer. Finally if the part is included in the remanufacturing program, the damaged part can be sent in

and it will be replaced. If the damaged part can not be refurbished, GM has to dispose of it. This transaction includes a core-fee which is similar to a "bottle exchange fee."

5.8 Accessories

At General Motors accessories are considered to be different than service parts, and therefore have a separate supply chain (Figure 14). The accessories supply chain has four distinct entities, the suppliers, the Accessory Distributor Installers (ADIs), the dealers, and the Service Parts Operations (SPO) at General Motors.

Figure 14: Accessories Supply Chain



The process starts by the SPO, coming up with and designing an accessory. If the accessory is approved, it is the job of the Global Purchasing Organization at General Motors to find suppliers that can make the accessory, and to choose between them. None of the accessories are developed in house. Contracts are then made where the supplier has 48 hours to make a shipment when an order is received. General Motors determines the shipment method and pays for it. The suppliers are measured on their ability to make shipments to the ADIs on time.

The Accessory Distributor Installers (ADIs) are the party that warehouses the accessories, and supplies the dealers in their region, and even installs the accessories. Other tasks for the ADIs include helping the dealers with sales and marketing, because the dealers are often not

aware of the availability or functions of all the accessories. Currently General Motors is working on a collaborative inventory management program with ADIs. This would mean that the ADIs own the inventory, but GM takes over the orders and replenishes as needed according to the vehicle production forecast. The ADIs can be dealerships, wholesalers, or independent entities that are capable of handling the responsibility. Currently GM has 85 ADIs spread throughout the country in strategic locations that are closest to the major demand points.

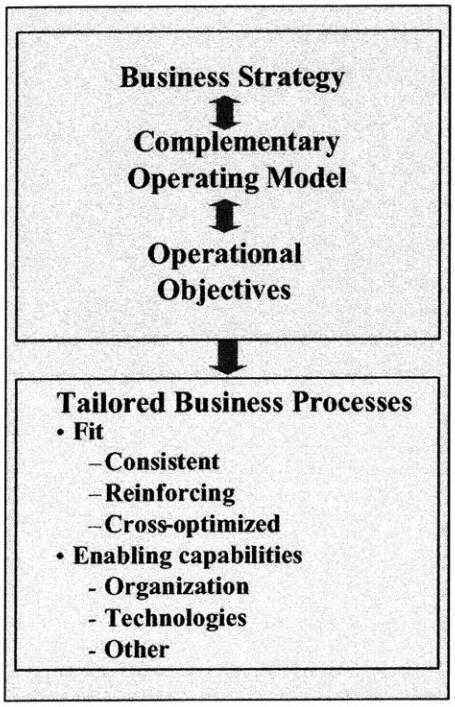
The main risks for accessories are obsolescence, and the ADIs having the capacity and capital to stock all of the accessories. Accessories are considered fashionable, and therefore will go out of style eventually. To manage this risk of obsolescence GM provides the ADIs with obsolescence protection. This means that GM will buy back unsold accessories. In regards to the capacity and capital issues of the ADIs, GM has programs to inform them of the features of all of the accessories, help them manage the inventory so as to keep the most demanded items in stock, and offer ramp-up programs to gradually introduce ADIs to their responsibilities.

In terms of transportation for accessories GM is mostly concerned with low cost and damage mitigation. Since accessories are fashionable items that often have aesthetic appeal, damage to the item will be noticeable and render it worthless. GM controls the transportation of accessories, and mostly uses trucks to the ADIs, and often UPS or Fed-Ex to the dealers.

6 The Supply Chain Framework for the 360 Platform

The final chapter of this thesis analyzes the 360 platform from a high-level strategic perspective. It describes the business strategy, the complementary operating models, Just-in-Time (JIT) production and Build-to-Order, and the corresponding operational objectives. It then discusses three "tailored" business processes that support the operating model. These processes are sourcing, supplier collaboration, and logistics management, which reinforce each other and the higher level objectives. The layout of the analysis can be seen in Figure 15.

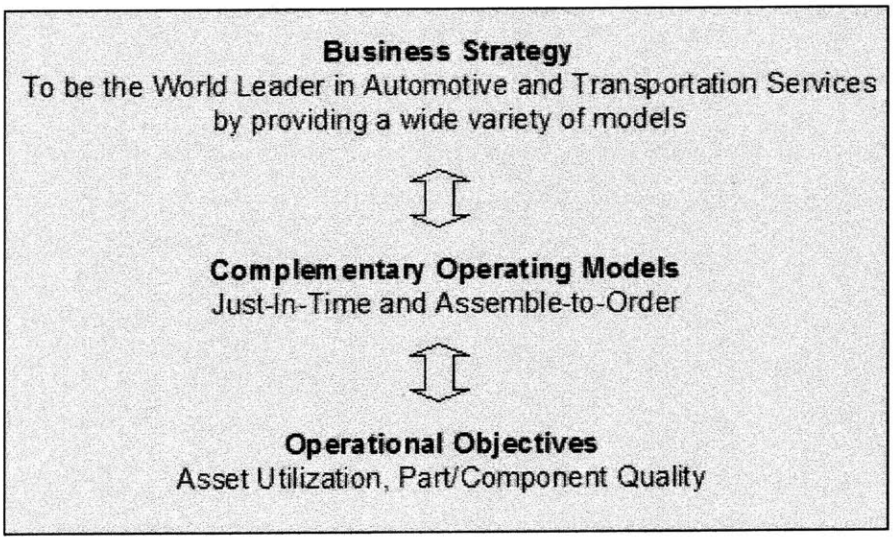
Figure 15: Supply Chain Framework



6.1 Business Strategy, Operating Models, and Operational Objectives

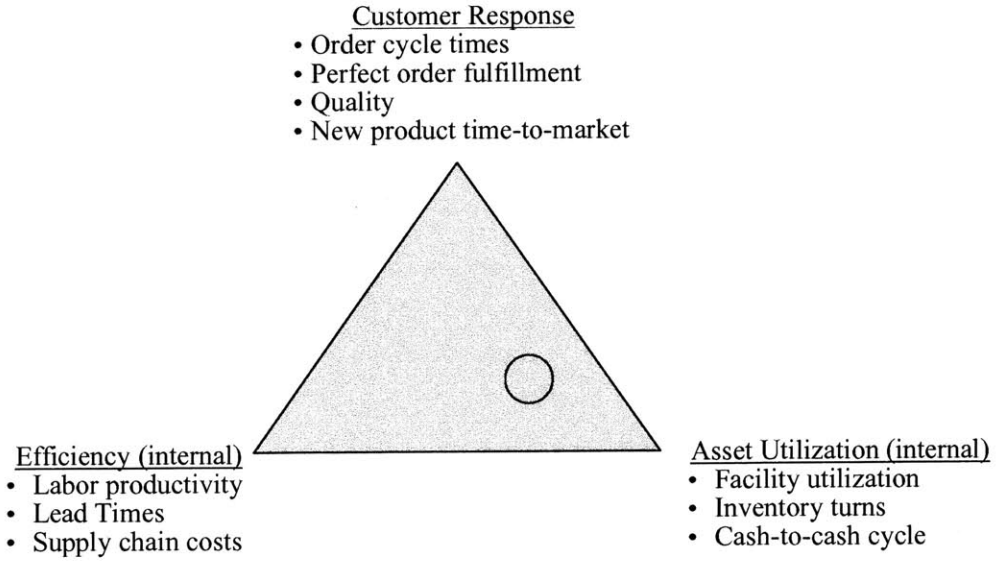
General Motors company wide business strategy is to be the "world leader in transportation and automotive services." This means having the most market share and providing a large selection of products on a global basis. The strategy heavily relies on two factors. The first is to produce and sell as many vehicles as possible. To achieve competitive advantage this requires a high level of operational efficiency in assembly time, the supply of parts, and the delivery of finished vehicles. In the automotive industry the Just-In-Time operating model is widely used to complement this strategy. The second factor requires making a significant number of models and options available for end consumers to choose from and being able to have the correct specifications at the right time. Automotive manufacturers have been trying to overcome the difficulties in implementing a Assemble-to-Order operating model for several years now. This type of model requires reductions on overall supply chain lead time to function well. Figure 16 illustrates the framework that is used.

Figure 16: GM's Framework



There are three elements which have different impacts on the business strategy and can determine company success are customer response, efficiency, and asset utilization (Figure 17). The elements can be measured through several operational objectives, such as order cycle times and inventory turns. General Motors heavily focuses on the asset utilization elements, which is common for the industry because of the high investments required to build machinery and assembly plants. Asset utilization is how economies of scale are upheld, which is one of the primary industry drivers. General Motors also focuses on quality and lead times, but this is again to support operational objectives within the asset utilization category. By having suppliers provide high quality parts and having short and regular lead times GM can ensure low inventories due to a Just-In-Time environment, as well as a more flexible supply chain to make sure the assembly line keeps running and that customers are served more quickly. Note that while GM primarily focuses on asset utilization, they are also concerned with customer response and efficiency measures, just to a lesser degree.

Figure 17: Illustrative Operational Objectives



6.2 *Tailored Business Processes*

This section takes a detailed look at General Motors' business processes for sourcing, collaboration with suppliers, and logistics management. It will describe how each of these processes work, as well as how they link to the relevant operating models, and therefore also to the strategy, that were mentioned earlier.

6.2.1 Sourcing Decisions

When it comes to sourcing General Motors has recognized that developing certain parts in house can give them a competitive differentiation. As a result the company has decided to focus on building powertrains, which includes engines and transmissions, to go along with their vehicles. This is an important distinction as many end consumers are interested in buying a GM engine when they buy a GM vehicle. To support this behavior GM has made the development of powertrains one of its core competencies. The other parts in a vehicle, while certainly important, can be outsourced because they do not have as much of an affiliation with the brand name.

For all the outsourced parts General Motors is highly interested in using suppliers with qualities that fit into their just-in-time supply system to support the assembly process. These qualities from most important to least are generally quality, service, technology, and price, which are assessed by the Engineering, Supply Chain, Procurement, and Quality departments. If all departments approve, the supplier is selected. In some cases the importance of these qualities to make a supplier selection shifts around, such as for items where the suppliers all have similar levels of quality, service, and technology. In that case price would be the most important factor.

Quality in supplier selection is about choosing a supplier that consistently has few defects in their products. In a just-in-time environment this is very important. If a supplier sent a

shipment of defective parts, this could potentially mean that the production line would have to stop until a new shipment comes in. This is unacceptable when economies of scale need to be preserved. For this reason General Motors has a Problem Report and Resolution system (PRR). As described earlier, this system keeps track of a supplier's performance record, which includes qualities failures, how long it took to correct the situation, and who was at fault. General Motors uses this system in order to decide on new business with suppliers and whether or not to continue business with existing suppliers. If General Motors does not have a performance record for a new supplier, they will search the market for such reports.

Supplier service levels are about the supplier's capability to deliver their product reliably. This means that the product always arrives exactly on time. The key here is for suppliers to be able to supply frequently, and to have very little variation in the time it takes to deliver. In a just-in-time system General Motors does not want to necessarily hold inventory before they need it, nor do they want to run out of a part because of a late shipment. Consistency is what matters.

For General Motors to select a supplier, the two companies have to be able to integrate technologically to a certain degree. All plants at General Motors use the Materials Global Organization (MGO) to break orders up into their bill-of-materials and to send out order signals to the suppliers. The supplier has to be able to accept these order signals and work with them, as well as other collaborative technologies.

The last indicator for supplier selection is price. While General Motors wants to function on a just-in-time system, cost is also an issue. As a result the company will seek out the most competitive market prices for all parts, and will even renegotiate or switch suppliers for better prices, as needed.

6.2.2 Collaboration with Suppliers

To be effective in a Just-In-Time environment, and in order to develop means to cut lead times in the supply chain for a Assemble-to-Order model, General Motors needs to collaborate with its suppliers. This is mainly done in two types of interactions. The first is working with the suppliers for order management, and the second is collaborative new product design with suppliers.

When General Motors receives an order, the Materials Global Organization (MGO) sends out its own order signals to suppliers. This is a forecasted schedule 20 weeks in advance of the time General Motors will build it. This time period is further broken up into material authorization and fabrication steps. Material authorization is four weeks long, and during this time the supplier is allowed to procure the parts and raw materials it needs to complete General Motors' order. The fabrication period lasts two weeks and allows the supplier to make the specified parts. General Motors also provides a one year long term forecast. This forecast is at the vehicle level, and is primarily used for capacity planning at the supplier.

Collaborative new product development provides benefits in the form of General Motors being able to use the expertise of their suppliers to make better designed parts that are easier to manufacture. Making parts easier to build can significantly reduce costs and lead times. In order to support collaboration General Motors hosts a team of the suppliers' engineers for the development phase. This way both parties are present during the key aspects of design, and can work with other teams to ensure interoperability with all modules.

6.2.3 Logistics Management

For a Just-in-Time operational model variability of supplier delivery times have a negative impact, but transportation from the supplier to the assembly plant also play a role. A supplier can be reliable in producing its parts, but if a logistics service provider has issues of manpower or equipment, a problem still exists. For the Assemble-to-Order model, reducing the transportation lead times and variations are highly beneficial. As a result it turns out that management of the logistics operations has supported General Motors' overall strategy.

In 2000 General Motors formed a joint-venture with CNF called Vector SCM. GM This company became a fourth party logistics provider (4PL) for General Motors, and has since taken control of the majority of GM's annual logistics spend. The reason for founding Vector SCM is that GM realized that managing the logistics operations of their suppliers is not their core competency. Instead, it is better to allow a 4PL to manage the logistics, and to improve the lead times and reduce variability in deliveries. Vector SCM does not perform any logistics operations; they manage the thousands of logistics providers and warehouses that General Motors uses. As a result of their management, General Motors has been able to cut several million dollars worth of inventory costs over the last five years by making the transportation services on the supply side more efficient and reliable. On the customer side Vector SCM has been able to reduce the delivery lead times to the dealers by a couple of days.

6.3 Tying it all together

The three business processes all focus on achieving certain aspects of the operational objectives, which in turn support the operating models and strategy. The sourcing and collaboration processes ensure that the operational measures for customer response and

efficiency are met so that asset utilization is maximized, while the logistics management process is all about efficiency.

The process for sourcing decisions is most involved with determining the quality and service standards of suppliers because it helps General Motors support their Just-In-Time operating model. Since GM does not like to hold inventory, it takes time to replace parts when there is a quality failure. Therefore it is critical to reduce part defects. The other part for the Just-In-Time operating model is that the production of the supplier has to be reliable. General Motors requires that the parts are at the plant when they are needed, and there can be no delay if the assembly line is to keep running, which is an asset utilization measure.

Collaboration with suppliers involves the same operational objectives as the process for sourcing decisions, quality and service. By making the parts easier to manufacture they are less likely to have defects, and production is more reliable. This again directly supports the asset utilization operational objectives and the Just-In-Time operating model. Also by having better information sharing with suppliers because of compatible technical systems, lead times can be reduced, which works in tandem with the Assemble-to-Order model. In addition, General Motors shares the forecast with their suppliers, which helps to synchronize the production operations along the supply chain. Smoothing out the variability in production helps asset utilization.

Finally GM's logistics management process focuses on reducing lead times and variability in lead times, which reduce supply chain costs. Reducing lead times and variability is beneficial for both operating models. For JIT it means that if something goes wrong and there is a parts defect, the time to correct the problem is minimized. For the Assemble-to-Order model shorter lead times result in a more flexible supply chain can adapt to customer needs more

quickly. Supply Chain costs can also be reduced by using the services of third party logistics providers more effectively, therefore increasing efficiency measures.

Bibliography

Automotive News, (2000, May). 1999 Production by Platform. *Automotive News Market Data Book Supplement,* ISSN: 0005-1551, 20-27. Retrieved April 30, 2005 from Business and Industry online Database.

Camuffo, A., (2000). *Rolling out a 'World Car': Globalization, Outsourcing, and Modularity in the Auto Industry*, IMVP Working Paper, Retrieved January 6, 2005, from the Massachusetts Institute of Technology, International Motor Vehicle Program web site http://imvp.mit.edu/papers/0001/camuffo1.pdf

Carliss, Y., Baldwin C.Y., and Clark, B. (1997 September-October). Managing in the Age of Modularity. *Harvard Business Review*, 75(5), 84-93. Retrieved January 21, 2005 from EBSCO online Database.

Cocheo, S. (1986, December). New Directions in Auto Finance. *ABA Banking Journal,* 78(12, 43-55. Retrieved April 24, 2005 from EBSCO online Database.

Cole, D. E., Baron, J. (2003 September). Automotive Manufacturing's Changing. *Manufacturing Engineering*, 131(3), 136. Retrieved January 21, 2005 from ABI/Inform Global Database.

Detroit Free Press. (1999, May 29). General Motors spins off Delphi auto parts division through handing controlling stake over to GM shareholders; Delphi expects $28 bil in annual revenue. *Detroit Free Press*. Retrieved March 15, 2005 from Business and Industry online Database.

Detroit Free Press. (1999, April 13). General Motors plans to spin off its Delphi Automotive Systems auto parts unit to GM shareholders in 5/99. *Detroit Free Press*. Retrieved March 15, 2005 from Business and Industry online Database.

Dickinson, M., Buckley, S. (1997, July 17). Aluminum, Steel, Plastic vie for weight-cutting Crown. *Automotive News,* 71(5723), 24G. Retrieved April 24, 2005 from EBSCO online Database.

Doran, D., (2003). Supply chain implications of modularization. *International Journal of Operations & Production Management,* 23(3), 316-326. Retrieved January 6, 2005 from ABI/Inform Global Database.

Eskigun, E., Uzsoy, R., Preckel, Paul V., Beaujon, G., Krishnan, S., Tew, J. D. (2003). Outbound supply chain network design with mode selection, lead times, and capacitated vehicle distribution centers. *European Journal of Operational Research.* 165(2005), 182-206. Retrieved April 12, 2005 from Science Direct online Database.

Fine, C. H. (1998). *Clockspeed: Winning Industry Control in the Age of Temporary Advantage.* Cambridge, Massachusetts: Perseus Publishing

General Motors Corporation. (2003). 2003 Annual Report. Retrieved February 22, 2005, from General Motors Corporation web site http://www.gm.com/company/investor_information/docs/fin_data/gm03ar/download/gm03arfull.pdf

General Motors Acceptance Corporation. (2003). General Motors Acceptance Corporation 2003 10-K report. Retrieved February 26, 2005 from GMAC website http://www.gmacfs.com/investment/financial_statements/pdf/gmac10k2003.pdf

General Motors Corporation. (2003). General Motors Corporation 2003 10-K report. Retrieved February 23, 2005 from Thompson Research Database.

Guilford, D. (2002, October 28). GM vows to keep competitive incentives. *Automotive News,* 77(6009), 3-4. Retrieved March 2, 2005 from EBSCO online Database.

Halliday, J. (2002, June 24). Bevy of new models cause swoon. *Advertising Age,* 73(25), 10. Retrieved April 30, 2005 from ABI/Inform Global Database.

Holweg, M., and Pil, F. K. (2004). *The Second Century: Reconnecting Customer and Value Chain through Build-to-Order*, Cambridge, Massachusetts: The MIT Press.

Hoover's, Inc. (2005). DaimlerChrysler AG Record: Fact sheet. Retrieved February 13, 2005, from Hoover's online Database.

Hoover's, Inc. (2005). Ford Motor Company Record: Fact sheet. Retrieved February 13, 2005, from Hoover's online Database.

Hoover's, Inc. (2005). General Motors Corporation AG Record: Fact sheet. Retrieved January 31, 2005, from Hoover's online Database.

Hoover's, Inc. (2005). Toyota Motor Corporation Record: Fact sheet. Retrieved February 13, 2005, from Hoover's online Database.

Hoover's, Inc. (2005). Volskwagen AG Record: Fact sheet. Retrieved February 13, 2005, from Hoover's online Database.

Howell, L. J. (2003 May/June). Adapting GM Research to a New Corporate Strategy. *Research Technology Management,* 46(3), 14-20. Retrieved March 16, 2005 from ABI/Inform Global Database.

Howell, L. J, Hsu, J. C. (2002, July/August). Globalization within the Auto Industry. *Research Technology Management,* 45(4), 43-49. Retrieved March 16, 2005 from ABI/Inform Global Database.

Liker, J. K.; Choi, T. Y.. (2004 December). Building Deep Supplier Relationships. *Harvard Business Review*, 82(12), 104-114. Retrieved February 6, 2005 from EBSCO online Database.

Muller, J. (2000, April 24). Maybe What's Good for GM Is Good for Ford; It hopes that a spun-off Visteon will be as successful as Delphi. *Business Week.* 3678, 60. Retrieved March 15, 2005 from ABI/Inform Global Database.

Murphy, J.V. (2004, September). The Automotive Supply Chain: Where Only the Best And the Tough Survive. *Global Logistics and Supply Chain Strategies,* September, 58-66.

Porter, M. E. (1996 November-December). What is Strategy? *Harvard Business Review*, 74(6), 61-78. Retrieved November 15, 2004 from EBSCO online Database.

Standard & Poor's (2005). Industry Surveys: Autos & Auto Parts (December 23, 2004). Retrieved January 15, 2005, Standard & Poor's Market Insight online Database.

Shilling, G. A. (2005, April 25). What's Bad for GM... *Forbes Magazine*, 175(9), 112. Retrieved April 27, 2005 from EBSCO online Database.

Taylor, P. (2004, May). NADA Data. *AutoExec Magazine,* 43-63. Retrieved February 27, 2005 from National Automobile Dealers Association web site http://www.nada.org/Content/NavigationMenu/Newsroom/NADAData/20043/NADA_Data_2004.pdf

Urban, D. J., Hoffer, G. E. (2003). The virtual automotive dealership revisited. *The Journal of Consumer Marketing*. 20(6), 570-578. Retrieved January 17, 2005 from ABI/Inform Global Database.

Veloso, F., Kumar, R. (2002). The Automotive Supply Chain: Global Trends and Asian Perspectives. *ERD Working Paper No. 3, Asian Development Bank.* Retrieved January 16, 2005 from Asian Development Bank web site http://adb.org/Documents/ERD/Working_Papers/wp003.pdf

Waurzyniak, P. (1999 August). Automotive Manufacturing's Technology Evolution. *Manufacturing Engineering,* 123(2), 54. Retrieved January 17, 2005, from ABI/Inform Global Database.

Womack, J.P., Jones, D.T., Roos, D. (1990). *The Machine that Changed the World.* New York: Rawson Associates.

Interviews

UPS Supply Chain Solutions, February 28, 2005. Phone interview.

CSC Consulting March 9, 2005. Phone interview

i2 Technologies February 28, 2005. Phone interview.

General Motors Corporation, April 4th, 2005. General Motors Headquarters, Michigan.