

2010

A Major Study of American (Ford) Compared with Japanese (Honda) Automotive Industry: Their Strategies Affecting Surviabilty

Patrick F. Callihan
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**A MAJOR STUDY OF AMERICAN (FORD) COMPARED WITH JAPANESE
(HONDA) AUTOMOTIVE INDUSTRY – THEIR STRATEGIES AFFECTING
SURVIABILTY**

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ACKNOWLEDGMENTS

First I would like to express my sincere appreciation to Dr. Keys, my advisor, for spending so much time with me and providing me with such valuable experience and guidance.

I would like to thank each of my committee members for their participation: Dr. Paul Bosela, Dr. Baham Ghorashi, Dr. Chien-Hua Lin and Dr. Hanz Richter.

I want to especially thank my wife, Kimberly and two sons, Jacob and Nicholas, for the sacrifice they gave during my efforts.

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ABSTRACT

Understanding the role of technology, in the automotive industry, is necessary for the development, implementation, service and disposal of such technology, from a complete integrated system life cycle approach, to assure long-term success.

This dissertation provides a unique complete characterization of the system life (cycle) business major cost elements of the automotive industry; the subsystems, cost elements, interplay and interdependencies that affect the total real life cycle cost and value; the various stated product, organizational, and process initiatives intended to produce significant improvements in the American automobile industry, as compared to the Japanese.

This dissertation adds a perspective, understanding, and new insights of the drivers of business/technology changes and challenges that are likely to occur over the next 5-10 years. Research was carried out by an extensive review of publications, technical journals, articles, government agency documents, industry publications, annual reports and company bulletins, data and announcements. Results were generated and compared with past industry leaders' efforts.

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CHAPTER 1

INTRODUCTION

1.1 Issues

The internal combustion engine (ICE) automobile from its humble beginnings over 100 years ago quickly grew to become a symbol of independence and status, and through Henry Ford's innovative work helped establish a middle class to support the growth of this Industry. Automotive purchase is the second most expensive purchase (and in fact, most people through multiple automobile purchases spends more on automobiles than their house) one will make in their life (next to their mortgage), for which, unlike the typical house, it is more of a disposable appliance (begins depreciating the minute it leaves the lot) and from the 1960s to the turn of the century almost double in price every ten years. Vehicles (cars/trucks/SUVs/Vans) still represents the number one (by a wide margin) killer of Americans by Americans annually.

Over approximately a recent 30 year period of time, from 1963 to 1993, the American automotive industry has been on a gradual, long-term downward trend in profitability, competitiveness, global market share and technological leadership in the development and introduction of major new fundamental core technologies and products

(Altshuler, Anderson, Jones, Ross, & Womack, 1984; Keller, 1989, 1993; Keys, 1993, 1995; Maynard, 2006). Some studies have even indicated that this industry has not provided a good return on its large overall research and design (R&D) investment since the early 1930s (Foster, 1986).

This dissertation will support how this trend has continued and/or accelerated since 1993. If some of the remaining U.S. automotive industries are to survive, there needs to be a thorough documentation and understanding of those key variables and their effects. When this research began approximately six years ago, the current problems were foreseen, but not expected to arrive so quickly. Furthermore, as products have gradually become more complex since the 1940s and 1950s, project and program management, system engineering, new product development life cycle (late, poor quality, warranty returns and recalls) problems, then concurrent and collaborative engineering have evolved along with more sophisticated quality and reliability initiatives to address the product delivery and warranties issues that this new complexity has introduced.

At the time of initiation of this research, it was intended to completely document the management and technology elements that were contributing to the above mentioned decline, but recent events (bankruptcy filing of GM and Chrysler) have corroborated these forecasts of doom. This dissertation therefore will further document the major elements of the “Big 3” U.S. automobile manufacturer problems, with some perspective, and recommendations for a reversal of fortune.

There is substantial literature suggesting that over the last 40 years for a number of major U.S. industries, the historical focus has been mainly around short-term revenue and profit success from new product development and evolution of older generation

technology platforms, versus longer term commitment (new technology-based) continuous and new innovation process/product development (Keys, 1995, 1997, 1998). This latter focus has led to the demise of a number of major U.S. leaders and significant market loss to others. Rather than investing in R&D to continually strengthen the technology cores and product lines, they chose to diversify into other business to quickly grow revenue. They demonstrated a lack of understanding of technology life cycle and discontinuities.

Keys (1997), Keller (1989,1993), Carson and Vaitheeswaran (2007) suggest that over the last 40 years it has been observed that shifting from one core technologies business based product architecture system to a second new different core technologies based product architecture system is very difficult. For a company transitioning from or leaping from one s-curve technology core system (see Figure 1) to another s-curve technology base innovative system is often fatal for the historically successful larger older technology-based companies (Betz, Keys, Khalil & Smith, 1995).

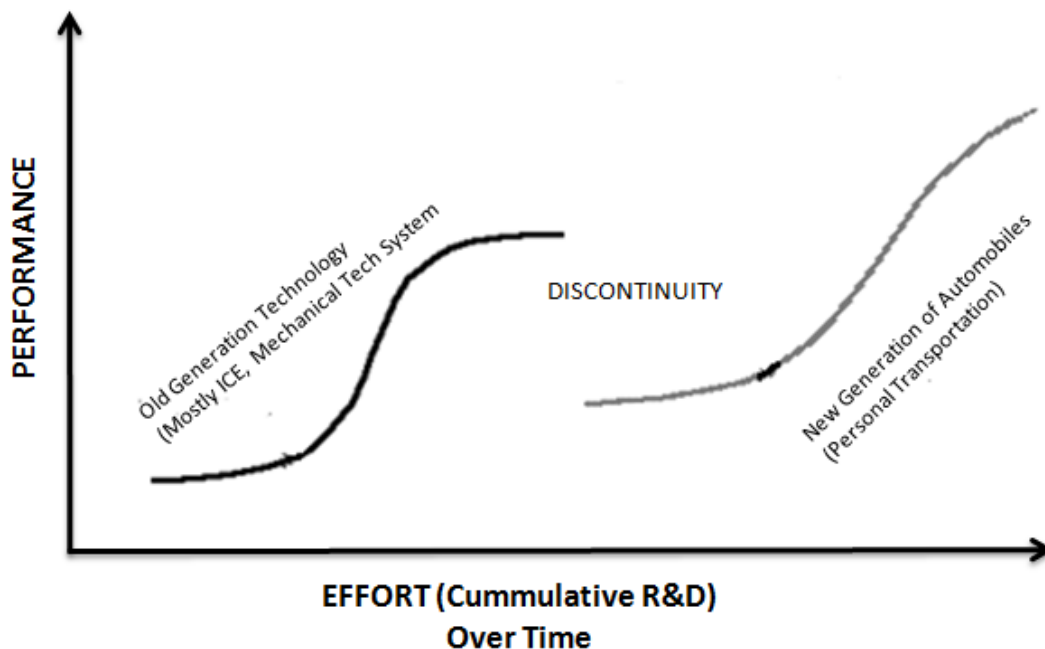


Figure 1 Technology S-Curve with Discontinuity (source: adapted from Keys, 1997)

Some examples include: RCA missing the leap from tube base to solid state based consumer electronics; IBM/PC missing the leap from large mainframe to personal computers; Xerox's missing the market segment major threat for a significant new market, dry copier technology to wet copier based technology, PC/workstation innovation, and also becoming a distant number three, far behind the number one, Cannon, in the copier business, which it had established and owned for many years.

The American companies have struggled with the system engineer, project/program management, concurrent engineering, now collaborative engineering, new product development, quality and reliability processes required to deliver the cost effects, robustness, and defect free products expected by consumers. The Japanese have done an excellent job of accomplishing the above as measured by their vehicle performance in the field (Juran, 1988). Along the way they have demonstrated the ability to add in, blend in, continuous evolving new technologies with minimal initial negative effects while obtaining longer term accumulated benefits.

This perspective has also indicated that the priority of international competition focus (principally Japanese) has been, in a number of industries, one of continuing new technologies process innovation improvement more than just new product development, much of it around leading the incorporation of solid state microprocessors and mechatronics systems into products and manufacturing processes. What is often missed, however, is that their process innovation tends to be around new technologies that invent or reinvent the market place through new product developments (Narayanan, 2001). This persistent strategic difference in priorities has helped lead Japanese companies, in recent years, to achieve dominance in their major strategy product industries, in which they have

identified and upon which they have focused, as critical to their future economic success. In particular they are building upon their solid state semiconductor, robotics, and mechatronics (Schodt, 1998). A number of emerging South Korean companies, (e.g. Samsung, LG Electronics, Hyundai, etc) are now pressing the Japanese companies for leadership in a number of new consumer industries.

Over the past 40 years there has been steady erosion of the American automobile industry, accelerating in the past 10+ years. This has occurred primarily as a result of the Japanese industry persistence strategy and successes and now additional international players.

1.2 Dissertation Goals and Objectives

This dissertation extensively assesses a variety of literatures (information data mining) in attempts to define a reference cost model: a unique complete characterization of the system life (cycle) business major cost elements of the current automobile industry. The research will build on the academic studies of process versus product research and development (Mansfield, 1988) and the difference in focuses of engineers and engineering between the American and Japanese as suggested by Lynn (2002). It will analyze from a system/enterprise and integrated life cycle perspective a significant number of the major technology, management, and business economic factors that are attributed to the presented continued evidence of shrinkage of the native U.S. automobile industry. It will draw example parallels to similar major U.S. and foreign company past success patterns in a number of other industries.

The results of the research will be instrumental in analyzing and identifying the

directions, and potential new directions, challenges and likely possible outcomes of the U.S. automotive industry for the future. This research will build on and extend several documented early academic based analysis (Keys, 1993, 1995, 1997, 1998; Mansfield 1988; Lynn 2002; Martin 1994; Perel 2002; Sobek, Liker & Ward 1998; Tucker 2002; Handy 1994; Chanaron & Jolly 1999; Betz, et al., 1995), of the American automotive and other industries. The study focuses on the U.S. automobile industry's inability to speedily move from one S-curve paradigm changing base to another while the Japanese competitors are steadily making, driving, and leading the actual transformation and evolving into the new global industry leaders.

A thorough comprehensive multi-discipline business technology (environment intelligence) literature search (form of information, data mining) will be compiled, integrated, and presented on the various enterprise elements of technology. Those elements include: product and business leaders, society and success over the recent 10-15 years of major U.S. automobile companies. The major examples focus on a comparison between America's number two automobile company, Ford, representing the typical "old guard" or complacent risk-adverse business model and Japanese's number two automobile company, Honda, as the aggressive new continuous technology development/improvement and implementation model. Some comparisons, where appropriate, will be drawn from other automobile manufacturers' experiences.

It will be argued that the major American automotive companies are headed rapidly toward a similar manufacturing extinction or extinction path similar to many other U.S. industry leaders (Kodak wet chemistry film; Motorola cell phone; RCA's VCR and television; Xerox's dry copiers; and IBM's personnel computer business, recently

sold to a Chinese firm, Lenovo) if their old business paradigms do not change. This core technology system and industry loss may cause the United States to lose or transfer the lead and major wealth and jobs to international competition, which ultimately could also lead to the American automobile industry going the way of a number of the other major American pioneered industries.

Despite the fact that for years, the automobile industry has had gross revenues that exceed many countries gross domestic products (GDP), and even annual research and development budgets that exceed many other competitive companies annual revenues they seek government research support. They have sought government handouts and corporate breaks for initiatives to produce multi-fuel capabilities for breaks in CAFÉ requirements (where CAFÉ is the corporate average fuel efficiency that the Government mandates that the automotive manufacturers' vehicles, both cars and light trucks, must average on a miles per gallon basis or pay penalties). These issues and now government bail outs and guaranteed loans to address shorter new initiatives while paying executives and the rest of their employees high annual salaries for a track record, are sustaining poor performance.

Thus, the first objective of this research is to clearly present evidence that the American automotive industry has been on a longer-term downward trend in profitability, competitiveness, and global market share of automobiles. The American automotive industry seems to have been at best stagnant in response over the last few decades and only recently has desperately tried to “wake up” and save itself with government assistance. In general it has not offered real leadership in most, new major performance improving fundamental core technologies, and playing catch up with the international

leaders only offering added peripheral features and larger vehicle models with “add-ons” to maintain price increases in an attempt to be profitable and preserve market share.

The second objective is to clearly present that the American automotive industry has addressed recent vehicle market growth by introducing additional large trucks, vans, and truck platform based and sport utility vehicles (SUVs). As a result the U.S. industry has to increase its R&D budget to incorporate leading the introduction of major new technologies (including fuel efficiency) including electronics and mechatronics into its product and corporate culture as proposed by Keys (1998). The perspective is that American automotive industry has been stuck in this historical ICE mechanical product system average or less R&D investment budget culture, and related business paradigm, from as far back as the 1940s to the present.

The third objective is to demonstrate the paradigm that the real Japanese unique strategy is to grasp the electronics/mechatronics complex system of new process technology innovation. This promise of new product innovation re-invigoration drives new product and the continuous development and improvement in performance drives their knowledge base into new and additional conceptual product developments. Strategy drives them to deliver products of better performance, at reduced costs, with greater reliability, higher quality, and overall better customer satisfaction with subsequent market share growth.

The fourth objective is to demonstrate that the economic and technological environment of the American automotive industry is very similar today to that of a number of historical high technology industries. Examples of those industries include: the American consumer electronics industry (television, camcorder, VCR) of 40 years

ago; the American led photocopier industry of about 30 years ago; and the more recent telecommunication and information system and cellular phone industry of the past 10 years. The American consumer electronics industry of the 1960s failed to recognize the impact of American invented solid state electronics technologies on their business and effectively transition from the old product technology based on vacuum tubes, to the new product technologies, based on American invented solid-state devices. The American business leaders disappeared dramatically and relatively quickly, as a result. The American photocopier pioneer (Xerox) and leader failed to grasp the potential competitiveness of new core wet chemistry based technologies, and their potential for developing new product markets. As a result, today it has a fraction of the market it used to dominate. The past 10 years of changes in the voice based telecommunications system to broadband (internet able) information system, which makes voice communication free (non-revenue generator), has cost these providers or suppliers/leaders (Nortel, Lucent) their leadership. And more recently the cellular phone industry pioneered by Motorola now trails Nokia, Samsung, and others.

It now appears that the American automotive industry has also declined by failing to lead transitioning from the same 50-plus year mechanical/materials and internal combustion engine technology system bases to new high mileage, lower pollution hybrid and alternative technology systems leading to the new energies based electronic systems (and hydrogen) economy. The American companies' historical approach has been, for example, characterized by battling legally to minimize government regulations, fighting lawsuits over poorly designed/developed products, and their supposedly negative impact on their business rather than strategically and aggressively invest in appropriate new

process core technologies, revolutionary new products, and new market strategies. The above occurred while having a multi-billion dollar R&D budget.

The American consumer electronics industry from 1950s through 1970s was so consumed in the successes of its old culture or paradigm, that they were blind to the Japanese companies' new game changing initiatives (Keys, 1997). The management leaders were so arrogant in their success that they totally failed to understand the potential impact of new core process technologies on their product's performance and business. Keys experienced this first hand while working in the industry as a research engineer during this period. The Japanese consumer electronics new innovations hungry leaders, seeing the self preservation/economic growth possibilities surpassed the Americans in cost savings, performance and reliability. They did so by developing and implementing new core technologies and related process discipline while the United States companies remained relatively stagnant in their old comfortable winner take all old paradigms. The Japanese were then able to extend warranties (system life cycle thinking) far longer than the Americans. This caused the Americans to forgo their profitable tube replacement business to match the cost of maintaining their products and ultimately leading to the extinction of the American consumer electronics industry. Similar analogies can be drawn for the American copier industry and more recently on the camera film (35mm) and the digital camera business of the historical industry pioneer/leader Kodak.

An additional expected result of this research is that it will add to the documented academic knowledge base. There will be a better understanding of recognizing when and how a maturing older technology core industry S-curve appear and manifests itself and

how new technology core elements make-up the beginning of the new technologies opportunities S-curve. This is also important to academies because of the need to be more aware of these beginning new curves so they can anticipate, strategize and plan for revising, and implementing new courses and curricula to prepare their students for this new millennium techno-economic future. This is where students' future jobs and careers will lie, and their success will come from being prepared to help make that happen.

It is still unclear how long, or with what risk, the traditional automotive industry, or any other similar major American maturing industry can survive in an increasing competitive global market place without major changes in how it established and integrates its R&D and how it does business. This risk increase given the apparent unwillingness or sluggishness of historically successful American industries to effectively adopt or embrace the effective development and incorporation of new process technologies with their associated organizational and cultural changes. Following the Japanese and, more recently, South Korean leaders there are other increasingly competitive and successful future threats from Chinese and Indian companies. Thus, coming back to the theme of this dissertation, there is no clear understanding of these factors, or the drivers of change, and how these factors could negatively affect the historical American ICE-based automotive industry and threaten its survival.

1.3 Research Methodology

The hypothesis being examined is that the ICE-based vehicle system world is in the process of transitioning through a major economical discontinuity to the next generation electronic vehicle systems technology based on techno-economic global

economy; Honda, as the number two Japanese automobile company, though smaller than Ford, is better positioned to make this transition more successfully than Ford, the number two U.S. automobile company.

The auto industry has been studied and analyzed several times over the decades, however, these studies reviewed small aspects of the entire entity. Some examples are: MIT through the International Motor Vehicle Program studied the difference between production systems – a study between lean manufacturing and mass productions; studies performed on product design versus process design (Caravitti, 1992); and several publications, surveys and studies on quality (and systems), reliability, supplier relationships, to name a few.

This dissertation constitutes a more in-depth system study analysis, from a system engineering, system integration and management of technology approach, and examines the areas as outlined in section 1.4, their interrelations and determined which are more significant and which affects (need to be addressed by the automotive manufacturers) future direction.

Supporting information/data for this dissertation was obtained by an extensive search and review of academia publications, technical journals and studies (SAE, Quality Progress, Reliability Engineering, etc), articles and news/conference releases, industry publications, seminar presentations, governmental data bases (café database, highway and safety data base, EPA data base, CIA world fact book), academia text books, automotive industry publication books, and published interviews of auto industry leaders. By using this broad and recent variety of information sources, this research will have the most current and relevant perspective in today's fast changing environment world; using only

reviewed, published academic references would mean, in general, that information is four-five or even seven plus years old. Using multiple sources, cross checked, helps create a more complete picture of the patterns of “behavior” being evidenced; this is also a contributor to the large bibliography reference list at the end of this dissertation.

Finally this data was compiled, presented, and tested against past industry leader failures. Reviewing of past industry leaders who survived and current high technology leaders to draw conclusion and define necessary recommended actions that must be addressed to assure longer-term survivability is presented.

1.4 Organization of Dissertation

Chapters 2, 3, 4 and 5 addresses the early years of the American automotive industry development and expansions through the 1950s. Chapter 2 presents a brief history of the early entrepreneur/innovative automotive industry and the development of manufacturing (interchangeable parts, mass production and lean manufacturing). Chapter 3 looks at the development of Ford’s Model T and associated technologies. Chapter 4 investigates early oil and the development of the industry up to the first oil embargo (part I) and will later be followed by Chapter 13 that will look at the oil industry post the first oil embargo and the affects that it has had in the automotive industry. Chapter 5 presents how General Motor’s Sloan revolutionized the marketing of the automobile industry and the model change methodology as well as a brief look at current General Motors performance.

Chapters 6, 7 and 8 address the growth of the major Japanese automobile companies, culture, and management discipline. Chapter 6 examines the Japanese culture

and early Japanese auto industry and development followed by Chapter 7 that examines how Toyota revised the mindset or paradigm on the manufacturing process (shift from mass production to lean manufacturing). Chapter 8 looks at early Honda history, specifically their motor cycle business and early Honda Civic.

Chapters 9, 10, 11, and 12 address the improved system engineering, reliability, quality, management discipline and the increasing complexity of the automotive system architecture. Chapter 9, 10 and 11 sets the basis definition and requirements for system engineering, quality and reliability. Chapter 12 investigates and defines the automobile as a complex system and architecture, and how the electronics is affecting the automobile.

Chapter 13 presents the effects of the increased dependence of foreign oil on the American (and European) automobile industry and the increased usage of oil by the growing nations of China and India.

Chapter 14 and 15 examines the roles, expectation and pay of the U.S. employees. First, Chapter 14 looks at the union issues. Second Chapter 15 examines management structure and executive compensation. These two chapters are then followed by the description of foreign implants in the U.S., their locations, and the resultant effects on the “Big 3” operations (closures), covered in Chapter 16.

Chapter 17 and Chapter 18 focus on Ford Motor Company and Honda Motor Company respectively; strategies and performance characteristics and results. Chapter 19 focuses on management of technology and investigates previous American leaders in other industries, the consumer electronics industry, how they failed and how the Japanese managed to become the new industry leaders. Chapter 20 compares Ford and Honda’s

performance and characteristics. Conclusions and Summaries are presented in Chapter 21 including some perspective on the disruptive technologies challenges to the volume industry leaders, including Ford and Honda. Necessary recommended actions that must be addressed to improve the U.S. automotive industry longer-term chances of survival and re-growth in the presence of an ever increasing investment (currently \$10 billion plus) in new U.S. manufacturing plants base competition invasion by leading foreign vehicle companies is discussed.

CHAPTER 2

AUTOMOTIVE HISTORY

2.1 Automotive Industry Historical Overview

To better understand how and why the automotive industry is where it is today, a brief historical background of the automotive industry is offered. The development of the automobile can be tracked back to 1769 when Nicolas Joseph Cugnot of France built the first vehicle, (Olsen 2002). Cugnot is recognized by the British Automobile Club and the Automobile Club de France as being the first producer of a car. The United States on the other hand recognizes inventor, Oliver Evans, from Philadelphia, who in 1805 invented the automobile when he patented the first steam-powered vehicle. The idea was short lived when his attempt to find financial backers for his company, Experiment Co., failed.

An inventor in Massachusetts, Sylvester Roper, followed Evans in 1860, claiming that he developed a steam engine vehicle, which was capable of a top speed of 25 miles per hour, fueled by coal, and could carry two passengers. Again, no financial backing could be found to produce this vehicle. Several other attempts at steam-powered vehicles were made with similar fates. It was not until the internal combustion engine was developed and improved upon that the automobile industry ignited.

To briefly look at the historical development of the internal engine we must go back to 1680 to a Dutch physicist, Christian Huygens, who designed a combustion engine fueled by gunpowder. It would be an additional 127 years prior to the building of a functional internal combustion engine. In 1807, Francois Isaac de Rivaz invented an internal combustion engine that used a mixture of hydrogen and oxygen for fuel. He then designed a car for his engine – the first internal combustion powered automobile (Banham 2002; Erjavec 2005). Jean Joseph Etienne Lenoir invented and patented a double-acting, electric spark-ignition internal combustion engine in 1858. Nikolaus Otto, in 1876, produced the first four-stroke “gasoline” engine in Germany, while the first successful two-stroke engine was invented by Sir Dougald Clerk. Within nine years of Otto’s development of the four-stroke engine, fellow Germans, Karl Benz and Gottlieb Daimler, had built what is often recognized as the prototype of the modern gas engine, vertical cylinder with gasoline injected through a carburetor (patented in 1887) and produces a low volume marketable vehicle. This marketed vehicle was possible due to the characteristic of the engine that had relatively high power and was lightweight for the time; two essential factors for a viable automotive application (motorera.com, retrieved 9/15/07).

Everything was basically in place to develop and market the car to the public. By 1894, Henry Ellis of the English Parliament endeavored to purchase an automobile. This venture led him to the Paris machine-tool company of Panhard et Lavassor (P&L) and he commissioned an automobile, (Womack, Jones, & Ross, 1990). The P&L was building several hundred automobiles per year, with the basic architecture of today’s vehicles – System Panhard – meaning the engine was in front, with passengers seated behind and

drive shafts turning the rear wheels.

Even though it was the Germans that pioneered the technology base for the automobile of today, it is the United States that is really credited with the development of, and driving the volume industry in the present mass market form today.

2.2 Time Line of Developing Technologies

Keys (1993) argued in 1993 that major technologies within the volume (American) automotive industry had remained largely unchanged for almost the previous 50-60 years, with only modest incremental improvements and feature additions. This section will detail some of the more important technologies and the associated timing of invention. This chapter will be broken down into mechanical/hydraulic section followed by early electrical and electronic applications and lastly engine design (cylinder type and turbo chargers and superchargers); and demonstrating how long that we have relied on “old” historical internal combustion engine technologies.

2.3 Mechanical/Hydraulic

This section will define several non-engine related items and the technology development. Beginning with one of the earliest is the differential. A **differential** is a device, usually consisting of gears, that allows each of the driving wheels to rotate at different speeds, while supplying equal torque to each of them. In 1827 the modern automotive differential was patented by watch maker Onesiphore Pecqueur (Duffy, 2009). In 1913 Packard introduces the spiral-gear differential, which cuts gear noise and in 1926 introduces the hypoid differential, which enables the propeller shaft and its himp

in the interior of the car to be lowered, (Newton, 1999). Other transmissions are described below:

Manual Transmissions – used to provide a speed power conversion, or gear reduction, from a higher speed motor to a slower but more forceful output. A rudimentary three-speed transmission was developed in 1832 by W.H. James. The modern transmission was developed by Panhard and Levassor in 1895 and was patent on April 28, 1908.

Automatic Transmissions – are an extension of the manual transmission with the exception that the transmission shifts itself with little intervention from the operator. Oldsmobile's 1940 models featured Hydra-Matic drive, the first mass-production fully automatic transmissions. The Hydra-Matic had a fluid coupling versus today's torque converter, and three planetary gear-sets providing four speeds plus reverse (Olsen & Cabadas, 2002). The first torque converter automatic was introduced in the 1948 model year as the Buick Dynaflo, which was followed by Packard's Ultramatic in 1949 and Chevrolet's Power glide for the 1950 model year. These were two speed transmissions relying on the torque converter for additional gear reductions. In the 1950s Borg-Warner developed a series of three-speed torque converter automatics for American Motor Company, Ford, Studebaker and several other manufacturers. By the 1980s automatic transmissions were adapted with an overdrive equipped transmissions providing four or more forward drive speeds and many transmissions were built with the lock-up torque converters (a mechanical clutch locking the torque converter impeller and turbine together to eliminate slip at cruising speed) to improve fuel efficiency. Minor modifications have been made since incorporating computer controls which will be

discussed in greater detail in the next chapter.

Power Steering – Invented by Francis Davis in the 1920s. He developed a hydraulic power steering system that led to power steering that became commercially available by 1951 by the Chrysler Corporation. It was on their 1951 Chrysler Imperial under the name Hydra guide to make it easier to steer due to the heavier weight. It added a larger consumer base (basically for smaller statured people, mostly women) and easier to maneuver on narrow streets as vehicles became larger (Olsen & Cabada, 2002). With safety and stability becoming increasingly important, vehicles have trended to front wheel drive, greater vehicle mass and wider tires, all of which make steering a vehicle without power steering extremely difficult, especially at lower speeds and when parking.

Brakes – In simplest definitions, a brake is a device for slowing or stopping the motion of a machine or vehicle. The modern automobile drum brake was invented in 1902 by Louis Renault. In the first style brakes, shoes were mechanically operated with levers and rods or cables. However, examining the kinetic energy formula ($E = \frac{1}{2} m * v^2$), which means as the vehicles doubles in velocity (speed) it has four times as much energy, thus, brakes must therefore dissipate four times as much energy to stop the vehicle. As can also be seen from the above formula, mass also increases the energy required linearly, so as vehicle mass increases energy required to stop the vehicle also increases.

As vehicles became heavier and faster the need for hydraulically assisted braking became a necessity to compensate for the additional weight. From the mid-1930s the

shoes were operated with oil pressure in a small wheel and pistons. Disc brakes eventually replaced drum brakes in beginning of the 1950s. The first reliable disc brakes were developed in the UK by Dunlop and first appeared in 1953 on the Jaguar C-Type racing car. The first American production cars to be fitted with disc brakes were the 1963 Studebaker Avanti, standard equipment on the 1965 Rambler Marlin, and the 1965 Chevrolet Corvette Stingray. The disc brakes offer better stopping performance than comparable drum brakes, including resistance to “brake fade” caused by overheating of brake components. They were able to recover quickly from immersion (wet brakes).

2.4 Early Electrical Systems

One of the earliest inventions for the newly created car with an internal combustion engine was the electric starter. Prior to the invention of the electric starter, hand cranks were used to fire the engine. Charles Kettering was credited with the invention of the first electric starter, which for all practical purposes created the first hybrid vehicle (combination of mechanical and electrical motor systems). The true hybrid vehicle, as we know it today, electrical engine supplemented by an ICE engine was actually created by Porsche in 1899, (Gordon 2009). His starter was first installed on the Cadillac on February 17, 1911. The electric starter required a battery to initiate the starter on ignition. This required mechanism to re-charge the battery; hence the powered electric generator was also then introduced to the vehicle.

The **electrical generator** is a device that changes kinetic (mechanical) energy to electrical energy. Typically the mechanical energy, retrieved from turbine steam engines, water-falls, wind mills, internal combustion engines, generates electricity through

electromagnetic induction. The most common generator used was the Gramme dynamo, which was developed in Paris in the 1870s by Zenobe Gramme (Wikipedia.org as viewed 1/15/2004). Early motor vehicles used DC generators with electro-mechanical regulators. These generators were not particularly reliable. They created different voltages at different RPMs, or inefficient, and with the addition of more electronics putting a larger strain on the electrical system led to the creation of the alternator.

An **alternator** is also an electromechanical device that converts kinetic energy to alternating current electrical energy (Erjavec, 2005; Duffy, 2009). Alternators generate electricity by the same principals as DC generators. When the magnetic field around a conductor changes, a current is induced in the conductor. Alternators have the great advantage over direct-current generators by not using a commutator, which makes them less complex, lighter, less expensive and more durable than the DC generator. The availability of low-cost solid state diodes from about 1960 allowed the auto manufacturers to replace generators with alternators.

Other miscellaneous early electronic feature inventions include:

- Car Radio – Invented in 1929 by Paul Galvin, the head of Galvin Manufacturing Corporation.
- Cruise Control – Invented by Ralph Teetor in 1945 and was offered on the 1958 model Chrysler Imperial, New Yorker and Windsor Car. By 1960, all Cadillacs had cruise control.
- Airbags – Rudimental airbag patents go back to the 1950's submitted by German Walter Linderer and American John Hedrik. Ford built an experimental airbag fleet in 1971 followed by General Motor experimenting in 1973 (inventors.about.com/od/astartinventions/a/air_bags.htm).
- Power Windows – Power windows were first introduced in 1941 on the Lincoln custom vehicles, limousines and larger passenger vehicles (seven plus), and on the largest Packard vehicles (CBS News, Power Windows are Perilous, retrieved 2/11/09).

2.5 Internal Combustion Engine (ICE) Design (Early Years)

There are basically two types of internal combustion engine, the two-stroke and the four stroke. Not much time will be spent discussing the two-stroke engine since the majority of automotive engines are the four-stroke type. There are basically two fundamental differences between the two-stroke and four-stroke engine. First, the two-stroke uses a mixture of lubricating oil and fuel to power the engine, because it had no self-lubricating system. The second difference is that the two-stroke engine's cylinder is slightly taller, and has a reed valve which permits the total cycle of the engine in one piston stroke versus two cycles for the four-stroke engine (four stroke consist of the induction, compression, power and exhaust) (Erjavec, 2005).

The power generation from a four-stroke engine comes from several components that over the years have remained relatively unchanged or had changed slowly over the last 100 years. Components are: exhaust, cam shaft, intake cam shaft, crank shaft, exhaust valve, intake valve, piston, spark plug, and timing mechanism. Original engine design put the cam shaft below the engine using push rods to open and close the intake and exhaust valve, with only single valves. This type of cam system was replaced with the over head cam valve train configurations. This system placed the camshaft within the cylinder heads, above the combustion chambers, and drive the valves or lifters directly versus the use of pushrods. When compared with pushrod systems with the same number of valves, the reciprocating components are fewer and in total will have less mass (hence producing more power with less over all weight, making the system much more efficient). Though the system that drive the cams become more complex, it is accepted

by most engine designers for increased performance.

The first over head cams were produced by Isotta Fraschini's Giustino Cattaneo, Austro-Daimler's Ferdinand Porsche Stephen Tomczak (in the Prinz Heinrich), and W. O. Bently (in 1919); Sunbeam built small numbers between 1921 and 1923. The first over head cam engines were two- or four-valve per cylinder designs from companies like Fiat (1912), Peugeot Grand Prix (1913, 4 valve), Alfa Romeo GP (1914, 4 valve) and 6C (1925), Maserati Tipo (1926), Bugatti Tyoe 51 (1931) and Audi (1935).

Couple with the over head cam, the multi-valve designs became a popular engine design improvement. All four-stroke engines have at least two valves, the exhaust valve and the intake valve. Adding more valves improves the flow of the intake and exhaust gases, potentially improving combustion efficiency, power and performance. It is not very practical to just enlarge the two required valves for reasons of simple geometry (two smaller intake valves will fit side-by-side on one side of the combustion chamber, whereas a single valve cannot be made too much larger), and to keep the mass (and inertia) of individual valves as low as possible. Multi-valve designs can be tracked back as far as 1922, when many Bugatti engines used three valves per cylinder actuated by a single overhead camshaft. Many engines were made with two valves per cylinder; however, starting in the later 1980s (mostly due to the Japanese use) there was a virtual explosion of multi-valve and double overhead cam engines which came to market to improve the performance of their small four-cylinder engines.

One of the major challenges in engine design and operation is the control of engine efficiency. Engine efficiency is simply the measurement of the relationship between the amount of energy put into an engine and the amount of energy available

from the engine. The following factors affect the overall efficiency of the engine

(Erjavec, 2005):

- Thermal Efficiency – is a measure of how much of the heat formed during the combustion process is available as power from the engine. Usually a third of the heat is available for power while two-thirds is lost to surrounding area (air or engine parts). Technology in material engineering is advancing and perhaps a ceramic engine, which will be close to 90% efficient, is not too far off in the future.
- Mechanical Efficiency – is a measure of how much power is available once it leaves the engine compared to the amount of power that was exerted on the pistons during power stroke. Friction generated by moving parts account for the power loss.
- Volumetric Efficiency – the engine's ability to have its cylinders filled with air/fuel mixture. If the engine's cylinders are able to be filled with air/fuel mixture during its intake stroke, the engine has a volumetric efficiency of 100%. Typically, engines have a volumetric efficiency of 80 to 100% if they are not equipped with a turbo- or supercharger.

Following on the last item, volumetric efficiency, there are several ways to improve the efficiency without increasing the size of the block, or cylinders. Two of the ways are superchargers and turbo chargers. Both of these devices are used to increase the effective displacement and volumetric efficiency of an engine. This occurs by pushing more air into the cylinders, it is as if the engine has larger valves and cylinders, resulting in a larger engine that weighs less.

TURBO CHARGERS

The turbo chargers main purpose is to increase the pressure at the point where air is entering the cylinder, and the amount of air brought into the cylinder is largely a function of time and pressure, more air will be drawn in as the pressure increases by using waste exhaust gas from the engine. The additional air makes it possible to add more fuel, increasing the output of the engine, (Erjavec, 2005). The intake pressure can

be controlled by a waste gate, which controls shaft speed and regulate boost pressure in the inlet tract. The challenge with turbo chargers is that since they run off the extremely high exhaust gas, coming from the exhaust manifold, the components must be made of very robust materials to have a useful long term life and reliability. This has been at times difficult in the recent history of higher volume consumer vehicles to produce turbo charges from having a high early failure rate.

The turbo charger consists of the turbine, impeller, and compressor wheels which are contained within in their own folded conical housing on opposite sides of the center housing and hub rotating assembly (Erjavec, 2004). The housings fitted around the compressor impeller and turbine collect and direct the gas flow through the wheels as they spin. The size and shape can dictate some performance characteristics of the overall turbo charger. The area of the cone to radius from center hub is expressed as a ratio (AR, A/R, or A:R).

Often the same basic turbo charger assembly will be available from the manufacturer with multiple AR choices for the turbine housing and sometimes the compressor cover as well. This allows the designer of the engine system to tailor the compromises between performance, response, and efficiency to application or preference. Split-inlet exhaust housings permit the exhaust pulses to be grouped (or separated) by cylinder all the way to the turbine so that the exhaust pulse, individual package of energy can stay intact and undisturbed by other pulses, all the way to the turbine. This in turn can give the turbine a better kick to get it moving. This is specifically useful in four-cylinder engines. A four-cylinder engine only sees one pulse every 180 degrees of crank rotation, it needs all the energy it can get from each pulse. Keeping them separated and

undisturbed will therefore pay back some dividends. The turbine and impeller wheel sizes also dictate the amount of air or exhaust that can be flowed through the system, and the relative efficiency at which they operate. Flow capacity can be increased by enlarging the turbine wheels and compressor wheels.

Measurements and shapes can vary as well as curvature and the number of blades on the wheels. The center hub rotating assembly houses the shaft which connects the compressor impeller and turbine. It also must contain a bearing system to suspend the shaft, allowing it to rotate at very high speed with minimal friction. For instance, in automotive applications the CHRA typically uses a thrust bearing or ball bearing lubricated by a constant supply of pressurized oil. The CHRA may also be considered “water cooled” by having an entry and exit point for engine coolant to be used to keep the lubricating oil cooler, avoiding possible oil cooking from the extreme heat found in the turbine (Erjavec, 2005).

The turbo charger was invented by Swiss engineer Alfred Buchi. He applied for a patent in 1905, (Sherman, 2009). The first production turbo charged automobile engines came from General Motors (GM) in 1962; some of the models included the F85 Cutlass with an aluminum block with steel block inserts on the V8. The A-body Oldsmobile Cutlass Jetfire and Chevrolet Corvair Monza Spyder were both fitted with turbo chargers. The Oldsmobile is often recognized as the first, since it came out a few months earlier than the Corvair. Its Turbo Jetfire was a 215 in³ (3.5 L) V8, while the Corvair engine was either a 145 in³ (2.3 L), 1962-1963, or a 164 in³ (2.7 L), 1964-1966, flat-6. Both of these engines were abandoned within a few years, and GM’s next turbo engine came more than ten years later (Sherman, 2009).

Offenhauser's turbo charged engines returned to Indianapolis in 1966, with victories coming in 1968. The Offy turbo peaked at over 1,000 HP (750kW) in 1973, while Porsche dominated the Can-Am series with a 1,100 HP (820kW) 917/30. Turbo charged cars dominated the Le Mans between 1976 and 1988 and then from 2000-2007.

BMW led the resurgence of the automobile turbo charger with the 1973 Turbo, with Porsche following with the 911 Turbo in 1974. Buick was the first GM division to bring back the turbo in the 1978 Buick Regal, followed by the 1978 Mercedes-Benz 300D, and the 1978 Saab 99. Japanese manufacturers and Ford followed suit, with Mitsubishi Lance in 1978, Ford Mustang in 1979, Toyota Supra in 1980, Nissan 280ZX in 1981, and the Mazda RX-7 in 1984.

The world's first product turbo diesel automobile was also introduced in 1978 by Peugeot with the launch of the Peugeot 604 turbo diesel. Today, nearly all current automobile diesel engines are turbo charged.

Alfa Romeo introduced the first mass-produced Italian turbo charged car, the Alfetta GTV 2000 Turbo Delta in 1979. Pontiac also introduced a turbo in 1980 and Volvo followed in 1981. Maserati in 1980 was the first to introduce twin or bi-turbo Maserati Biturbo. Renault however took another step and installed a turbo charger to the smallest and lightest car they had, the R5, making it the first Supermini automobile with a turbo charger in 1980. This gave the car about 160 HP (120 kW) in street form and up to 300+ HP in race setup, which was extraordinary output for a 1400cc engine. The R5's powerful engine was complemented by an incredible lightweight chassis, and as a consequence it was possible for a R5 to compete with the Ferrari 308.

In Formula One (F1), in the so called “Turbo Era” of 1977 until 1989, engines with a capacity of 1500 CC could achieve anywhere from 1000 to 1500 HP (746 to 1119 kW). Renault was the first manufacturer to apply turbo technology in the F1 field, in 1977. The project’s high cost was compensated by its performance, and led to other engine manufacturers to follow suit. The turbo charged engines took over the F1 field and ended the Ford Cosworth DFV era in the mid 1980s. However, the FIA decided that turbos were making the sport too dangerous and expensive and from 1987 onwards the maximum boost pressure was reduced before the technology was banned completely in 1989.

In rallying, turbo charged engines of up to 2000 cc have long been the preferred motive power for the Group A/N World Rally Car (top level) competitors, due to the exceptional power-to-weight ratios (and enormous torque) attainable. This combines with the use of vehicles with relatively small body shells for maneuverability and handling. As turbo chargers output rose to similar levels in F1 category the FIA rather than banning the technology enforced a restricted turbo inlet diameter (currently 34 mm) effectively “starving” the turbo of compressible air and making high boost pressures unfeasible. The success of small turbo charged four wheel drive vehicles in rally competition, beginning with the Audi Quattro, the Peugeot 205 T16, the Renault 5 Turbo, the Lancia Delta S4 and the Mazda 323GTX. This has led to exceptional road cars in the modern era such as the Lancia Delta Integrale, Toyota Celica GT-Four, Subaru Impreza WRX, and the Mitsubishi Lancer Evolution.

In the late 1970s, Ford and FM looked to the turbo charger to gain power, acceleration with reduced fuel consumption, during the emissions crunch mandated by

the federal government (as the second oil embargo created further gasoline shortages). Gm released turbo V6 versions of the Pontiac Firebird, Buck Regal, and Chevy Monte Carlo, Ford responded with a turbo charged Mustang in the form of the 2.3L in the Pinto. The engine design was dated, but it worked well. The 2.3L Turbo was used in early carbureted trim as well as the fuel injected and inter-cooled versions in the V6 Mustang SVO and the Thunderbird Turbo Coupe until 1988.

Although late to use turbo charging, Chrysler turned to turbo chargers in 1984 and quickly churned out more turbo charged engines than any other manufacturer, using turbo charged, fuel injected 2.2 L and 2.5 L four cylinder engines in minivans, sedans, convertibles, and coupes. Their 2.2 L turbocharged engines ranged from 142 HP (106 kW) to 225 HP (168 kW), a substantial gain over the normally aspirated ratings of 86 to 93 HP. The 2.5 L engine had about 150 HP (110 kW) and had no inter-cooler. Chrysler also pioneered variable geometry turbo charging with the introduction of the 1989 Shelby CSX, a system that completely eliminated the “turbo lag”. Though the company stopped using turbo chargers in 1993, they returned to turbo charged engines in 2002 with their 2.4 L, boosting its performance by 70 HP.

SUPERCHARGER

Supercharging technically refers to any pump that forces air into an engine – but in common usage, it refers to pumps that are driven directly by the engine as opposed to turbochargers that are driven by the pressure of the exhaust gas. The advantage of the turbo charger is that it is initiated by waste gas (exhaust); therefore, it utilizes no extra energy. The major down fall is the “lag” or the time it takes the exhaust gasses to build

pressure as the engine speeds up. With the supercharger, since it is mechanically driven, the lag is nonexistent; however, extra energy is consumed to provide extra efficiency, or power (Harris, 2006).

The first supercharger was designed and patented by Francis Root in 1860. Gottlieb Daimler, of Daimler-Benz, became the first person to patent the use of superchargers of the internal combustion engine. By the 1920s auto racing had already been slowly replacing horse racing, and superchargers were already being added to customer racing cars. Coupled with the racing, the U.S. Government outlawed alcohol, which in-turn created the “moon shiners/runners”. These people created faster and faster cars to out run the drug and alcohol officers, the Internal Revenue Service, attempting to end their illegal moon shining runs. The superchargers were increasingly refined by these runners in order to produce faster vehicles. Ultimately, these competitions created what is known today as the NASCAR circuit.

The first superchargers used on production vehicles were being built by Mercedes and Bently. Supercharges became modernized in the 1930s by Robert Paxton McCulloch by his McCulloch Engineering Company. Superchargers would dramatically shorten engine life due to the extreme temperature and pressure created by the supercharger. With advancements in machining and modern materials, most notably by the Japanese, superchargers have made a major comeback in smaller engines to produce higher output (increasing performance) for smaller vehicles while increasing miles per gallon. Modern supercharges are quite compact and can sit either on top of or next to the cylinder head. The most common type, called the twin-screw supercharger, uses a pair of interlocking Archimedes screw compressors that suck air in and compress it at the same time.

Centrifugal superchargers are almost a hybrid between turbochargers and twin-screw superchargers; they are still driven by a direct mechanical connection. Rather than having two screws that mesh together, they have a single centrifugal compressor that looks like an intake turbine (Erjavec, 2005).

FUEL INJECTION

Fuel Injection systems - Operational benefits to the driver of a fuel-injected car include: smoother and more dependable engine response during quick throttle transitions; easier and more dependable engine starting; better operation at extremely high or low ambient temperatures; reduced maintenance intervals; and increased fuel efficiency. The first mechanical fuel injection system was introduced by General Motors in 1957 and the first electronic system was introduced in 1966 (Nice, 2001).

COOLING AND HEATING SYSTEM

The first heating system and cooling system for the automobile were very simplistic. The cars with these systems produced at the turn of the 19th century were open cabin vehicles. As the popularity of the Model T continued to grow, Ford introduced the first closed cabin Model T in 1910, the Coupe (McCalley, 1994). At this point in history, heating the vehicle was accomplished by either a kerosene space heater, or heated bricks and placed in the vehicle. By 1914, exhaust gas was being filtered into the cabin to provide for heat, and eventually three years later, the return water from the engine was being used to heat the vehicle.

Cooling of the cabin was either accomplished by opening and closing mechanical

vents, or windows, or by purchasing blocks of ice. It was not until 1939 that the Packard Prototype usable air conditioner was displayed at the November 4, 1939, 40th National Automobile show in Chicago (Daly, 2006). It would be additional an ten-years, before Cadillac introduced it as a production vehicle option; it was not until the 1980s when the air con cooling system was small and economically affordable before becoming common place.

ENGINE (WATER) COOLING

Cooling Systems – Very early vehicles relied on air cooled systems to cool the engine down. However, as car engines became more complex and packed tighter under the hood, and increasing horsepower and torque, air cooling became less desirable. Ford's Model T however, was a 4-cylinder, four cycle water cooled internal combustion engine (thermal siphon system). Early vehicles built with water cooled systems with water pumps had problems with leaking, running out of water and overheating. During World War II, the US Government needed a reliable vehicle that would not over heat. What was discovered was that water pumps with a leaky graphite-lubricated “rope” seal (gland) on the pump shaft, after isolating the pump problem, cars and trucks built for the war effort were equipped with carbon-seal water pumps that did not leak. Today practically no air-cooled automotive engines (exception is the Volkswagen Beetle) are built (Newton, 1999).

2.6 Early Challenges

Few major changes occurred in engine design from the early model T days. Most

wanted power that was available from the large V-8 engines. One of the most dramatic changes that occurred and started to reshape the industry, most notably the engine design, was the 1965 legislation passed limiting the levels of exhaust emissions. Although not many quick changes were noticed, the automobile manufacturers realized the need to build cleaner burning engines.

In the 1970s, world events began shaping the industry. In 1973 the oil embargo by Arab nations caused the price of gasoline to quickly increase to four times the normal price. This event enlightened many US residents that gasoline, like many other nonrenewable resources, was limited. Buyers wanted cars that were not only environmental friendly but also had better miles per gallon of gasoline.

In 1975, Congress passed the Corporate Average Fuel Economy (CAFÉ) standards, which required auto makers, not only to manufacture clean-burning engines, but also to equip these vehicles with more efficient gasoline burning engines. Under the CAFÉ standards, different models from each manufacturer are tested for the number of miles they can be driven on a gallon of gas. The fuel efficiencies of these vehicles are averaged together to arrive at a corporate average. The CAFÉ standards have increased many times since they were first established. A manufacturer that does not meet these standards is subjected to penalties.

In slowly producing some more efficient vehicles, the Domestic Three manufacturers began producing and installing four-cylinder and other smaller engines into some of their vehicles, instead of the larger eight-cylinder engines; however, their major focus and drive was still around increasing the size, torque, horsepower of engines and large (V8) vehicles (cars and trucks) to their mostly captive North American markets.

Some basic engine systems like carburetors and ignition breaker points were replaced by electronic fuel injection and electronic ignition systems first by Honda as discussed in Chapter 8, and further reviewed in Chapters 18 and 19.

CHAPTER 3

FORD'S EARLY HISTORY AND EARLY INNOVATION INTRODUCTION

3.1 Introduction

The early 1900s was an extraordinary period of discovery, innovation and invention, not only for Ford and the model-T but for many other totally new products as well. This time period saw community electricity systems, light bulbs, color photography, telephones, silent movies, etc. Science itself took a tremendous leap forward as Albert Einstein formulated his theory of relativity, the Curies discovered radium, the Panama Canal was built, and the Wright Brothers made the first heavier than air flight (Banham 2002).

The Model-T was ready for full production on October 1, 1908, (Banham, 2002; Ford 2007; McCalley 1994), and as Henry Ford predicted, the model T put America on Wheels. First year production reached 10,660, breaking industry records and as the price dropped from the initial offering of \$825 to a low of \$259, many American families bought their first automobile. Henry Ford had insight into the importance of integrating design and manufacture to drive the shift in an innovation s-curve, and the production process learning curve which ultimately led to the driving down of costs, and eventually

lowering the selling price while maintaining profit margins. The model T also sold very well in many parts of Europe (half a million in England alone).

3.2 Pre-Henry Ford

Everything was basically in place to develop and market the car to the public. By 1894, Henry Ellis of the English Parliament endeavored to purchase an automobile. This venture led him to the Paris machine-tool company of Panhard et Lavassor (P&L) and he commissioned an automobile, (Womack, Jones & Roos, 1990). The P&L was building several hundred automobiles per year, with the basic architecture of today's vehicles – System Panhard – meaning the engine was in front, with passengers seated behind and drive shafts turning the rear wheels.

In the beginning, prior to World War I, cars that were manufactured were done so by craftsmen, usually, by machine shops or similar type of manufacturers. Economies of scale were not in existence, understood, or even possible. Individuals who wanted an automobile typically had it custom designed and built to suit one's own needs. Womack (et.al, 1990) summed the necessary characteristics of automobile manufacturers as follows:

- A work force that was highly skilled in design, machine operations, and fitting. Most workers progressed through an apprenticeship to a full set of craft skills. Many could hope to run their own machine shops, becoming self-employed contractors to assembler firms.
- Organizations were extremely decentralized, although concentrated within a single city. Most parts and much of the vehicle's design came from

small machine shops. The system was coordinated by an owner/entrepreneur in direct contact with everyone involved-customers, employers, and suppliers.

- The use of general purpose simple machine tools to perform drilling, grinding, and other operations on metal and wood.
- A very low production volume-1,000 or fewer automobiles a year, only a few of which (50 or fewer) were typically built to the same design. And even among those 50, no two were exactly alike since individual craft techniques inherently produced variations.

The first United States car company was Duryea in 1896. By its third year it had produced 800 cars. Annual automotive industry growth by 1910 was 50%, achieving 458,000 registered cars. The number of car manufacturers also grew rapidly, from 1900 to 1910, when more than 300 companies began producing vehicles in North America (Olsen 2002).

3.3 Henry Ford

The growth in the number of entrepreneurial automotive manufacturers in North America was substantial in the early 1900s; however, it would be the vision of Henry Ford that would revolutionize the automotive industry into what it is today. Ford believed the industry should move towards simplicity (Ford, 2007,). Ford defines simplicity as, “gives the very best service and is most convenient in use, start with an article that suits and then study to find some way of elimination the entirely useless parts, removal of waste, basis for some of the lean manufacturing techniques developed

decades later. As you do this the price will drop (pg 147).” This became the basis of what became known as driving the learning curve.

He felt that the past paradigms of manufacturing must always be challenged. To Ford, manufacturing is not about buying materials or items low and selling high to make a profit. It was about the buying of materials fairly and, with the smallest possible addition of cost, transforming those materials into a consumable product and selling it to the consumer. This chapter will look at the architecture of developments that led to the success of the model T and the definition of the modern car which in many aspects is still similar to the model T. Figure 2 depicts graphically the concepts of this architecture followed by Figure 3 that breakdown the technology developments either developed for the model T or introduced throughout its 19-year run.

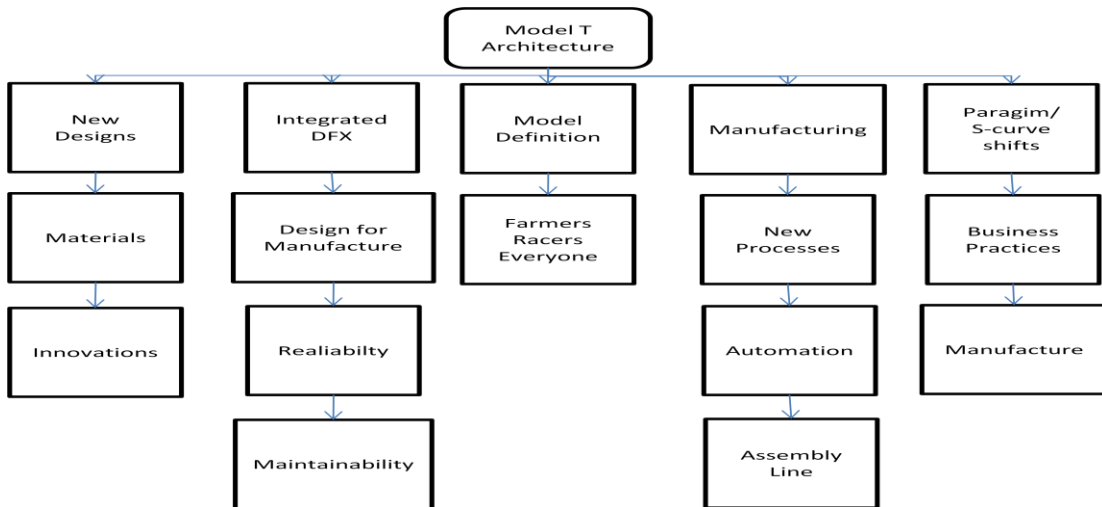


Figure 2 Model T Architecture Concept (source: author’s depiction)

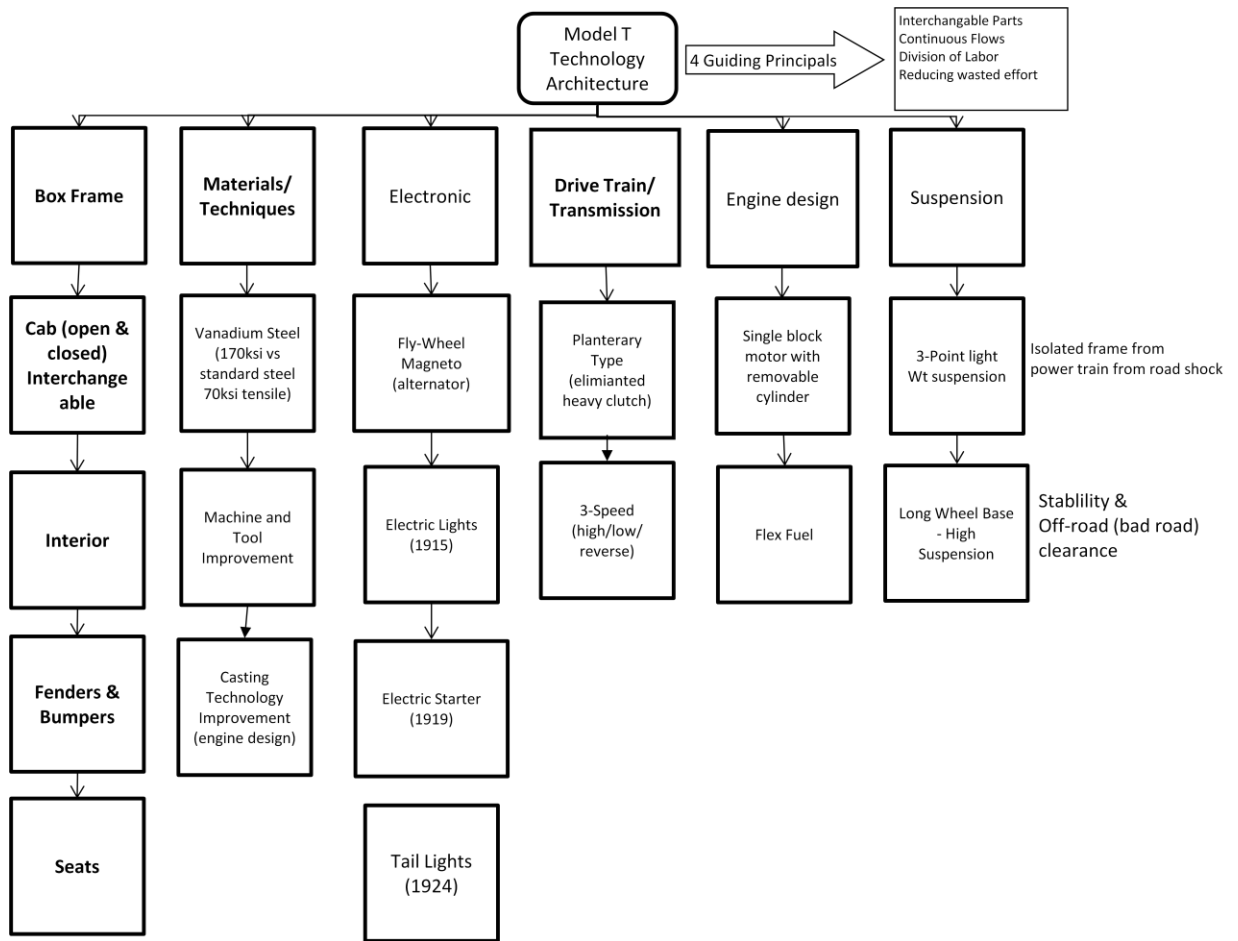


Figure 3 Model T Technology Architecture Evolution (source: author's depiction)

3.4 Standardization and Maintainability

Ford's first efforts to assemble automobiles involved setting up assembly stands on which an entire vehicle was manufactured, usually by a single fitter. This was basically the business model for most small automotive manufacturers of the time. When the Model T was introduced in 1908, it took the average fitter (task cycle time) 8.56 hours. Each worker would assemble a large part of the vehicle before moving to the next assembly station. These workers performed the same task moving from one assembly stand to the next. The worker had to go and get the parts, perform some minor rework

(not perfectly interchangeable at this point) and assemble the parts onto the vehicle. Ford noticed the time it was taking to performed each of these tasks (walking to get the parts, minor rework of the parts and assembly), so he moved all of the parts to the assembly area so that the fitters no longer had to retrieve the parts. Ford was also relentless on making parts completely interchangeable, and by 1913 had made everything completely interchangeable, hence, with these two changes, had reduced the cycle time of fitter from 8.56 hours down to 2.3 minute (Banham, 2002; Womack, et al. 1990; Halberstam, 1986).

Ford combined the concept of more standardized precise parts interchangeability, developed in the textile industry and weapon's industry during the Civil War, with a continuous moving assembly line, utilizing an extreme subdivision of labor to produce mass production. Prior to mass production, as stated above, parts were produced individually and fitted together by expensive and slow skilled craftsmen, with each operation unique and different. The craftsmen each individually made hand fitted parts for a complete product.

Ford's 1908 Model T was his twentieth design over a five-year period, which set the stage to mass production. Ford had made each part completely interchangeable and best yet, with the design for manufacture and usage and maintenance, made an automobile that was user-friendly and easy to maintain and repair.

Ford took complex products broke them down into their standardized dimension components, which could be repetitively produced and repetitively assembled from randomly produced standardized parts because of the interchangeability.

Interchangeability of parts eliminated the need for hand adjustments and fitting, and removed much of the margin of error out of operations. These changes along with the

design for easy assembly, disassembly and reassembly made repair in the field possible if not easy. It also allowed for the stocking of replacement parts in areas near the end use customers. Prior to this the old paradigm and S-curve was that no thought be given to the car operation after it was sold, for example:

- How much gasoline it used per mile,
- How much service it actually gave did not matter,
- If it broke down it was hard luck for the owner

It was considered good business to sell parts at the highest possible price on the theory that, since the customer had already bought the car they simply had to have the part and would be willing to pay any price for it. An industry of replacement parts grew. Later other industries have destructively gone down this same path. Later the automotive industry returned to this business methodology.

3.5 Reliability

It was Ford's ambition to have every piece of machinery, or other non-consumable product that he turned out, so strong and so well made that no customer had to buy a second one. Ford would study every process and every item and perform tests after tests to prove designs out prior to implementing them into use. The Model T was tested and proven out in eight other prototype models prior to its introduction (Ford, 2007; McCalley, 1994; Banham 2002). No part was used on the model T that was not already tested in service on previous models. As will be discussed later in this chapter, to achieve the desired performance, Ford's research and development lab developed new alloys of steel.

With these developments Ford removed and studied every part in his car to determine types of steel (alloys) each part should be made of, based on strength, toughness, elasticity, hardness, and other criteria to maximize reliability. While other automotive manufacturers were using four different types of alloy steels, Ford's Model T used 20 grades, 10 of which were based on the newly developed vanadium steel. Reliability and strength was an absolute requirement, mainly because of the varied uses (farms, county, city) to which cars would be put, and the variety of road conditions over which they would travel at the time. These steps laid the foundation of what would evolve into the design for reliability and ease of repair (e.g. DFX) which will be discussed in greater detail in Chapter 9.

3.6 Innovation and Invention of Materials

Ford knew the type of vehicle he wanted to build for the masses, but did not have all the materials on hand to do so. He needed to find and/or develop material with greater strength to weight ratio to reduce overall weight. He knew that weight had to be reduced in transportation. Basically why put weight in a vehicle, if you are better off putting it into the payload it must carry (Ford, 2007). For example, in the early Model Ts the wood used in a vehicle naturally contained 30 pounds of water that was of no use.

Perhaps the greatest innovation came from Ford's design laboratory where research was performed on new materials and casting technologies. Ford's laboratory did much work developing vanadium steel (versus the traditional nickel steel), which is stronger and lighter. This steel was developed mainly for the crank shaft and chassis, which in turn, makes the vehicle lighter weight, hence reducing the need for larger

horsepower motors and improving efficiency (Womack, 1990; Banham, 2002). Ford's material laboratory also developed tungsten and chromium steel. This again was a shift in innovation life cycle, it was an example of early design for performance, being light weight, robust, tough, reliable, or in other words DFX (Keys 1990).

Couple with the new material the laboratory, Ford also spent much time experimenting with casting technologies. This ultimately led to the ability for Ford to cast his 4 cylinder engine with the crank case as one block. Prior to this the four individual cylinders were bolted together to a separate crankcase. This substantially reduced the time to manufacture an engine and greatly improved reliability; this coupled with the removable cylinder head, made Ford's engine maintenance and repair much easier. Ford's front mounted engine also was water cooled, where previous versions of the car relied on air cooled or ambient dissipation of the heat, another example of DFX. The engine designed was a 22.5 horse power capable of pushing the Model T to over 50 miles per hour. The gas mileage rating of the model T was 25 miles per gallon (McCarthy, 2007).

Another major innovation of the Model T was the design, development, and application of the flywheel magneto (early generator). This device replaced the dry batteries required to create the spark necessary to start the combustion of the engine on all vehicle produced prior to the Model T. This device also opened the door for replacing the kerosene (and other types of fuels) lamps used in evening hours by the electric headlights. The headlights were introduced on the Model T in 1915 (Ford, 2007). This established the basis of an automobile electrical wiring system.

Several other innovations include the transition from the two-point engine

mounting system to a three-point engine mounting system to provide for smoothing (less vibrating) running. To address rocky ruts, Ford installed huge arc springs cross wise over the axles to provide for a smoother ride. Equally revolutionary was the planetary gear transmission, which reduced stripping of gears by drivers and did away with the heavy clutches that were especially difficult for women to use and permitted the incorporation of a reverse gear. Two gears were provided in one forward pedal, one to climb hills or overcome starting sluggishness, the other for speed. These innovations coupled, together with the ease of repair, made the Model T very useful for many different applications (Banham, 2002).

Although the Model-T was revolutionary, Ford failed to implement other important new technologies and ultimately paid dearly for it. Probably the most infamous issue was Henry Ford's widely discussed, but factually unsubstantiated statement, that the customer can have any color as long as it was black. Henry Ford was so driven by mass production and producing at the lowest price that he would only use black enamel paint because of the much faster curing time versus the other colors. Adding colors to the Model T could potentially add two to four weeks curing, and potentially would not bond to the metal bodies. Du Pont developed pyroxylin-based lacquer paint, dubbed Duco that solved this long curing problem. Du Pont de facto control over General Motors gave General Motors the advantage to offer several colors first. General Motors was given a two-year advantage over the rest of the manufacturers until Du Pont started selling to others. Ford ultimately offered several colors beginning in 1926.

Ford also failed to see the S-curve changing in consumer desires in other areas.

Chevrolet and Dodge increased horse power up to 30, while the Model T maintained 22.5. The interiors of Chevrolets and Dodges were more lavishly appointed, while Ford's were simple. Electric starters, hydraulic brakes (for smooth braking versus rough jumping braking) and sliding gear transmissions that shifted more reliably and also had a separate clutch and accelerator pedal that became standard on the newer Chevrolets and Dodges as well as other automobiles. Ford ignored these changes and stuck with his manual cranking ignition systems, mechanical braking and his antiquated planetary gear system. If someone from today sat in a 1920 Chevrolet they could drive the car without any instructions, the same is not true with a 1920 Model T (McCalley, 1994).

The consequences were felt hard by Ford. Ford's market share in the second half of 1926 fell to one-third of all automobiles sold, compared with two-thirds in 1924. On May 26th, 1927 Henry Ford and his son Edsel drove the final Model T off of the assembly line, from 1908-1927 the Ford Motor Company has produced 15 million units. Khalil (2000) points out that Ford's thinking lost its popularity as General Motors produced more "affordable" luxury cars. They implemented the technologies that made it possible for everyone to afford a new car, a demand created by rising employment and incomes.

After the last Model T rolled off the assembly line, Ford shut his company down for six months to retooled and re-invigorate his company with more of the newer inventions and innovations. Followed by Dodges totally enclosed steel body design introduced in 1922 Ford introduced many more innovations in his 1928 Model A (McCarthy, 2007). Some of these innovations include:

- Standard transmission,
- Four wheeled-hydraulic braking system,

- Hydraulic shock absorbers,
- Windshield wipers, and
- Laminated safety glass windshield,

Many of these technologies will be explored in greater detail in later chapters.

3.7 Start of Mass Production (Model-T)

The start of Model-T mass production at Ford came from an unlikely source, a production engineer in the flywheel magneto assembly area, (Banham, 2002). This engineer wanted a different way to put his parts together. He divided the operation into 29 separate steps. He then instructed the workers to place only one part in the assembly and then push the fly wheel down to the next person. Prior to this breakthrough, it had taken one employee about 20 minutes to assemble a flywheel magneto. When the job was divided among 29 employees, the time fell to 13 minutes. Further tweaking and modifications pushed this time to five minutes. Gradually, this concept was adopted for the construction of engines and other parts.

Ford soon recognized the problem with moving the fitter from one assemble station to the next assembly station took too much time. Not only would walking waste time, if one fitter was faster/slower than the next, this would create a bottle neck. On October 7, 1913, at the Highland Park plant in Detroit, Ford introduced the moving assembly line which banished the assembly stands. The assembly line was inspired and brought to Ford by William C. Klann after he returned from a visit to a slaughter house at Chicago's Union Stock Yards. The slaughter house used a "disassembly" line when processing beef and chickens. Klann observed animals being cut apart as they moved

along a conveyor, where he realized an improvement in efficiency when a person removed the same part time after time. Ford realized if he brought the work to the workers, they spent less time moving about, (Ford, 2007).

Instead of the worker moving from assembly station to assembly station, the vehicle was placed on a moving line and was brought to the worker. With the introduction of the assembly line, worker cycle time dropped even further from 2.3 minutes to 1.19 minutes. Ford then called in Frederick Taylor, creator of “scientific management”, to do time and motion studies to determine the exact speed at which the work should proceed and the exact motions workers should use to accomplish their tasks.

With this mass manufacturing system process and integration success, it subsequently later opened the door for automation of parts with equipment such as numeric control, and then computer control, machine tools, which also permitted the interchangeability of cross-trained labor. This reduced the overall number of workers and skill level needed to complete any given task.

3.8 Vertical Integration

As demand for the Model T grew, the ability to meet this demand could no longer be provided at the Highland Park facility. Ford had a vision to create a perfect uninterrupted “flow”. Ford wanted to create the Rouge complex as encompassing everything that was needed to build a car – blast furnaces, coke ovens, a massive foundry, coal and ore bins, railroad yards, and large dock facilities, so as not to be dependent on suppliers’ limitations.

The Rouge Complex was completed in 1925, and it encompassed everything

needed to build a car: steel mills, paper mills, a glass factory, and a power plant that could generate enough electricity to power the city of Boston. It was the chief reception depot for coal, iron ore, rubber and lumber. Ford established a lumber operation in northern Michigan to provide wood for car components and a rubber plantation in Brazil for tire production. Not everything was produced at the Rouge Complex; however, many smaller plants, termed “Village Industry” by Ford, located on the rural riverbanks and powered by hydroelectricity, were responsible to produce parts and components for automobiles.

CHAPTER 4

OIL'S EARLY HISTORY AND NEW REFINING

4.1 Introduction

This chapter presents a brief history of the beginning of the oil industry in the United States. This chapter examines early oil retrieval, refinement and charts the history of oil production over the first 70 years of the twentieth century, up to the first oil embargo.

4.2 Birth of the Industry

Dr. Abraham Pineo Gesner (1797-1864) has been given much credit for the birth of the oil refining industry (Murray, 1993). Dr. Gesner developed a process in 1846 to refine liquid fuel from coal, eventually named kerosene. Kerosene was found to be a much cleaner burning and less expensive than the current whale oil and oils from other animals. In 1850, Gesner created the Kerosene Gaslight Company in Canada and began installing lighting in streets in Halifax and other cities. He followed this creation with the North American Kerosene Gas Light Company at Long Island, New York in 1854 and expanded throughout the United States. Demand grew so much that the Company's

ability to produce kerosene from coal was inadequate, until the discovery of petroleum and a method to produce kerosene from petroleum.

In the same era of Dr. Gesner, Ignacy Lukasiewicz, of Poland, was working on a method to distill kerosene from oil and 1853 registered his distillation process (Sjuggerd, 2008). Lukasiewicz is also credited with the invention of the kerosene lantern; however, American inventor Robert Dietz is also credited and patented one of the first practical kerosene lamps in 1859, (Leffler, 1958). The first oil refinery, which used atmospheric distillation to produce kerosene, was constructed in 1862 (Arabe, 2003). The R.E. Dietz Company went on to manufacture hundreds of lantern models, and became a pioneer in the automotive electric lighting industry, to be discuss in further details in a later chapter.

4.3 Early Oil Extraction in the U.S.

Titusville, PA

Oil Creek in western Pennsylvania was well known for oil seeps, and in fact, was known and harvested by the Seneca Indians as far back as 1400 AD for medicinal purposes, (Paleontological Research Institution, retrieved 9/27/08). In the early 1850s, George Bissell, a New York lawyer, conceived a plan to try and produce oil commercially. A Yale Chemist, Benjamin Silliman, was hired by Bissell to analyze the properties of the “Seneca Oil” for feasibility as a fuel for illumination lanterns. Silliman determined that this oil could in fact be distilled to satisfy this requirement. With this information, Bissel put together some financial backing and formed the Pennsylvania Rock Oil Company, (latter renamed the Seneca Oil Company).

The Pennsylvania Rock Oil Company hired Edwin Drake, an unemployed railroad conductor and express agent in 1857 to set out to Titusville, a town on Oil Creek, to begin the oil collection process. Drake originally attempted to retrieve oil as it had been done in the past, dam a small portion of the creek and collect the oil off the top of the formed reservoir. With minor improvements he increased production from four gallons per day to ten gallons per day, still lacking economically feasibility. Drake realized that other people in the past had accidentally drilled for oil when seeking salt water or drinking water and discarded the oil as a nuisance. Drake also realized that there was potential in drilling a seep to its source.

He hired a black smith, Billy Smith, who had drilled several brine mills, to help him drill for oil. Drilling began in the summer of 1859; they drilled on average of three feet per day, finally reached a depth of 69.5 feet on August 27, 1859. Oil came rising to the top the morning of August 28, 1859. A hand operated lever pump was installed and the first day extraction was 25 barrel. Oil production settled to 10 barrels per day for a little over a year. An oil industry then grew almost over-night in Western Pennsylvania, leading to the East Texas oil boom in 1901. Pennsylvania was responsible for over half of the world's oil production from 1859 through the Spindletop discovery, (Flannery 2005).

East Texas Oil Boom

The modern oil industry was born on January 10, 1901, in an area south of Beaumont, Texas, on a hill called Spindletop (McCarthy 2007; Gordon 2009; Carson & Vaitheeswaran, 2007; Arabe 2003). Anthony Lucas, a Louisiana mining engineer, believed that oil accumulated around salt dome structures. Lucas, the leading United

States expert on salt dome formations, made a lease with the Gladys City Texas Company in 1899. With Lucas in charge of the drilling operation, an attempt was made on the John Allen Veatch survey on Gladys City Company lands. Lucas was able to drill to a depth of 575 feet before running out of money. He was also having great difficulty with the tricky sands of the salt dome. Despite the negative reports from contemporary geologists, Lucas remained convinced that oil was in the salt domes of the Gulf Coast. He finally secured the assistance of John H. Galey and James M. Guffey of Pittsburg, Pennsylvania.

Much of the Guffey and Galey support was financed in turn by the Mellon interest. Lucas pressed ahead in his effort to vindicate his theories. Galey and Guffey played a crucial role by bringing in Al and Curt Hamill, an experienced drilling team from Corsicana. From October to January 1901, Lucas and the Hamills struggled to overcome the difficult oil sands, which had stymied previous drilling efforts. On January 10, 1901, six tons of four-inch drilling pipes came shooting up out of the ground. After several minutes of quiet, mud, then gas, then oil spurted out. The Lucas geyser, found at a depth of 1,139 feet, blew a stream of oil over 100 feet high until it was capped nine days later and flowed an estimated 100,000 barrels a day. Out of desperation they pioneered the first gusher capping process.

The oil gusher of 1901 led to a doubling of the population in Beaumont to 20,640 by 1910. With this great wealth and petroleum based economy, three large oil companies were formed in the first year of the boom, truly ushering in the modern oil industry: the Texas Company (later Texaco), Gulf Oil Corporation, and Humble (later Exxon).

By September 1901, there were at least six successful wells on Gladys City Company lands. Rapid decline in production occurred due to the overabundance of wells at Spindletop (as many as 285). After yielding 17,500,000 barrels of oil in 1902, the Spindletop wells were down to 10,000 barrels a day in February 1904. A second boom came when Marrs McLean speculated that production could be found on the flanks of the dome. Miles F. Yount also believed more oil was present at deeper depths. Their convictions proved correct; on November 13, 1925, the Yount-Lee Oil Company brought in a flank well drilled to 5,400 feet. This and other discoveries on the flanks of the salt dome set off another speculative boom.

The Gladys City Company participated with the Yount-Lee Oil Company and others in this second boom (Handbook of Texas On-Line, retrieved 9/29/08). By 1927, Spindletop production reached its all-time annual high of 21,000,000 barrels. Within five years 60,000,000 barrels had been produced, largely from the new-found deeper Marginulin sands of the flank wells. Additional deposits were found in the Midway (Eocene) formations in 1951. Over 153,000,000 barrels of oil had been produced from the Spindletop fields by 1985.

4.4 Oil and Automotive Connection

In 1859, two separate events would jumpstart the petroleum and the auto industries. The timing was pure coincidence. In that year, as mentioned earlier, Drake drilled the world's first working oil well in Titusville, Pennsylvania, and as mentioned in Chapter 2, French engineer Lenoir made the world's first dependable internal combustion engine, which was powered by gasoline. Drake's oil well kicked off the petroleum

industry, and Lenoir's work paved the way for the creation of the modern automobile. But 40 years would pass before the interdependency/intersection of the oil and auto industries would become clear.

That early period from 1860 to 1900 was marked by many technological innovations as auto inventors sought to tap the potential of the internal combustion engine. Petroleum pioneers got better at producing, refining, and delivering oil products to the oil lamp market. Oil industry entrepreneurs as mentioned above discovered new oil fields, drilled deeper oil wells than Drake's first 70-foot well, and made great strides in both refining and distributing refined products.

The first oil refinery, which used atmospheric distillation to produce kerosene, was constructed in 1862 primarily for kerosene illumination lamps. Naphtha (gasoline) was a byproduct of these early distillation units, and in a few decades, would emerge as their most important product (McCarthy 2007). But first, the oil industry would have to languish through the boom-and-bust cycle of the latter part of the nineteenth century. Aside from wildly fluctuating oil supplies and prices, refiners struggled with Standard Oil's domination of railroads, which was the main mode of transportation for crude oil and refined products at the time. When inventory threatened to overwhelm storage capacity, independents and Standard Oil (which would be broken up in 1911) undersold each other in the market, often selling refined products, especially gasoline, at below cost.

However, the automobile's rise in the early nineteenth century bolstered oil demand. While the country only had roughly 8,000 passenger cars at the turn of the century, by 1908, the year that Henry Ford's Model T made its market debut, that figure

had swelled to 125,000. By 1911, gasoline dethroned kerosene, used for lighting, as the top-selling product of Standard Oil of New Jersey, the country's largest refiner.

Kerosene's slide was also hastened by the 1910 invention of the tungsten filament for electric light bulbs by William David Coolidge.

Refiners met the skyrocketing demand for motor fuels by advancing beyond the basic distillation processes that had been in use since the 1860s. In 1913, they developed thermal cracking, which was able to produce more gasoline and diesel from a barrel of oil. The technique was only the first of many processing innovations that allowed refiners to fulfill market needs and greatly reduced the average cost per gallon of gasoline. By 1920, there were enough buried pipelines throughout the United States to circle the earth at the equator and have 5,000 miles to spare, with operating pumps every 40 (Petroleum History Institute, retrieved 1/2/08).

The growth of the amount of crude oil extracted by the oil from the oil fields grew along with the rise of the automobile, Figure 4 depicts this growth from the turn of the century up through 1970; Figure 5 depicts the growth of discovered oil fields and Figure 6 depicts the growth of refinery capacity.

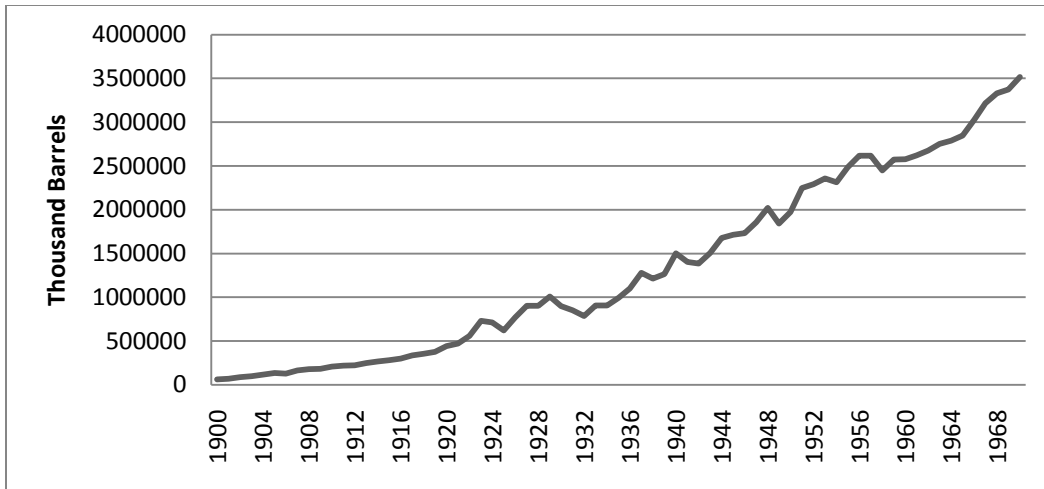


Figure 4 U.S. Crude Oil Production (source: Energy Information Administration, 2009)

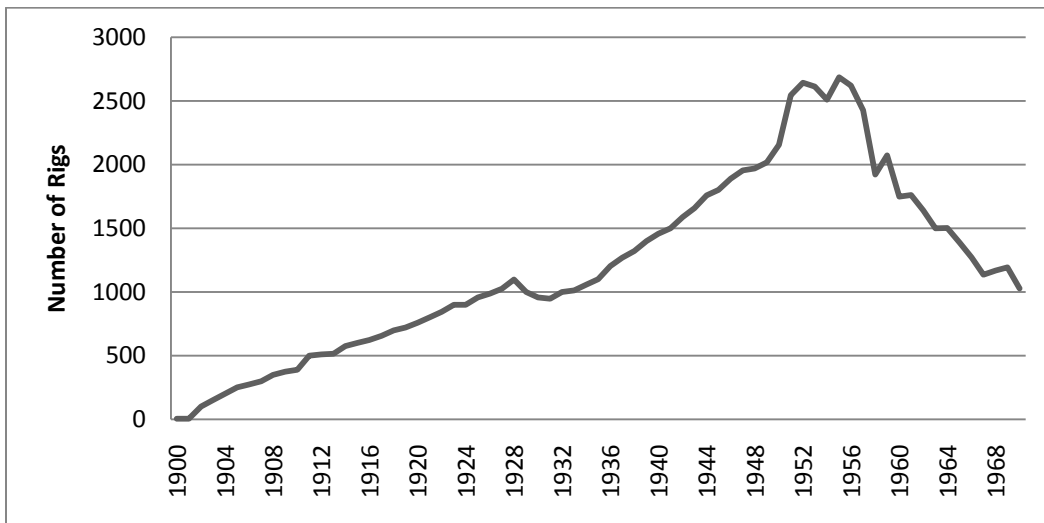


Figure 5 U.S. Crude Oil and Natural Gas Rigs (source:Energy Information Administration, 2009)

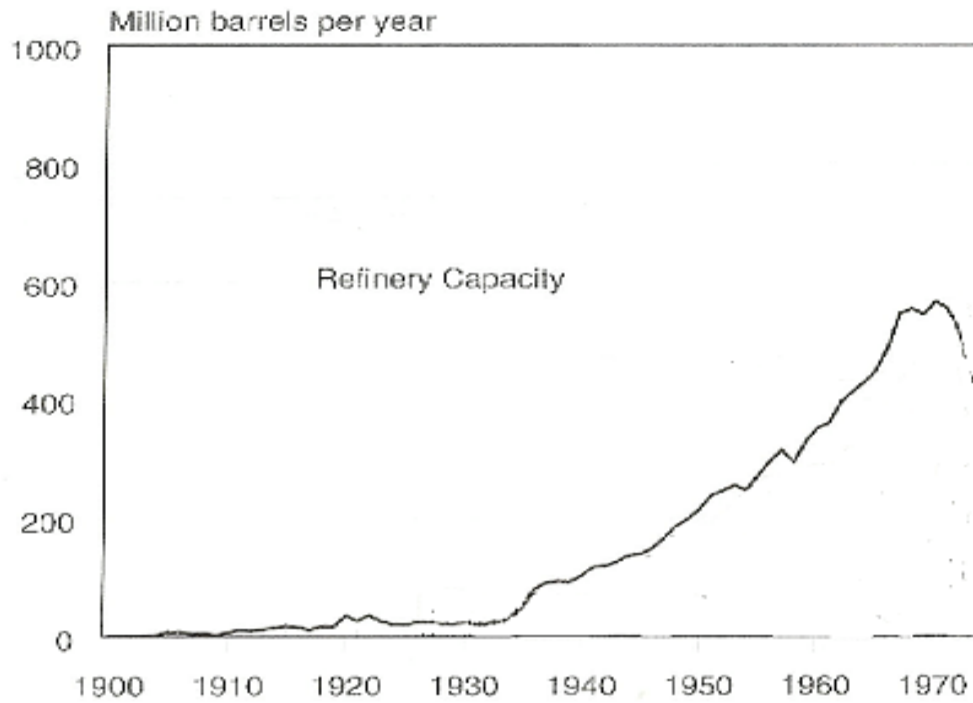


Figure 6 U.S. Refinery Capacity (source:Energy Information Administration, 2009)

The early trend of gas prices, as technologies in refinement and supply improvements grew, can be seen in Figure 7, both the actual selling price for that period and the price adjusted to 2007 dollars. This helped both fuel the increase in growth and the demand for vehicle sales, which in return, increased the necessity for more oil fields and refinement. Figure 8 represents the U.S. Vehicle sales while Figure 9 represents the motor vehicle production in the U.S. and the world combined.

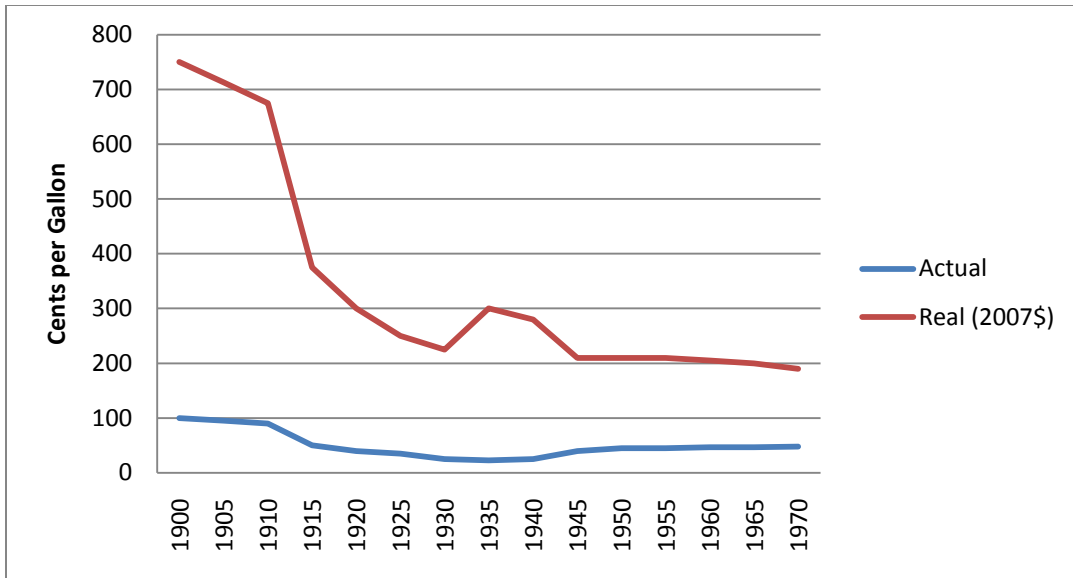


Figure 7 Gas Prices (Source: Energy Information Administration, 2009)



Figure 8 U.S. Vehicle Sales (source: Energy Information Administration, 2009)

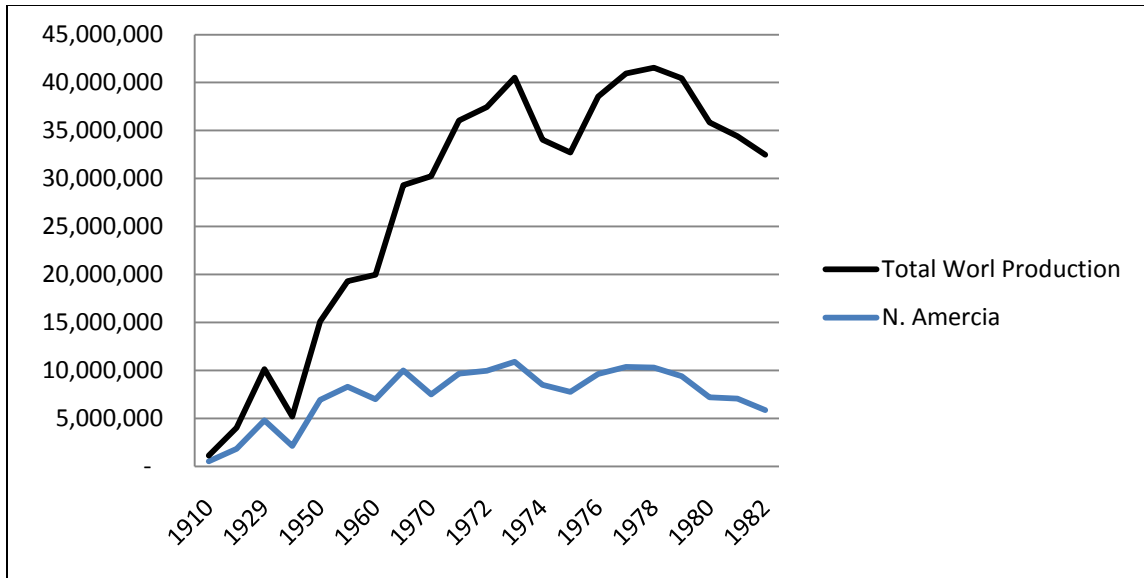


Figure 9 Motor Vehicle Production (source: created from data from Womack, 1990)

The country emerged from World War I to enjoy a period of economic growth with much of the prosperity also linked to the rapid road and bridge construction that gave America's automobiles a place to perform. From 1920 to 1930, the number of cars owned by Americans jumped from 8.1 to 26.7 million. The Great Depression put a temporary dent on vehicle sales, especially during the early 1930s, but the auto industry was definitely rolling.

Oil companies prospered along with automakers. Refiners built more refineries and expanded existing facilities. They also improved thermal-cracking techniques and developed other catalytic processes to produce high-grade products. High-octane gasoline emerged in the 1930s from refiners' tireless efforts. High-octane gasoline would play a role in World War II. As oil demand rose technologies were developed that ultimately also led to the lowering of the cost of extracting the oil. As the popularity of oil increased, the realization of the energy density of oil versus coal, and the new developments of aero technology, other opportunities were present: replacement of coal

and wood for heating houses and building (fuel oil); replacement of steam with diesel in freight trains (and ships); and introduction of airplane (and eventually jet fuel) fuel. However, demand and price correlation analysis began to show imports as a way to keep prices stabilized while meeting the extra demands. Figures 10, 11, 12 and 13 represents crude oil prices, crude oil consumption, growth of air/train/heating fuel, and crude oil imports.

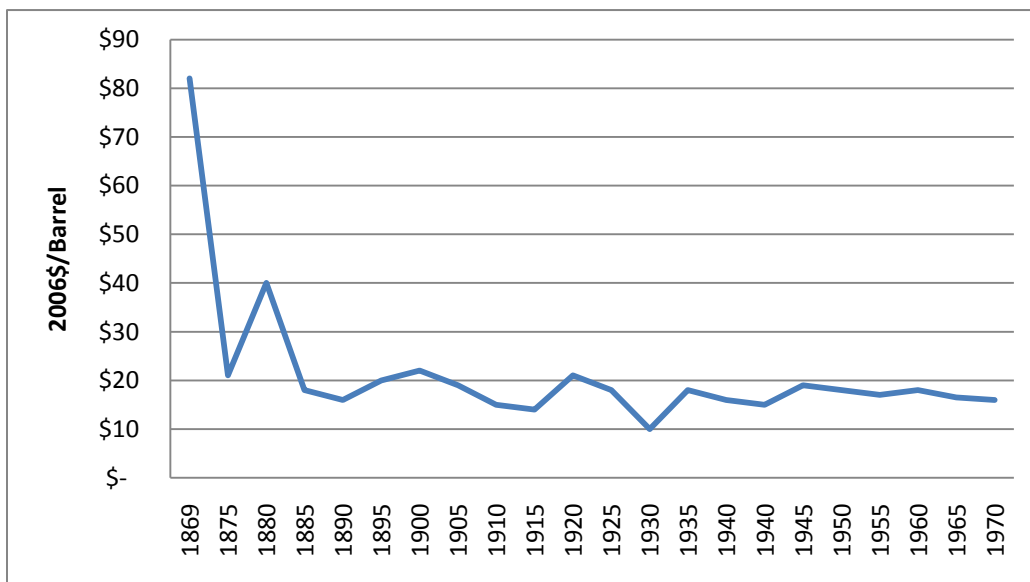


Figure 10 Crude Oil Prices (Source: WTRG Economics, 2008)

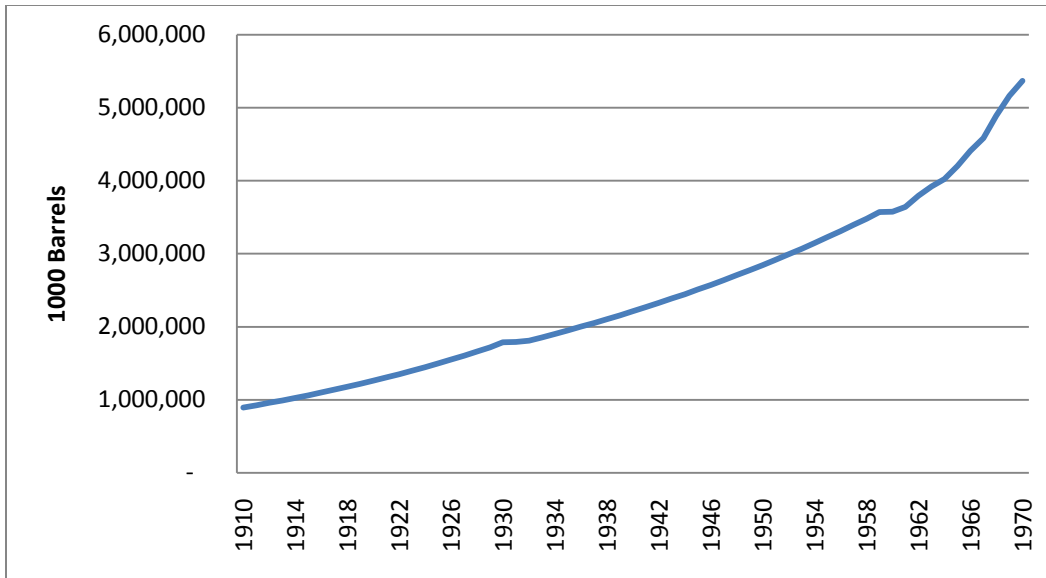


Figure 11 Crude Oil Consumption (Source: Energy Information Administration, 2009)

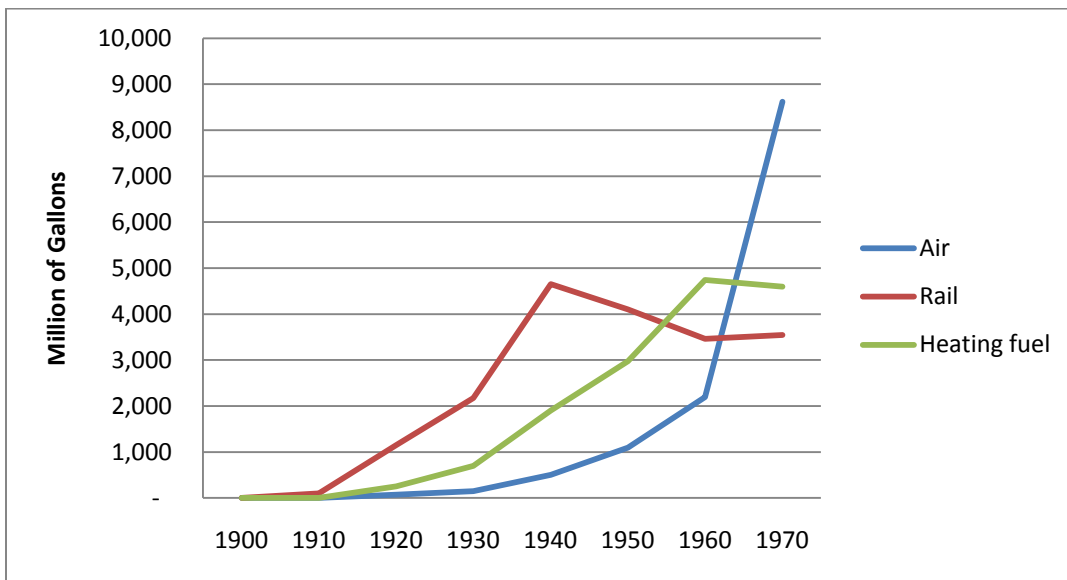


Figure 12 Growth of Oil Uses (Source: Energy Information Administration, 2009; Us Department of Transportation, 2010)

Examining the graph on consumption, it can be seen and concluded that the demand correlates precisely with automotive demands for the better part of the twentieth century.

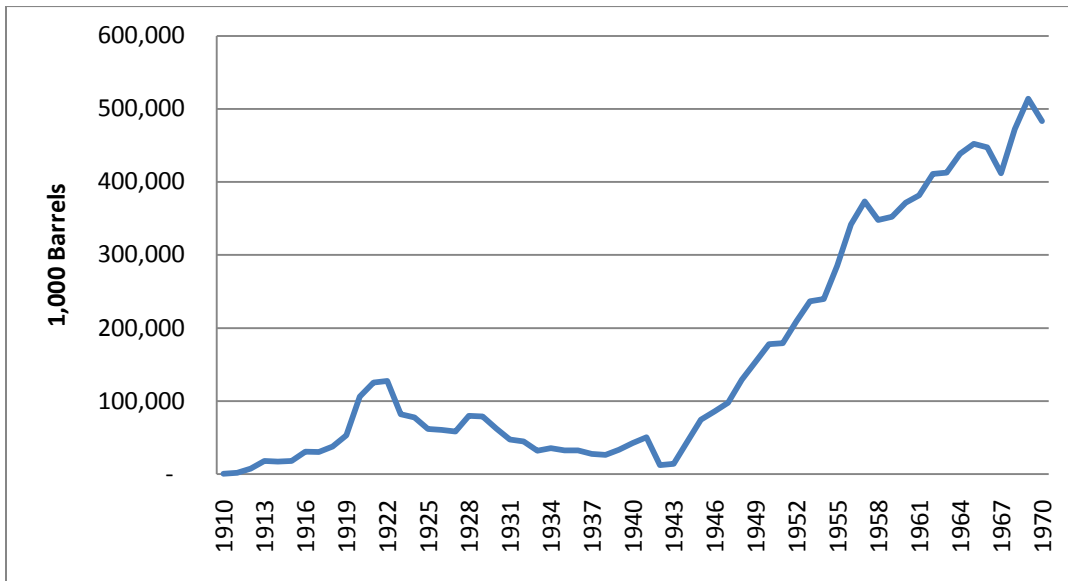


Figure 13 Crude Oil imports (Source: Energy Information Administration, 2009)

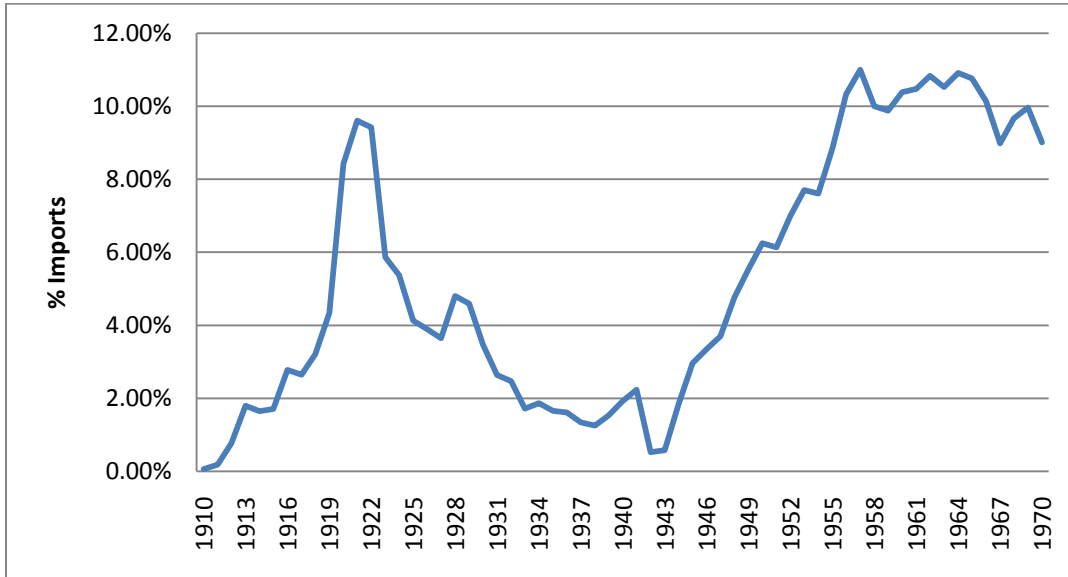


Figure 14 Percent Oil imports (Source: Energy Information Administration, 2009)

Figures 13 and 14 show the growth in imports from 1910 to 1970. It can be deduced that the demand for oil/gasoling refinement outpaced the ability of the domestic

oil rigs to keep up with demand. Chapter 13 will look in more detail of what happened in the oil industry after the following occurred: environmental standards took hold, including emissions from the refineries; CAFE standards being adopted; and local government, federal governments restricting off shore drilling and drilling in Alaska wilderness; and political constrictions (OPEC formation, rouge nations).

CHAPTER 5

GENERAL MOTORS MARKETING EXPLOSION AND MODEL CHANGES

5.1 Introduction

General Motors, the largest global vehicle manufacturer from 1931 until dethroned by Toyota Motor Company in 2007, did not have the same type of beginning as the Ford Motor Company. While Henry Ford created a rags to riches type-company, General Motors started from the beginning as a large conglomerate (Keller, 1989). At the turn of the nineteenth century, it was estimated that there were 50 car companies a year entering into the automotive industry (Halberstam, 1986) and by 1910 there were over 300 car manufacturers (Olson & Cabadas, 2002). And by World War I, approximately 50 auto manufactures were left.

General Motors (GM) was founded in 1908, by Billy Durant, to consolidate several motorcar companies: Buick, Oldsmobile, Cadillac, Oakland (Pontiac), Ewing, Marquette, and some other small companies along with Reliance and Rapid Trucks. Durant even considered purchasing Ford Motor Company in 1909. Within the first two years, GM assimilated 30 companies including eleven automakers (Keller 1989). The Chevrolet Auto Company and Delco Products joined General Motors in 1918, and the

Fisher Body Company and Frigidaire joined in 1919. Some of the early highlights and items leading to GM include:

- Ransom Olds and Henry Leland development of the “curve-dashed” Oldsmobile in 1902. This vehicle was the first automobile built using interchangeable parts;
- Leland splits from Olds and forms the Cadillac Motor Company. Becomes world-renown for building of the highest quality cars;
- Max Grabowsky and his family build the first commercial truck in 1900. Two years later they organized the Rapid Motor Vehicle, incorporating it under Grabowsky Motor Company (GMC). Durant consolidates Rapid and Reliable Motor Company as a component of General Motors in 1911 to form the GM Truck Company;
- Durant lost control of GM to the banking interests when he over extended the company financially in 1910;
 - Rebounding very quickly and forming the Little Motor Car Company in 1911;
- Combining with Louis Chevrolet to join the Chevrolet and Little Motor interests to form Chevrolet Motors in 1912;
- Together, Durant and Chevrolet began a large volume production of Chevrolet cars at multiple production facilities across the United States. The “490” Chevrolet became the first serious competitor to the Model-T at comparable price, quality and volume in 1914. With this product, Durant had what GM did not, a mass-market, low-cost, high-profit automobile;

- As a result, Durant was able to use the more valuable Chevrolet stock, in a five-to-one trade, to regain control of General Motors in 1918(Wysner, 1994).

Over the history of the company, diversification has also played a role. GM has diversified into appliances, electronic communication devices, banking, and other manufacturing practices.

5.2 Background

Ford introduced the Model T in 1908 and by the time it was discontinued in 1927, approximately 15 million vehicles had been sold. As discussed in Chapter 3, Ford wanted to produce a car for everyone, he wanted to build a car that served its primary function. Ford completely believed in reducing wastes to make vehicles more affordable and also believed that customers were only interested in basic transportation. What Ford failed to understand was that there are two basic components to products and service: the core (the product's primary purpose) and the augmented (additional features and functions) (Tedlow, 2008).

One of the major focuses of this paper is to identify the inability of leaders of industries, and in this case the automotive industry, and understand the affects of those companies that miss the shift in the business S-curve. The Dow Jones was originally established in 1896 and currently today, only General Electric out of those 12 companies on that list is still there. Economist Paul Ormerod comments, that on average, 10 percent of all companies that are formed will eventually fail within the first two years, others will fail due to the inability to remain viable, or transitioning product lines, or technologies in the United States, (Tedlow, 2008).

5.3 Factors of Augmentation

As the automated mechanical assembly lines were introduced with other automated equipment, Ford realized that he had a serious issue with turnover of his workers (380% in 1913) (Halberstam, 1986). Ford calculated that a five-dollar day would attract the best workers, diminish labor unrest and ultimately lead to greater profits. From 1914 through 1916 Ford's profits after taxes went from \$30 million to \$60 million, it was probably the first time that the fruits of the oil-filled industrial age had reached down to the average worker. With the five-dollar per day wage many other industries had to follow suit to attract workers. Workers now had money and purchasing power and more leisure hours; however, Ford expected productivity and continuous productivity gains and process improvement gains from his workers.

By 1920 roughly a million cars were being produced a year, by 80,000 workers. With the amount of vehicles being produced, more and more road ways were being constructed and the maintenance and shape of the roadways were much better. With more and more industries coming on line, cities grew exponentially; the vehicle became a way for people to traveling to work, earn a living, and enough to enjoy recreational activities. The automobile became more than just required transportation, it became a status symbol.

Taiichi Ohno, Toyota VP, reiterated in his 1978 book, *Toyota Production System* and, quoted Alfred Sloan, "an incident occurred between 1924 and 1926 that changed America's automobile industry drastically. The smaller but higher-class market that had existed since 1908 was transformed into a larger market demanding better-class for the general public," (Ohno, 1988 pg 103); once they offered more inspiring products.

As economic growth continued in the early 1920s four elements are considered to be the driving force behind the drastic change in the automotive industry:

1. The introduction of installment plans (creation of finance arm followed for GM, which already existed in a number of other industries;
2. Used car trade-ins (which fits into Sloan's car for everyone program, talked about later);
3. Closed Sedan-type body; and
4. Changing models yearly, and drastically (product appeal improvements)

5.4 Augmentation

Model changes prior to 1922 were few and far between, however, that changed with innovations in technologies in both products and processes. The most notable being two processes that made it possible to do more with styling and appearance, the low-cost production of all-steel, closed body automobiles, and the development of fast-drying lacquer-based paints, (McCarthy, 2007). Dodge introduced the first all-steel body with closed cabin in 1922, (McCarthy, 2007). This was made possible by advancements by American Rolling Mills Company in sheet and rolled steel making technologies. The ability to paint vehicles other than black through Dupont's development of multiple fast drying lacquer-based colored paint, gave General Motors a competitive advantage in that Dupont for the first year only permitted General Motors access to these new paints.

On May 10, 1923, Alfred Sloan became President of General Motors. Sloan brought two main ideas, from a marketing standpoint, to General Motors:

- A car for every purse and purpose (full-line policy), a market segmentation; and
- Planned obsolescence

Prior to Sloan, car buyers were limited to those purchasing a car for the first time; typically they paid cash or acquired a special loan. Many cars were of the “touring” type or “roadster” type, styles that did not change from year to year. This situation continued for some time. When a model was changed it was not conspicuous until the entire changeover was completed. Different or changed elements developed at different times and rates were added separately until all changes eventually came together as a completely new model.

By the 1920s the used car industry was coming to life. The second hand reliable automobiles allowed people to fulfill their basic need for transportation for less money than a new Model T could be purchased. What Sloan recognized was that people trading their cars in were looking to upgrade what they currently had. That is when Sloan developed the car for every purse and purpose, full-line policy. As stated above, Ford was caught in his “old” S-curve product technology, while Sloan was moving General Motors ahead. Some of the technologies that Sloan added to his line up were:

- General Motors introduced hydraulic brakes on their vehicles in 1924, while Ford introduced hydraulic brakes 14 years later,
- General Motors introduced radiator cooling thermostats on all of their vehicles in 1925 while Ford introduced on Model A five years later,
- General Motors vehicles came in different colors a couple of years prior to Ford,

- General Motors introduced the straight 6-cylinder engine in 1929 while Ford did not introduce the 6-cylinder until 1936,
- Standard Gear Shift was standard on General Motors vehicles in 1923 while Ford introduced it on Model A in 1927,
- Balloon Tires became standard five years prior to Ford using them, and
- A foot accelerator was used in 1923 with General Motors while the Model T would never have one

Sloan's purse policy or slogan was, as depicted by *Fortune*, "Pontiac... for the poor but proud, Oldsmobile for the comfortable but discreet, Buick for the striving, Cadillac for the rich", (Tedlow, 2008, pg 19). A review of the *Car and Driver*, *Road and Track*, and *Motor Trend* magazines from the early to mid 1960's on show that Pontiac (just being announced closure in April 2009) from the mid 1960s became the Sport Sedan/Coup hot cars; GTO tripower (3 Deuce carburetors), Quad Power (2 and 4 barrel carburetors), Fire Bird, TransAM and Bonneville.

Sloan also was the first to introduce planned obsolescence, to make major changes to models each year, by changing body styles, adding additional features, and/or introduction of new technologies. While the Ford Motor company stuck to basic transportation and refusing to introduce newer technologies as they were developed.

General Motors also had a large advertisement campaign to let the customers know what they had was upgraded and hopefully send them back to the show rooms longing for the new vehicles prior to their older cars being passed their useful life (Olson & Cabadas 2002). In 1924, General Motors bought more magazine advertising than any other company in the United States and maintained this number one spot for decades.

Ford was not spending any money on advertising and still selling the ideas of long life, and to make parts so cheap that it is better to replace versus repair them. In fact, that these ideas led to the point that by 1926 some 50 percent of Ford's profit was from service and replacement parts.

The last element listed above that created the increase in automobile purchases was the ability to obtain financing to purchase a vehicle. Again this was mostly led by General Motors. In December 1913, E. F. Weaver established the first automobile consumer finance company (McCarthy, 2007). General Motors then quickly formed General Motors Acceptance Corporation (GMAC) in March 1919 to extend credit primarily to its dealers. Consumer lending began as an ancillary business and then excelled from that point. By the 1920s it was estimated that 70-75 percent of vehicles purchases were done through these types of financing. Ford being the type of business man he was and his inherent distrust in bankers led to Ford Motor Company's late arrival into the financing world.

The work Sloan completed at General Motors and the above four elements that opened the auto industry up for growth was substantial. By the end of the 1920s the United States Automotive Industry became the largest industry in the United States and had the largest economy in the world. General Motors growth from 1924 to 1925 was 70 percent with the production of 512,000 vehicles, versus production of the Model T of 1.6 Million. By 1927, the Model T was discontinued and Ford shut the doors for several months to retool for the Model A, basically incorporating some newer technologies but again stalling from upgrades after release. In 1931 General Motors passed Ford Motor Company sales for the first time, not to relinquish again for decades.

5.5 Losing Share

After the first couple of oil embargos and the change of manufacturing practices, most notably the lean manufacturing concepts being introduced by Toyota, GM responded by the development of the Saturn Plant. The Saturn plant, built in Springhill, Tennessee, and first producing cars in 1990, was introduced to take the most economical, lost cost, import fighting response. It was to do this by the introduction of all the latest technologies and manufacturing systems: just-in-time; kanban systems; employee circles; single minute exchange of dies (SMED); and self-directed programs. Over the decade of its development, it quickly moved to the position of taking more of a role left behind by the old retired Oldsmobile Company. As part of receiving bailout funds in 2009, Saturn is now named as one of the divisions that GM plans on discontinuing.

5.6 Current (10-Year) Status

General Motors net sales and net income over the past 11 years is graphically depicted in Figures 15 and 16. As can be seen from the charts, General Motors total net sales and net income demonstrates a large instability. Figure 17 shows the trend in automotive sales from General Motors in North America over the same time period. It can be seen that General Motors has had a fair drop off in total sales, and as Figure 15 shows, the market share has followed similar suit, showing that North America has favored moving away from General Motors vehicles in exchange for Toyota and Honda.

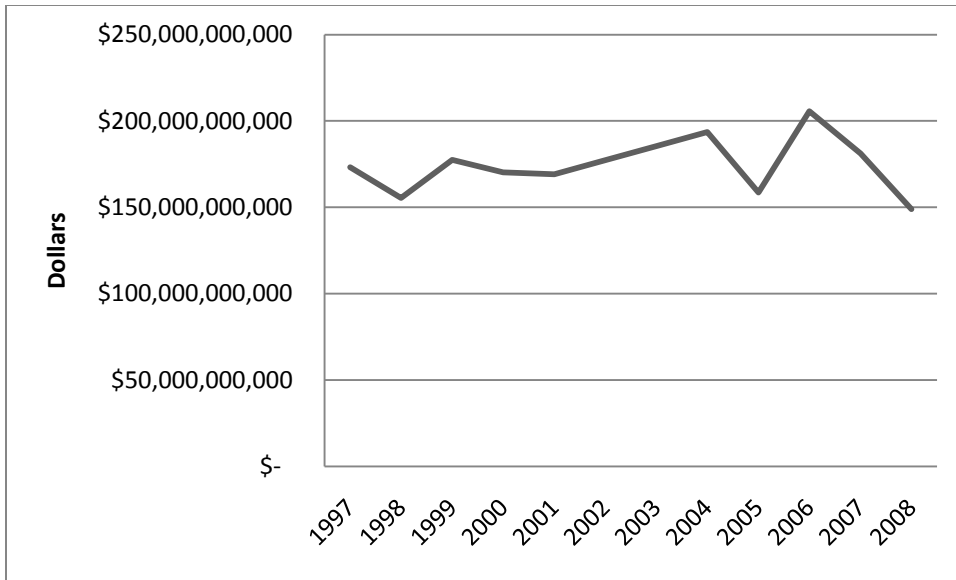


Figure 15, GM Net sales (source: Created with data from GM's Annual Reports, 1997-2008)

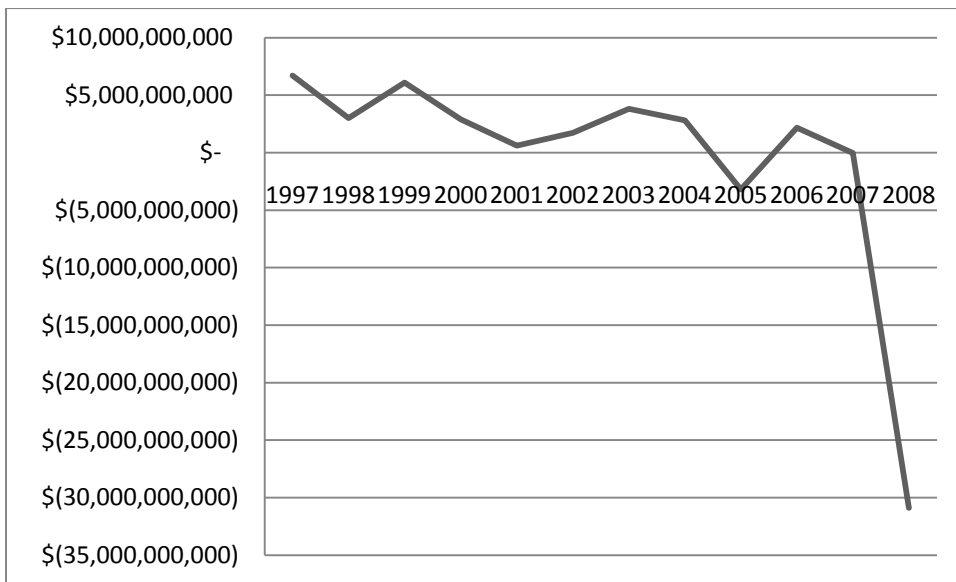


Figure 16, GM Net Income (source: Created with data from GM's Annual Reports, 1997-2008)

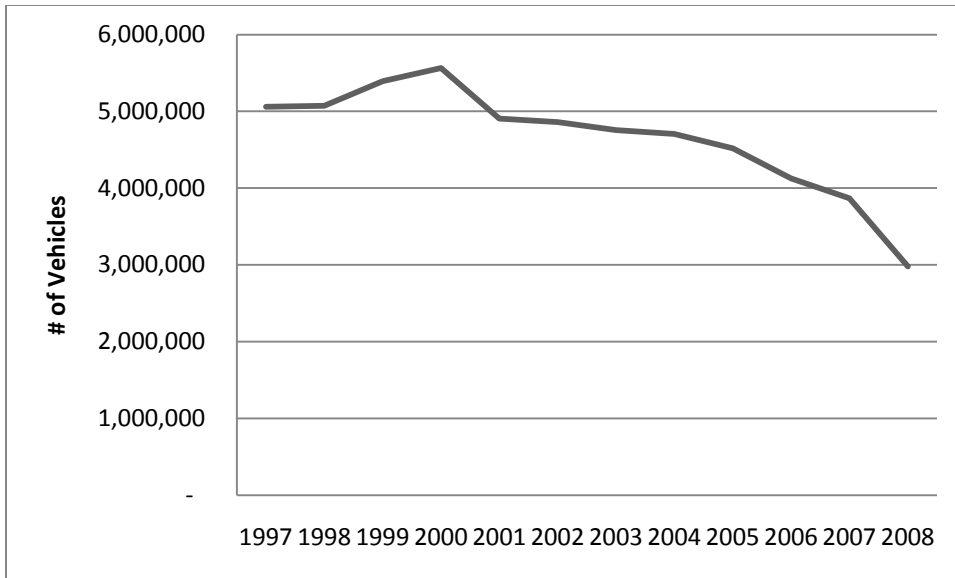


Figure 17, GM Vehicles Sold (source: Created with data from GM’s Annual Reports, 1999-2008)

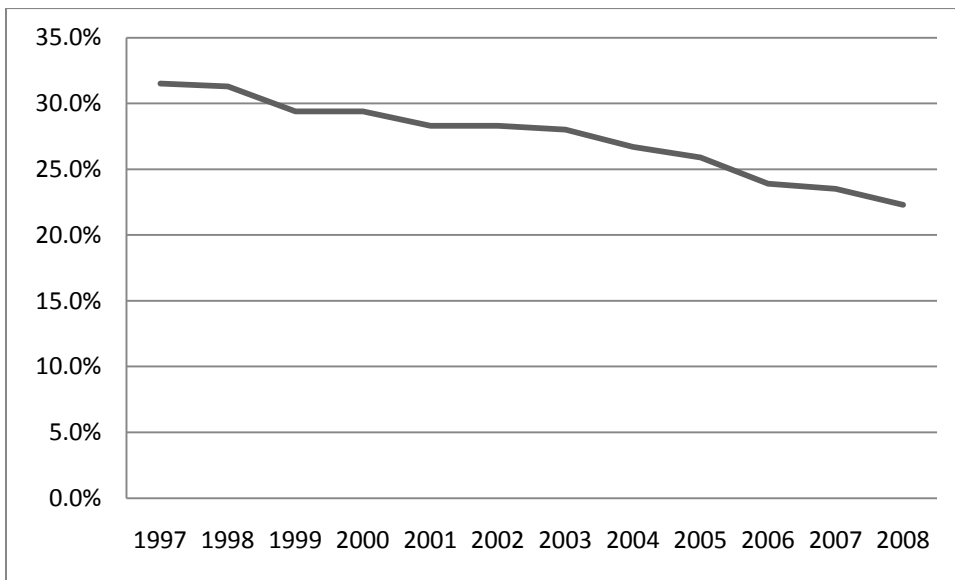


Figure 18, GM Market Share (source: Created with data from GM’s Annual Reports, 1997-2008)

Figures 17 and 18 show that there has been a downward trend in both total vehicles sold and total market share. Market share has dropped off by approximately twenty-four percent while total number of vehicles sold has declined by approximately 18.5 percent.

2009 is shaping up to be even the most difficult year for all of the automotive suppliers. General Motors is attempting to shed off much of its legacy costs by entering into bankruptcy and having the government bail it out by providing billions in loans.

Figure 19 represents the total North American employment levels over the last decade.

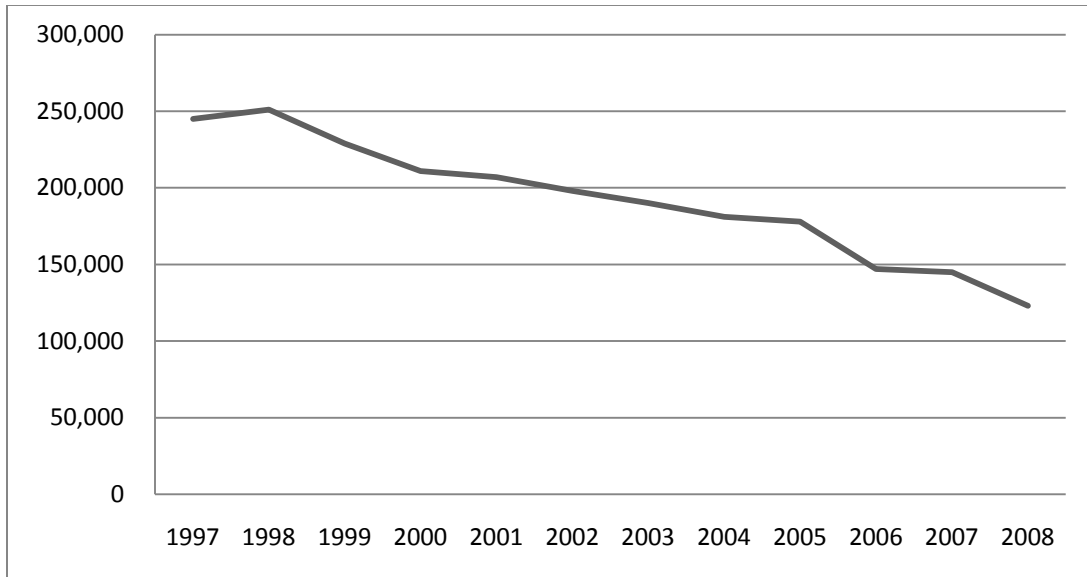


Figure 19, GM Total Number of Employees (source: Created with data from GM's Annual Reports, 1997-2008)

This figure shows a total decline of approximately forty percent over the last decade.

More cuts are expected to come as General Motors shed other legacy costs and closes additional factories and sell off or close down brands such as Saturn, Hummer, and Pontiac.

Some of additional interesting information is a look at the total dollar amounts and percentages against net income that General Motors states that it is paying in dealers' claims, and incentives, for either repairing warranty issues or providing incentives to sale its vehicles; Figures 20 and 21 represents graphically this data.

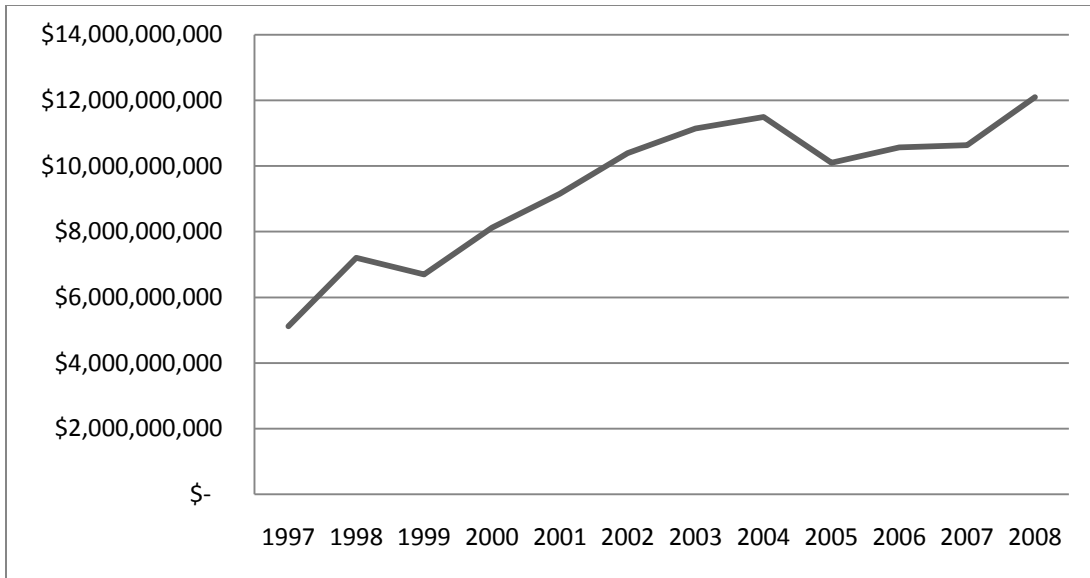


Figure 20, GM Allowances, Claims, Incentives (source: Created with data from GM's Annual Reports, 1997-2008)

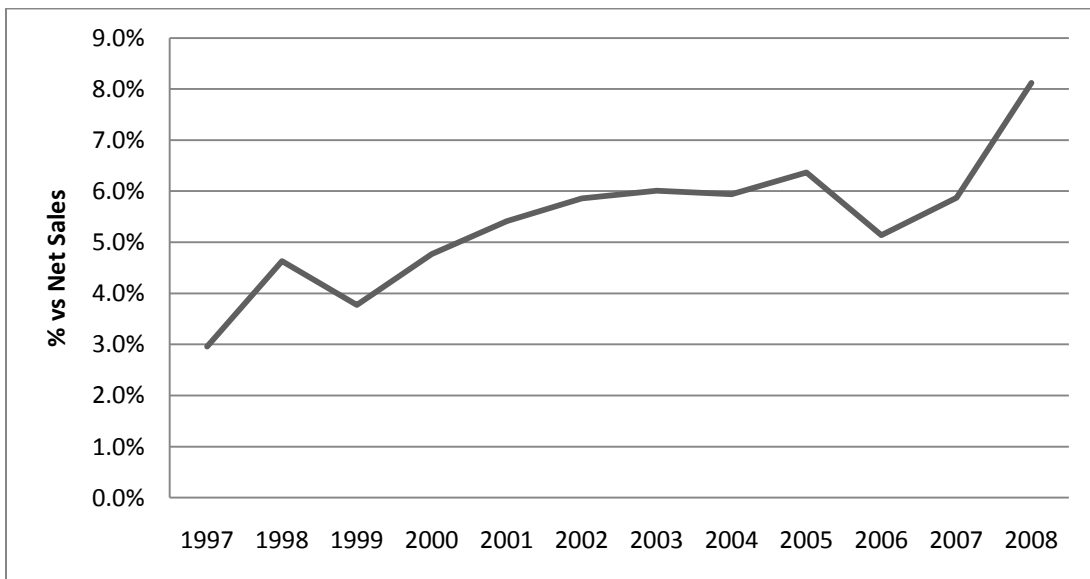


Figure 21, GM ACI vs Net Sales (source: Created with data from GM's Annual Reports, 1997-2008)

Figure 22 depicts the total dollars spent by General Motors on research and development while Figure 23 depicts advertising and research and development against net revenue.

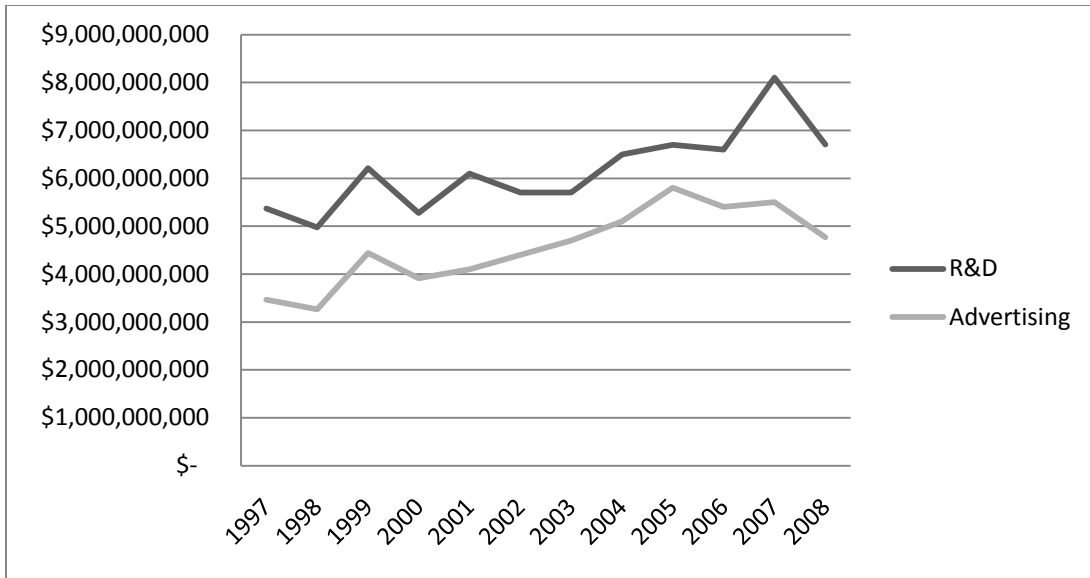


Figure 22, GM R&D and Advertising (source: Created with data from GM's Annual Reports, 1997-2008)

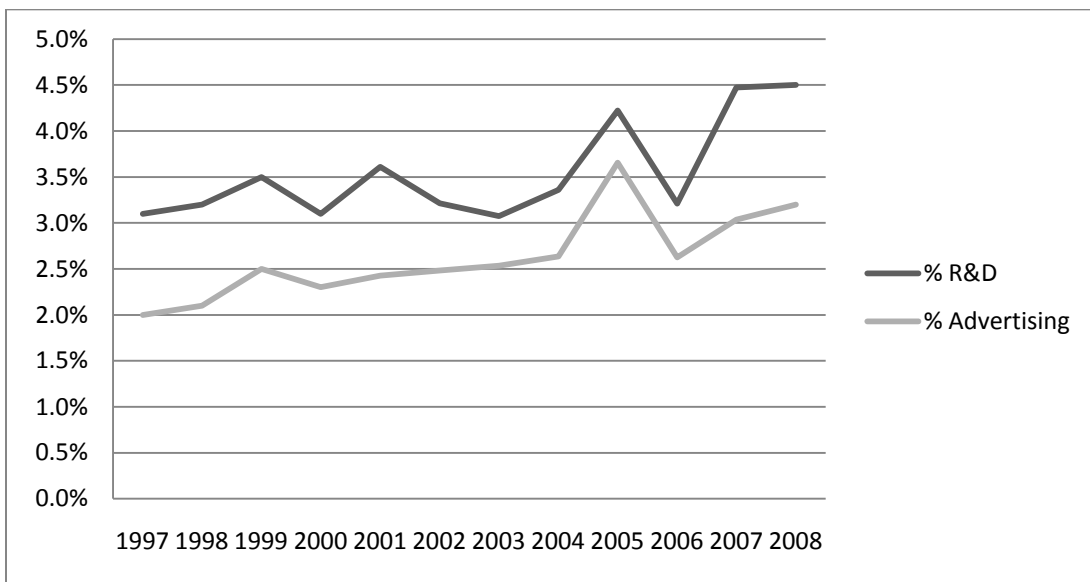


Figure 23, GM R&D and Advertising vs. Net Sales (source: Created with data from GM's Annual Reports, 1997-2008)

CHAPTER 6

JAPAN CULTURE AND EARLY JAPANESE AUTOMOTIVE INDUSTRY

6.1 Introduction

Chapter 6 examines the development of the Japanese Automotive Industry and the circumstances/factors that shaped their economy and created the environment to be the largest automotive producing country in the world. This chapter begins with an examination of the environment that permitted the infiltration of importing into the United States and how the Japanese manufacturing characteristics mandated by their own environment/culture contributed to these successes.

6.2 Cultural and Local Factors

Japan is an archipelago country, being made up of over 3,000 islands and a total land area of 374,744 square kilometers (slightly smaller than the state of California), with 70 to 80 percent of the land mass being unsuitable for agriculture, industrial use or residential use due primarily that the land is forested, mountainous, (World Fact Book-Japan, retrieved 3/27/07).

Japan's population is estimated at 127.3 million and is made up of 98.5% Japanese, 0.5% Korean, 0.4% Chinese, and 0.6% other, (World Fact Book-Japan, retrieved 3/27/07), making Japan, for the most part, linguistically and culturally homogeneous. Given that Japan's land mass is 374,744 square kilometers, of which 70-80 percent is unusable, and an estimated population of 127.3 million, Japan is one of the most densely populated countries in the world. There are roughly 339.7 people per square kilometer. To put this in perspective, California has an area of 423,970 square kilometers and 2006 census of 36,756,666 people with its largest city, Los Angeles at 1,290 square kilometers and 2006 census of 3,849,378. Tokyo has an area of 2,187 square kilometers and a 2007 census population of 12,790,000. The United States has a population of 303.8 million and a land mass of 9,161,923 square kilometers, of which 80 percent is usable, the density is roughly 33.2 people per square kilometer, Table I represents these data including age data.

Table I U.S. and Japan Statistics,

	Japan	U.S.
Population	127,288,416	303,824,640
Land Area	374,744	9,161,923
Median Age	43.8	36.7
People/SQ Km	339.7	33.2
Usable Land	30%	80%

(source: created with data from World Fact Book, 2007)

From an arts and crafts standpoint, Japan is famous for its calligraphy, ikebana (great detail flower vases), origami, ukiyo-e (fine detail wood blocks), dolls, pottery, metalwork, lacquerware, dying, weaving and tapestry as well as garden design and

flowering arrangement. These have created a long history of (1) very well refinement, (2) attention to great detail and (3) the ability to work with very fine small items.

Given these details on land density, arts and culture the population of Japan exhibits the following characteristics and has developed for a very long time given their celebrated independence (National Foundation Day) dates back to February 11 660 BC (World Fact Book-Japan, retrieved 3/27/07):

- Mostly 100% homogeneity,
- Attention to Detail, no waste,
- Refinement,
- Smallness and precision are important and a hobby (bonsai trees),
- Small tiered rice farms, and
- Small apartments, multi-functional/flexible rooms.

In summary, the Japanese are a creative/artistic culture with great attention to small fine detail, combined with a strong sensitivity to the use of space and resources (a drive and loyalty to use land, resources effectively, and efficiently), which, has and continues to have a significant influence on Japan's approach (and strategy) for its economic development.

6.3 Japan's Resource Situation

Unlike the United States, Japan has no real natural mineral resources, minor farming industry (Japan still imports 55-percent of food that is consumed) and a large fishing industry fleet (Japan accounts for 15-percent of the global catch). World FactBook (2007 estimates) put Japan at \$572.4 billion imports a year consisting of fuels,

foodstuffs, chemicals, textiles, and raw materials. Since Japan must import much (most) of what it uses and consumes, Japan must use these items efficiently and effectively to produce very high value added (and profit) competitive exports to other countries; to generate the revenues and profit margins to support and grow its economic well being and sustain its independence is a top priority. Chapter 7 explores the driving factors behind the development of Toyota's Manufacturing System (AKA Lean Manufacturing) for raw material conservation manufacturing, and waste reduction at every step of the process. All of these variables led to a different type of thinking and led to an entirely different type of manufacturing.

6.4 Japan's Motorized Vehicles Industry

Pre World War II

The Japanese automotive industry began in 1902, with limited production of small (12 horsepower) vehicles assembled by a number of companies on a trial basis. Japanese companies were unable to compete against imported cars from the United States. Ford and General Motors established subsidiaries in Japan and assembled trucks and cars from imported parts (knock downs). Cars and imported fuel were expensive for the ordinary Japanese citizen, so buses and motorized bicycles were popular. In 1923, there were about 100,000 automobiles in the country (around 65,000 cars, 35,000 trucks). The majority of these cars were taxis (James, 2005).

The zaibatsu were involved in joint ventures to produce and sell cars in Japan under license in the middle to late 1910s. The companies circumvented this by either designing their own trucks (the market for passenger vehicles in Japan at the time was

small), or partnering with a European brand to produce and sell their cars in Japan under license. From 1935, increasingly restrictive imports duties help protect new Japanese manufacturers. The demand for domestic trucks was greatly increased by the Japanese buildup to war before World War II.

However, outside of the major cities, the road system of Japan was limited. The unfavorable topography, as described earlier, of Japan therefore favored the development of transport by sea. Motor transport had a low priority to the government as opposed to the railroad system. Figure 24 represents the time frame from 1916 to 1939. As a result the major motorized personal transportation vehicle which evolved was the small motorbike/motorcycle vehicles.

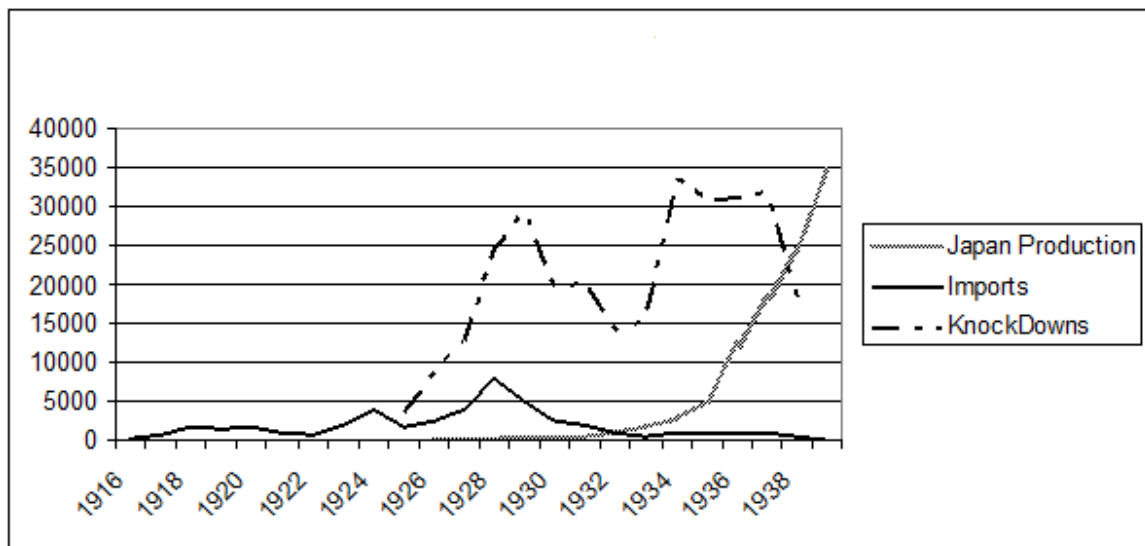


Figure 24 Early Japanese Auto Industry (source: Cusumamano, 1985)

The early domestic automotive companies were comprised of the following with associated formation times:

- 1907 - Hatsudoki Seizo Co., Ltd. established

- 1911 - Kwaishinsha Motorcar Works established
- 1917 - Mitsubishi Motors first car
- 1918 – Isuzu first car
- 1924 -1927 Otomo
- 1931 - Mazda Mazdago - by Toyo Kogyo Corp., later Mazda
- 1935 - Toyota first car
- 1937 - Suzuki first prototypes (Cusumamano, 1985)

Post World War II

Japan was destroyed during World War II by allied bombings; Japan had an opportunity to rebuild itself using the latest technologies. In the years following the end of the war, transition and survival were related questions for the entire Japanese automotive industry. The Japanese army was no longer requisitioning large number of trucks, the domestic manufacturers had to transition from trucks to small vehicles (and motorcycles). Resources were limited, operating capital could not be found and installment loans were not available for the public. As Cusumano (1985) identifies some production data: 1947, Nissan produced only 4421 vehicles, down from 19,688 in 1941, yet the number of workers had risen from 7550 to 8500; vehicles per employee year thus fell from 2.6 to 0.5.

However, During the Korean War (1950–1953), the United States government commissioned Japanese automobile manufacturers to produce army trucks. This was advantageous due to Japan's proximity to Korea, and the United States had close ties to Japan because the country was still under Allied occupation since the end of World War

II. These army truck commissions led to enormous growth in Japan's auto industry, leading to the boom of Japanese cars during the 1960s.

By the early 1950s many Japanese had the income to afford vehicles; however, as stated above, resources were extremely limited and availability of fuel to power the vehicles was limited and expensive. These two combinations, coupled with the behavior of the Japanese people as stated in section 6-2, led to small, refined, high quality/consistent reliability, and good fuel economy manufactured at low cost “kei” cars (as discussed in more detail in Chapter 7).

During the 1960s, Japanese automakers launched a bevy of new “kei” cars in their domestic market. These tiny automobiles usually featured very small engines (from 360cc to 600cc) to keep taxes much lower than larger cars. The average person in Japan was now able to afford an automobile, which boosted sales dramatically and jumpstarted the auto industry toward becoming what it is today. The first of this new era, actually launched in 1958, was the Subaru 360. It was known as the "Lady Beetle", comparing its significance to the Volkswagen Beetle in Germany. Other significant models were the Mitsubishi 500, Mazda Carol, and the Honda N360. Many of the automakers sought to expand into other markets, mainly the U.S. In 1957, the first Japanese car to be imported to the United States was the Toyota Crown, followed by the 1958 Datsun 1000(PL210).

Also During the 1960s the American consumer gained confidence and knowledge of the higher quality standards and reliability of the Japanese manufacturers, so when the first oil embargo occurred, the Japanese imports filled an important need, better quality, better mileage, and better reliability at a lower price. Also, the reliability had to be much greater since the Japanese lacked the resources to build a vast network of dealerships and

repair parts, inventory; cars had to be manufactured to last since it was far too expensive to repair vehicles sold in the United States. Growth occurred so fast that by 1980, Japan became the largest producer of automobiles in the world.

Figure 25 represents the growth of the Japanese production numbers while Figure 26 represents the percentage of imports as a whole in the Japanese auto industry (cars either made in Japan or imported).

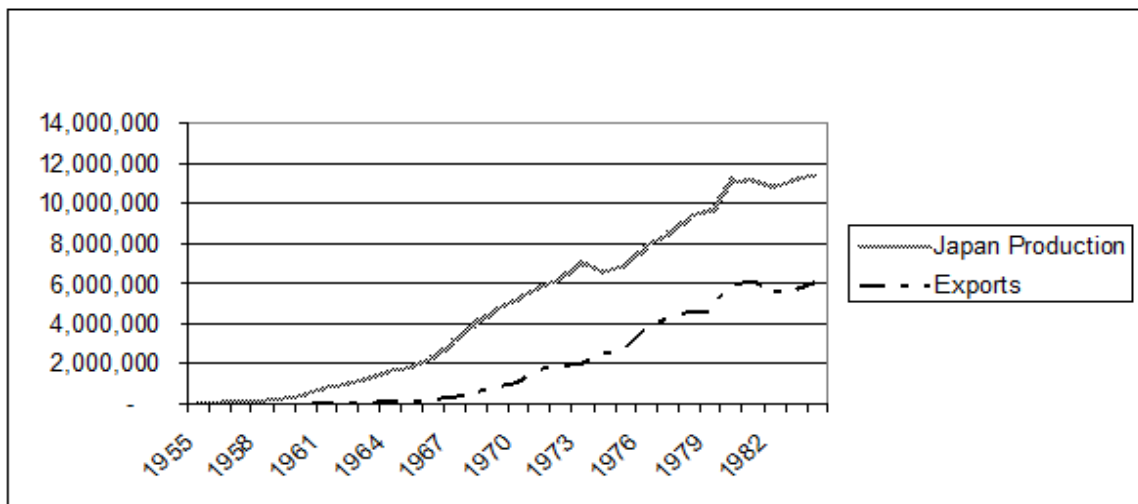


Figure 25 Japanese Post WWII Production (source: Cusumano, 1985)

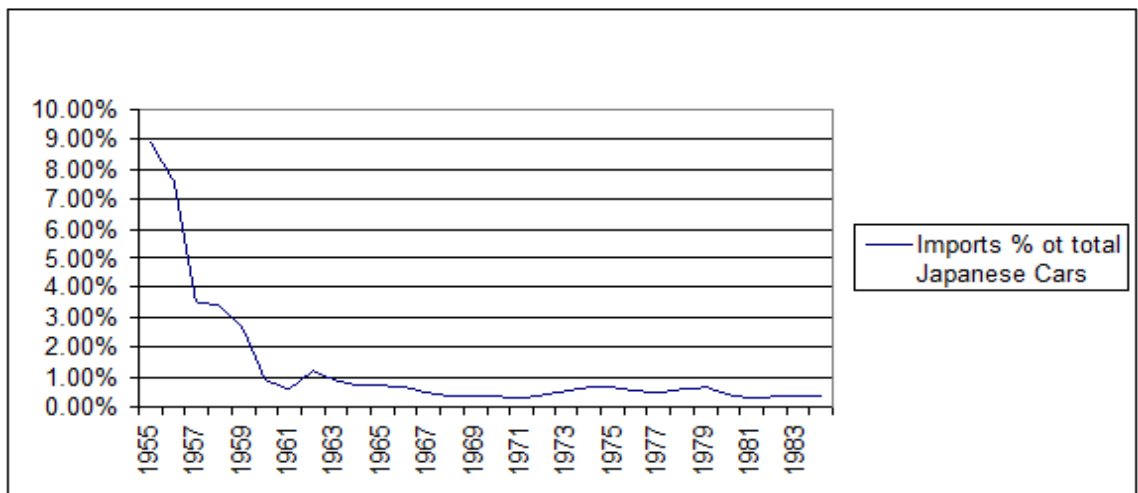


Figure 26 Imports into Japan (Source: Cusumano, 1985)

The Japanese automotive manufacturing Companies realized from the earlier Japanese solid state consumer electronics industry (most notably television) that they had to manufacture and ship automobiles to the United States with much higher quality and reliability because they did not have the national dealership service network (with replacement parts) to handle repairs, maintenance work and warranty work. Nor could the Japanese companies afford to build this type of networking in the short-term or even for many years to come. They could not afford to build or develop a reputation for cheap (not just inexpensive) products if they planned to expand in the United States.

The American market had become dominated by very large vehicles, so the appearance of a new concept in car design of small fuel efficient and affordable models was only seen as a niche market and an act of defiance. Yet amid this highly unfavorable situation, Honda of America Motors (HAM) began (first with motorcycles) its nationwide search for sales outlets. The company's sale staff consisting of a dozen people each took a territory covering several states. With these efforts, owners of dealerships of cars began including the Civic as part of their product lineups. The affordable Civic, however, was nearly always positioned at the bottom of the product lists and was generally assigned to a lonely corner of their outdoor display. The lack of the Civic receiving high visibility eventually led HAM to develop their networks of dealers, (Chapter 8 will take a detail look at this early strategy).

From mid-1973 to the following year, the United States auto industry found itself struggling under the effects of the first oil embargo (see chapter 13). This promoted many American consumers to change their interpretation of what value was – no longer

was it good to own a large, luxurious “gas guzzler” but to own a more practical, lower cost, sensible size, outstanding fuel efficient vehicle.

Japan’s history of producing smaller fuel efficient vehicles, while reducing waste (improving quality and reliability), coupled with the oil embargo gave the Japanese an avenue to capture market share in the United States. Even though Japan was producing better quality higher reliable vehicles, the domestic manufacturers were busy explaining the success in other regions. Holweg (2006) lists six “excuses” by the domestic suppliers, shown later to be false because of the success of the Japanese implants, are as follows:

1. Cost advantage: Japan was seen to have lower wage rates, a favorable Yen/Dollar exchange rate and lower cost of capital, elements that combine to an ‘unfair playing field’;
2. Luck: Japan had fuel-efficient cars when the energy crisis came, or it was simply a fortunate effect of the ‘business life cycle issue’;
3. Japan, Inc.: MITI, Japan’s Ministry of International Trade and Industry, was suspected of orchestrating a large-scale industry policy;
4. Culture: Cultural differences in Japan allowed for more efficient production, which cannot be replicated in other countries;
5. Technology: The use of advanced automation in Japanese factories (it was all done by advanced robotics). Some even suggested that the Japanese were acquiring Western technology, which they then exploited; and

6. Government Policy: Trade barriers against the United States, more lenient labor laws in Japan, and a national health care program lowered the overall labor costs.

Figure 27 represents this increase in Market Share of the Japanese imports.

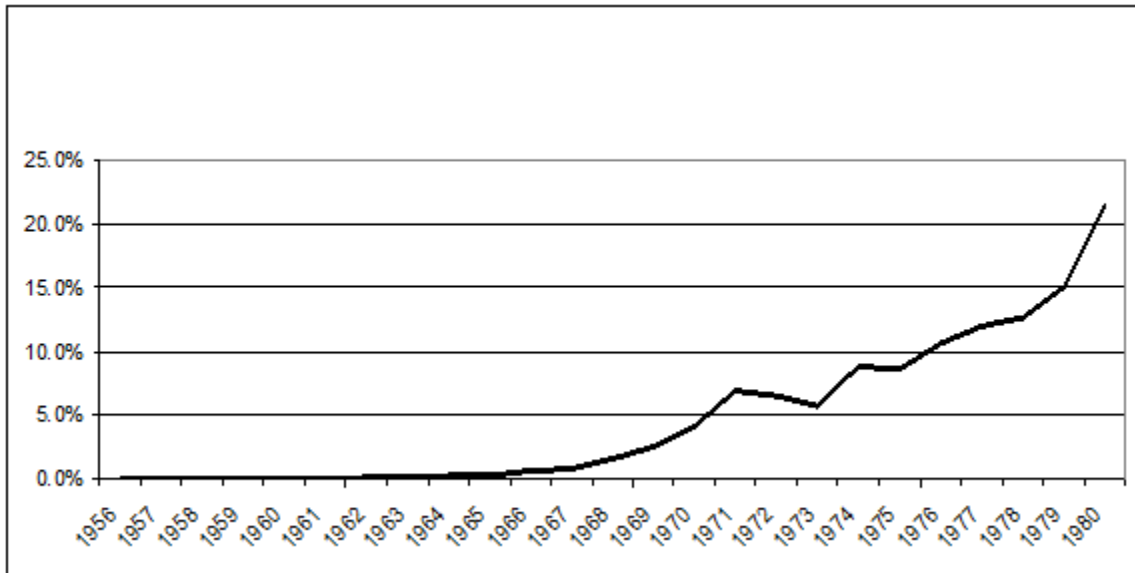


Figure 27 Japanese Import Market Share of US (source: International Trade Administration, retrieved 7/8/2009)

6.5 Early Rise of the Implants

In the early 1980s, based on pressures from the United States, the Japanese instituted a voluntary limit on the number of imports from Japan to the United States; however, this eventually led to two events happening:

- Japan Manufacturers begin building/expanding manufacturing facilities in North America, and

- The Japanese enter into the higher end luxury market where higher profits can be realized, and where these brands were only sold outside of Japan
 - Honda's Acura – established in 1986
 - Nissan's Infiniti – established in 1989
 - Toyota's Lexus – established in 1989 (1st to be offered in Japan, 2005)

Table II identifies those implants, year established and location:

Table II Japanese Implant Assembly Plants

Manufacturer	Location	Established	Products
Honda	Marysville, OH	1982	Accord, Acura TL, CL
Nissan (NMMC)	Smyrna, TN	1983	Quest, Altima, Maxima, Sentra, Frontier, Xterra
NUMMI (Joint Venture, GM and Toyota)	Freemont, CA	1984	Chevrolet Nova, Prizm Pontiac Vibe Corolla, Hilux, Tacoma, Voltz
Honda	Alliston, Ont	1986	Odyssey, Civic, Acura EL, Acura MDX, Pilot
Mazda Auto-alliance owned by Ford	Flat Rocks, MI	1987	Mazda 626 MX-6
Mitsubishi Joint venture with Chrysler	Bloomington-Normal, IL	1988	Mitsubishi Eclipse, Galant, Mirage
Toyota (TMMK)	Georgetown, KY	1988	Camry, Avalon, Solara, Sienna, Pronard
Toyota (TMMC)	Cambridge, Ontario	1988	Camry, Corolla, Matrix, RX330, Solara

Honda	East Liberty, OH	1989	Accord, Civic, Element
Subaru-Isuzu Automotive Inc Joint Venture	Lafayette, IN	1989	Isuzu Rodeo, Aximo Subaru Legacy, Baja, Outback Honda Passport
CAMI Suzuki-GM joint venture	Ingersoll, Ontario	1989	Suzuki: Swift, Sidekick, Vitara
Avon Lake Ford-Nissan joint venture	Avon Lake, OH	1993	Lincoln/Mercury Villager Nissan Quest
Honda	El Salto, Mexico	1995	Accord
Toyota (TMMI)	Princeton, IN	1999	Tundra, Sequoia, Sienna
Honda	Lincoln, AL	2001	Odyssey
Nissan	Canton, MS	2003	Quest, Titan, Pathfinder, Armada, QX56
Toyota (TMMTX)	San Antonio, TX	2003	Tundra

(source: created with data from the International Trade Administration, 2009)

CHAPTER 7
THE MANUFACTURING RE-VISION
(The Toyota, Lean Way)

7.1 Introduction

In the earlier days of the automotive industry, prior to the oil embargo, manufacturers could basically sell what they built. The Maxcy-Silberston curve (Maxcy 1956), from Model-T paradigm or learning curve effect, have been frequently used. According to this principal of mass production, given some limits, the cost of a petroleum automobile decreases drastically in proportion to the increase in quantities produced (Cusumano, 1985). The high cost of tooling and the very high cost of changing over this tooling (in some cases days with high labor cost) created the environment of the domestic three manufacturers to depend on long lives of their models, with added minor annual changes that usually just added minor technology improvement. When the oil embargo came to being, the domestic manufactures were in no position to competitively react. As discussed in the previous chapter, Toyota, based on the environment of Japan, was perfectly suited to rewrite the manufacturing process.

This Chapter briefly looks at: the history of the foundation of Toyota; talk about their alternate approach to mass production; define briefly their drive towards quality, reliability and development of new technologies; and presents some key financial and result data over the last 10 years.

7.2 Foundation of Toyota (Brief History)

Sakichi Toyoda (1867-1930) was very similar to Henry Ford in his keen abilities in understanding mechanical machines. Toyoda, who was a weaver, could not comprehend the idea of having an automatic loom machines, that when there was an error, it would continue to produce waste (part of the natural culture of Japanese as define in Chapter 6), hence, in 1924, he invented a loom that would detect an error and automatically cease production, preventing the creation of defective goods. He later sold the patent on his machine to a British firm for about \$150,000. That money was used to help his son, Kichiro Toyoda, 1867-1952, found/established the automobile department at the Toyoda Automatic Loom Works. This was spun off as Toyota Motor Company, LTD., in 1937 (Toyota Website – retrieved 9/11/09).

Toyota was supported by the Japanese Government for military purposes. The Japanese relied on foreign trucks in the war in Manchuria, but with the Depression, money was scarce. Domestic production would reduce costs, provide jobs, and make the country more independent. By 1936, just after the first successful Toyoda vehicles were produced, Japan demanded that any automakers selling in the country needed to have a majority of stockholders from Japan, along with all officers, and stopped nearly all imports.

Kiichiro Toyoda began experimenting with two cylinder engines, however ended up copying the Chevrolet 65-horsepower straight-six, with same chassis and gearbox and the Chrysler Airflow's styling (James, 2005). The first engine was produced in 1934 (the Type A), the first car and truck in 1935 (the Model A1 and G1, respectively), and its second car design in 1936 (the model AA).

From 1936 to 1943, only roughly 2,000 cars were manufactured; however Toyoda did find more success building trucks and busses. The Toyota KB, a 4x4 production started in 1941. It was a two-ton truck similar to the prewar KC; it had a loading capacity of 1.5 tons and could run up to about 43 mph. The GB was based on the peacetime, 1.5 ton G1 truck, which in turn was based on the Model A1 cars.

The first Toyota truck was approximately one-ton to one and a half-ton design, using an overhead valve six-cylinder engine that was very similar (if not exact) to the Chevrolet engine of the time (a large number of parts were interchangeable, and Toyota trucks captured in the war were serviced by the Allies with Chevrolet components).

7.3 Alternative to Mass Production

Immediately Following World War II, the numbers of cars produced, compared with today's models and features were relatively few. For decades, American automakers cut costs by producing fewer types of cars. The Maxcy-Silberston curve or "economies of scale" became widely used in the American automotive industry to determine the reduction of automobile costs with increasing production volumes (Maxcy & Silberston, 1959). The American mass production model based their "budgeted" savings on

economies of scale, and these mass production approaches became quite common throughout the world.

The Japanese had a different vision for the automotive market. Their challenge was how to cut costs while producing relatively small numbers of many car types because of their lower volume of cars. The Toyota Production System (TPS) was born out of the principle, and necessity, of producing many models in small quantities. During the decades of the 1960s and 1970s they began putting these principles into practice (Shingo, 1989; Ohno, 1988; James, 2005). The focus was on: smaller lots, removing wastes, driving machine and tooling costs down, concentrating on single minute exchange of dies (SMED), and shorter, or nonexistent, changes from model to model on single production lines. Soon others took notice and embraced the Toyota Production System.

7.4 Start of Toyota Thinking

Looking back a bit earlier in history to around 1945, just following the Japanese defeat in World War II, a new beginning was being launched for the Toyota Motor company. The company president, Toyoda Kiichiro (1894-1952) set a goal to catch up with American automakers in three years in quality, costs, and productivity (Juran, 1988). At that time, it seemed like an unachievable goal. The American automotive industry worker was more productive than the Japanese worker by a ratio of 9 to 1. If Japan was to survive, they needed to learn American ways and improve upon them. They must also find out how to recognize and do a better job at eliminating the “waste” (muda) in everything they were doing. If they could find and eliminate the waste in their processes, then they could catch, and maybe even pass the Americans. Toyoda himself actually

visited American industry, studied it, and brought his ideas back to his homeland. He enlisted the support of Taiichi Ohno, Toyoda's successor, and Shigeo Shingo, the father of setup reduction (SMED), to help with the business transformation.

The basis of the Toyota production, as defined by Taiichi Ohno is the absolute elimination of waste as already identified by Henry Ford as far back as 1907 and documented in his book, *My Life and Work*. Ohno defined six types of waste and eventually an additional item was added:

- Over Production,
- Inventory,
- Transportation,
- Motion,
- Over Processing,
- Time Spent Correcting Mistakes,
- Human Intellect (added later, approximately 1990s)

The two pillars needed to support the systems are: 1) Just in Time (JIT) and 2) Autonomation, or automation with a human touch. Just in time means that, in a flow process, the right parts needed reach the assembly line at the time they are needed and only in the amount needed. An ideal JIT factory is a factory that is approaching zero inventory. Ironically, one of JIT's founding fathers was an American automaker named Henry Ford. In his automobile factories, the sheet metal that arrived on the shipping dock in the morning, was exiting the factory in the form of a finished automobile by the end of the same day.

Unfortunately, Ford did not recognize the need for “short runs” of a wide variety of models, or product types. Ford's motto became, “Americans can have any color car they want as long as it is black”. Just as ironic is the fact that Deming’s (Deming history and contributions to the Quality Assurance Field to be discussed in greater detail in Chapter 11) TQM principles were not widely embraced in the states. It was not until he received wide acclaim for helping the Japanese gain market superiority, that the US automakers took notice and came to accept the principles of TQM. While popularized by the Japanese auto industry, these disciplines are originally American; however, it was not until the US auto industry was faced with a dramatic declining market share that they started trying to reinvent themselves through the use of these techniques.

The second pillar of TPS is autonomation. Autonomation includes: automating manual processes; providing the correct level of process automation to ensure that quality is built into the product; and ensuring that the quick and accurate changeover of the automation equipment is established. Flexible Manufacturing Systems (FMS) are often employed to help organizations achieve Autonomation. The FMS helps an organization with its agility, flexibility, and rapid response time, particularly in a “high-mix” environment where the number of unique parts and differing designs are high. An FMS is a highly automated system for discrete part manufacturing, with ability to process different kinds of operations. These FMS systems are highly automated and integrated systems that automate processing, material handling and storage retrieval operations (Kalpakjian, 1995).

An FMS is usually a Computer Numerically Controlled (CNC) operation that is controlled by a distributed central computer system. It is characterized by conveyors,

robotics for handling, automated processing, computer controllers, part programming, and automated part storage and retrieval systems. An FMS has the ability to identify and distinguish between the different parts and possesses the ability to changeover quickly and easily during the physical part setup.

FMS have evolved naturally from traditional manufacturing facilities attempting to respond to JIT and world class manufacturing principles. The driving forces that give rise to the FMS are many. A wide variety of product types required from a single facility are one key driver. The short product life cycles with a need for shorter times to markets play right into the hands of the FMS facility. Small volumes, short lead times, tight due dates, and stringent quality requirements drive the need for high degrees of automation, computer controllers and intelligent operating software. This computer automation and control becomes the cornerstone of the FMS.

Most US manufacturing companies today look towards CAD/CAM and CIM to provide the basis for their flexibility (Kalpakjian, 1995). Where CAD/CAM is computer aided design and manufacturing, and CIM is computer integrated manufacturing. With CIM, design data are integrated with manufacturing processes and equipment to perform the production automation process. These automation tools provide the infrastructure that is needed to run an effective FMS. The use of computers in manufacturing today is quite common, and the benefits of CIM are becoming quite well known. Not only are today's manufacturing systems being designed with high levels of automation for machining and part-processing, but also the handling and movement of parts from machine to machine, or operation to operation, as well as the sequencing of these operations is being computer controlled. These systems are capable of producing a wide range of parts, and as

computer integrated manufacturing becomes realized, a greater range of computer and engineering knowledge is required to setup and operate these manufacturing systems. The importance of integrating product design and process design to achieve a design-for-production system has never been more important. Furthermore, manufacturing science principles, mechanical design skills, industrial engineering disciplines, and computer science knowledge are needed more than ever by the FMS engineer. These flexible systems, in particular, provide the solution for the automated production for a low to medium batch size manufacturing facility.

7.5 Toyota's Thinking of Quality and Reliability

Kaizen – process of continuous improvement, was born out of necessity. Cash-strapped Japanese plants, notably Toyota, could not afford to hire large amounts of labor as was done in the United States. Some U.S. employees were hired to rework defects. So Japanese line workers were enlisted to conduct their own quality control to correct any defects they found on the spot. If a problem required more extensive repair the worker was authorized to pull a cord stopping the assembly line, and then to systematically trace the problem back to the root. This process, usually employing several layers of whys, eventually becoming the 5-whys, was developed so that a permanent fix could be developed to prevent reoccurrence.

The system developed by Toyota and adopted by much of Japan gave the Japanese firms an advantage in both quality and reliability. The Japanese system forced engineers to build quality and reliability into the design of their vehicle by utilizing past

experiences and cross-functional teams. The Japanese also pursued for slow continuous improvement as well.

The first step of the Japanese movement to a total quality culture has been credited to Dr. Deming's lecture in 1950 to the Union of Japanese Scientists and Engineers (JUSE), (Cusomor, 1985; Juran, 1988; Mitra, 1998). Deming's 1950 lecture notes provided the basis for a 30-day seminar sponsored by the JUSE and provided the criteria for Japan's famed Deming Prize. The first Deming Prize was given to Koji Kobayashi in 1952. Within a decade, JUSE had trained nearly 20,000 engineers in SQC methods. Today Japan gives high rating to companies that win the Deming prize; they number about 10 large companies per year. Deming's work has impacted industries such as those for radios and parts, transistors, cameras, binoculars, and sewing machines. In 1960, Deming was recognized for his contribution to Japan's reindustrialization when the Prime Minister awarded him the Second Order of the Sacred Treasure.

In 1954, Dr. Joseph M. Juran of the United States raised the level of quality management from the factory to the total organization. He stressed the importance of systems thinking that begins with product designs, prototype testing, proper equipment operations, and accurate process feedback. Juran's seminar also became a part of JUSE's educational programs. Juran provided the move from SQC to TQC (total quality control) in Japan. This included company-wide activities and education in quality control (QC), QC circles and audits, and promotion of quality management principles (Barton 1991). By 1968, Kaoru Ishikawa, one of the fathers of TQC in Japan, had outlined the elements of TQC management and the fundamentals of the Japanese Quality Circles that were eventually copied by so many industries in Europe and the United States:

- Quality comes first, not short-term profits,
- The customer comes first, not the producer,
- Customers are the next process with no organizational barriers,
- Decisions are based on facts and data,
- Management is participatory and respectful of all employees,
- Management is driven by cross-functional committees covering product planning, product design, production planning, purchasing, manufacturing, sales and distribution, (Ishikawa, 1991; Watson, 2004).

Ishikawa can be credited with much of the transition and further development of Japanese quality movement having learned from Deming and Juran. He also outlined several principals of quality as an adaptation of Deming's 13 points, the six principals that became fundamental in his teaching are:

- All employees should clearly understand the objectives and business reasons behind the introduction and promotion of companywide quality control;
- The features of the quality system should be clarified at all levels of the organization and communicated in such a way that the people have confidence in these feature;
- The continuous improvement cycle should be continuously applied throughout the whole company for at least three to five years to develop standardized work. Both statistical quality control and process analysis should be used and upstream control for suppliers should be developed and effectively applied;

- The company should define a long-term quality plan and carry it out systematically
- The walls between departments or functions should be broken down, and cross-functional management should be applied; and
- Everyone should act with confidence, believing his or her work will bear fruit.

7.6 Toyota Technology (Hybrid)

With the limited resources of Japan as discussed in Chapter 6, it seemed obvious to Toyota (and other Japanese firms) that alternatives to the ICE were needed. Also, the strength of California's environmental policies and the Kato agreement (not signed by the United States) was leading to a massive reduction of global warming gasses, more specifically CO₂. So Toyota took a strong stance and began diligently designing the Hybrid, and in 1997, launched the first hybrid, Prius.

The Prius was launched while the U.S. domestic three were still investing mostly in larger gas-guzzling SUVs and launching lawsuits to prevent California's emissions regulations to take effect. Although, unlike Honda, Toyota aggressively went after the larger SUV market; they were still heavily pursuing and redeveloping their Hybrid technology for the future. It was not until 10 years later when the large SUV market crashed because of \$3-\$4/gallon gasoline prices. At that time the domestic three began seriously pursuing hybrid technology. Toyota had already launched its second generation hybrid with the third not far behind. Figure 28 shows the growth of the hybrid in sales.

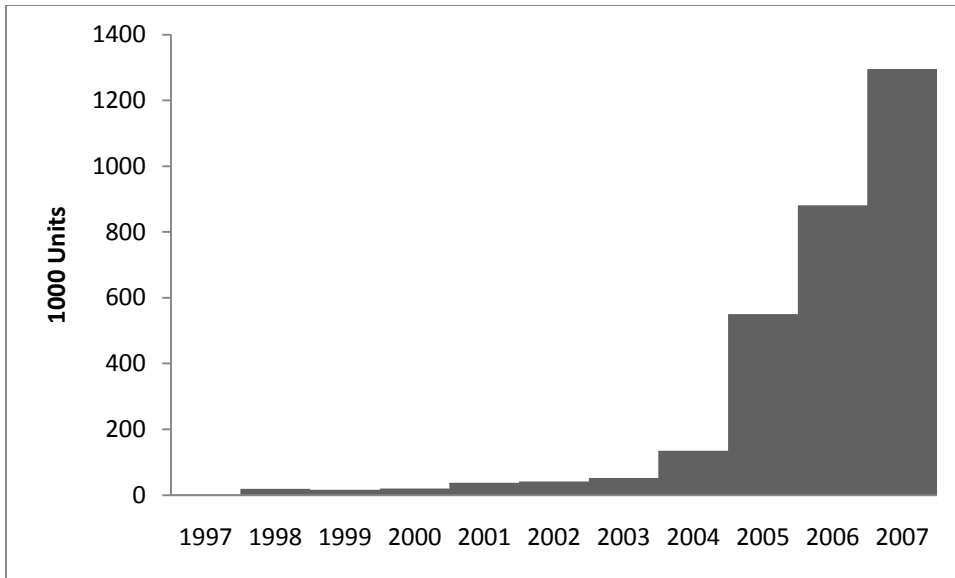


Figure 28 Toyota Hybrid Sales (source: Toyota Annual Reports, 1997-2007)

7.7 13 Year Statistics

The following are some statistics of Toyota over the previous 13 years created from Toyota annual reports. Figure 29 represents gross sales while Figure 30 shows the percent of net income versus gross sales:

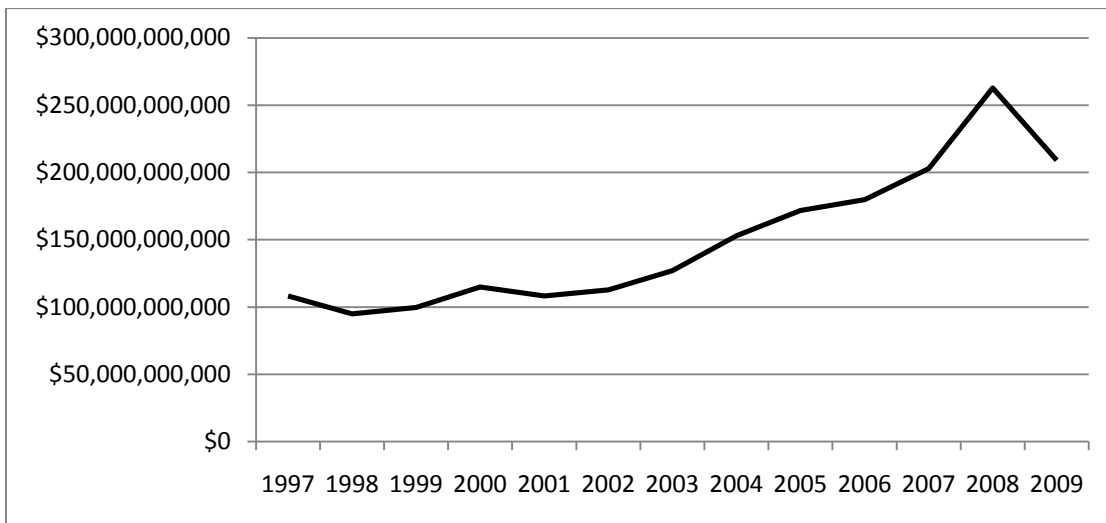


Figure 29 Toyota Gross Sales (U.S. Dollars) (source: Toyota Annual Reports, 1997-2008)

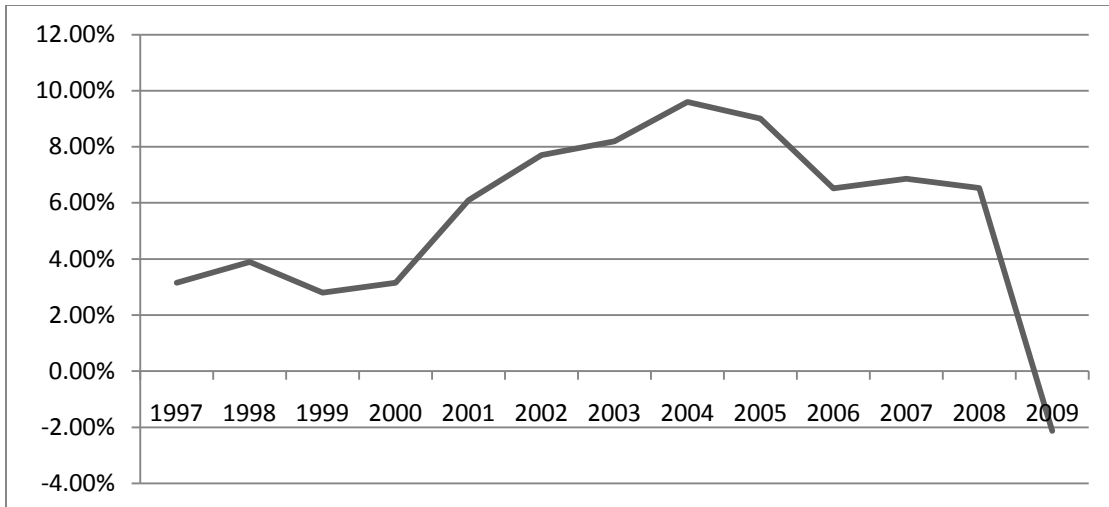


Figure 30 Toyota Percent Net Income (source: Toyota Annual Reports, 1997-2009)

As can be seen from these two charts, Toyota Motor Company has been performing fairly well until the recent decline in the automotive industry, which led to both Chrysler and General Motors losing billions of dollars and entering into bankruptcy protection.

Figures 31 and 32 represent the dollars investing into R&D and advertising.

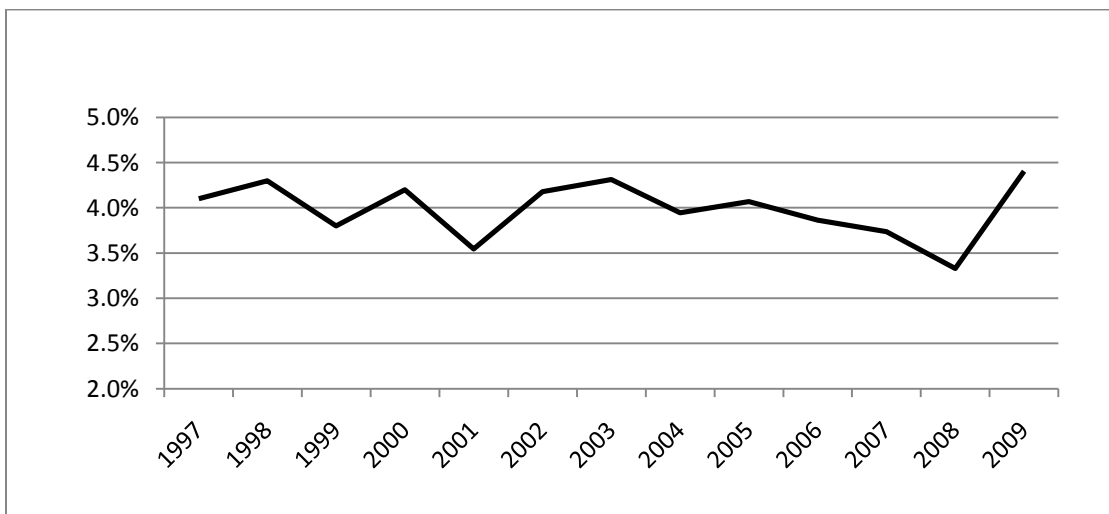


Figure 31 Toyota R&D vs Net Sales (source: Toyota Annual Reports, 1997-2009)

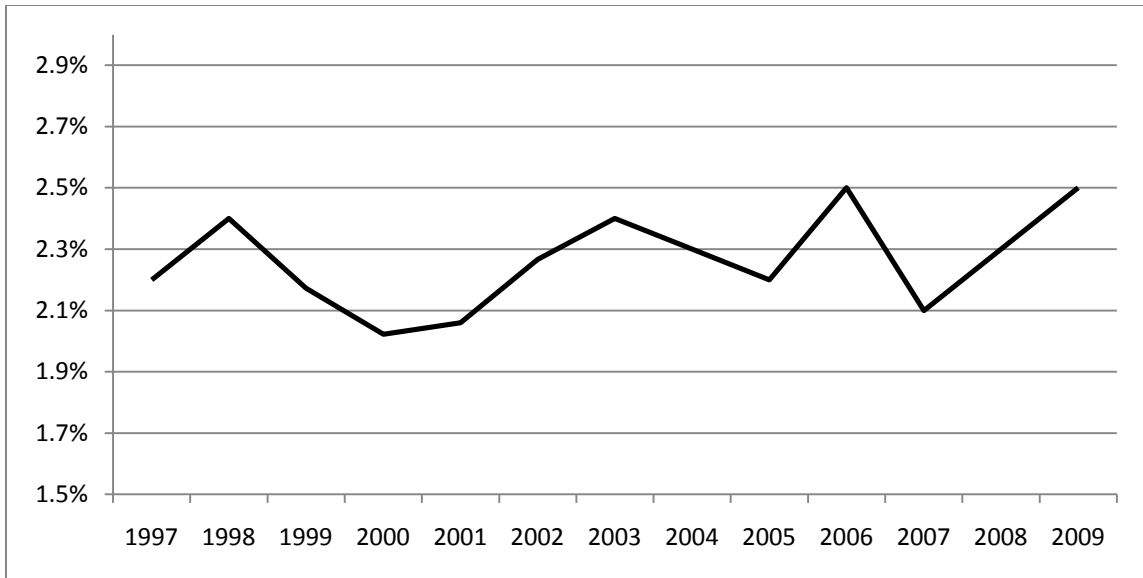


Figure 32 Toyota Advertising against Gross Sales (source: Toyota Annual Reports, 1997-2009)

The final three charts represents the number of vehicles Toyota sold in North America in those periods, the market share that they commanded, and the associated dealer warranty costs.

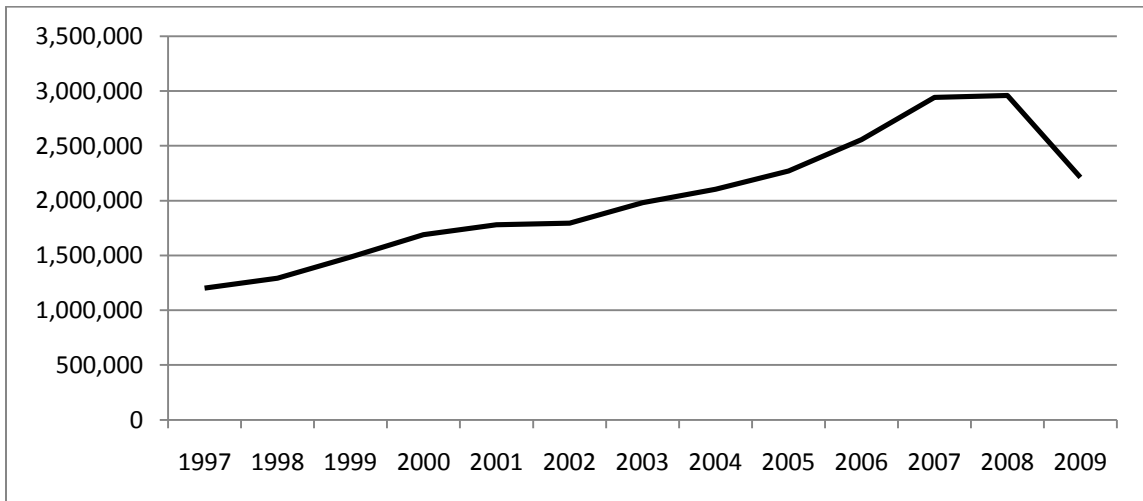


Figure 33 Toyota North America Unit Sales (source: Toyota Annual Reports, 1997-2009)

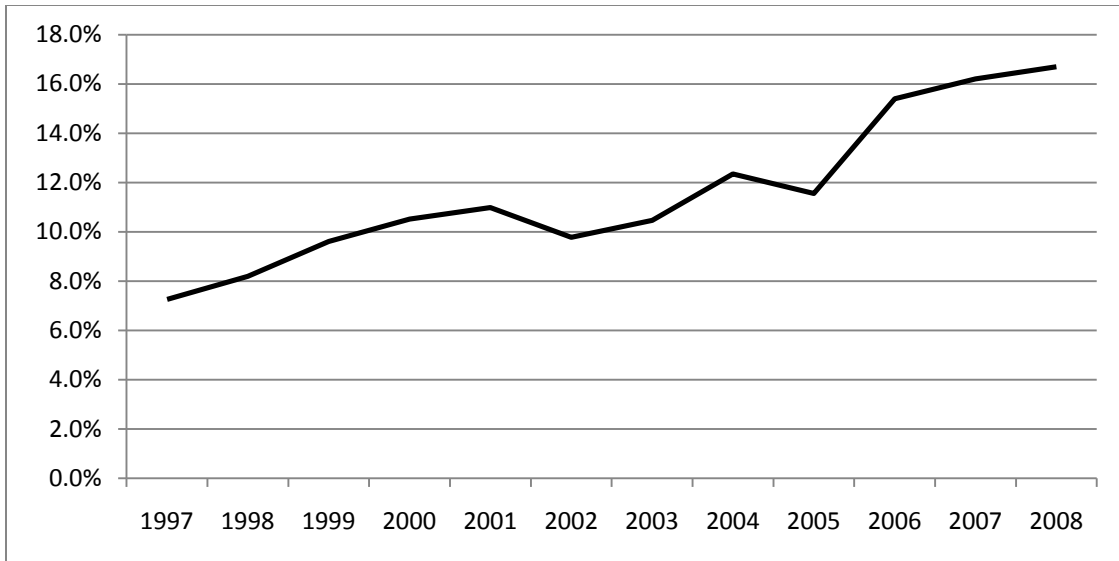


Figure 34 Toyota North America Market Share (source: Toyota Annual Reports, 1997-2009)

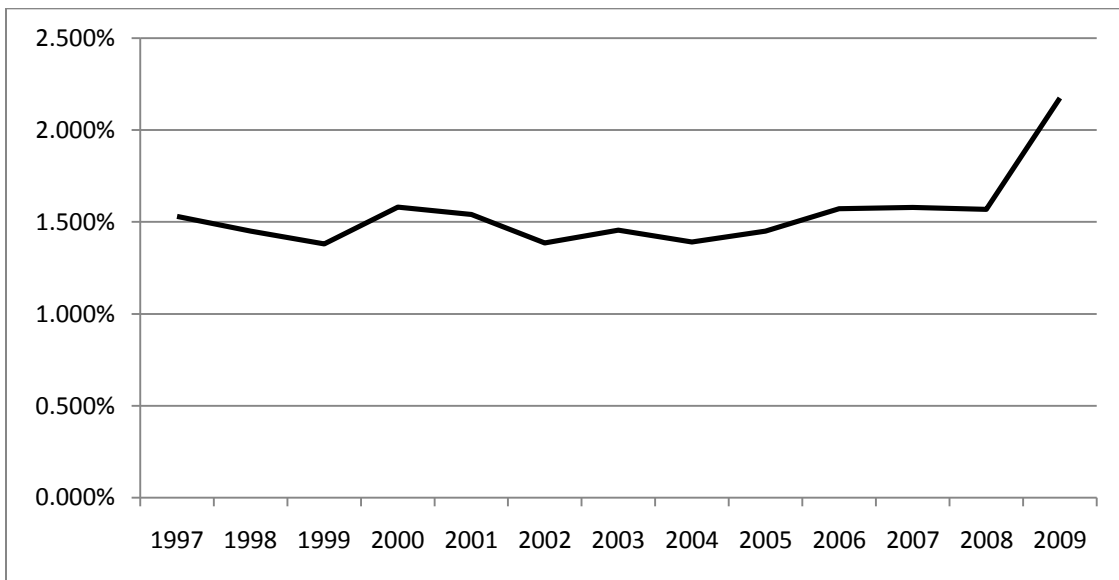


Figure 35 Toyota Warranty vs Net Sales (source: Toyota Annual Reports, 1997-2009)

CHAPTER 8

EARLY HONDA HISTORY

8.1 Introduction

Honda Motor Company is different from the other Japanese automotive companies in that they were not established prior to World War II. They did not have the support of the Japanese government as did Toyota, nor were they present after the World War II to receive support from the United States Government as were Toyota and Nissan. Honda got its start from the development of engine technology, starting with research and development at its core. From this core they move into motorcycles and then automobiles (Sato, 2006).

8.2 Honda – It's Motorcycle and Roots

In October 1946, Soichiro Honda established the Honda Technical Research Institution in Mamamatsu, Japan, to develop and produce small 2-cycle motorbike engines. From the beginning, Honda was founded on research and development, taking this methodology to the racing environment. This required relentless energy spent developing and implementing new technologies to remain competitive.

Two years later, Honda Motor Company, Ltd. was born. Honda had designed his first motorbike in the early post war years when gasoline was very scarce and the need for a low fuel-consuming vehicle was great. The first motorbike went into production in 1949 and was available in 1950, the “Dream D” was a two-stroke, 98cc motor bike, perfectly suited for the landscape of Japan and for the price tag for the typical Japanese consumer. It had the fuel efficiently for the hard to get resource, gasoline. After Honda’s first motorbike was introduced in Japan, Honda introduced a 4-stroke engine, the “Dream E”, which had double the horse power of a conventional 4-stroke engine (James, 2005). By 1954, Honda, due to his design advantages, captured 15 percent of the Japanese market. Honda’s innovations were applied at first to the racing industry and by end of the 1950s had won all of the most prestigious motorcycle racing prizes in the world.

In 1958, the racing innovations were being applied to commercial sales and Honda released the Honda 50cc Super Club. The Super Club featured an automatic clutch, three-speed transmission, automatic starter, and the look of a bicycle. Its inexpensive price was due mostly to its high-horse power, yet lightweight 50cc engine. By the end of 1959, Honda had taking first place in market share with sales of \$55 million.

With the success of the Super Club and dominating the Japanese market, Honda decided to expand and begin exporting into the United States. Honda conducted market research and surveys in Europe and Southeast Asia from late 1956 through early 1957. They found that in Southeast Asia motorcycles and mopeds imported from Europe were making their first appearance in cities and towns, signaling the emergence of a popular new means of economical and inexpensive transportation that would soon rival bicycles.

Honda concluded that as the economies improved motorcycles would over-take bicycles and that this market was very promising. Honda then conducted the same study in the United States (James 2005).

In the United States Honda found that cars were an absolute necessity amid vast expanses of rural territory, which had for years lacked a viable commuter network of railroads. Motorcycles were seen merely as adjuncts to cars, like toys one could use for leisure or, if one was daring, racing. In the end, although Honda found that Southeast Asia market would be easier to begin with, it was not the decision. America is the stronghold of capitalism, and the center of the world's economy. To succeed in the United States is to succeed worldwide. On the other hand, if product does not succeed and become a hit in the United States market, it may never be a hit internationally.

Kawashima was named General Manager tasked with starting Honda American Motors (HAM). He began in 1958 with tours to decide where the home office would be located. Los Angeles, in November 1958, with its mild climate and little rainfall was thought to be the perfect location for the start of selling motorcycles and was chosen. Los Angeles was also convenient and a perfect shipping port for products from Japan. Now Kawashima had to approach the Ministry of Trade and Industry and the Ministry of Finance to get permission to take \$1 million out of Japan and into the United States. Japan's government regulates how much currency is permitted to be taken out of the country. After initial rejections, the Ministry finally settled on \$250,000 to start HAM.

Contrary to what most foreign companies were doing with distributors, Honda established a U.S. subsidiary, American Honda Motor Company. Honda's strategy was to create a market of customers who had never given thought to owning a motorcycle.

This was a taunting task since the American market was only roughly 50,000 to 60,000 units per year, which is only about one-tenth the size of Japan's motorcycle industry. Honda started its enterprise in America producing the smallest, most lightweight motorcycles available (a three-speed transmission, automatic clutch, five horsepower, American motorcycles had two and half horsepower, electric starter, and a step through frame for female riders). Honda sold this motorcycle for \$250 while the American manufacturers were selling their units for \$1,000-\$1,500 (James, 2005).

In 1963, HAM sold more than 40,000 motorcycles annually and had built the number of dealers that sold Honda to nearly 750, more than any other competitor. Honda wanting to grow more business put a marketing and advertising blitz on in 1964, even sponsoring the American Academy Awards by buying a 90 second commercial slot for \$300,000. By 1964, one out of every two motorcycles sold in the United States was a Honda. Within six years Honda's annual sales volume exceeded 500,000 units.

Due to the success of the motorcycle, and of the strategy of establishing a network of dealerships that Honda had built and expanded, Honda decided on a strategy to diversify into building cars and trucks. In addition, utilizing their huge advantage in small engine technology, they also decided to manufacture portable generators, power tillers, lawn mowers, pumps and outboard motors (Honda Annual Reports, 1994-2009).

Within 20 years Honda had made its 10 millionth unit and by 2006 it had sold roughly 50,000,000 Supercubs (Honda annual reports, 1994-2009). Now, the motorcycle arm of Honda equates to 14.1 percent of Honda's total business. Figure 36 represents Honda's worldwide motorcycle growth over the last 58 years.

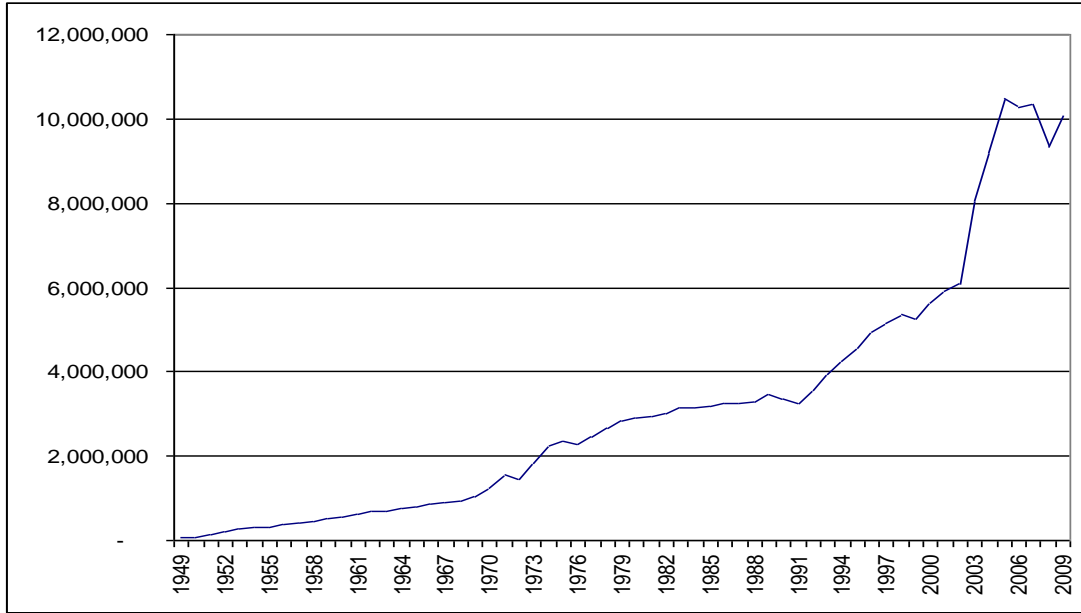


Figure 36 – Honda Motorcycle Production (source: created from Annual reports, 1994-2009; James, 2005)

8.3 Honda – Entering the Automotive Industry

Honda’s first attempts at a car were not very successful. Honda began the idea of entering in the automotive industry in 1963 with the development of its first sports car, the S500. Three years later, Honda produced the S800, a very small motorcycle type vehicle with four wheels. This was the first automobile that Honda began exporting, mostly to Southeastern Asia, where roads are narrow and better suited for bikes. In 1967, Honda released the N-series mini-car that topped the Japanese market in 1968 (Honda History, World.Honda.Com, retrieved 7/15/2009).

In 1969 with the success in the Japanese market, Honda launched the N600 model in Hawaii and a few months later in 1970, began launching the car in the mainland utilizing their current motorcycle dealership networks. Nevertheless, the basic

foundation of America's car market was well established with customers believing strongly that cars should be purchased exclusively from automobile dealers. Honda began building its own network for automobile sales in 1973, when a new model, the Civic, went on sale.

Up to the point of 1973, the American market had become dominated by very large vehicles, so the appearance of a new concept in car design, a small fuel efficient and affordable model, was seen as a niche market and an act of defiance. Yet amid this highly unfavorable situation, HAM began its nationwide search for sales outlets. The company's sale staff consisting of a dozen people each took a territory covering several states. With these efforts, owners of dealerships of cars began including the Civic as part of their product lineups. The affordable Civic, however, was nearly always positioned at the bottom of the product lists and was generally assigned to a lonely corner of their outdoor display.

Two main items created an avenue or perfect opportunity for Honda. In 1970 the United States passed the job of environmental administration to the newly created Environmental Protection Agency (EPA). It was then stipulated that vehicles produced for sales in 1975 and thereafter needed to emit one-tenth the level of carbon-dioxide and hydrocarbons. Vehicles for sale in 1976 and thereafter also had to emit one-tenth the level of nitro-oxides. Coupled with the new emissions standards for mid-1973 to the following year, the United States auto industry found itself struggling under the effects of the first oil embargo (see Chapter 12). This promoted many American consumers to change their interpretation of what value was. It was no longer was good to own a large,

luxurious “gas guzzler” but to own a more practical, lower cost, sensible size, outstanding fuel efficient vehicle.

Honda was currently already researching the possibilities of producing a low emissions engine so this lined up perfectly with their goals. With their racing history of close tolerance machining and their development and use of electronics in the control of their engines, Honda designed and produced a special cylinder head with a precombustion chamber that allowed the spark to spread slowly resulting in a more complete burn of the lean air and fuel mixture. While the other automotive producers were addressing the new environmental regulations with the newly designed catalytic convertor and sacrificing performance, Honda produced an engine that met standard with no other necessary performance destroying equipment (Carson & Vaitheeswaran, 2007).

The Honda Civic was introduced as an 86.6-inch wheel base, 139.8-inch overall length, a small transversely mounted 1,169cc – 50 horsepower engine that obtained 40 mile per gallon on the highway. The engine represented a leap in innovation considering its small size in terms of displacement, producing 0.71 horsepower per cubic inch in a total vehicle weight of 1,500 pounds.

In 1974, the Civic placed first in a fuel economy test conducted by the Environmental Protection Agency (EPA). That same year, HAM began selling Civics equipped with the unique electronic controlled vortex combustion chamber engine (CVCC) which had an innovative head design that promoted cleaner, more efficient combustion. Since CVVC unique engine design eliminated a need for a catalytic converter for unleaded fuel to meet emissions standards they did not have to go through the costly and performance degradation change to the catalytic converter and the

requirement to use only unleaded fuel. Due to California's stricter pollution emissions standards of the time, only the Civic CVCC was available in the state. The Civic became America's leader in both fuel economy and low emissions and has not relinquished that reign, these qualities coupled with fine performance and reliability, helped the Civic win a broad base of support and ultimately a rise in sales and market share.

Honda then took America by storm when it introduced the Accord in 1976. Motor Trend named the Accord "Import of the Year" in 1976. In its first year it sold 18,643 units. The Accord was originally a 1,993 pound vehicle with a 1600 cc in-line four-cylinder engine producing 68 horsepower with 85-ft-lb of torque. The Accord at launch was 162.8 inches in length and had a 93.7 inch wheel base. Within three years of its launch the number of units sold was at 370,000, (James, 2005).

CHAPTER 9

SYSTEM (PRODUCT) LIFE CYCLE ENGINEERING & MANAGEMENT

9.1 Introduction

This chapter will define a system, discuss system engineering and the product system life cycle engineering and management and review the concept that reliability of a product or a service is its dependability or how well it fares within the field that it was designed for; how the product/service stands up when performing its operation over a predetermined number of use cycles or time under given performance definition/limits and manufactured warranty limits. In order to assure and extend performance, reliability engineering carries out design and engineering robustness studies and tests for the product/service developer in order to provide probabilities that the product/service will meet the developer and customer promise performance (levels).

This chapter will also introduce a new updated six-phase new product/process development process, and why reliability of a product/service's performance has to be design/engineered in from the beginning (and amplified in Chapter 10), followed by a Total Quality Systems (Assurance) Engineering life cycle management process (talked about in more detail in Chapter 11) must be put into place from the very conceptual start,

to be sure that nearly all (ideally all) the product/service specified performance levels (range) is maintained/preserved throughout the product/service useful(or expected/warranted) life.

9.2 Current System Environment

Keys (1990, 2009) and Blanchard (1998, 2004) argue that over the last few decades, dramatic increases in product/technology sophistication (multiple integrated technologies including mechatronics and software engineering) with dramatic increases in product/system features/functions have occurred to deliver ever more enhanced, user friendly performance. This increase of technology and expectations have created a product system of components, modules has evolved into a multi-technology system of subsystems. These current complexity trends demonstrate that the complexity of systems is continually increasing and many of those systems in use currently are not meeting the robustness needs or expectations of consumers from an actual product user life performance, reliability and total cost standpoint. Simultaneously while these new technologies are being developed, integrated and implemented, current systems user lives are being extended because of the increasing purchase price of the product. The development process time length of the new systems is being challenge constantly while resources and skill bases are being challenged and exhausted and additional external regulations are being applied. In the automotive product system, the evolution of the mechanical systems have evolved into electrical, chemical and hybrids of all, which has created an increase in the system complexity adding to the requirements to those engineers who must design and provide for the reliability. As stated in previous chapters,

these systems have seen an increase in electrical components to manage engine combustions, timing, fuel injections, as well as environmental controls. Coupled with this, there is a growing expansion of global competition (Korea, China and India). Figure 37 represents this view of the current environment.

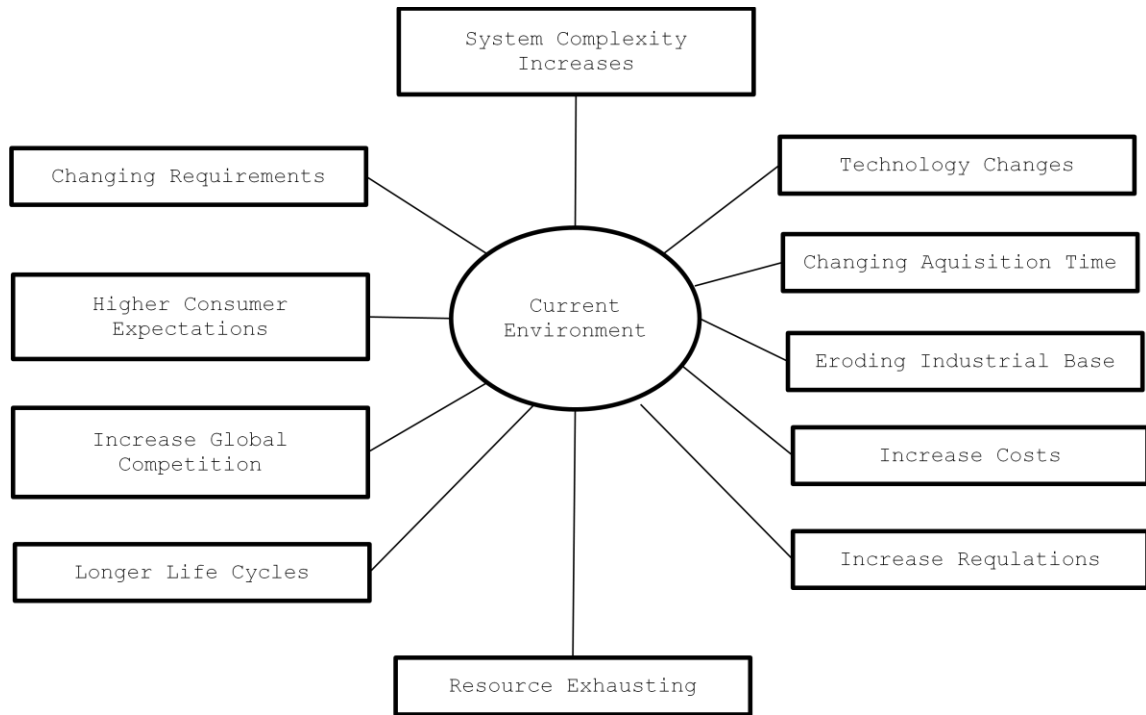


Figure 37 System Current Environment (source: Blanchard, 2004)

As can be seen from Figure 37, there are many factors that are affecting the development of today's product systems. When examining past practices versus current practices, one can only extrapolate that this trend in complexity increase will only continue into the future without major product system elements redesign and integration. Therefore, to better understand these effects, we must clearly identify what is meant by a system and transition into what is meant by system engineering/development.

9.3 System Definition

Blanchard (1998), defines a system as a set of interrelated components working together to achieve a common objective. This being a simplistic definition, he further explains four characteristics of a system:

- A system constitutes a complex combination of resources (materials, equipment, software, money, etc),
- A system is contained within some type of hierarchy structure. For example, a bus is part of an overall transportation system,
- A system may be broken down into subsystems and related components. For example, breaking the automobile down into the frame, power train, suspension, engine, etc, and
- A system must have a purpose (use).

Blanchard (1998) uses Figure 38 as a way to graphically depict the input, output functions of a system, what is comprised within a system as well as the constraints being faced when creating a system and the necessary resources to create the system.

Blanchard further breaks the system down into the major system elements as depicted in Figure 39:

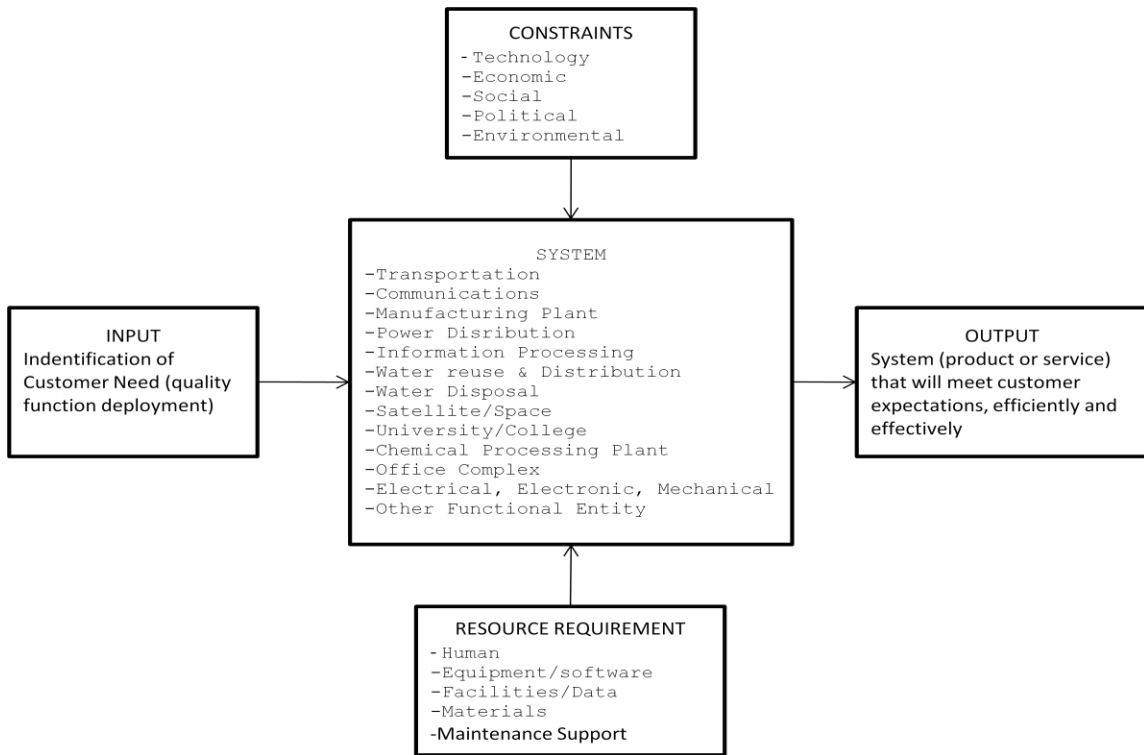


Figure 38 The System (source: Blanchard, 1998)

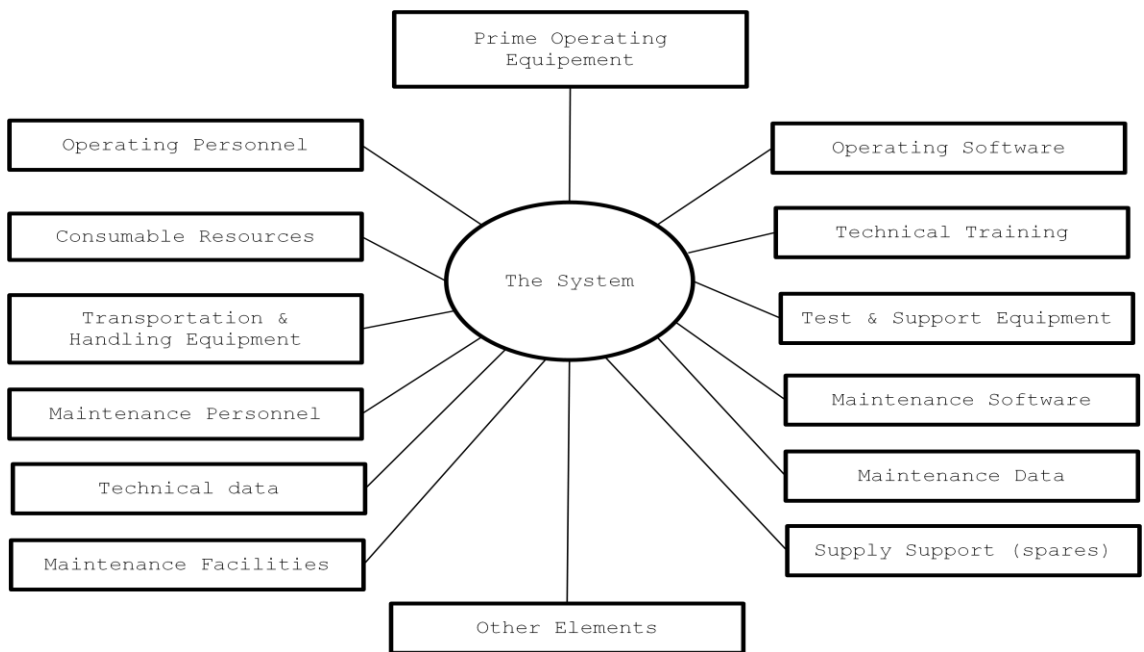


Figure 39 Major Elements of a System (source:Blanchard, 1998)

Now that the system is clearly defined, we can take a look at the entire life-cycle of the system. Figure 40 simplistically represents, pictorially the system life cycle and its feedback and control process:

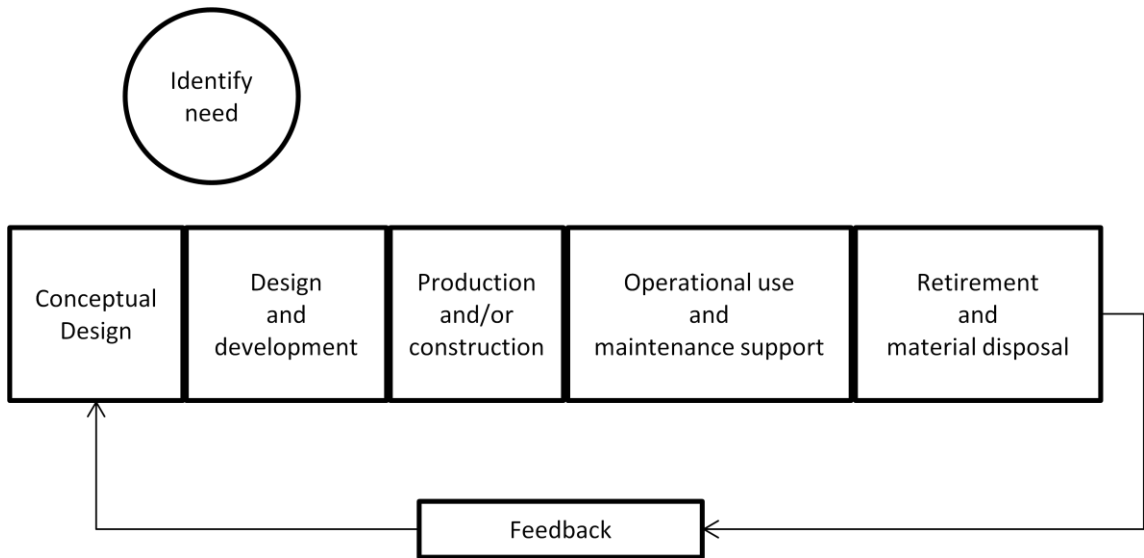


Figure 40 System Life Cycle (source: Blanchard, 1998)

As can be seen simplistically from figure 40, the system life cycle must start with a need and move from conceptual design through the entire life up to disposal. Now that the life-cycle is clearly presented lets define the management process for the implementation of this system.

9.4 System Engineering Management & Product Development

System engineering and technology management today must manage and integrate several different technologies in order to bring discipline to the development, deployment and support of various enabling technologies at work in the global competitive economy. This requires a system analysis, architecture creation, design engineering, interfacing, integrated planning process. Figure 41 depicts the types of

disciplines that are pulled together in order to concurrently design and engineer the process, it can be seen the number of entities that must communicate, provide feedback and be managed in order to pull the process together:

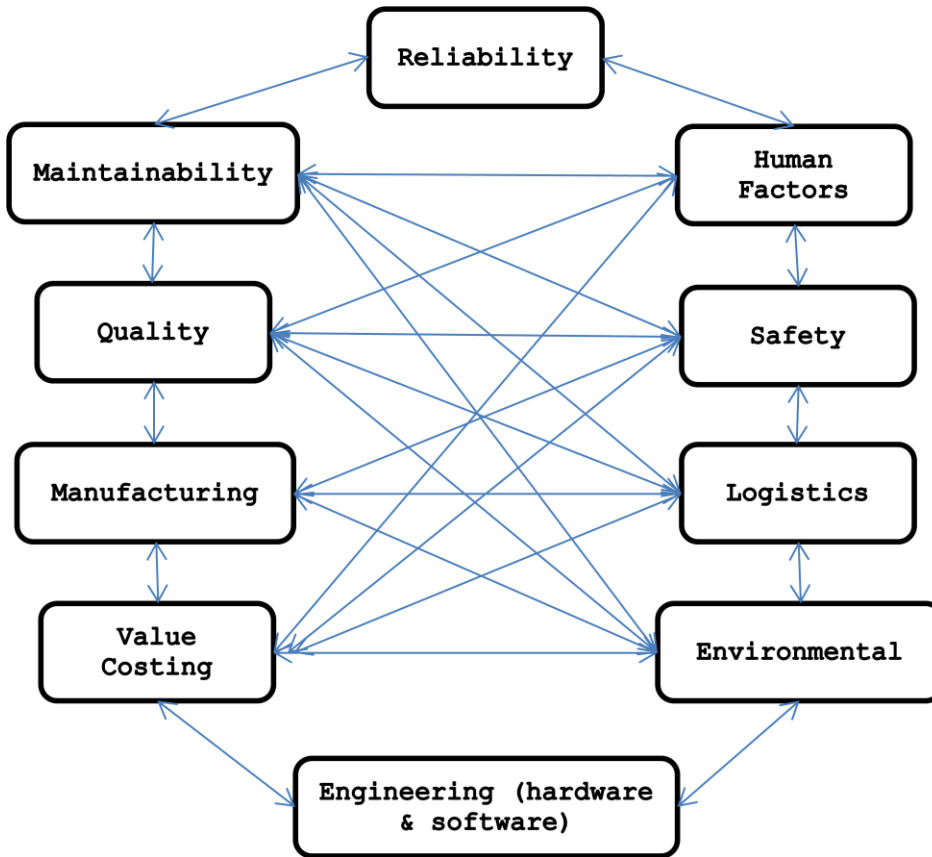


Figure 41 Engineering Discipline Feedback Loop (source: Blanchard, 1998)

System Engineering requires a hierarchal structured process, as depicted in Figure 42, to define, build and delivery the complex systems in today’s global competitive environment. Figure 3 depicts such a hierarchal product system architecture structure for the Model T as a simple automobile example.

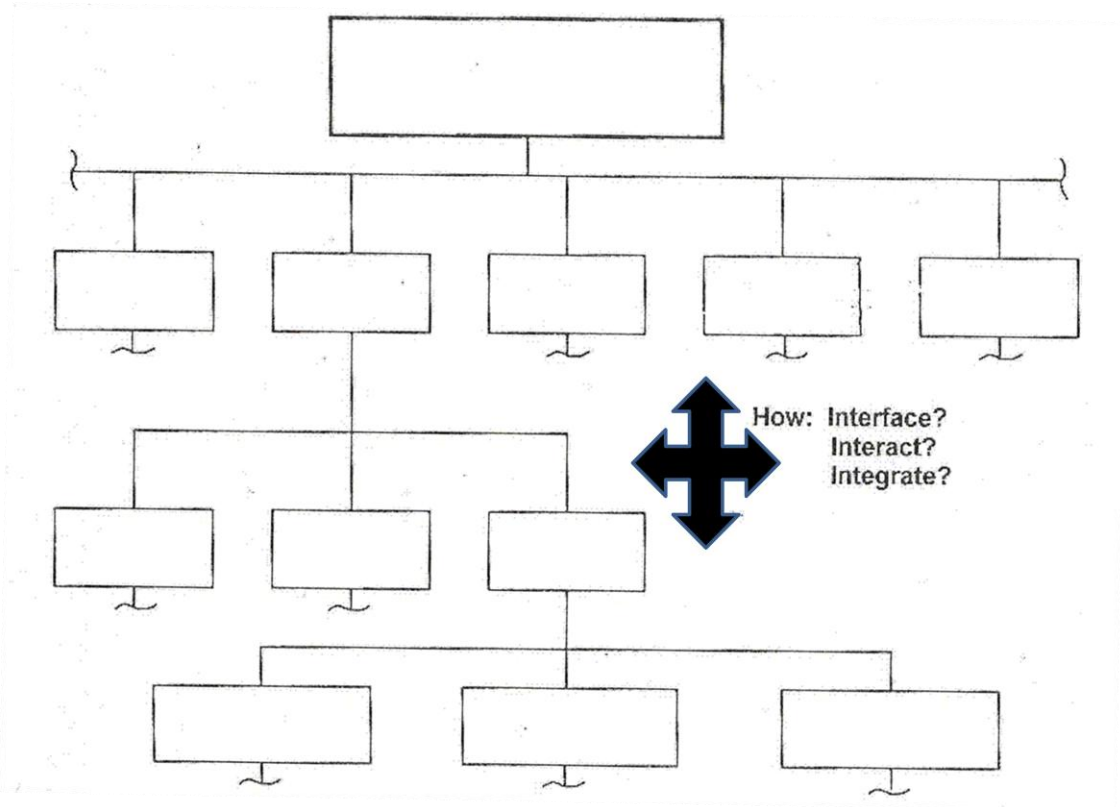


Figure 42 Hierarchy Architecture Structure of Product/Service Systems Components (source: Keys, 2009)

For the modern automobile this is extremely important because as previously stated, it encompasses over 10,000 individual and ever increasing complex system and subsystem elements (parts) see Chapter 13, Figure 108 for example of modern automobile. This requires many levels of system requirements and specifications, design documents with multiple interfaces, considering the interactions between the element components and their subsequent in the integration together.

Bringing all these complex technologies base system, subsystems, and components together involves managing the many different elements, as needed through the complex creation and development process management through the organization's different various skill bases positions as required or needed. That is the new product

system development and program management process. Figure 43 depicts this type of skill set within an organization.

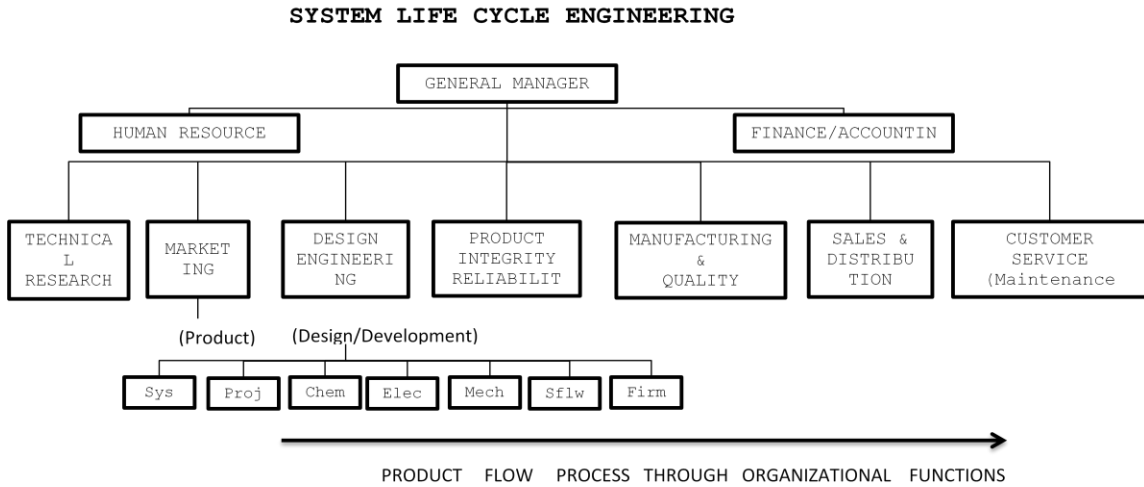


Figure 43 The mapping of the Systems Engineering Process into the Technical Organization, Technology (source: Keys, 2009)

A National Society of Professional Engineers (NSPE) committee in 1990 defined five-phases of systems engineering involvement in the new product development process (NSPE, 1990). The increasing complexity of process and products, with customer service importance, and reliability/warranty relationship has made design for customer service maintainability more important, so we have added this as a new additional sixth phase as depicted in Figure 44.

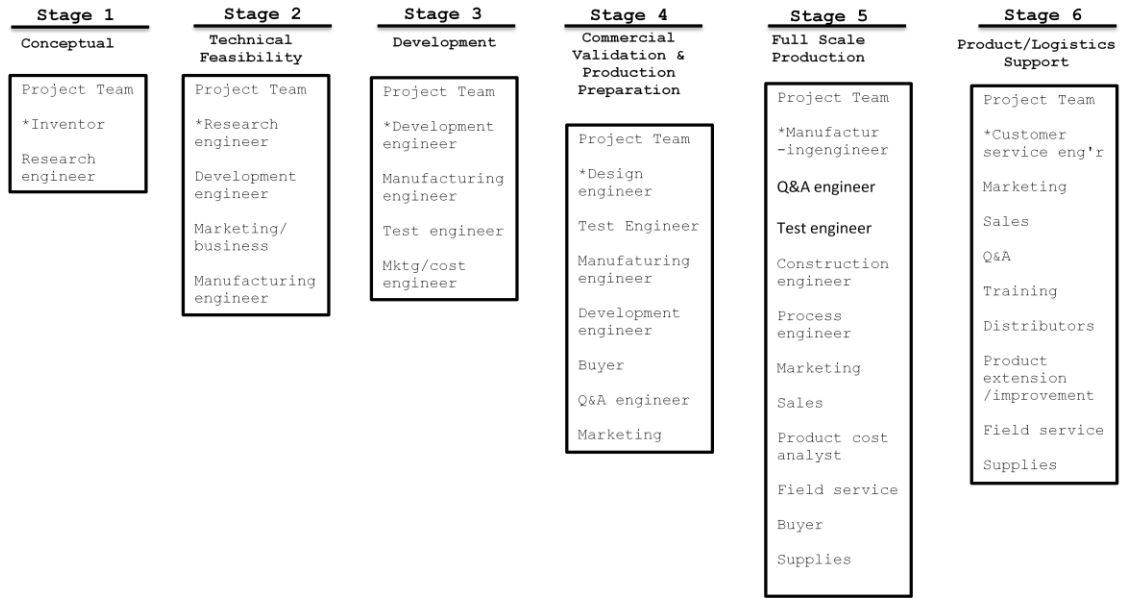


Figure 44 Six Phases of Engineering Involvement in Product Development (source: adapted from NSPE 5 stages, 1990)

This involves a complex program management process with system design coming from a process series with program review meetings, feedbacks, sequences and phases, as depicted in Figure 45. This management control feedback process scheme is presented in Figure 46.

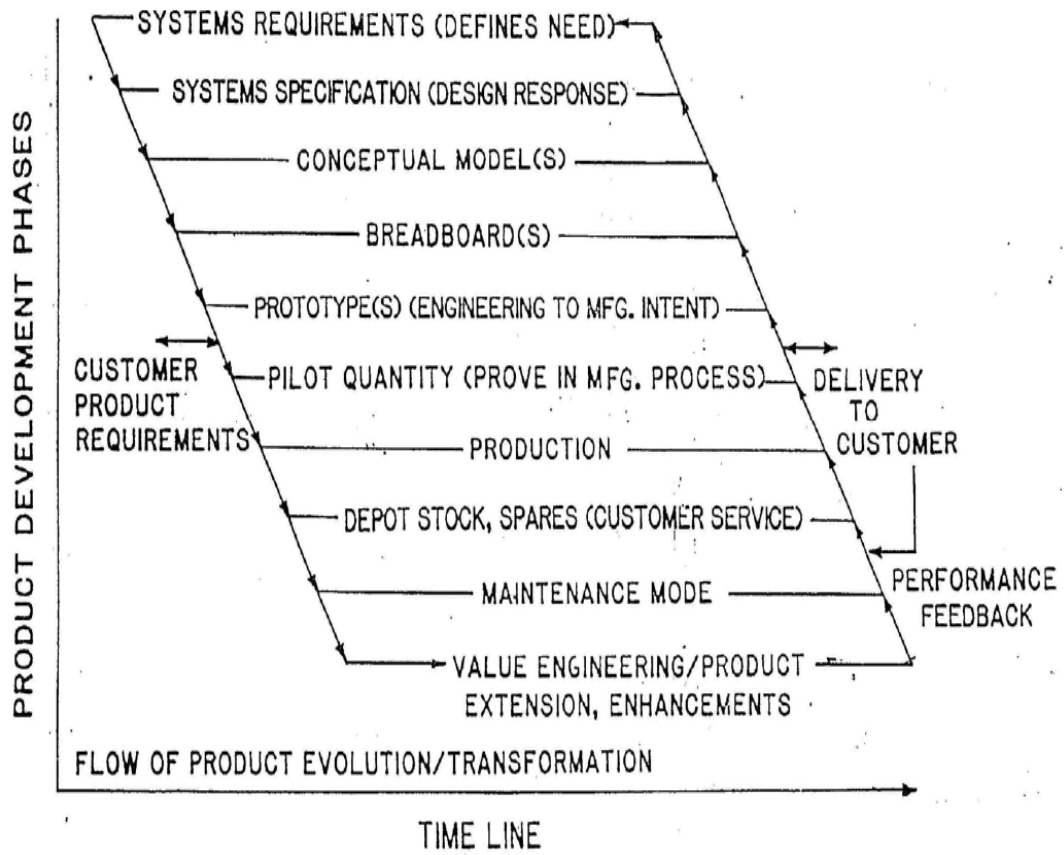


Figure 45 Scheme of Systems Planning and Implementation Process Steps (source: Keys, 1990)

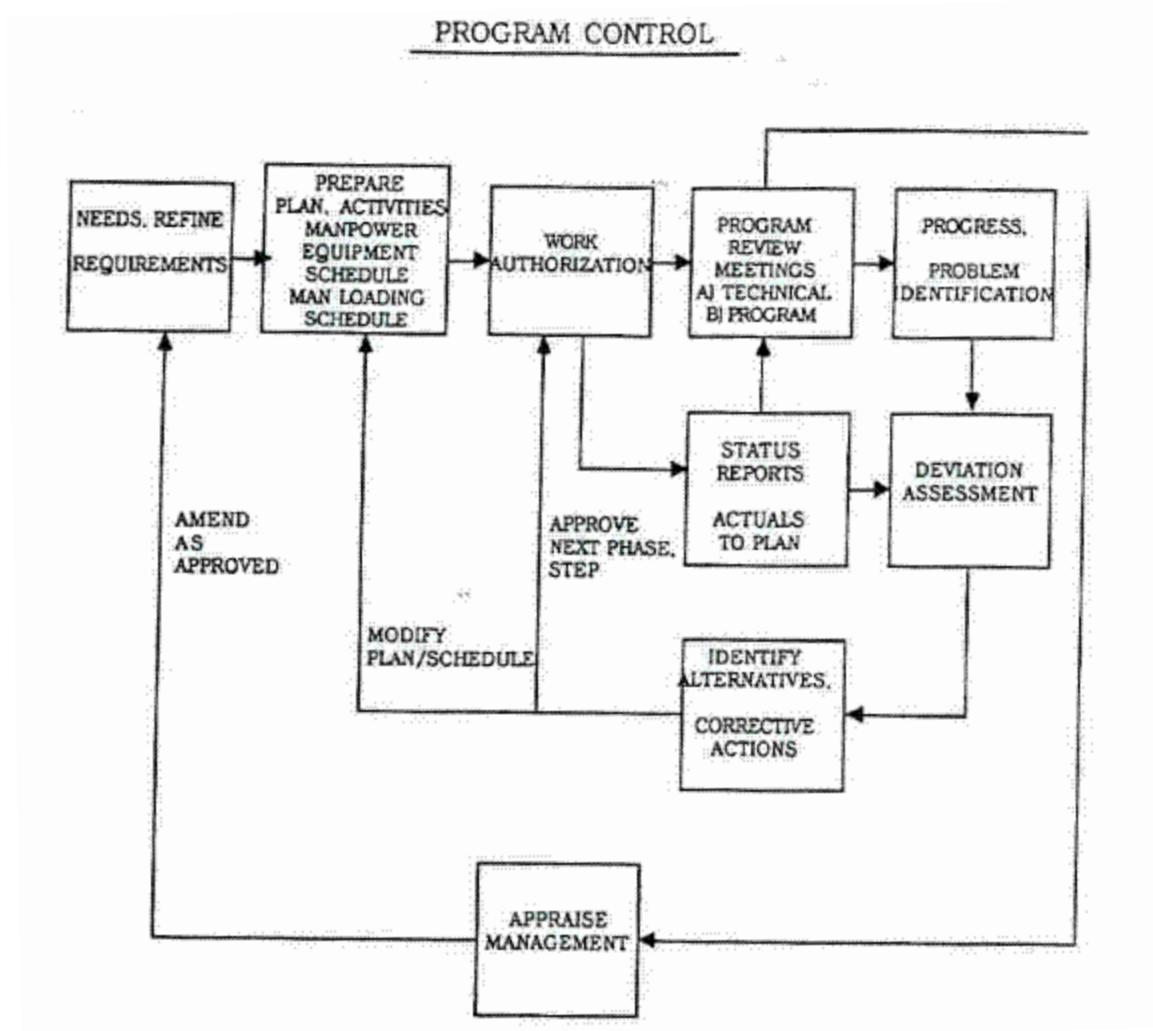


Figure 46 High-Level Project Management Control Process (source: Keys, 2009)

The management of this complex process has to be managed typically through a milestones (Gantt) chart; an example is given in Figure 47. Figure 48 then depicts the complexity of the design and development documentation elements process required to document this entire process.

Project Name

Company Name

Project Lead: John Doe

Today's Date: 3/5/2007 (vertical red line)

Viewing Weeks: 1/1/07 - 11/26/07

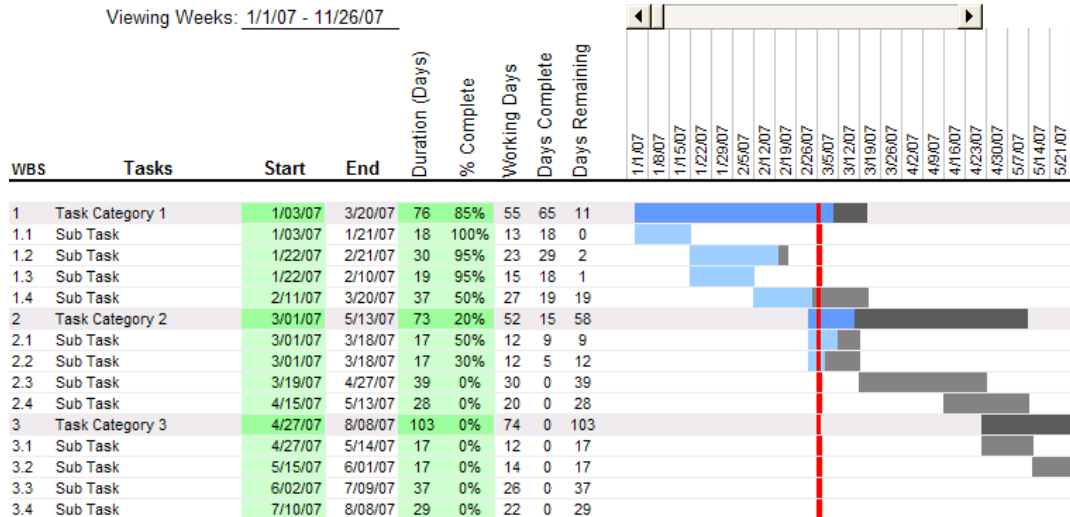


Figure 47 Generic Milestone (Gantt) Chart (source: created by author)

PROGRAM PLANNING

- Work Breakdown Structures -Equipment, Functional (by code/name)
- Functions -Responsibilities, Activities (by department name, code)
- Manpower -(skills), equipment, materials, supplies (by department name, code)
- Deliverables -drawings, prototypes, test results, documents, fixtures
- Costs -manpower (labor hours/dollars), equipment, materials, deliverables, etc.
- Schedule -(GANTT Chart, PERT Network) Time-Phased Activities/Priorities including Milestones, Reviews
- Manpower/Skills/Costs Distributed to Schedule
- Configuration Management -product/system modification, change management system process, standards
- Key Program Reviews -Decision points, criteria, purpose, how to be measured, who involved/attend
- Plan Integrating All Above With Schedule

Figure 48 Typical Project Management Planning, Organizing and Controlling Activities (source: Keys, 2009)

The importance of the design development management process discipline is presented in Figure 49 which shows that some 80% of the total product life cycle, development, and product costs are typically frozen in by design and development decisions made early in the first twenty-percent of the design life-cycle effort.

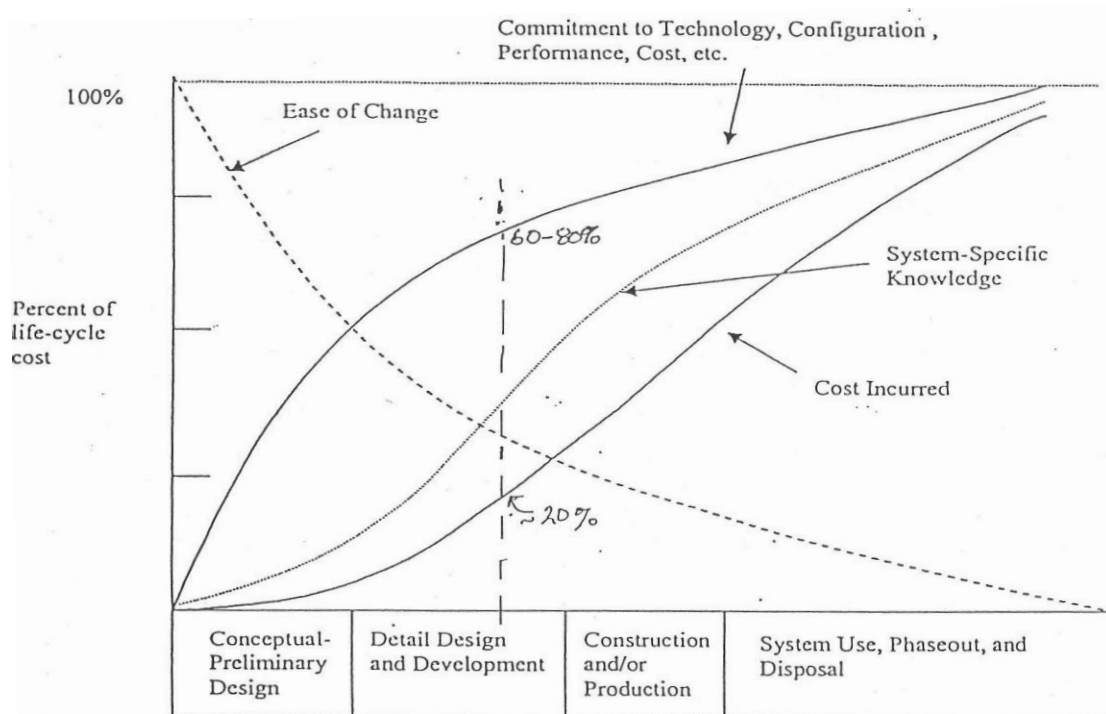


Figure 49: Increasing Phased Commitment to Technology(s), Architecture, Performance, Cost with Time, as Compared with Percentage of Life Cycle Cost Expended (source: Keys, 2009)

Figure 50 has also been updated to reflect this researcher's perspective of six-phases to modern life cycle engineering, see Figure 51.

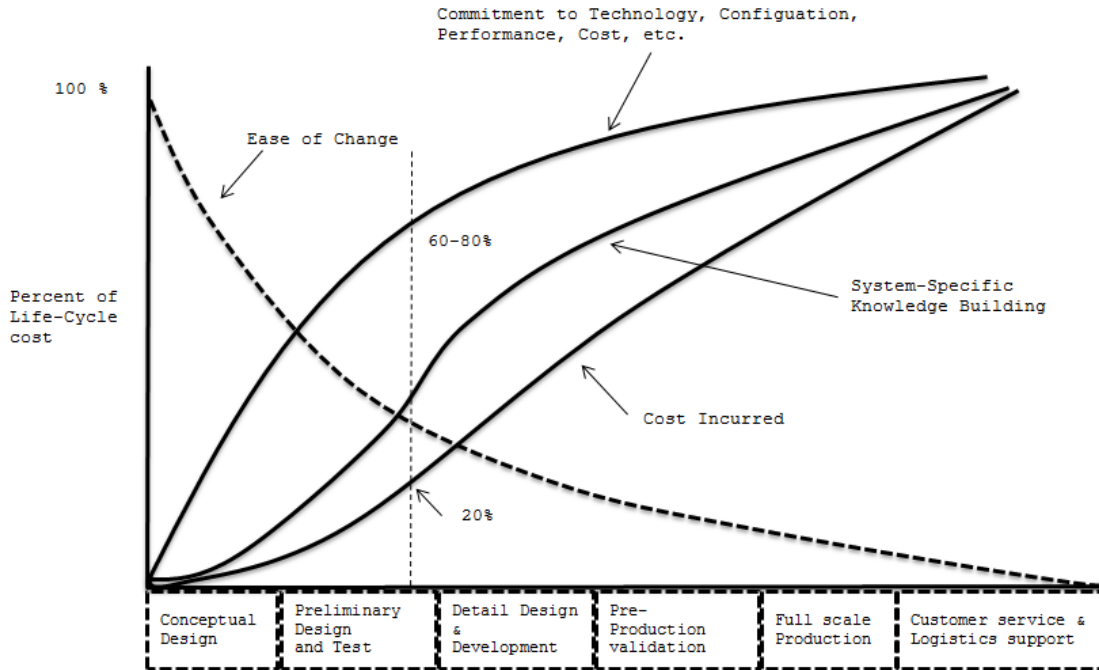


Figure 50 Added 6th Phase of System Engineering Involvement (source: Adaptation from Keys, 2009)

Figure 50 shows the typical (idea) new product development life cycle costs to the budget. In particular after delivery to the customer actual costs are often significantly higher than expected because the process is not well managed from the start which results to extra warranty and recall costs to both the manufacturer and the customer.

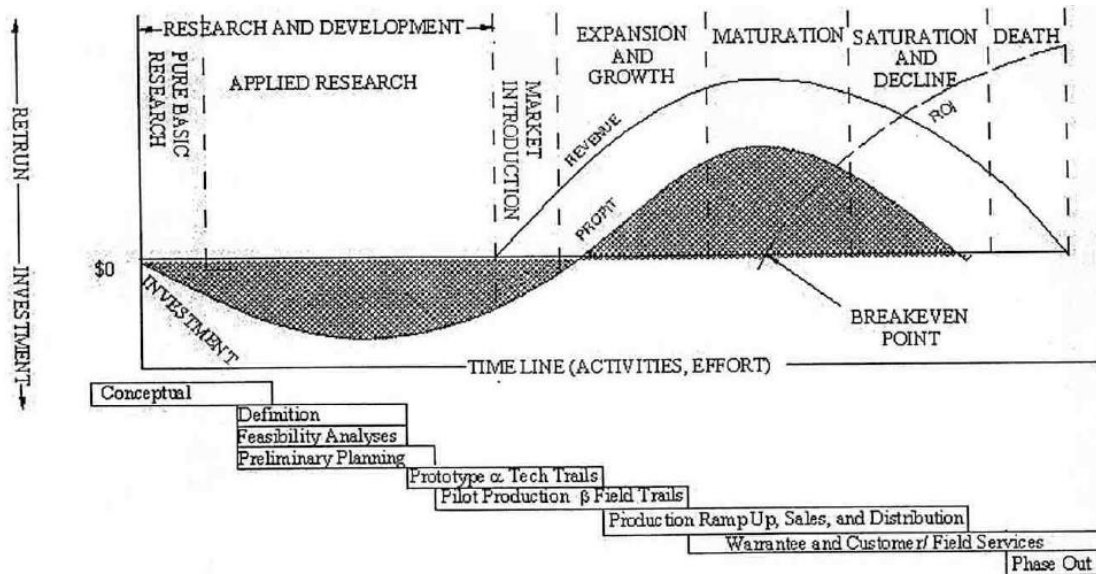


Figure 51 Typical Project/Product Development Management Budget Life Cycle (source: Keys 2009)

Problems with product life cycle management of this process often appear as extra time, efforts, costs, delays required from the original plan to get the products to market. In addition reliability problems, warranty/recall costs, extra maintenance costs to the ultimate customer can also appear over time after the final customer has made the purchase. Chapters 10 and 11 discuss in detail the importance and relevance of Reliability and Quality.

However, warranty, repair and recall activities can become a profit center to the manufacturer or service departments while adding costs to the customer over the useful product life. Figure 52 depicts the total visible and invisible costs associated with the product life cycle; while Figure 53 shows the product manufacturing costs (PMC) and the post-manufacturing product use cost (PMPC) breakdown to the customer after the purchase is made.

So as a successful company matures and its core technology based products achieve more success and grows organizationally in size and management structure (hierarchy); they can lose control of a lot of the new product development (life-cycle managerial) process. The product becomes more complex with each new product evolution phase, resulting in more complexity in the system inter-relationships, inter-dependencies, interactions of between product system and its various subsystems elements. As the organization cost centers, in time, grow to support this success, they become standalone service business profit centers (like customer service and logistics support). They then typically become more horizontally disconnected from the product success (and issues) feedback and control mechanism loops. The increased revenue and profits arising from selling more of these maintenance and repair parts and services by the company, and its dealers/distributors can become a significant source of revenues and profits; which ultimately have resulted from the new products development process deficiencies (e.g. vacuum tube-based televisions complexity leading to a lucrative, and increasingly expensive vacuum tube replacement business).

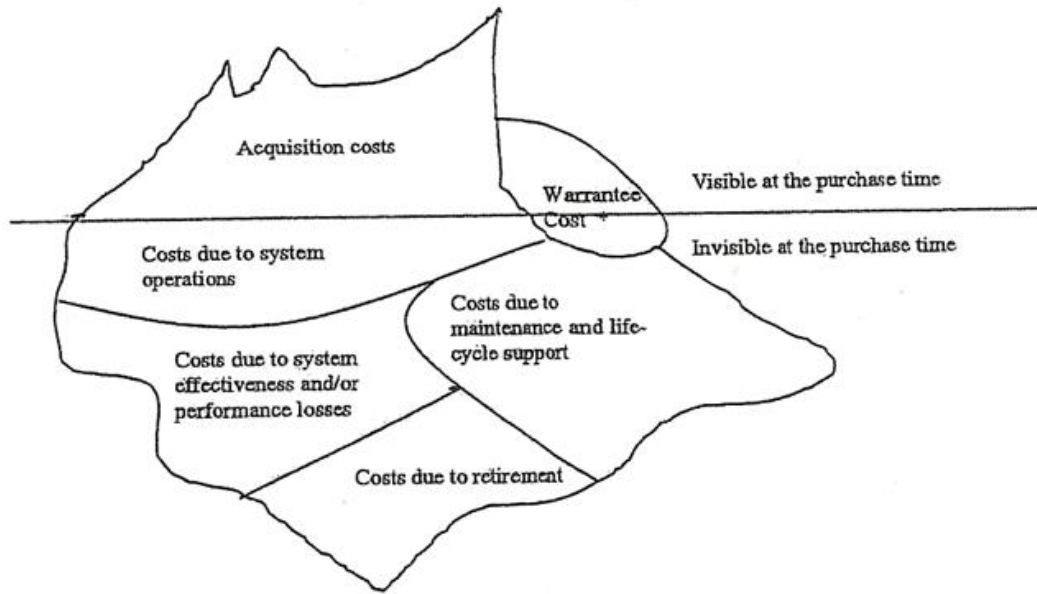


Figure 52 Total Visible Cost (source: Chen & Keys, 2003, 2009)

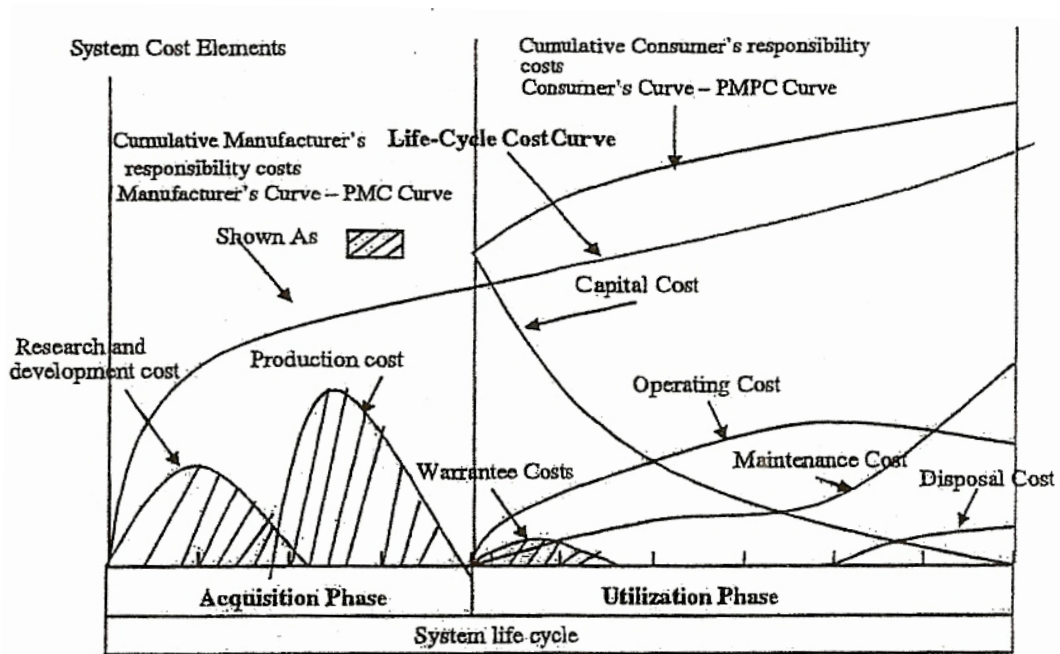


Figure 53 Depiction of PMC and PMPC Curves for Heavy Equipment (source: Chen & Keys 2003, 2009)

Also as previously discussed, this whole product life cycle management process is also affected by, and must also accommodate and incorporate continuous (periodic) technology (phases) components improvements over many years, such as depicted in Figure 54 (for the Intel micro processor family). In the previously mentioned and discussed in great detail in Chapter 19, the early American consumer electronics business success with televisions led to more evolved and developed, ever more complex power consuming vacuum tubes. This resulted from moving to larger television (CRT) black and white tube sets; to the early small color picture television tube sets and then to the larger (25-27") color television tubes and television consuls with improved sound entertainment functions. The vacuum tubes required to support these changes, along with needed better performance requirements; became much more complex, consumed more energy (requiring bigger different power supplies) resulted in higher initial product costs (and profits) and, higher replacement vacuum tube costs. The consumer electronics companies (customer service organizations), distributors and dealers did love the resulting increase revenues and profits; but the customers became more and more frustrated with these new fancier televisions sets, and the increased associated service problems and costs. This eventually created the opportunity, i.e., opened the door, for the Japanese companies to bring a new generation of more reliable solid state based television and other consumer electronics products to market in the 1970s.

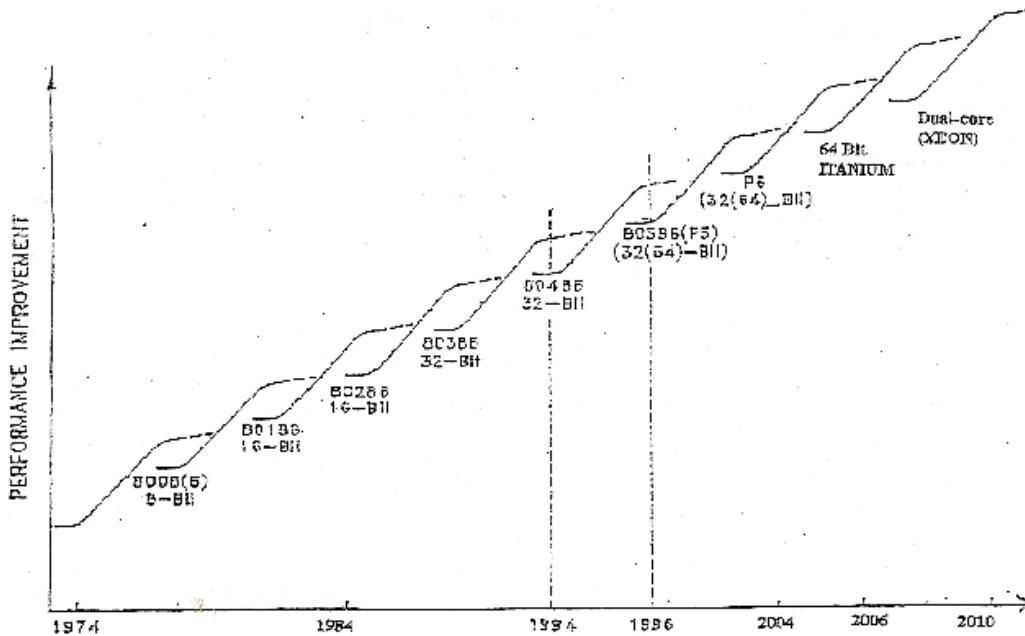


Figure 54 Succession of INTEL Microprocessor Generations (source: Keys, 2009)

As previously presented in chapter 1 and again presented as Figure 55 this basic complex product technology system of subsystems can be dramatically changed by major core technology base changes, e.g. vacuum tube to solid state devices or, analog to digital devices (some examples are consumer products like televisions, cellular phones, camcorders, VCRs and other electronic devices); some additional examples include rubber based tires to steel belted, radial tires, wet chemistry film based to digital cameras just to note a few. This generally also changes who the (new) business leaders (companies) ultimately become.

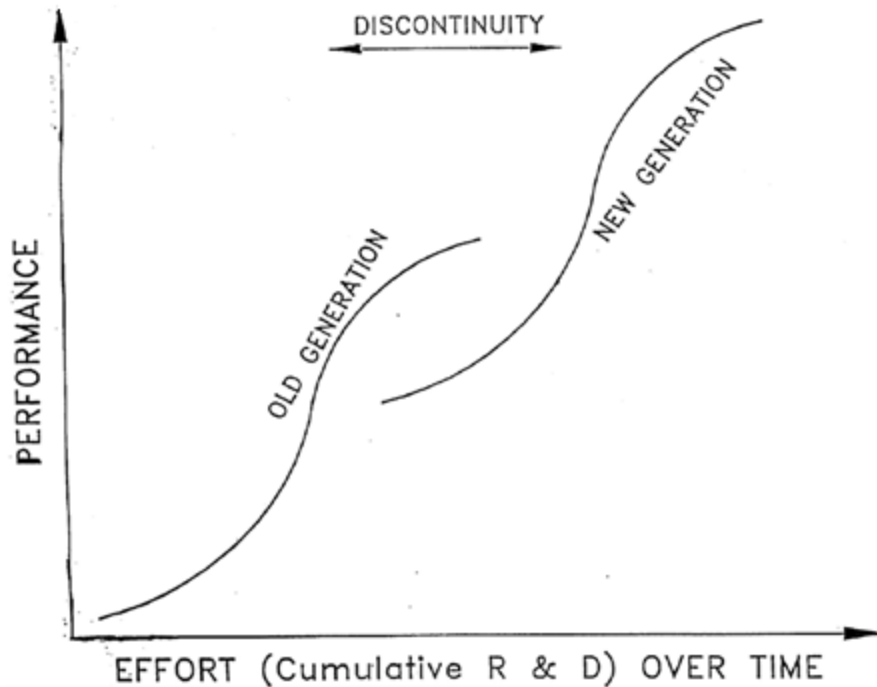


Figure 55 S-curve Technology Discontinuity (source: Keys, 2009)

One more item critical to mention of the “DFX” design process, is the necessity to also design for manufacturing and/or assembly. Though there have been many publications and models created to assist in this process, it can actually be traced back to Henry Ford and the Model “T” (see chapter 3); who began analyzing every part and every process, to eliminate unnecessary parts and combine integrated parts to eliminate unnecessary assembly steps. Keys (1990) offers a typical list of check-off items that can be utilized to discipline this process:

- Design with the minimum number of parts
- Develop a modular design (platform)
- Minimize part variations (six-sigma)
- Design Parts to be multifunctional
- Design Parts for multiuse
- Design parts for ease of fabrication

- Avoid separate fasteners
- Minimize assembly directions, design for top-down assembly
- Maximize compliance; design for ease of assembly
- Minimize handling; design for handling and presentation
- Evaluate assembly methods
- Eliminate or simplify adjustments
- Avoid Flexible components

Again, the overall concepts used here are: common and standard items should be built into the design; number of components should be minimized; materials used should be standard; assembly should be simple; and simplicity and flexibility should be built into the design.

Any given core technology based product generation system, such as vacuum tubes has a typical finite performance, economic improvement life cycle, before the law of diminishing returns begin to slow the rate of the performance improvement delivered to the customer (Betz 2002). This then requires additional research and development efforts to get the needed improvements; ergo, the beginning occurrence of the influence powering the shift in the S-curve.

This is what was previously presented from the consumer electronics products vacuum tubes. Early in the development stage of single transistors, i.e., needed for the possible future generation color televisions, there was a transitional period in which hybrid modules (composed of multiple single solid state devices) that were designed and developed to help bridge this transition.

Several problems got in the way of this “transition phase” thus preventing a smooth transition. One of these problems was that the rate of improvement in creating the desired increase in performance needed a more complex answer (solid state) for the television; it needed much more complex electronics. These new functional requirements

outpaced the development rate of proven technology and in getting the transitional generation of not as economically producible hybrids into production; and at a lower volume cost; and with better reliability; e.g. solid state device performance improvement moved progressively faster.

The second major problem was that the higher powered higher voltage component analogue tube based television console system had an entirely different and incompatible system architecture than the evolving low voltage analogue (active transistor) solid state device based system architecture being required and developed in parallel for the next (and needed) all solid state television. The attempt to blend the two different architecture interfaces into a “hybrid” system ended up being done on a slow, limited module/function by module/function equivalent basis, that ended up being very expensive, time consuming and ultimately impossible. It took the Japanese competitor companies continuous research and development investment over some ten-years to finally design, develop and produce the first generation solid state consumer electronics television. The Japanese also developed in parallel the highly automated (for the time period) manufacturing process to economically produce these solid state television sets.

In a similar manner as the incorporation of solid state in the consumer electronics industry, the automobile is seeing an increasing addition, incorporation, integration of more and more sophisticated solid state electromechanical and electronic sensors, controls, mechatronics (software control) subsystems. These are being used for sophisticated timing and control monitoring and spark control (engine management); to achieve reductions in pollutants (emission controls); increased power; and better fuel efficiencies.

Another example of this more sophisticated mechatronics use impact is an adaptive control suspension system, tire pressure monitoring and diagnostic communications with original equipment manufacturers to trouble shoot problems and potential problems.

So the simple hybrid system is now becoming, evolving into a much more sophisticated complex system, subsystem of more and more hybridization; similar to the consumer electronics hybrid paradigm. This also has drastically increased and added to the size, complexity, cost of the resulting new product design development process and maintenance challenges. From the additional expectations of the consumer; increased use and blending of electronics; computers and software; engineering skill base expansions; the reduced time to market; ever increasing expectation and requirements for reliability; ease and cost of maintainability and repair and cost of such parts; and many more items are all contributing to this process. Chapter 13 will address these changes in much more detail.

CHAPTER 10

RELIABILITY ENGINEERING

10.1 Introduction

As stated in the previous chapter, new products are coming to market at an increasing rate to stay globally competitive, also in response to advances in technologies and the higher demand and expectations of the customer. These products are consistently becoming more and more advanced (complex), which will be reviewed in greater detail in Chapter 13, and due to the higher initial costs, customers need a greater assurance that the product will perform as expected over the life of the product. Some automotive companies, most notably Hyundai and KIA, are providing these assurances to the customers by way of extended warranties (e.g. 100,000 mile or ten-year protection); when providing longer warranties, product reliability becomes ever increasingly more important.

Reliability must be built in from the design start, which can be expensive since it involves increased expenditure on research design, and development. However, not building it in can cost even more through negative consequences as increasing warranty costs, increased customer use costs and dissatisfaction (and/or resulting loss of market

share). As will be shown in later chapters, warranty and incentive costs are averaging between two-percent to roughly ten-percent of the sales revenue of the vehicle, for different manufacturers and their respective vehicles.

10.2 Reliability Explicitly Defined

In the most basic description, reliability is the probability that:

- The idea that something is fit for purpose with respect to time used,
- The capacity of a device or system to perform as designed over the expected useful life,
- The resistance to failure of a device or system over its designed life,
- The ability of a device or system to perform a required function under stated condition for a specified period of time,
- The probability that a functional unit will perform its required function for a specified interval under stated conditions,
- The ability of something to “fail well” or fail (soft) without catastrophic results (Juran, 1988; Smith & Mobley, 2008).

The more critical the application, the lower this probability of failure under use should be, (e.g. toaster oven versus an aircraft engine). Reliability can be decomposed into two concepts; series reliability and parallel reliability (Kalpakjian, 1995). For example, if examining the reliability of steel chain, each links’ individual reliability is important to the whole chain (system), or perhaps a gear in an automotive transmission, that one gear failure can affect the entire transmission (system). Both of these examples are the series (weakest link) reliability concept. Now for example, if a strand in steel

cable fails its affect on the entire system is minimal, or it is said to be parallel (or redundant) reliability. The parallel reliability concept is a very important concept as systems become more and more complex.

The parallel reliability concept is key when developing a redundant system - a system that when one component fails there is a secondary (or more, depending on the application) that will take the place of the original component to prevent the entire system from collapsing into catastrophic failure.

Reliability engineers rely heavily on statistics, probability theory, and reliability theory. Many engineering techniques are used in reliability engineering, such as reliability prediction, Weibull analysis, thermal analysis and management, reliability testing and various levels, degrees of stress and accelerated life testing. Because of this a large number of reliability techniques, with their expense, and the varying degrees of system and subsystem reliability analysis and predictions are required for different situations; all product development projects must develop a reliability program plan as a subset of the overall new product (life cycle) development plan; to specify the reliability tasks that will be performed for that specific system, and then establish what a system life cycle program must be comprised of.

10.3 Reliability Engineering

Reliability engineers are responsible for identifying how well, probabilistically, a system or product will perform against its defined requirements, for a given period of time and for a given operating condition (environment). Systems reliability directly affects the performance dependability promised and expected by the consumer; it is the

basis for providing (at the manufacture cost) the warranty period for the system and nature of coverage. The greatest concern of reliability engineering is to understand the overall performance of the system and creating ways to improve the overall reliability. Poisson distribution is used when dealing with failure distributions (assuming average failure rates and attempt to predict the expected, or average, number of failures in a given period of time) and is defined as:

$$P(x,t) = \frac{(\lambda t)^x e^{-\lambda t}}{x!}$$

Where λ represents the average failure rate, t is the operating time, and x is the observed number of failures. In addressing reliability, dealing with the probability of success, the exponential expression portion of the Poisson is used; basis for specifying, predicting and later measuring the reliability of the system and is given by:

$$R = e^{-\lambda t} = e^{-t/M}$$

Where M is the mean time between failure. Figure 56 represents a generic reliability exponential function.

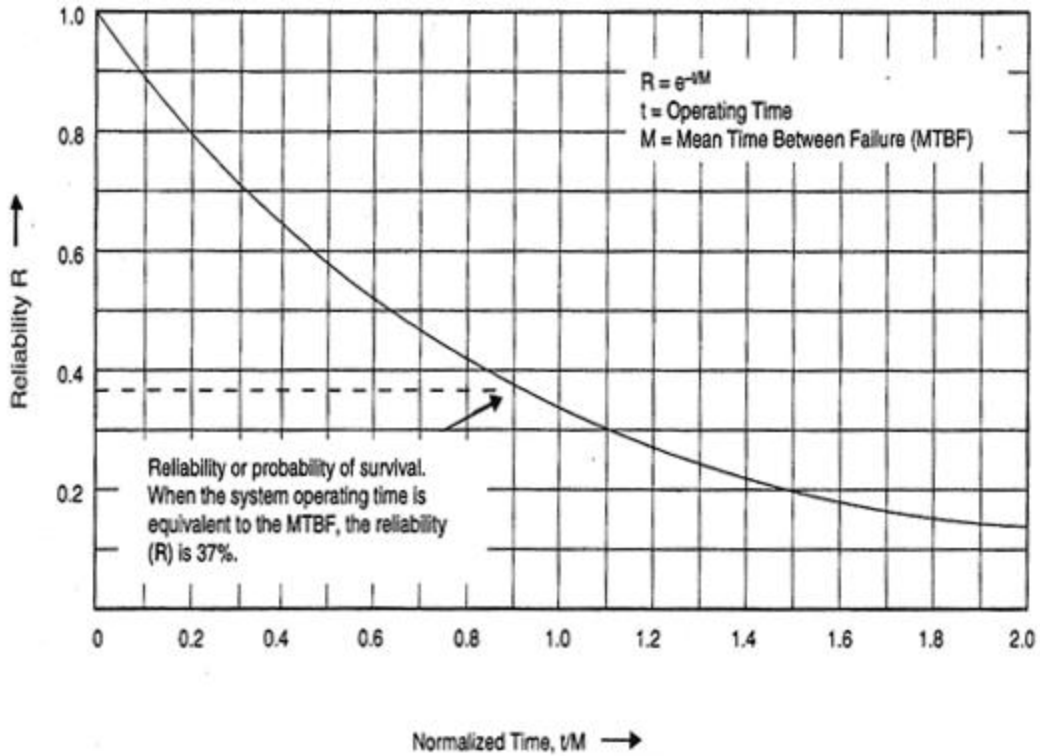


Figure 56 Traditional Reliability Exponential Function (source: Blanchard 2004)

The reliability curve is more recognizable in the “bath tub” probability curves, which are utilized to forecast how well the components of the system will perform. See Figure 57 for typical “bath tub” curves based on type of system:

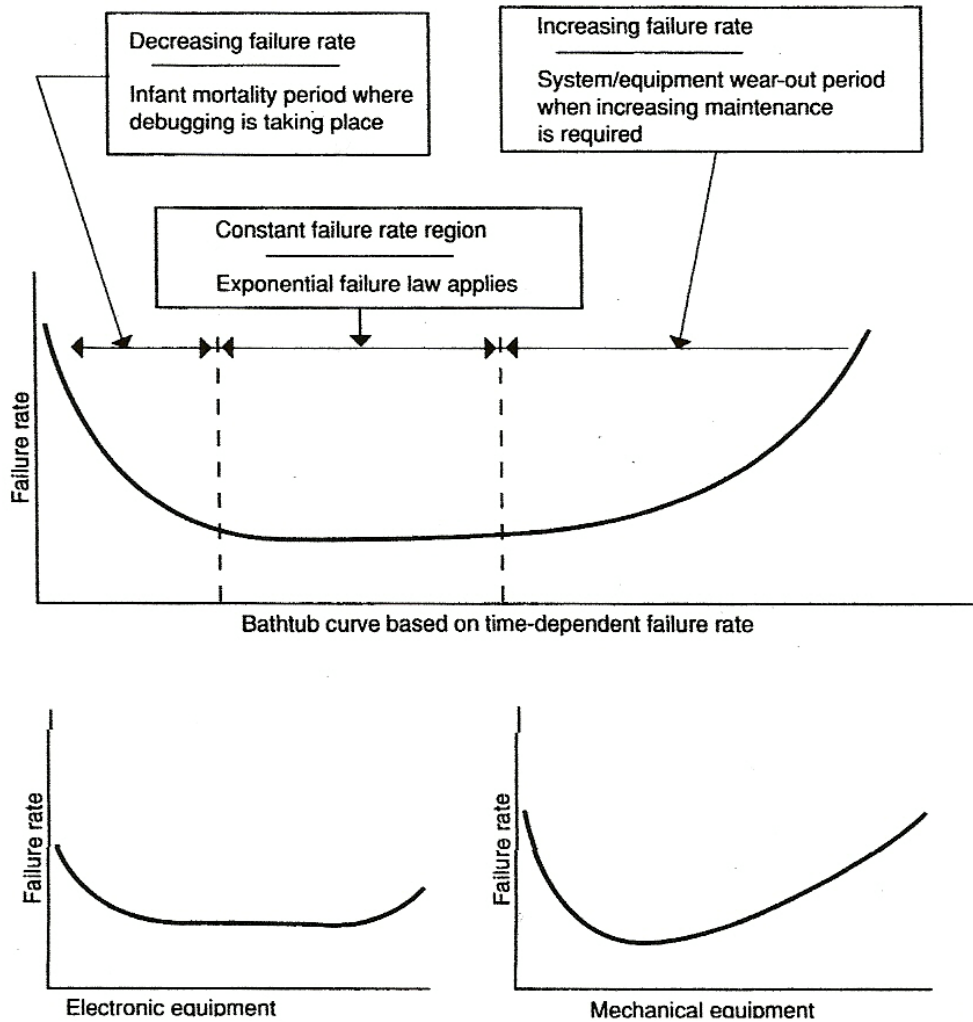


Figure 57 Typical Bathtub Curve (source: Blanchard, 2004)

Given enough units from a given population are observed operating and failing over time, it is possible to calculate week-by-week (or month-by-month) estimates of the failure rate $h(t)$. Over a period of time, and across a wide variety of mechanical and electronic components and systems, empirical population failure rates curves are calculated as the units age over time, or where:

$$\lambda = \frac{\text{number of failures}}{\text{total operating hours}}$$

Because of the shape of this failure rate curve, it has become widely known as the "Bathtub" curve. The initial region that begins at time zero when a customer first begins to use the product is characterized by a high but rapidly decreasing failure rate. This region is known as the Early Failure Period (also referred to as Infant Mortality Period, from the actuarial origins of the first bathtub curve plots). This decreasing failure rate typically lasts several weeks to a few months. After the initial failure rate, the failure rate levels off and remains roughly constant for (or should) the majority of the useful life of the product. This long period of a level failure rate is known as the Intrinsic Failure Period and the constant failure rate level is called the Intrinsic Failure Rate. The last portion of the tube is the wear out phase; the failure rate begins to increase as materials wear out and degradation failures occur at an ever increasing rate, given the units remain in service.

Once all components' probability curves are understood the reliability engineer can determine where redundant systems are needed to improve overall system reliability. A redundant system is one where if one component fails there is another to take its place. To calculate probabilities of failure, we will use a series calculation (no redundancy) and a redundant system. Figure 58 represents the series system and Figure 59 represents the redundant system to improve reliability and finally Figure 60 represents even more redundancy to further improve reliability. Ultimately the system engineer must determine a level of reliability versus the associated cost with producing extra redundancy. For example purposes assume the probability of each component's failure is all set 0.50% and we will calculate the reliability for each type of system.



Figure 58 Non-Redundant Series System (source: Blanchard 2004)

In the series system, the system fails when just one of the three components fails, and is simply the multiplication of the individual component reliability:

$$R_s = (R_a)(R_b)(R_c) = (0.5)(0.5)(0.5) = 0.125\%$$

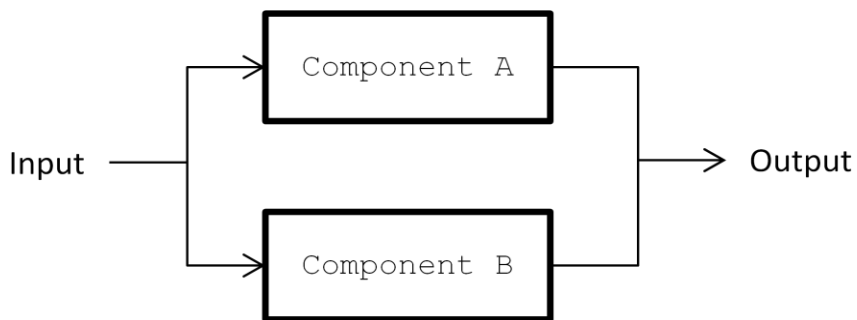


Figure 59 Parallel Redundant System, 2 Components (source: Blanchard 2004)

In a redundant system as in figure 59, the system does not fail unless both of the components fail; the reliability of the system for the two-component reliability is given by:

$$R_s = R_a + R_b - (R_a)(R_b) = 0.5 + 0.5 - (0.5)(0.5) = 0.75$$

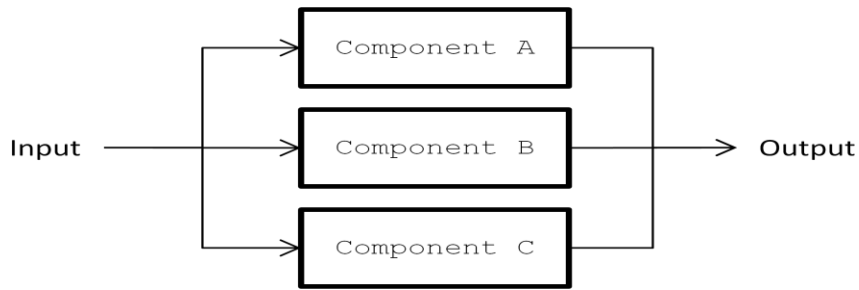


Figure 60 Parallel Redundant System, 3 Components (source: Blanchard 2004)

For Figure 60, the system does not fail unless all three of the components fail; The reliability for the three-component reliability is given by:

$$R_s = 1 - (1 - R_a)(1 - R_b)(1 - R_c) = 1 - (1 - 0.5)(1 - 0.5)(1 - 0.5) = 0.875$$

Figure 61 represents the effects of redundancy on the reliability designs.

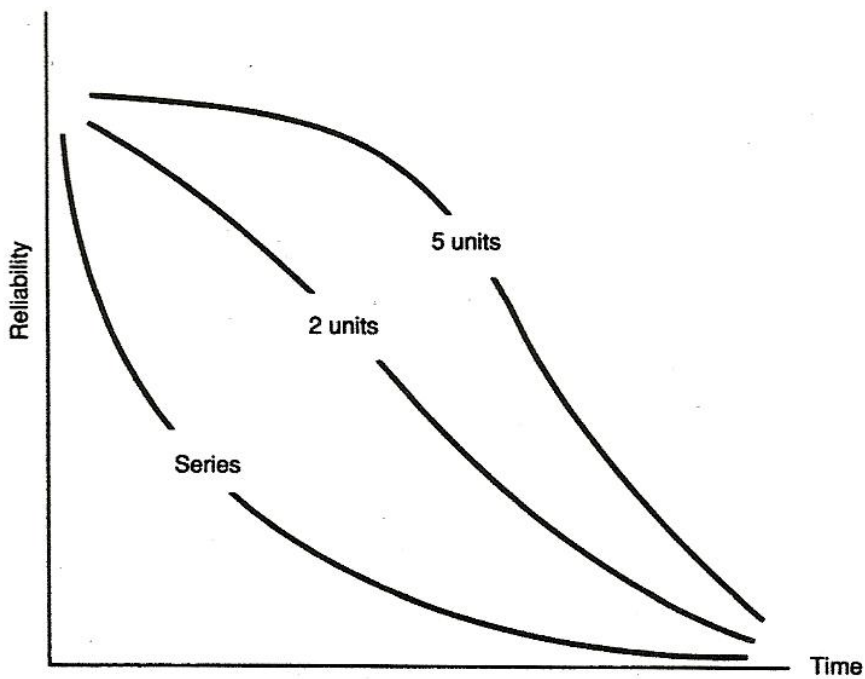


Figure 61 Effects of Redundancy on Reliability in Design (source: Blanchard 2004)

Obviously with the complex systems (products) in today's market place, we see a combination of series and parallel systems. Figure 62 represents this type of system:

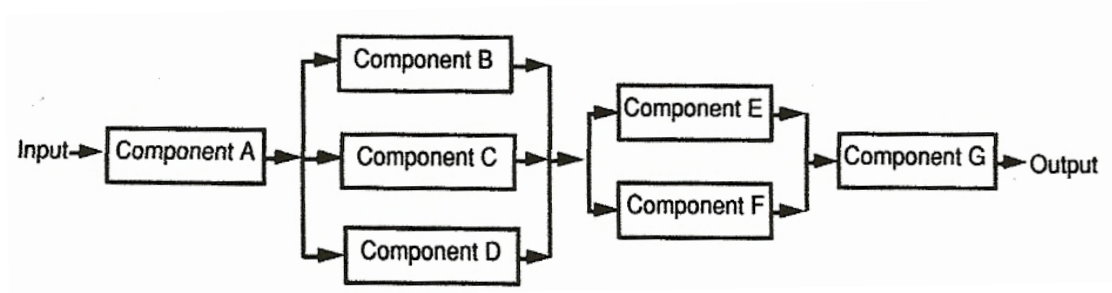


Figure 62 Series-Parallel Combination (source: Blanchard 2004)

Where the reliability is defined as:

$$R_s = (R_A)[1 - (1 - R_B)(1 - R_C)(1 - R_D)][R_E + R_F - (R_E)(R_F)](R_G)$$

When evaluating this combined system, the reliability engineer will first evaluate the parallel redundant elements to obtain the unit reliability and then combine the units with the other elements of the system in a series format. Overall reliability of the system is obtained by calculating the product of all series reliabilities. According to Blanchard (2004), through various applications of series-parallel networks, a system reliability block diagram can be developed for use in reliability allocation, modeling and analyses, and predictions. The reliability block diagram is derived directly from the system (functional) engineering analysis (see Chapter 9) and is illustrated in the military handbook, MIL-HDBK-388 and reproduced here as Figure 63, followed by an expanded block diagram as Figure 64.

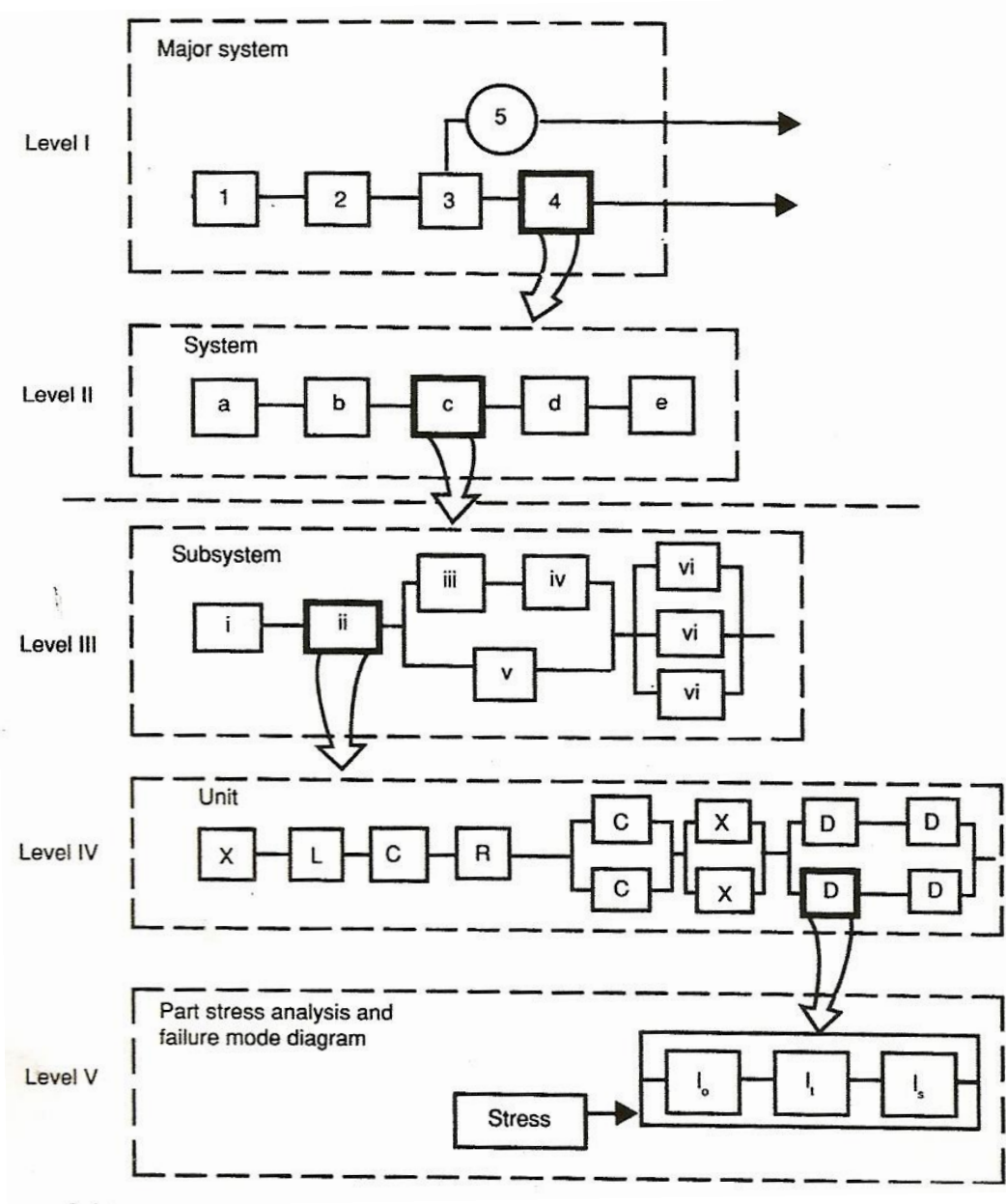


Figure 63 Reliability Block Diagram (Source: Blanchard, 2004)

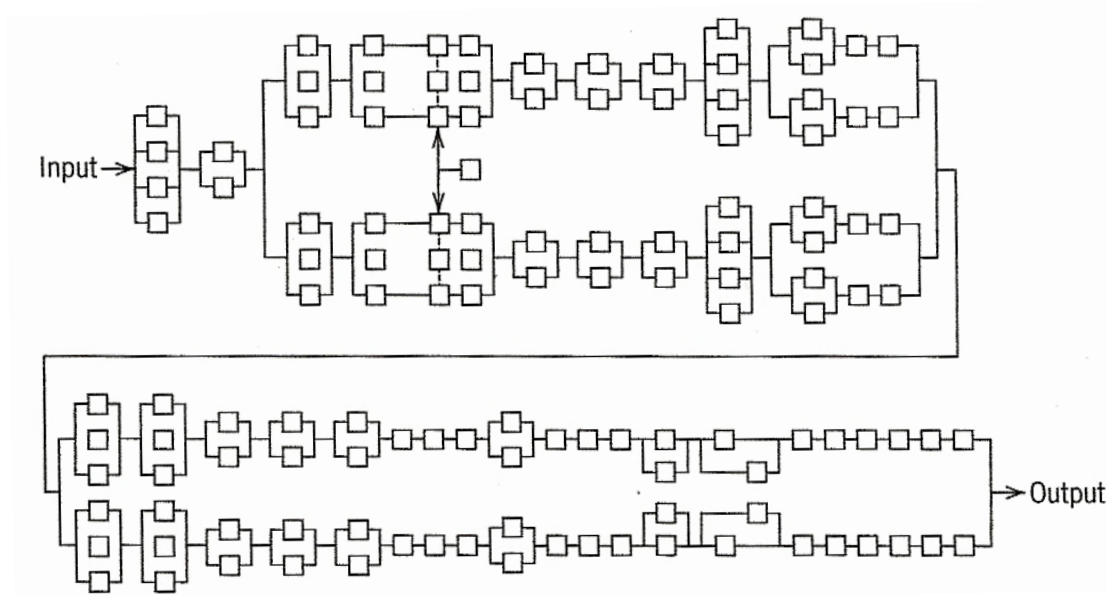


Figure 64 Expanded Reliability Block Diagram of Systems (source: Blanchard 2004)

Blanchard (2004) identifies seven key functions that need to be completed for the reliability-engineering portion:

1. Reliability program plan – how the reliability program is interfaced and intertwined with the overall system engineering (DF “x”) management plan,
2. Reliability modeling – developing the block diagrams to be used for analyses and predicting,
3. Failure mode, effect and criticality analysis – used to determine cause and effects relationships and identifying weak links, as well as identifying preventive maintenance requirements,
4. Fault tree analysis – graphically depicting different ways a system may potentially fail and establishing probabilities of these failures. Assists

in narrowing down failure potentials for further analysis in the failure mode and effects analysis process,

5. Reliability-centered maintenance analysis – an evaluation of the system/process, in terms of life cycle, to determine the best overall program for preventive maintenance. Emphasis is on identifying cost-effective preventive maintenance,
6. Failure reporting, analysis and corrective action system – developing a system to capture a history of what failed and the steps taken to implement corrective actions. System will serve as a historical library for future uses, and
7. Reliability qualification testing – testing performed to evaluate the overall system performance. The reliability analysis contributes greatly to the understanding of the types and kinds of maintenance the system will need and related cost, (Chen & Keys, 2009).

One of the biggest challenges of the increased use of complex mechatronics (smart products) is the significant increase in the complexity of the work that the reliability/quality analyst must perform in order to assure expected reliability and performance of the product over the user life cycle time, see Chapter 13 for the development and progression of ever increasing complex system/subsystem in the automotive industry.

10.4 Maintainability and Logistics

Maintainability in the simplest definition is the ease, accuracy, safety and economy in the performance of maintenance and serviceability actions and how easy and fast the system can be maintained. Maintainability deals with the interchangeability of spare parts, diagnostics, part standardization, accessibility. Maintainability can be measured in up-time, time the equipment is operating or is in standby ready, and in terms of downtime, when equipment is having corrective maintenance or preventive maintenance performed. Figure 65 represents the various time relationships.

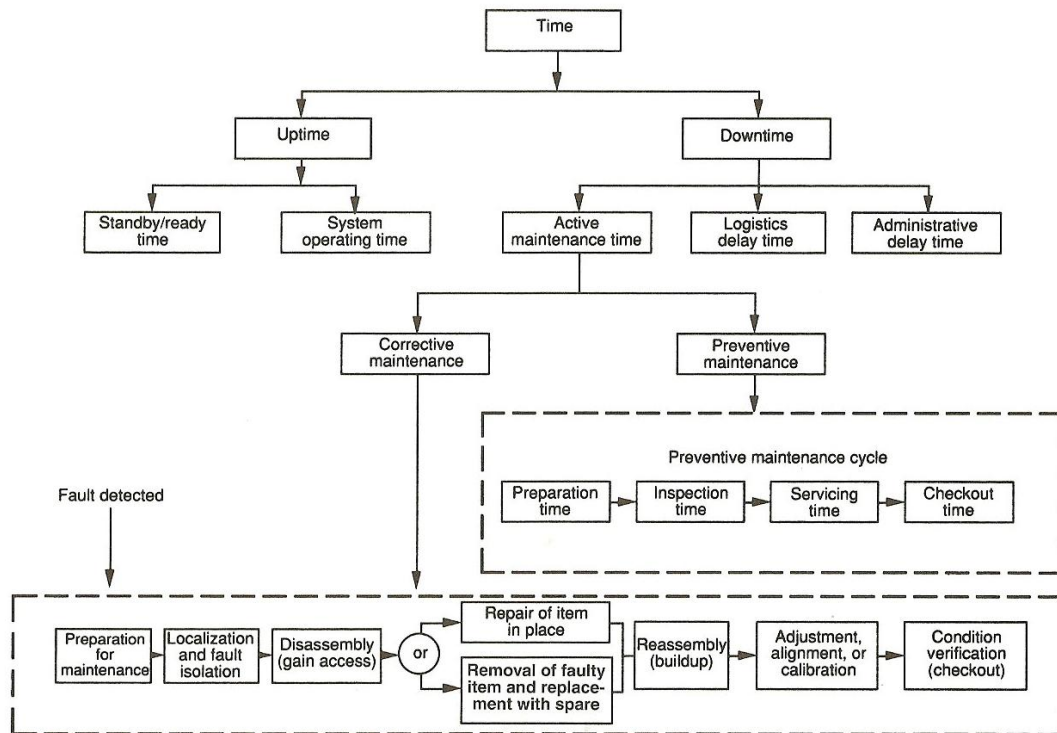


Figure 65 Time Relationships (source: Blanchard 2004)

Similar to reliability, maintainability in terms of corrective maintenance can be predicted by the use of probability functions, which the log normal distribution most closely resembles actual plots. There are seven key areas that Blanchard chose to focus

on during the maintainability analysis portion of the development of the system engineering planning:

1. Maintainability program plan – it is essential that this plan be developed as part, or in conjunction with both the reliability plan and the system engineering maintenance plan,
2. Maintainability modeling – similar to those developed for reliability,
3. Failure mode, effect and critical analysis – to identify areas of weaknesses in the maintainability program and identify needed corrective actions,
4. Maintainability analysis – levels of repair are identified, diagnostics protocols and needs are defined,
5. Maintenance task analysis – to determine maintenance and logistics necessities,
6. Level of repair analysis – determine which components should be repaired and which should be discarded and replaced, and
7. Maintainability demonstration – simulate different maintenance task sequences, record the associated maintenance items and verify the adequacy of the resources required to support the demonstrated maintenance activities.

10.5 Warranty, Costs and Replacement Parts

A warranty in the most basic description is a formal (sometimes lawful) obligation that the manufacturer contractually commits to the customer (or end user) to

assume certain responsibilities for product performance, reliability and dependability following the sale (purchase of) or delivery of their product. These warranties are put in place to assure guarantees for failure-free and acceptable service for a specified period of time or use by the customer under “normal” operating use conditions. In terms of the automobile industry, these terms are usually defined by number of months and miles driven, which is reached first. For example, a program of 36/36 is a warranty of 36,000 miles or 36 months, whichever is reached first.

For the manufacturers, a warranty program is a very important marketing tool, especially when dealing with: the large dollars associated with the purchase of a new automobile; the price associated with repair costs when a failure occurs; and its impact on subsequent resale value. This warranty program can be an expensive program for the manufacturer. Warranty costs actually represent the expenses that a manufacturer or producer incurs as a result of a given reliability level and resultant quality of the items produced (Thomas, 2005). Several studies confirm that consumers associate warranties with product reliability and quality expectation. If the reliability of a product is high, then its warranty cost will be low, and vice versa. As will be shown in later chapters, the warranty dollars reserved for expected claims can be quite high; from a small fraction of the gross revenue up to five-percent; and can be very high for major recalls (e.g. Ford Explorer roll-over case), see Chapter 12 for further examples of failure/recall occurrences.

In the automotive industry, these percentages against sales revenue are totaling in the billions of dollars; so with this, the necessity of adequate reliability modeling and testing to understand this cost has become imperative in such a generally low margin,

highly global competitive environment. Some of the benefits as defined by Rai and Singh (2005) include:

- Assessing impact of changes in warranty coverage,
- Early warning/detection of wrong design, production process, parts, materials or any other items,
- Selection and justification of engineering design improvement projects, and
- Comparison of performance before and after design fix

Rai and Singh graphically depicts some of the items that influence overall warranty cost of a new vehicle, see Figure 66.

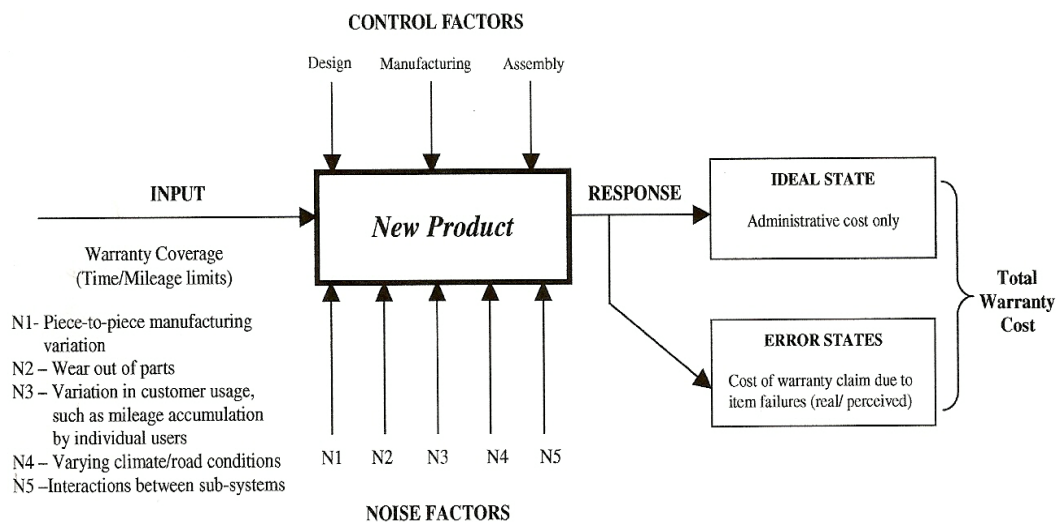


Figure 66 Factors that Influence Warranty Costs (source: Rai & Singh, 2005)

Each automotive company sets a certain dollar amount aside for dealership warranty and claims. There are several models being utilized to determine the total dollar amount, however, the models utilize data from several sources (warranty and claims data base, NHSTA recall data base, dealership complaint data bases, past performance of

components, reliability testing data) to calculate associated probabilities of failure and the associated severity of those failures. For example, the probability of a certain model to fail can be calculated based on the total amount of models sold in any particular year, the historical failure rate and the severity of the failure (cost of replacement parts, and time and expense of mechanic to repair). Each subsystem, regardless of how many different models the subsystem or component was used on can be calculated in similar fashion and probability of failure and cost of repair can be calculated.

As stated earlier in discussion, the decisions and actions during design, manufacturing and assembly determine the inherent reliability of the product (DF"X"). A vehicle that can perform well even in the presence of noise factors is said to be robust. When the DF "X" process is perfectly controlled, in an ideal situation, and the manufacturing process and assembly process is perfect and there is no associated affects by noise then the warranty costs will only be the administration portion, however, this in not realistic. The noise factors play a significant role and the error states lead to the major portion of the total warranty cost.

Warranty costs absorbed for a failure by the manufacturer is the cost of the subsystem that failed and the associated cost of paying the service professional to replace the subsystem. The notion here is that there is no such thing as an infinitely reliable component or system – that failure will occur but can be delayed through improved reliability. However this improved reliability often requires additional resources and comes at a price. With this, reliability specification requires choices and trade-offs. When the requirement is not imposed by environmental, safety, CAFÉ standards, the system design engineer must decide (through a multiple number of models), how much

reliability is needed and assesses how much reliability is worth and how much they are willing to pay for it.

This is an important note when identifying what replacement parts, components and subsystems are determined to be placed in stock. The design engineer has several data bases to obtain data when making the stocking decision; warranty and claims data base, NHSTA recall data base, dealership complaint data bases, past performance of components, reliability testing data. This data is pulled together to determine what parts are to be made available and in what quantities, it is also used to make economic decisions on which components are to be used in future models and which components are in need of redesign for better robustness.

10.6 Affects from Reliability Engineering

Perhaps the greatest contributor to raise the awareness by the mid 1960's of the necessity of dramatically improving quality and reliability of the automotive industry can be attributed to Ralph Nader in his book *Unsafe at Any Speed* (1965), where he focused on the handling and safety of the Corvair. "Unsafe at Any speed" was a full story of how and why cars kill; and why the automakers had failed to make vehicles safe enough, even though the technical expertise was available. This book and other safety advocates led to a Congressional Act on safety being passed in 1966. The Highway Safety Act of 1966 (P.L. 89-564, 80 Stat. 731) established a coordinated national highway safety program to reduce the death toll on the nation's roads. The act authorized states to use federal funds to develop and strengthen their highway traffic safety programs in accordance with uniform standards promulgated by the secretary of transportation.

The act was pushed by Nader and the other safety advocates of the time by educating and growing public concern over the rising number of traffic fatalities in the United States. Between 1960 and 1965, the annual number of traffic fatalities increased by nearly thirty percent. As President Lyndon B. Johnson stated at the signing of the act on September 9, 1966, " ... we have tolerated a raging epidemic of highway death ... which has killed more of our youth than all other diseases combined. Through the Highway Safety Act, we are going to find out more about highway disease—and we aim to cure it."

Over the last five decades since Ralph Nader's report, quality and reliability importance and awareness has proven to lead to many new understandings of good reliability versus poor reliability; how to achieve good/high reliability; and the ramifications for example:

- Increase sales and market share for high demonstrated reliability,
- Increased cost for poor demonstrated reliability (high warranty costs, see later chapter on economics),
- Increased liability and legal suits (Ford Explorer, Pinto, Crown Victoria, and General Motors' Corvair and Vegas, V8 automobile equivalent diesel engine all serve as great examples to be discussed in later chapters),
- Lower manufacturing costs due to decrease in rework and scrap (hidden factory),
- Higher post sales warranties and customer costs,
- Higher resale value for automotive used vehicle resale, and

- Consumer increase in awareness of safety/quality/reliability through internet services (Kelly Blue Book) and several publications and reports and rewards (e.g. JD Powers, Consumer Reports, Motor Trend)

All though more detail and data of Ford and Honda will be given and analyzed in later chapters, Figure 67 presents an over view of how reliability information can be analyzed and presented. This figure represents a grading/ranking of vehicles' ten year reliability by reviewing Consumer Reports ratings. The more popular passenger cars and pickup/sports utility vehicles were examined. Consumer Reports rates observed reliability from better to worse; with worse being problems being greater than three percent; middle rating being two percent; and the best rating being less than one percent. A worse rating was given a value of one and a best rating was given a value of five. The highest possible score was a point system of 85 over the following 17 assessed variables:

1. Engine Major
2. Engine Minor
3. Engine Cooling
4. Transmission Major
5. Transmission Minor
6. Drive System
7. Fuel System
8. Electrical
9. Climate System
10. Suspension
11. Brakes
12. Exhaust
13. Paint and Trim
14. Body Integrity
15. Body Hardware
16. Power Equipment
17. Audio System

It is very clear that there is a significant gap between the Japanese (Toyota and Honda) and the Domestic plants (Ford and General Motors) in quality on the passenger cars.

In the late 1970s and 1980s when at both General Motors and Ford were periodically in financial troubles, they developed the sports utility vehicles from small truck based platforms. General Motors and Ford were making most of their profits off of these larger vehicles in the 1990s, plus since being built from a truck platform circumvented the more stringent vehicle CAFÉ standards. Both Toyota and Honda made a decision to enter these markets as well, however, generally building these from an existing vehicle platform. As can be seen from Figure 66, the reliability of these vehicles is not good from the domestic manufactures. As a result an interesting point on this table is how this knowledge Toyota and Honda both enter into the market with very high scores and continues to improve while the domestic manufactures showed no real improvements until their market share became seriously challenged. The latter issues will be discussed more completely in later chapters.

Vehicle	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Camry	81%	80%	88%	91%	87%	88%	92%	96%	95%	87%
Corolla	86%	88%	84%	84%	86%	88%	95%	93%	94%	95%
Accord	81%	88%	93%	87%	92%	82%	91%	92%	96%	98%
Civic	78%	85%	87%	88%	88%	91%	94%	93%	92%	98%
Focus			47%	54%	48%	61%	74%	78%	82%	92%
Malibu	46%	42%	52%	45%	48%	60%	59%	69%	80%	
Impala			52%	36%	51%	67%	68%	72%	69%	86%
Tundra			76%	85%	91%	85%	87%	87%	86%	81%
Pilot						85%	91%	93%	92%	93%
Ridgeline									89%	93%
F150	68%	68%	61%	73%	79%	78%	68%	69%	81%	94%
Explorer	52%	59%	58%	60%	60%	58%	55%	73%	74%	89%
Silverado		60%	72%	68%	65%	56%	60%	69%	72%	87%
Suburban	47%	40%	67%	67%	66%	54%	61%	68%	80%	81%

Figure 67 Reliability Examples (source: created with data from Consumer Reports, April Issues, 1998-2007)

Figure 68 is a graphical representation pulled from the 2007 March Consumer Reports Annual Auto Issue which depicts the Japanese advantage in how the major brand vehicles age over time. It is based on the average problems per vehicle over a period of ten-years. This average combines all subsidiary brands (e.g. Hyundai incorporates the Kia nameplate and Volkswagen includes Audi).

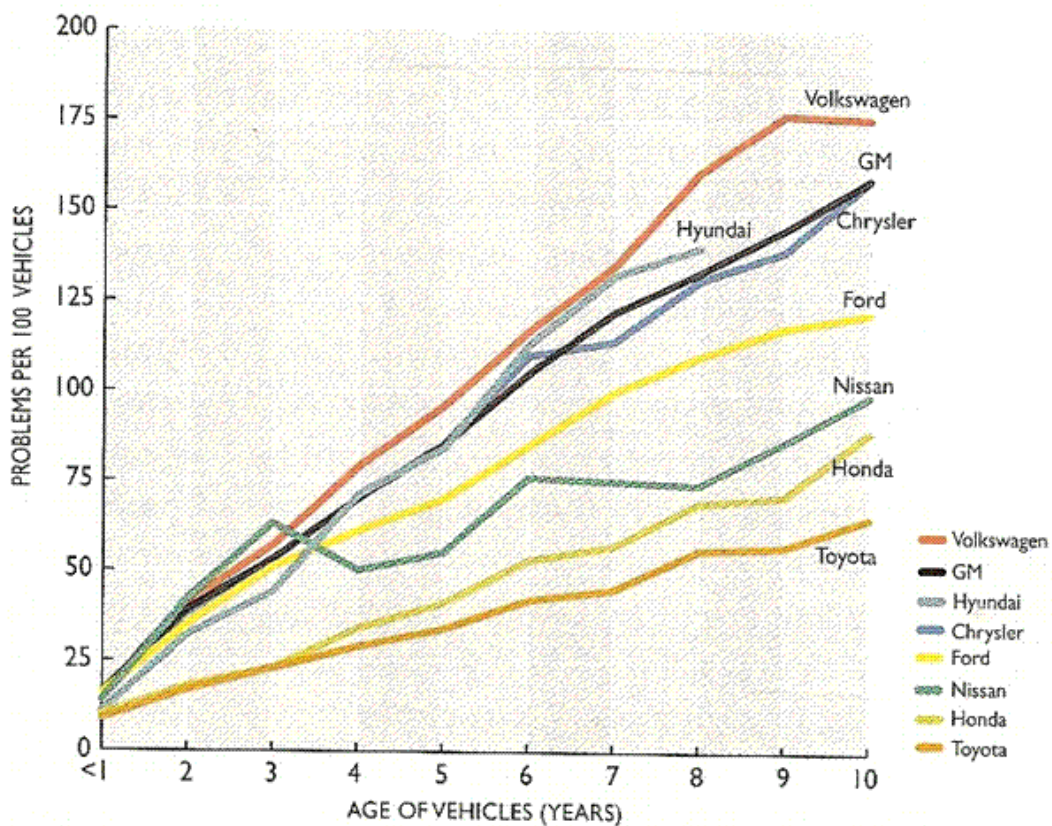


Figure 68 How Vehicles Age (Source: Consumer Reports, 2007)

This Japanese automotive industry's extra attention to product life cycle management costs mirrors the long-term strategy of how the early Japanese consumer

electronics companies used improved reliability and quality as part of the strategy to gain penetration, and growth and eventually achieve leadership and dominance in the market.

JD Powers also perform an annual survey of current owners. Figure 69 was constructed from data from the previous 10 years surveys. JP Powers survey, for example, the 2009 dependability survey was performed on over 46,000 original owners. Performance is measured using a “problems per 100 vehicles metric. The 2009 survey was conducted on vehicles that were three-years old (2006 model year). The study covers a total of 202 total problems in the following major categories:

1. Exterior,
2. The driving experience,
3. Features/controls/displays,
4. Audio/entertainment/navigation,
5. Seats,
6. HVAC,
7. Interior, and
8. Engine/transmission

Finally, JD Powers publish the dependability results ranking each brand in four classifications: among the best, better than most, about average, and the rest. One note should be made that JD Powers also state that studies show that those nameplates with higher dependability maintain 15-percent more of their value which can also affect the lease and used car markets as well.

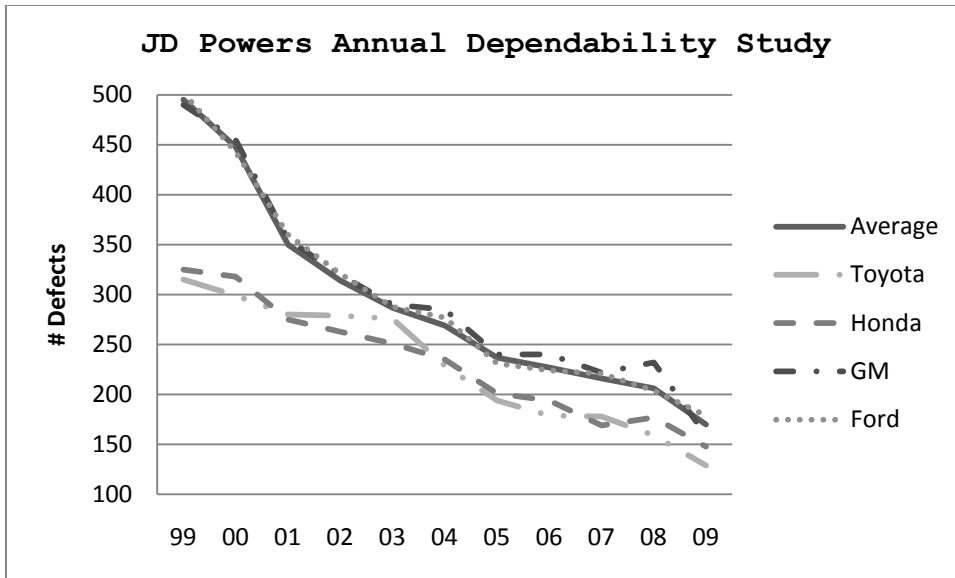


Figure 69 Dependability Study (source: compiled from JD Powers Annual Dependability Reports, 1999-2009)

CHAPTER 11

QUALITY ASSURANCE AND ENGINEERING

11.1 Introduction

This chapter will build around a simplistic definition of quality; quality can be defined as the preservation of a product or service (by the use of total quality management process) over an expected life cycle (as defined in Chapter 9), as supplied to meet the final customer's expectation as defined during the quality function deployment phase. This chapter will look at a brief historical development of quality, from inspection to today's total quality management.

Several definitions of quality will be documented as well as the effects that quality can potentially have on overall manufacturing costs, as defined by Juran. It will look at when and how the Japanese embraced those quality techniques, most notably Dr. Deming's teaching, developed, but not implemented in the United States.

This chapter will concluded discussing the quality function deployment (QFD) process and how using the house of quality tool can assist organization in properly defining life cycle expectations, and define modern quality systems; of Six Sigma, Lean Manufacturing tools, and Lean Six Sigma.

11.2 History of Quality Methods

Quality has gone through transitions over the last 100-years starting with inspection (Juran, 1988; Mitra 1998). The modern quality group and their functions were created out of a necessity from the industrial revolution due to the increased amount of mass production. The maturing of the industrial revolution, higher production rates led to the product manufacturing to be broken down into individual tasks, one of which was inspection. Production foremen were very familiar with the products so they would quite often over ride inspectors. However, as World War I approached it accelerated new product introduction, and more complicated products, which, the foremen no longer possessed the in depth knowledge of the product and could longer handle the quality responsibility.

The next phase of quality developed from Frederick Taylor which provided framework for the effective use of people in industrial organizations (Juran, 1988). Henry Ford was a major driver in these policies and through several years had Frederick Taylor developing Industrial Engineering concepts in the Ford Motor Company. Taylor's concepts were clearly defined tasks and performed under standard conditions. Inspection was one of these tasks and the following were key points:

- Was intended to ensure that no faulty product left the factory or workshop,
- Focuses on the product and the detection of problems in the product,
- Involves testing every time to ensure that it complies with the product specifications, and

- Is carried out at the end of the production process and relies on specially trained inspectors.

This movement led to the emergence of a separate inspection department. The problem is that defects were continually made and the options were to set the defects aside and either rework them or scrap. So a new and important idea emerged from this independent inspections department, defect prevention.

During this time the foundations of statistical aspects of quality control (SPC) were being developed, although not gaining wide usage in the United States industry. In 1924, Shewhart of Bell Telephone Laboratories proposed the concept of using statistical charts to control variable of a product (Johnson, 1993). These charts eventually became known as control charts, sometimes also referred to as Shewhart control charts.

Followed by Shewhart, as well at Bell Telephone Laboratories, were Dodge and Romig; these two engineers pioneered work in the area of acceptance sampling, which eventually replaced 100 percent inspection.

Up to this time, there were two dominant quality schools for thought:

1. Shewhart, Dodge, Romig, Deming focused on statistical methods for delivering high quality products throughout acceptance testing and statistical process control, and
2. In the early 1950s, Deming, Juran and Drucker also emphasized a “management based systems” approach to improve manufacturing performance and business practices.

About this time Feigenbaum advanced technology management through defining a new approach to quality based economics, industrial engineering – including an emerging

engineering discipline called systems theory – and management science, combined with the existing statistical and management theories. Feigenbaum referred to this development as a “total quality system” (Feigenbaum, 1983, Kubiak 2005). Feigenbaum defined the total quality system as:

A quality system is the agreed on companywide and plant wide operating work structure, documented in effective, integrated technical and managerial procedures, for guiding the coordinated actions of the people, the machines, and the information of the company and plant in the best and most practical ways to assure customer quality satisfaction and economical costs of quality.

The work at Bell Telephone Laboratories led to the next phase of quality development, Statistical Process Control, beginning roughly at the start of the Second World War. As described by Feigenbaum (1983), the United States was best positioned to adopt all of these quality principals but nonetheless, the United States did not capitalize on the unique advantage.

11.3 Post World War II Japanese Issues

Prior to the quality movement in Japan, the Japanese were known for cheap, low priced products, (Juran, 1988, Byron, 1981). Even though products were sold at ridiculously low prices, as relative to international levels, it was difficult to secure repeat purchases due to the low level of quality and repeatability of performance. The quality movement in Japan began in 1946 with the United States occupation force’s mission to revive and restructure Japan’s communications equipment industry. Statistical techniques were first introduced to Japanese academics, engineers and managers along with production management and personnel administration. The General Headquarters of

the Allied Forces (GHQ) needed companies to produce electrical equipment, trucks and other items up to American standards for U.S. troops in Japan and Korea.

Toshiba, NEC, Fuji and Hitachi were some of the first companies to apply American production management and the above mentioned quality techniques. GHQ gave special attention to the implementation of these techniques to the electrical equipment firms because it wanted to set up new communications network throughout Japan but found serious defects in the quality of Japanese telephone equipment. Simultaneously strict American standards for military vehicles also forced Nissan, Toyota and Isuzu to attend quality control lectures and to adopt quality control techniques.

Even though these tougher standards and techniques were being implemented in the automotive industry several things were uncovered:

- Quality problems were too severe to be solved by better methods of inspection,
- Better methods or improvements in the manufacturing process would be inadequate,
- Quality suffered from inferior materials,
- Quality suffered from inferior design,
 - Mono style bodies adopted from aircraft were hard to repair when rusting due to inferior materials, and
- Subcontractors and suppliers were even further backwards than the original equipment manufacturers.

To satisfy the more stringent requirements it required an extension of the quality control programs from inspection to process control and then to design and market analysis.

11.4 Japanese Adoption and Modification

The first step of the Japanese movement to a total quality culture has been accredited to Dr. Deming lecture in 1950 to the Union of Japanese Scientists and Engineers (JUSE), (Cusomor, 1985; Juran, 1988; Mitra, 1998). Deming's 1950 lecture notes provided the basis for a 30-day seminar sponsored by the Union of Japanese Scientists and Engineers (JUSE) and provided the criteria for Japan's famed Deming Prize. The first Deming Prize was given to Koji Kobayashi in 1952. Within a decade, JUSE had trained nearly 20,000 engineers in SQC methods. Today Japan gives high rating to companies that win the Deming prize; they number about ten large companies per year. Deming's work has impacted industries such as those for radios and parts, transistors, cameras, binoculars, and sewing machines. In 1960, Deming was recognized for his contribution to Japan's reindustrialization when the Prime Minister awarded him the Second Order of the Sacred Treasure. Deming went on to define his fourteen points, there are several minor modifications of the fourteen points, but the reviewed ten-point list below is from Deming's 1982 book, *Out of the Crisis*;

- 1."Create constancy of purpose towards improvement". Replace short-term reaction with long-term planning.
- 2."Adopt the new philosophy". The implication is that management should actually adopt his philosophy, rather than merely expect the workforce to do so.
- 3."Cease dependence on inspection". If variation is reduced, there is no need to inspect manufactured items for defects, because there won't be any.
- 4."Move towards a single supplier for any one item." Multiple suppliers mean

variation between feedstocks.

5. "Improve constantly and forever". Constantly strive to reduce variation.

6. "Institute training on the job". If people are inadequately trained, they will not all work the same way, and this will introduce variation.

7. "Institute leadership". Deming makes a distinction between leadership and mere supervision. The latter is quota- and target-based.

8. "Drive out fear". Deming sees management by fear as counter-productive in the long term, because it prevents workers from acting in the organization's best interests.

9. "Break down barriers between departments". Another idea central to TQM is the concept of the 'internal customer', that each department serves not the management, but the other departments that use its outputs.

10. "Eliminate slogans". Another central TQM idea is that it's not people who make most mistakes - it's the process they are working within. Harassing the workforce without improving the processes they use is counter-productive.

In 1954, Dr. Joseph M. Juran of the United States raised the level of quality management from the factory to the total organization. He stressed the importance of systems thinking that begins with product designs, prototype testing, proper equipment operations, and accurate process feedback. Juran's seminar also became a part of JUSE's educational programs. Juran provided the move from SQC to TQC (total quality control) in Japan. This included company-wide activities and education in quality control (QC), QC circles and audits, and promotion of quality management principles (Barton, 1991). By 1968, Kaoru Ishikawa, one of the fathers of TQC in Japan, had outlined the elements of TQC management and the fundamentals of the Japanese Quality Circles that we eventually copied by so many industries in Europe and the United States:

- Quality comes first, not short-term profits,
- The customer comes first, not the producer,

- Customers are the next process with no, organizational barriers,
- Decisions are based on facts and data,
- Management is participatory and respectful of all employees, and
- Management is driven by cross-functional committees covering product planning, product design, production planning, purchasing, manufacturing, sales and distribution, (Ishikawa, 1991; Watson, 2004).

Ishikawa can be credited with much of the transition and further development of Japanese quality movement having learned from Deming and Juran. He also outlined several principals of quality as an adaptation of Deming's 14 points, the six principals that became fundamental in his teaching are:

- All employees should clearly understand the objectives and business reasons behind the introduction and promotion of companywide quality control,
- The features of the quality system should be clarified at all levels of the organization and communicated in such a way that the people have confidence in these features,
- The continuous improvement cycle should be continuously applied throughout the whole company for at least three to five years to develop standardized work. Both statistical quality control and process analysis should be used and upstream control for suppliers should be developed and effectively applied,
- The company should define a long-term quality plan and carry it out systematicall,

- The walls between departments or functions should be broken down, and cross-functional management should be applied, and
- Everyone should act with confidence, believing his or her work will bear fruit.

Perhaps one of the more major contributions that helped Japanese automotive companies (as well as other Japanese industries, e.g. consumer electronics) is part of their culture of refinement and attention to details. As will be discussed later, the Japanese manufacturers constantly score better in reliability measurements as well as initial and on-going quality. These roots can be traced back to the attention to detail and the ever-evolvement and commitment to continuous improvement; the ever tightening of tolerances and standards (making parts almost perfect with no part variation to improve fit and performance); commitment to improve assembly and manufacturing; and reducing waste.

11.5 Quality Defined

As can be seen in the above sections, it took a better part of six-decades to hundred years to develop the modern quality assurance structure. Even today though, Quality has been and continues to be defined in several ways, just a few of those more popular definitions by organizations and quality gurus include:

- ISO 9000: “degree to which a set of inherent characteristics fulfils requirements”

- Philip Crosby: “Conformance to requirements.” However the difficulty here is that the requirements may not always include what the customer wants.
- Joseph Juran: “fitness for use.” Where fitness is defined by the customer/end user.
- American Society for Quality: “Quality is a subjective term for which each person has his or her own definition. In technical usage, quality can have two meanings: 1. the characteristic of a product or service that bear on its ability to satisfy stated or implied needs. 2. a product or service free of deficiencies.
- W. Edwards Deming: concentrating on "the efficient production of the quality that the market expects linked quality and management: "Costs go down and productivity goes up as improvement of quality is accomplished by better management of design, engineering, testing and by improvement of processes.
- Genichi Taguchi: with two definitions:
 - Uniformity around a target value. The idea is to lower the standard deviation in outcomes, and to keep the range of outcomes to a certain number of standard deviations, with rare exceptions.
 - The loss a product imposes on society after it is shipped. This definition of quality is based on a more comprehensive view of the production system.

11.6 Common Quality Philosophies

This section will take a brief look at the modern quality philosophies, more specifically, total quality management, kaizen, six sigma and lean six sigma. Lean manufacturing is another philosophy that was discussed in more detail in Chapter 7 so additional information will not be added at this point.

11.6.1 Total Quality Management (TQM)

Total Quality Management is a management approach that originated in the 1950s, stemming from Dr. Deming's work in Japan and the development of his fourteen points as defined above. TQM has been practiced and further refined and adopted throughout Japan, most notably in the automotive industry. It has steadily become more popular since the early 1980's when imported vehicles began taking large market share off of the domestic suppliers because of the higher quality and reliability that TQM brought to the Japanese manufacturers. Eventually, TQM, or the results in competitive advantage that practicing TQM led the United States Government in developing the Malcolm Baldrige Award in 1988 to recognize those manufacturers who strive for competitive advantages through quality achievements.

Total Quality is a description of the culture, attitude and organization of a company that strives to provide customers with products and services that satisfy their needs. The culture requires quality in all aspects of the company's operations, with processes being done right the first time and defects and waste eradicated from operations.

TQM is an enterprise (system) wide management philosophy that seeks to integrate all organizational functions (marketing, finance, design, engineering, and production, customer service, etc.) to focus on meeting customer needs and organizational objectives. TQM views an organization as a collection of processes and TQM maintains that organizations must strive to continuously improve these processes by incorporating the knowledge and experiences of workers. The simple objective of TQM is "Do the right things, right the first time, every time". TQM is infinitely variable and adaptable. Although originally applied to manufacturing operations, and for a number of years only used in that area, TQM is now becoming recognized as a generic management tool, just as applicable in service and public sector organizations.

There are a number of evolutionary strands, with different sectors creating their own versions from the common ancestor. TQM is the foundation for activities, which include:

- Commitment by senior management and all employees,
- Meeting customer requirements,
- Reducing development cycle times,
- Just In Time/Demand Flow Manufacturing,
- Improvement teams,
- Reducing product and service costs,
- Systems to facilitate improvement,
- Line Management ownership,
- Employee involvement and empowerment,
- Recognition and celebration,

- Challenging quantified goals and benchmarking,
- Focus on processes / improvement plans, and
- Specific incorporation in strategic planning,

Given these above mentioned points it dictates that TQM must be practiced in all activities, by all personnel, in Manufacturing, Marketing, Engineering, R&D, Sales, Purchasing, HR, as well as all other functions.

Martin, (1993) suggests the following as key principals for the TQM process:

- Management Commitment
 1. Plan (drive, direct)
 2. Do (deploy, support, participate)
 3. Check (review)
 4. Act (recognize, communicate, revise)
- Employee Empowerment
 1. Training
 2. Suggestion scheme
 3. Measurement and recognition
 4. Excellence teams
- Fact Based Decision Making
 1. SPC (statistical process control)
 2. DOE, FMEA
 3. The 7 statistical tools
 4. TOPS (FORD 8D - Team Oriented Problem Solving)
- Continuous Improvement

1. Systematic measurement and focus on CONQ
 2. Excellence teams
 3. Cross-functional process management
 4. Attain, maintain, improve standards
- Customer Focus
 1. Supplier partnership
 2. Service relationship with internal customers
 3. Never compromise quality
 4. Customer Driven Standards

TQM can be looked at like a house with several ties/structures that pull the process together with several key elements. Figure 70 depicts this house.



Figure 70 TQM House (source: author created)

To be successful implementing TQM, an organization must concentrate on the eight key elements:

1. Ethics
2. Integrity
3. Trust
4. Training
5. Teamwork
6. Leadership
7. Recognition
8. Communication

11.6.2 Quality Function Deployment (QFD)

QFD is a method for a analytical/structured product planning process and development that permits a design team to clearly specify and document the desired characteristics of the product from the customers' view point (wants and needs), and to evaluate each proposed product of service capability (reliability) systematically in terms of its impact of meeting/exceeding the desired results (Terninko, 1997; Cohen 1995).

The QFD process involves constructing one or more matrices. The first, and most commonly used, is the House of Quality (sometimes called the voice of the customer but actually the voice is part of the house), see Figure 71. This House of Quality (HOQ) displays the customers' wants and needs (Voice) along the left and the developments team's technical response to meeting those desires across the top.

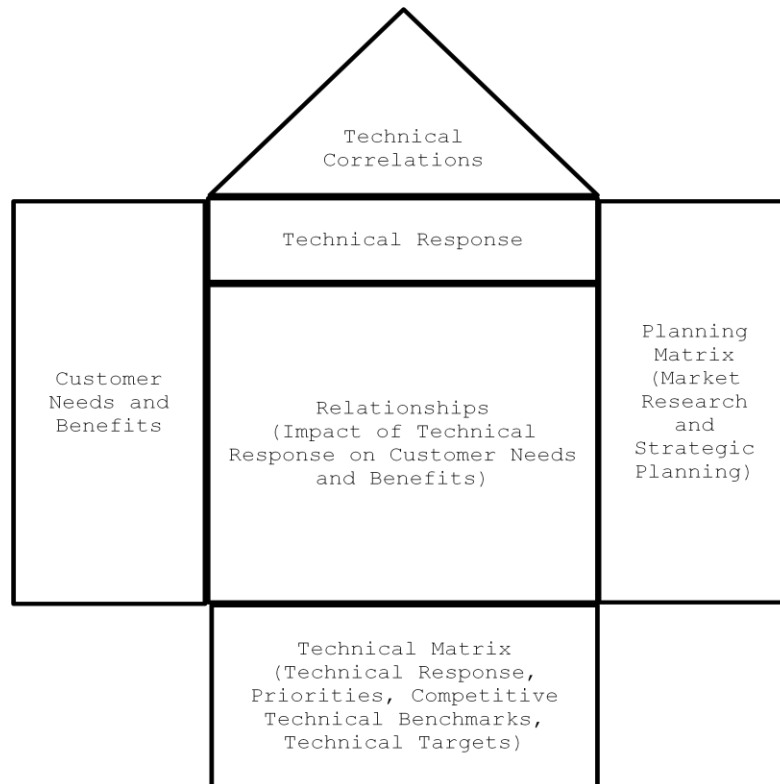


Figure 71 House of Quality (source: Wortman, Richardson, Glenn, Williams, Pearson, Bensley, Patel, DeSimone & Carlson, 2007)

The initial steps in constructing the HOQ include clarifying and determining and specifying the customers' needs/desires. These steps lay the foundation for a clearly documented and defined venture and will ensure a good analytical thought out process prior to moving further.

Customer Needs and Benefits

Clarifying Customer Needs/Desires

The first step, Clarifying Customer Desires/Needs, requires to know that people buy benefit (product must have a purpose or need), and the manufacturer must understand and satisfy this need. So unless customers and manufacturers are perfectly in tune with

one another, it may be difficult to anticipate these features or the underlying benefit. It is important to translate the wishes of each and every customer into some tangible value that can be turned into engineering specifications. These wishes include the following:

- Quality and reliability – must thoroughly understand the need and translate into manufacturing,
- Costs,
- Functions, and
- Processes

Specifying the Customer Needs/Desires

After determining the desires of the customer, the development team must create the specifications and standards that need to be met. Organizations can use known data from market research, or conduct new studies to gather necessary information.

Reliability of each subsystem/component is critical, especially in the automotive industry when it comes time for resale or repeat customers.

Technical Response

The next step in QFD is identifying what the customer wants and what must be achieved to satisfy these wants. In addition, regulatory standards and requirements (e.g. Highway Safety Standards, Emissions or CAFÉ standards) dictated must be identified. Once all requirements are identified it is necessary to answer what must be done to the product design to meet these requirements. Table III is helpful check in meeting these requirements.

Table III Requirements Table

Requirements	What
A list of requirement from customers, management and regulatory standards	An expanded list of what needs to be done to the product to fulfill the requirements

(source: Author generated)

Planning Matrix

The main purpose of the planning matrix is to benchmark against competitors (compare how well the team met the customer requirements compared to competitors). The planning matrix shows the weighted importance of each requirement that the team and its competitors are attempting to fulfill. Customer ratings ranging from 1 to 5 are given to each company under each requirement. The customer ratings are combined with the weighted performance of each demand to produce an overall performance measure for the companies.

Interrelationship Matrix

The purpose is to relate the customers' product requirements and the performance measures designed to improve the product. The opinions of the consumers of what they need and require is needed to form a specific product. These views are drawn from the planning matrix and placed on the left side of the interrelationship matrix. With this complete the company can now formulate a strategy to improve their product. Knowing what improvements need to be made allows a list of performance measures to be generated and displayed across the top of the interrelationship matrix. The company must take the voice of the customer and translate it into engineering terms. The matrix

will have at least one performance measure for each demanded quality/reliability. Once the basic matrix is set, it is necessary to assign relationships between the customer requirements and the performance measures.

Technical Correlation Matrix

Performance measures in existing designs often conflict with each other.

Technical correlation matrix (called the roof) is used to aid in developing relationships between customer requirements and product requirements and identifies where these units must work together otherwise they will be in a design conflict. Any cell identified with a high correlation is a strong signal to the team, and especially to the engineers, that significant communication and coordination are a must if any changes are going to be made. If there is a negative or strongly negative impact between requirements, the design must be compromised unless the negative impact can be designed out. Some conflict cannot be resolved because they are an issue of physics, while others can be design-related, which leaves it up to the team to decide how to resolve (negative impacts can also be a constraint which may be bi-directional). Sometimes an identified change impairs so many others that it is just simply better to leave it alone. Terninko (1997) asks the following question to help clarify the relationships among requirements when completing this portion, “if technical requirement X is improved, will it help or hinder technical requirement Z?” Many technical requirements can be related, so when working to improve one may help a related requirement and a positive or beneficial effect can result. However, it can also have a negative result. One of the principal benefits of the technical correlation matrix is that it does flag these negative relationships so they can be

addressed. If not address properly it can and probably will result in a final product that will dissatisfy the customer in some way.

Technical Matrix

The technical matrix uses specific items to record the priorities assigned to the technical requirements. It provides a technical performance achieved by competitor's products and the degree of difficulty in developing each requirement. The final output of the matrix is a set of target values for each technical requirement to be met by the new design. Constraints such as cost, technology and other items may prevent an optimum design creation.

The customer's requirements are then distributed across the relationships to the quality/reliability characteristics. This gives the ability to prioritize quality/reliability characteristics. These characteristics can be benchmarked technically against the competition. Organizations should not be surprised to find out that the competition is sometimes better at certain characteristics. QFD assists organizations to identify technical areas and to develop areas where they can achieve the most cost effective customer satisfaction. Organizations can then examine the customer context for usage concerns that must be accounted for and set design target specifications for quality/reliability characteristics. At a very minimum, the performance standards should be maintained.

In summary to the QFD process, Figure 72 summarizes a four-phase approach.

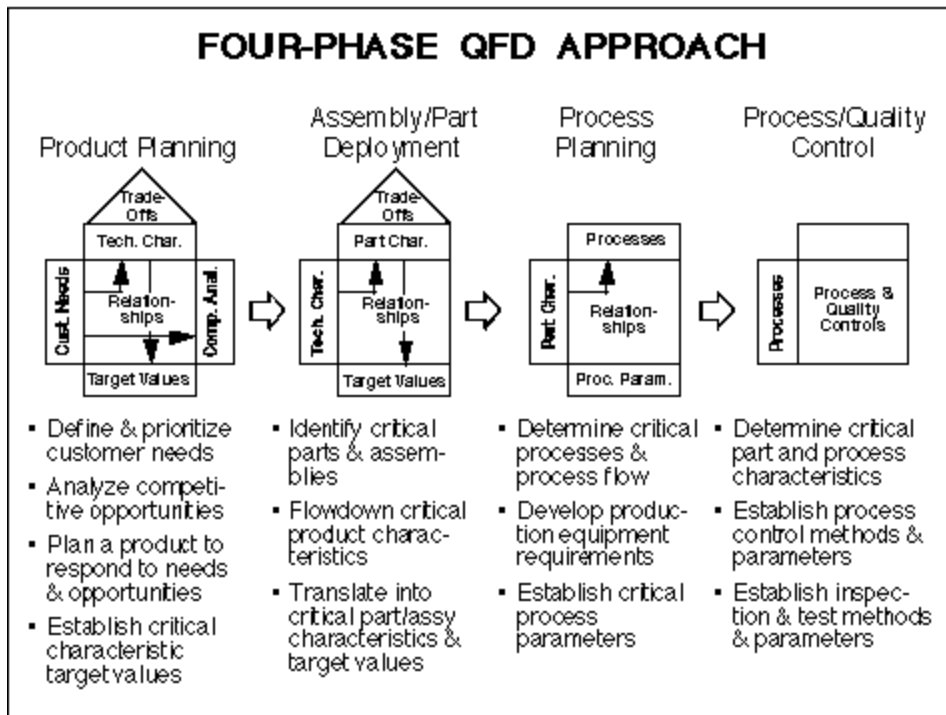


Figure 72 Four-Phase QFD Approach (source: Wortman, et al., 2007)

11.6.3 KAIZEN

Kaizen was created in Japan following World War II. The word Kaizen means "continuous improvement". It comes from the Japanese words ("kai") which means "change" or "to correct" and ("zen") which means "good". Kaizen is a system that involves every employee - from upper management to the cleaning crew. Everyone is encouraged to come up with small improvement suggestions on a regular basis. This is not a once a month or once a year activity. It is continuous. Japanese companies, such as Toyota and Canon, a total of 60 to 70 suggestions per employee per year are written down, shared and implemented. In most cases these are not ideas for major changes. Kaizen is based on making little changes on a regular basis: always improving productivity, safety and effectiveness while reducing waste (Shingo 1959). Suggestions

are not limited to a specific area such as production or marketing. Kaizen is based on making changes anywhere that improvements can be made. Western philosophy may be summarized as, "if it isn't broke, don't fix it." The Kaizen philosophy is to "do it better, make it better, improve it even if it isn't broken, because if we don't, we can't compete with those who do." Kaizen in Japan is a system of improvement that includes both home and business life.

Kaizen even includes social activities. It is a concept that is applied in every aspect of a person's life. In business Kaizen encompasses many of the components of Japanese businesses that have been seen as a part of their success. Quality circles, automation, suggestion systems, just-in-time delivery, kanban and 5S are all included within the Kaizen system of running a business. Kaizen involves setting standards and then continually improving those standards. To support the higher standards Kaizen also involves providing the training, materials and supervision that is needed for employees to achieve the higher standards and maintain their ability to meet those standards on an on-going basis.

There are five basic steps involve with Kaizen:

- Standardize an operation,
- Measure the standardized operation; find cycle time and amount of in-process inventory,
- Gauge measurements against requirements,
- Innovate to meet requirements and increase productivity,
- Standardize the new improved operations, and
- Continue cycle ad infinitum

Kaizen involves every employee in making change in small, continuous, incremental ways. It focuses on identifying problems at their source, solving them at their source, and changing standards to ensure the problem stays solved. It's not unusual for Kaizen to result in 25 to 30 suggestions per employee, per year, and to have over 90% of those implemented. For example, Toyota is well-known as one of the leaders in using Kaizen. In 1999 at one U.S. plant, 7,000 Toyota employees submitted over 75,000 suggestions, of which 99% were implemented. These continual small improvements add up to major benefits. They result in improved productivity, improved quality, better safety, faster delivery, lower costs, and greater customer satisfaction. On top of these benefits to the company, employees working in Kaizen-based companies generally find work to be easier and more enjoyable--resulting in higher employee moral and job satisfaction, and lower turn-over. With every employee looking for ways to make improvements, you can expect results such as:

- Kaizen Reduces Waste in areas such as inventory, waiting times, transportation, worker motion, employee skills, over production, excess quality and in processes,
- Kaizen Improves space utilization, product quality, use of capital, communications, production capacity and employee retention, and
- Kaizen Provides immediate results. Instead of focusing on large, capital intensive improvements, Kaizen focuses on creative investments that continually solve large numbers of small problems. Large, capital projects and major changes will still be needed, and Kaizen will also improve the capital projects process, but the real power of Kaizen is in the on-going process of continually making small improvements that improve processes and reduce waste.

11.6.4 Six Sigma

Six Sigma was originally developed by Bill Smith at Motorola in 1986 as a set of practices designed to improve manufacturing processes and eliminate defects, but its application was subsequently extended to other types of business processes as well, (Breyfogle, 1999). Six Sigma was heavily inspired by six preceding decades of quality improvement methodologies as mentioned earlier such as quality control, TQM, and Zero Defects, based on the work of pioneers such as Shewhart, Deming, Juran, Ishikawa, Taguchi and others. Unlike these quality programs prior, Six Sigma is expanded to include:

1. Reduced process variation to provide continuous efforts to achieve stable and predictable process results which are of vital importance to business success,
2. Manufacturing and business processes have characteristics that can be measured, analyzed, improved and controlled, and
3. Achieving sustained quality improvement requires commitment from the entire organization, particularly from top-level management.

Some of the more desirable traits of a Six Sigma program versus other programs are:

1. A clear focus on achieving measurable and quantifiable financial returns from any Six Sigma project,
2. An increased emphasis on strong and passionate management leadership and support,
3. A special infrastructure of "Champions," "Master Black Belts," "Black Belts," etc. to lead and implement the Six Sigma approach, and

4. A clear commitment to making decisions on the basis of verifiable data, rather than assumptions and guesswork. The term "Six Sigma" is derived from a field of statistics known as process capability studies. Originally, it referred to the ability of manufacturing processes to produce a very high proportion of output within specification. Processes that operate with "six sigma quality" over the short term are assumed to produce long-term defect levels below 3.4 defects per million opportunities. Six Sigma's implicit goal is to improve all processes to that level of quality or better.

Statistically speaking, six sigma is no more the plot of the normal distribution with the process contained within 6-standard deviations from the nominal with a 1.5 shift in mean. The 1.5 sigma shift based on experience and documented by Motorola has shown that in the long term, processes usually do not perform as well as they do in the short. As a result, the number of sigmas that will fit between the process mean and the nearest specification limit is likely to drop over time, compared to an initial short-term study. To account for this real-life increase in process variation over time, an empirically-based 1.5 sigma shift is introduced into the calculation (Wortman, et al., 2007).

According to this idea, a process that fits six sigmas between the process mean and the nearest specification limit in a short-term study will in the long term only fit 4.5 sigmas – either because the process mean will move over time, or because the long-term standard deviation of the process will be greater than that observed in the short term, or both.

Therefore the widely accepted definition of a six sigma process is one that produces 3.4 defective parts per million opportunities (DPMO). This is based on the fact that a process that is normally distributed will have 3.4 parts per million beyond a point that is 4.5 standard deviations above or below the mean (one-sided capability study). So the 3.4 DPMO of a "Six Sigma" process in fact corresponds to 4.5 sigmas, namely 6 sigmas minus the 1.5 sigma shift introduced to account for long-term variation, see Figure 73 for a graphical representation of Six Sigma with shift

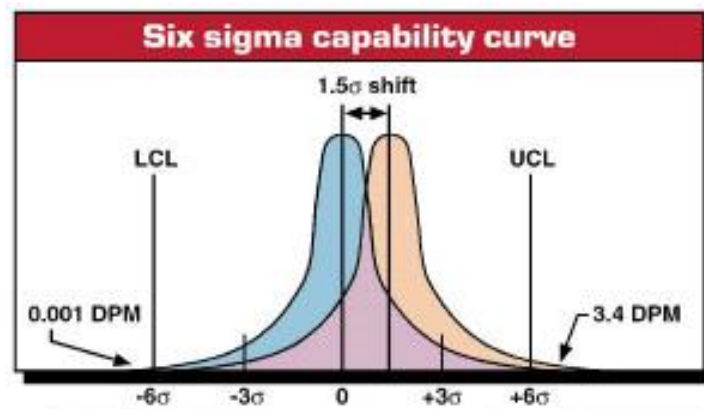


Figure 73 Six Sigma Shift, (source: Wortman, et al., 2007)

When examining the normal distribution the percent of process outside of each sigma is defined as follows:

- 1 sigma = 31% efficiency
- 2 sigma = 69.2% efficiency
- 3 sigma = 93.32% efficiency
- 4 sigma = 99.379% efficiency

- 5 sigma = 99.977% efficiency
- 6 sigma = 99.9997% efficiency

These figures assume that the process mean will shift by 1.5 sigma towards the side with the critical specification limit some time after the initial study determining the short-term sigma level. The figure given for 1 sigma, for example, assumes that the long-term process mean will be 0.5 sigma beyond the specification limit, rather than 1 sigma within it, as it was in the short-term study.

Going past the statistical definition, the Six Sigma key method, Define, Measure, Analyze, Improve and Control (DMAIC), was inspired by Deming's Plan-Do-Check-Act Cycle. DMAIC is used to improve an existing business process, see Figure 74. DMAIC 5-steps are defined as follows:

- Define high-level project goals and the current process.
- Measure key aspects of the current process and collect relevant data.
- Analyze the data to verify cause-and-effect relationships. Determine what the relationships are, and attempt to ensure that all factors have been considered.
- Improve or optimize the process based upon data analysis using techniques like Design of experiments.
- Control to ensure that any deviations from target are corrected before they result in defects. Set up pilot runs to establish process capability, move on to production, set up control mechanisms and continuously monitor the process.

Six Sigma - DMAIC

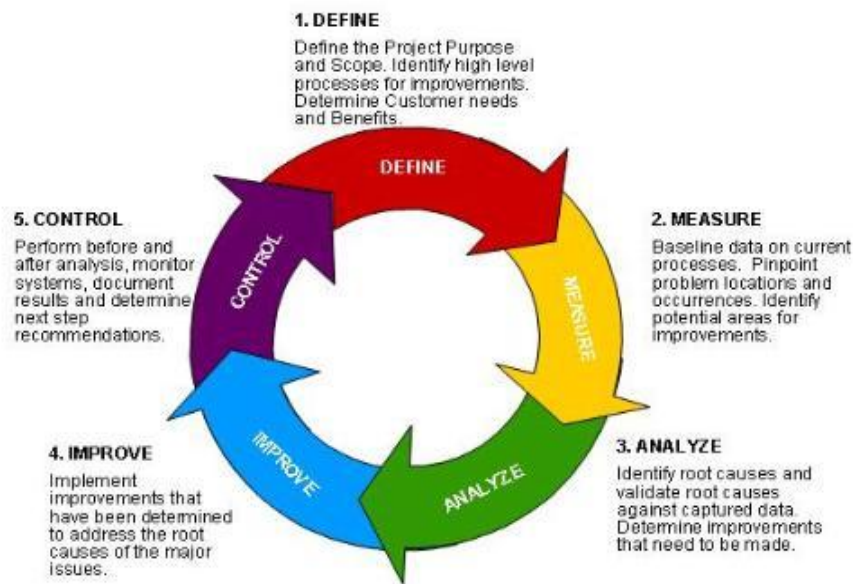


Figure 74 DMAIC Cycle (source: Adapted from Juran, 1988)

Six-Sigma makes use of a great number of established quality management methods that are also used outside of Six Sigma. The following table, IV shows an overview of the main methods used.

Table IV Six Sigma Tools

5 Whys	Histograms
Analysis of variance	Homoscedasticity
ANOVA Gauge R&R	Quality Function Deployment (QFD)
Axiomatic design	Pareto chart
Business Process Mapping	Pick chart
Catapult exercise on variability	Process capability
Cause & effects diagram (also known as fishbone or Ishikawa diagram)	Regression analysis
Chi-square test of independence and fits	Root cause analysis
Control chart	Run charts
Correlation	SIPOC analysis (Suppliers, Inputs, Process, Outputs, Customers)
Cost-benefit analysis	Stratification
CTQ tree	Taguchi methods
Quantitative marketing research through use of Enterprise Feedback Management (EFM) systems	Taguchi Loss Function
Design of experiments	Thought process map
Failure mode and effects analysis	TRIZ
General linear model	

(source: Author generated)

11.6.5 Lean Six Sigma

Working in manufacturing most quality specialists will realize that not every problem can be solved by using the lean manufacturing tools and techniques discussed in Chapter 6 nor can every problem can be solved using the DMAC process and sophisticated statistical techniques as utilized in a six sigma project. Table V looks at the summary of each of the techniques and Figure 75 graphically represents how the two transcend together to define which technique is applicable to the problem on-hand:

Table V Lean and Six Sigma Summary

	LEAN	SIX SIGMA
Goal	Create flow and eliminate waste	Improve process capability and eliminate variation
Application	Primarily manufacturing process	All business processes
Approach	Teaching principal and "cookbook style" implementation based on best practices	Teaching a generic problem-solving approach relying on statistics
Project Selection	Driven by Value Stream Mapping	Various approaches
Length of Projects	1 week to 3 months	2 to 6 months
Infrastructures	Mostly ad-hoc, no or little formal training	Dedicated resources, broad based training
Training	Learning by doing	Learning by doing, many hours of formal training

(source: Wortman, et al., 2007)

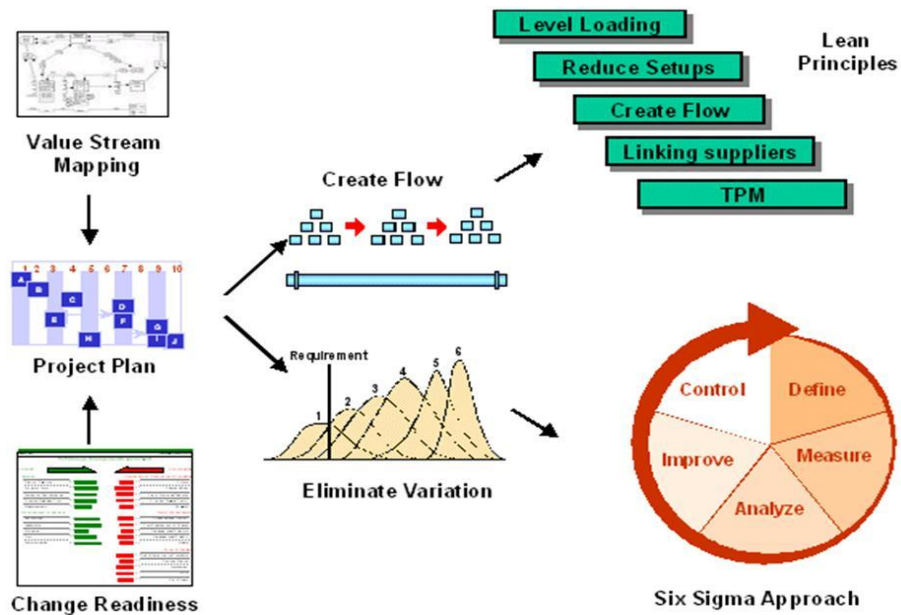


Figure 75, Lean and Six Sigma Choice Map (source: Wortman, et al., 2007)

As can be seen from Figure 75, the first step in a problem is to document the value stream map; define where the issues are. Complete the project plan and charter – defines what is the issue; who is responsible for solving; and who is sponsoring the

problem (has to have senior leadership buy-in and commitment). Now the decision is in place to choose whether it is necessary to improve flow or whether the process has too much natural variation.

As Figure 74 shows, there can also be some strong synergies between the two techniques. Table VI reviews some of the synergies:

Table VI Lean and Six Sigma Synergies

Lean	Six Sigma
Establish a method for improvement	Policy deployment methodology
Focus on customer value stream	Customer requirements measurement, cross functional management
Use a project-based implementation	Project management skills
Understand current conditions	Knowledge discovery
Collect product and production data	Data collection and analysis tools
Document current layout and flow	Process mapping and flowcharting
Time the process	Data collection tools and techniques, SPC
Calculate process capability and takt time	Data collection tools and techniques, SPC
Create standard work combination sheets	Process control planning
Evaluate the options	Cause-n-effect, FMEA
Plan new layouts	Team skills, project management
Test to confirm	Statistical methods for validation methods, SPC
Reduce cycle times, product defects, changeover times, equipment failures, etc.	Seven management tools, seven quality control tools, design of experiment

(source: Generate with Information from Wortman, et al., 2007)

11.6.6 Quality Tool Summary

The most difficult task for a quality profession is probably in the ability to recognize which type of problem needs resolution and which tool one should use. Figure 76 depicts the three problem solving tools discussed, a summary of problem type and the time commitment one should expect:

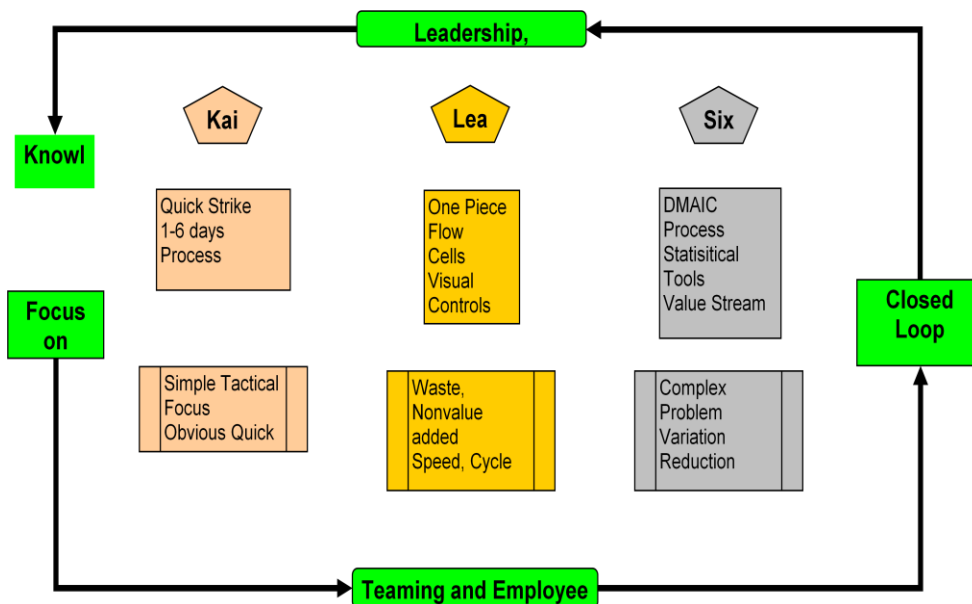


Figure 76 Kaizen, Lean Mfg and Six Sigma Summary (source: Breyfogle, 1999)

11.7 Quality Results

One of the more popular measurements of quality in the automotive industry is the JD Powers initial quality. JD powers initial quality is a survey of new car ownership. For example, the 2009 survey of model year 2008 was created by surveying roughly 81,000 certified owners after 90-days of ownership. The survey includes rating on defects and malfunctions as well as design quality (e.g. how well a feature actually works). The survey for quality is based on defects reported in several categories; overall quality of mechanical issues, power train mechanical issues, body and interior, and features and accessories.

Here we will examine JD Powers and Associates initial quality report by looking at the number of defects per new vehicle found for a sample number of Japanese

Company manufactured vehicles in comparison to American car company manufactured vehicles. Figure 77 represents the previous ten-years of this measurement.

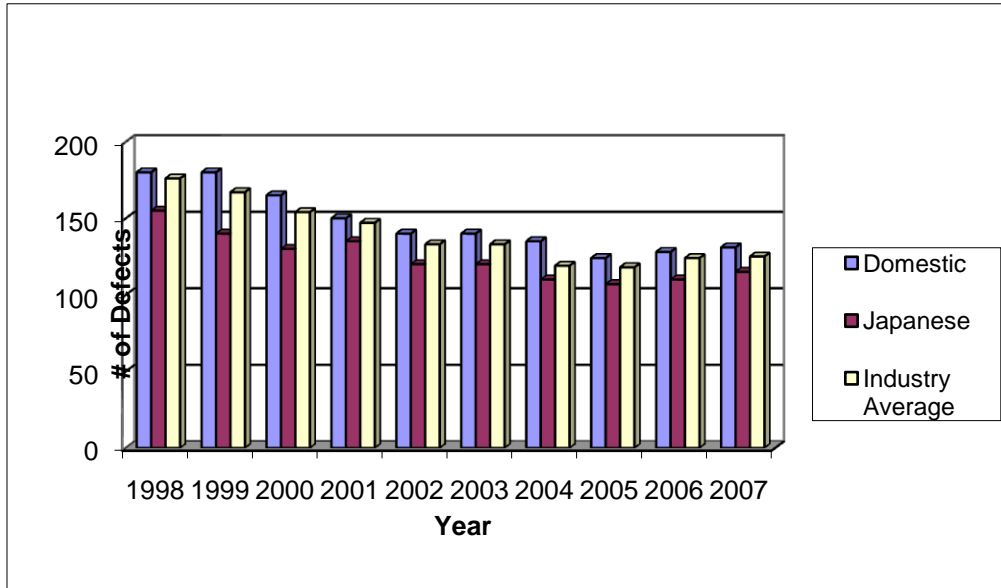


Figure 77 Initial Quality Report (source: created with data from JP Powers initial quality reports, 1998-2007)

This chart clearly shows the domestic manufacturers, as a whole, behind the Japanese manufacturers. The Japanese every year have less than the Industry average number of defects while the domestic plants have more defects per vehicle than industry average.

Assigning a value of 1 to 5 in each category in the reliability measurement and quality measurement then adding up the entire score and dividing by the maximum total score we can calculate a potential resale percentage. Table VII represents the resale grade.

Table VII Resale Grade

Vehicle	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Camry	100%	80%	100%	100%	100%	100%	100%	100%	100%	0%
Corolla	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%
Tundra			60%	60%	60%	60%	60%	40%	40%	0%
Accord	100%	100%	100%	100%	100%	80%	100%	100%	100%	100%
Civic	80%	100%	100%	100%	100%	100%	100%	100%	80%	100%
Focus			40%	60%	40%	60%	60%	80%	60%	80%
Malibu	40%	20%	20%	20%	20%	40%	40%	60%	60%	
Impala			60%	20%	40%	60%	60%	60%	40%	60%
Pilot						100%	100%	100%	100%	100%
Ridgeline									80%	80%
F150	60%	60%	60%	80%	80%	60%	40%	60%	60%	60%
Explorer	60%	60%	60%	60%	20%	40%	20%	60%	40%	60%
Silverado		60%	60%	60%	60%	40%	40%	40%	40%	60%
Suburban	40%	20%	60%	60%	60%	40%	40%	40%	60%	40%

(source: Created with data from Consumer Reports Annual Automotive Report, April 1998-2007)

When examining Table VII, it can be concluded that the Toyota and Honda results are more stable and of a higher value than the comparison to General Motors and Ford. The only exception is the results obtained on the recently introduced new Tundra, however, it can be expected that improvements will be made and the reliability and quality will be equal to those levels that Toyota produces on their passenger car lines based on their long history/legacy of continuous improvement.

A final look at quality is the ability of the automotive companies to produce vehicles that are not recalled. The following is a list of the top 11 recalls associated with the largest number of affected automobile at any one time (national highway safety administration database, 2010):

- 2008 Ford Recall – 12 million cars, cruise control switch catching fire when parked,
- 2010 Toyota Recall – 10 million cars, accelerator issues (note, this can be increased even further),

- 1996 Ford Recall – 8.6 million vehicles, ignition switch fires,
- 1971 GM recall – 6.7 million vehicles, engine mount bracket bolts coming loose and catching on throttle,
- 1981 GM recall – 5.8 million vehicles, suspension bolt failure causing steering failures,
- 1971 Ford recall – 4.1 million vehicles, seat belt shoulder harness failure,
- 1973 GM recall – 3.7 million vehicle, stones causing damage to steering assembly causing steering loss,
- 1995 Honda recall - 3.7 million vehicles, seat belt failures causing release and sticking after accidents,
- 1972 Volkswagen recall – 3.6 million vehicles, wiper arm failure affecting visibility during rain/snow weather,
- 2004 GM recall – 3.6 million vehicles, corroded tailgate cables causing tailgate drops, and
- 1987 Ford recall – 3.6 million vehicles, engine compartment fires

Figure 78 depicts the total number of recalls by Ford, General Motors, Honda and Toyota from 1995 through 2008:

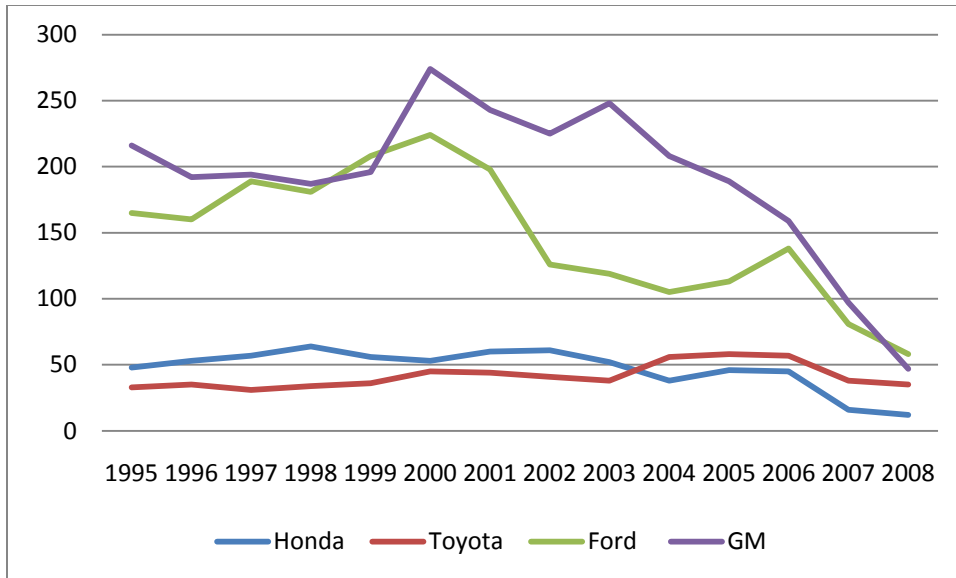


Figure 78 Total Number of Recalls (source: National Highway and Safety Administration database, 2010)

When looking at 2008, Honda sold 154,000 cars in North America per recall, while Ford sold 40,000, GM sold 63,000 and Toyota sold 84,000. Even though Toyota has been leading this area in the least amount of recalls, it is expected to be much worse for them in 2010 with the associated recalls of vehicles for the accelerator issue. More detail will be discussed for Ford and Honda in Chapters 17 and 18 respectively.

CHAPTER 12
ARCHITECTURE AND DEVELOPMENT OF THE PRODUCT/COMPLEX
SYSTEM

12.1 Introduction

The automobile is a technology that can be credited with changing society drastically over the last century. The automobile itself has changed drastically over the same period of time: the mode automobile's commonality with the first car is basically just four wheels and an engine to make it move. Little attention, from an academic standpoint, has been given to the history of the car nor has there been much attention to the technical history of the car itself.

One of the difficulties on studying the technology changes in the automotive industry is the sheer size of the population: there has been hundreds of millions of passenger vehicles produced since 1900 and there is a large variance of vehicle produced. Figure 79 depicts the number of vehicles produced by U.S. companies in the U.S. from 1897 through 2000 while Figure 80 represents the growth in the annual number of models available for sale in the U.S. from 1945 through 2008. Figure 79 shows that over 415 million cars have been produced in this period of time, by US companies alone.

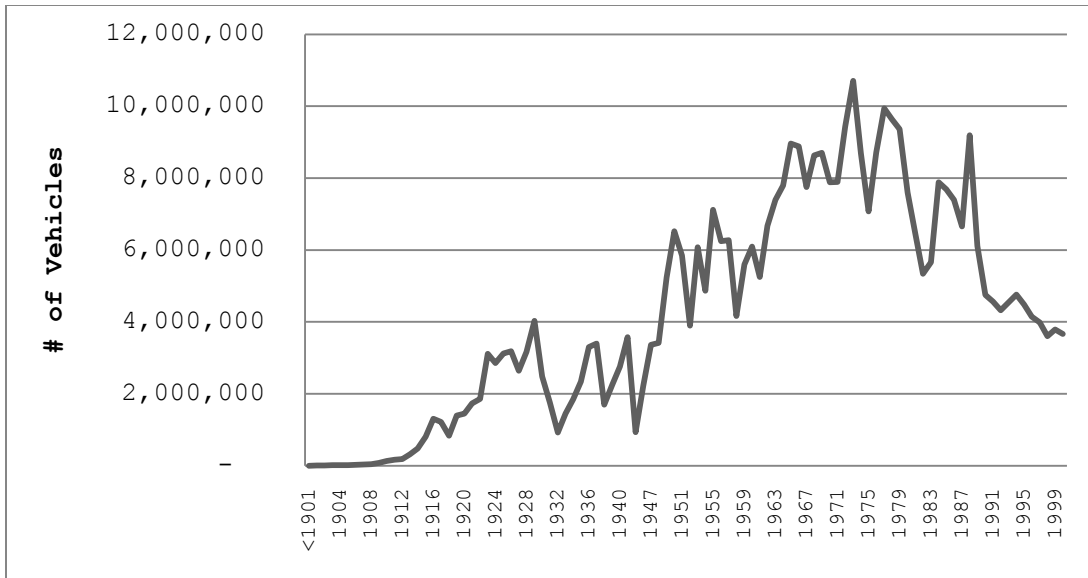


Figure 79 US Companies Auto Production Numbers (source: Ward’s Auto Data, 2010)

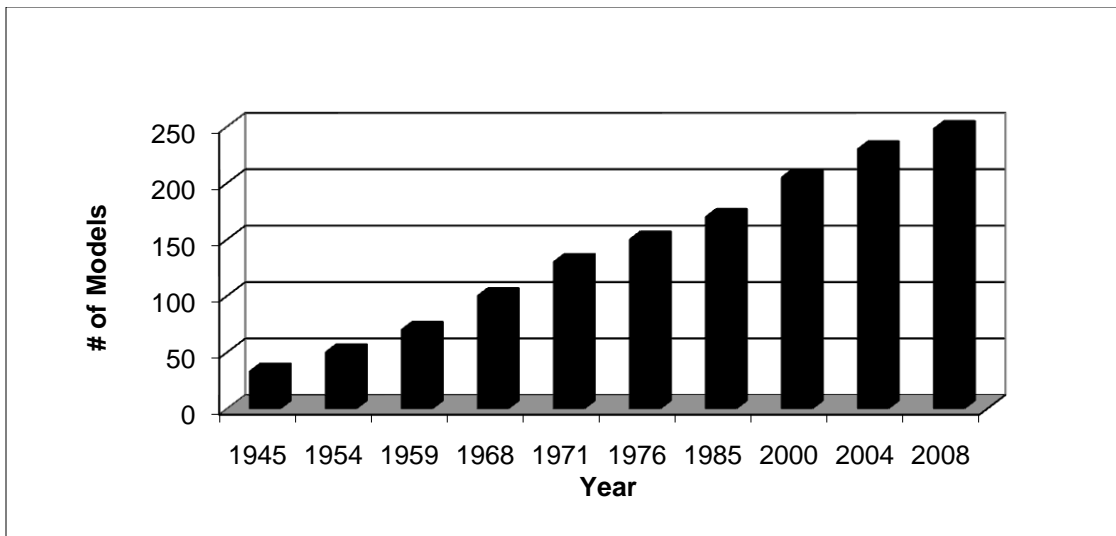


Figure 80 Increased Models of Vehicles (source: Ward’s Auto Data, 2010)

This chapter will examine the expansion of automotive complexity, how the vehicle is made up by a large number of components that work together in different systems. Automakers tend to make consumers believe that every model they introduce is “new” and “revolutionary”, in terms of design and technology. However when examined

closely at the actual changes, automotive technology progresses slowly with major innovations occurring infrequently.

This chapter will take “snapshots” at the early evolving automotive complexity/technology of mechanical/hydraulic systems and subsystems and evolving features over the last century and will use specific examples/illustrations to reinforce the evolving complexity of the systems and subsystems of a vehicle, (e.g. evolving tire technology, mechanical/pneumatic, hydraulic system, seat technology, safety features). This increase in these later systems, subsystem cost, weight, and complexity also began to pave the way for the later appearance and penetration of electronics, similar to how electronics penetrated many other industries.

12.2 System Approach Structure

Figure 81 depicts the architecture that will be used to outline the changes in automotive technologies. The system will start with the technologies used on Ford’s Model T automobile and be extended as technologies were improved, developed and implemented. Further examples of specific components, e.g. tires, will be expanded on to further clarify the extent of added complexity in the automobile industry.

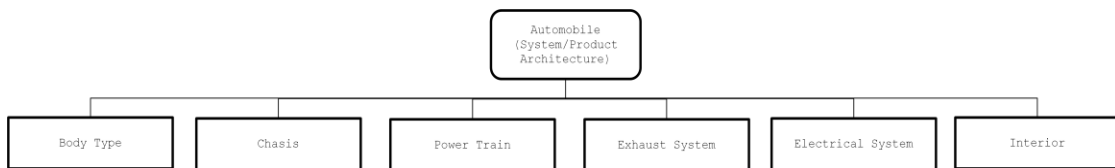


Figure 81 Automotive Architecture Structure (source: created by author to define system architecture for graphical representation)

12.3 Model T Architecture

As discussed in Chapter 3, Henry Ford developed many technologies in order to full-fill his dream of providing the average American the ability to afford a dependable, cheap car. Figure 82 represents the systems architecture of the technologies/components of the Model T.

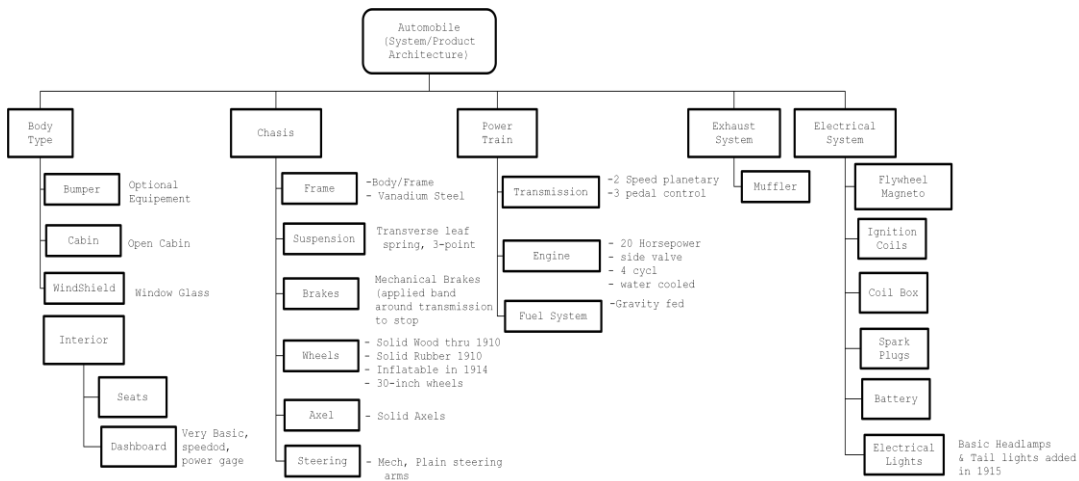


Figure 82 Model T Architecture (source: created with data from, Olson & Cabadas, 2002; Banham 2002; Erjavec 2005; Duffy 2009)

As can be seen from the figure, the architecture was very basic with no added features, no hydraulic systems and very basic and minimal electrical systems. The interior was very basic with only a few minor gages in the dash board. The cabin design was open with no side shields and wind shield constructed out of regular plain window glass, that when an accident occurred was very dangerous and caused severe injury. The next section will look at the developments from 1920s through the 1930s.

12.4 Developing Technology (1920s through 1930s)

The 1920s began the start of the consumer wanting/desiring augmentation to their vehicles. The population was demanding added features and comforts. General Motor came out with the car for every wallet, thus creating the path of the automobile being something of status. Figure 83 depicts the progression of the automobile architecture.

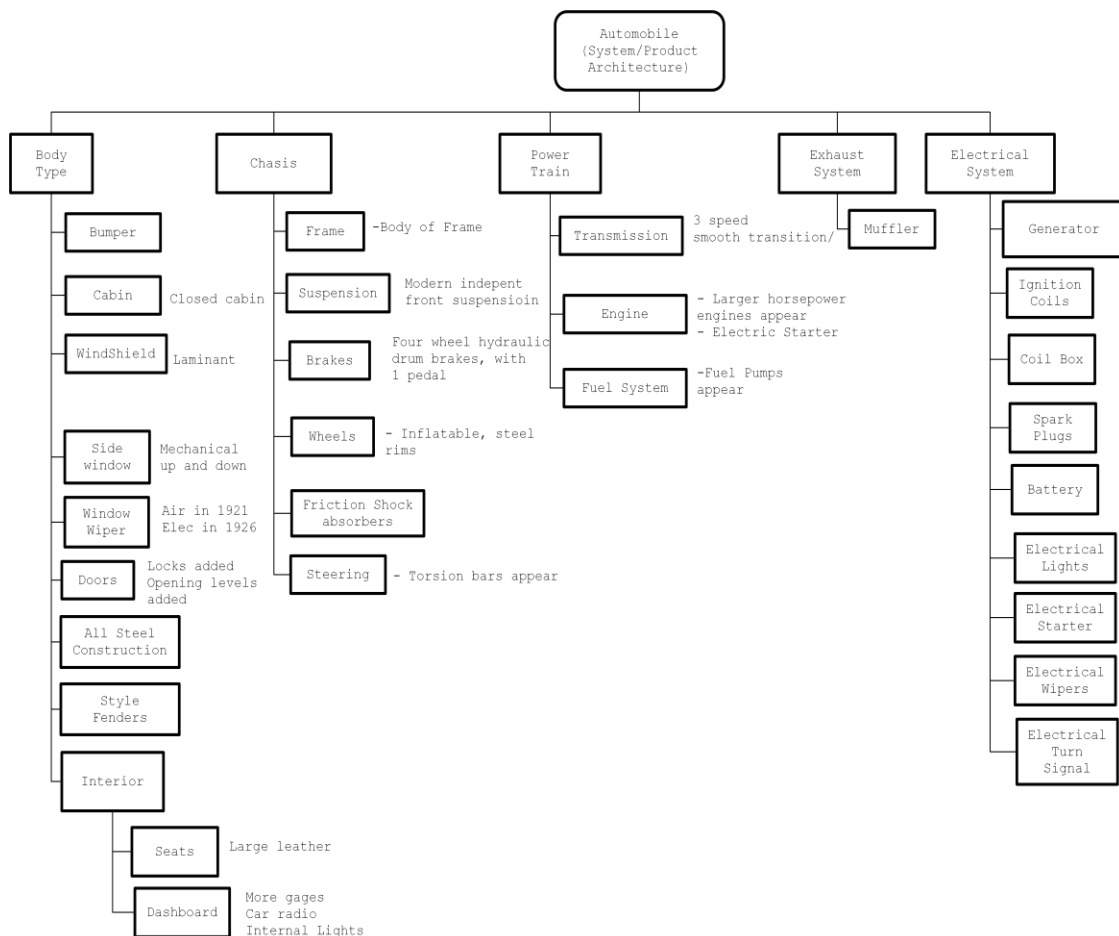


Figure 83 Automotive Architecture 1920s through 1930s (source: created with data from, Olson & Cabadas, 2002; Banham 2002; Erjavec 2005; Duffy 2009)

As can be seen from the above architecture, the main growth area was augmentation, something that still dominates as the main feature from model year to

model year. More people were driving and earning better incomes due to the growth of the automotive industry and supporting industry (incomes discussed in great detail in Chapter 14), which meant people were in their cars for a longer period of time and wanting added comfort. However, with the added improvements in comfort and control features, the downfall was a more complicated system to design and build. For example: an additional piping/plumbing network of tubing to support the hydraulic braking system was needed and a network of array of electrical wiring to support the additional electrical features (electric starter with ignition switch, wipers, radio, turn signals, interior lighting) was also necessary; thus, entering the automobile in a path of increasing complexity.

Figure 84 depicts a basic hydraulic braking system.

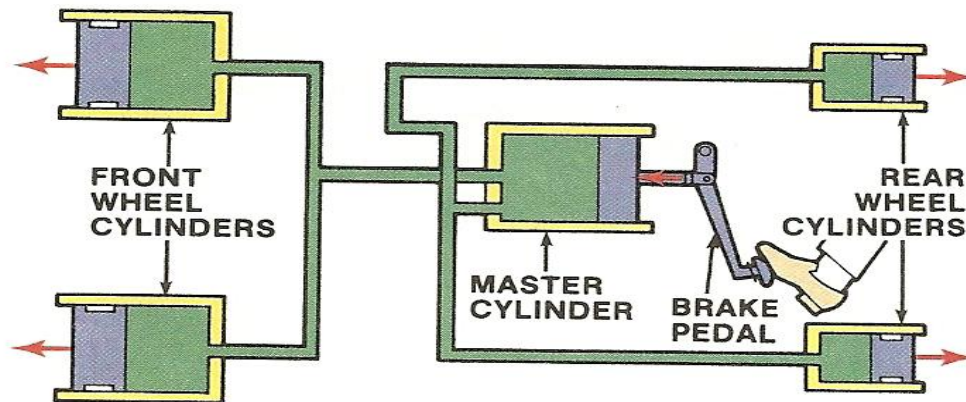


Figure 84 Simple Hydraulic Braking System (source: Erjavec, 2005)

With this addition of the braking system, it became necessary to add hydraulic lines throughout the entire frame, with clips and clamps, rubber absorbers and additional room under the hood for the pedal linkages tying into the master cylinder. The next section

looks at the additional development in complexity in the automobile from the 1940s through the 1950s.

12.5 1940s through 1950s increasing complexity

After the Great Depression and World War II, Americans found themselves in a tremendous industrial growth period, mostly due to the lack of global competition from around the world due to the heavy destruction of factories in Europe and Japan. Figure 85 depicts the changing architecture from early decades into the 1940s through the 1950s.

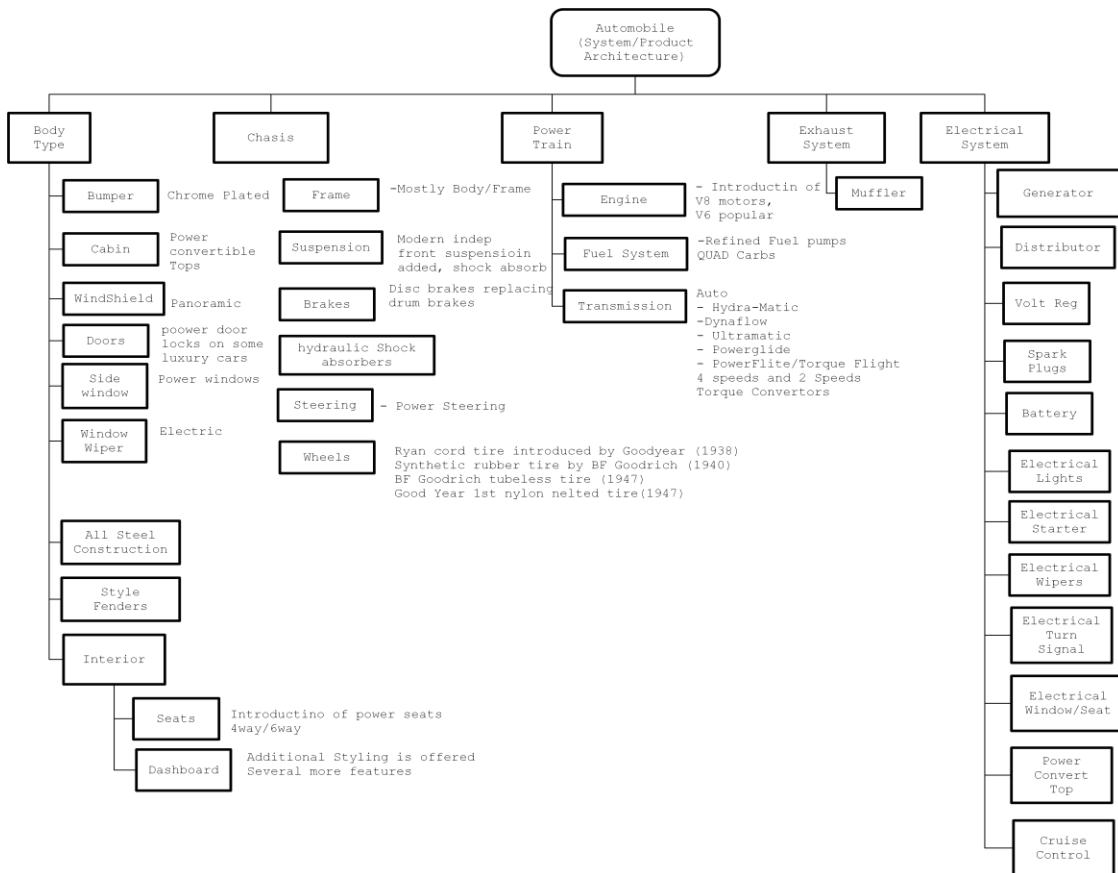


Figure 85 Automotive Architecture 1940s-1950s (source: created with data from, Olson & Cabadas, 2002; Banham 2002; Erjavec 2005; Duffy, 2009)

The mode of operation for the U.S. auto industry was slow innovative additions and augmentation of features. Styling in hood and fender was accelerating with other comfort and convenience features (e.g. hydro-electrical convertor power roofs, power locks, electric windows, electric seats, cruise control). Some refinement of engine technology was taking place in order to make the cars bigger and more powerful to “cruise” the newer road systems with the top down. Many of the automotive manufacturers were developing their first three-speed automatic transmissions as noted above. All of these added features are making the system more and more complex making communications between modules even more necessary (e.g. transmission needing to sense rpm values of the engine). An example of these augmentations and additional styling can be seen in as something as the dashboard. Figure 86 depicts some changes from 1915 to 1955.



Figure 86 Dashboards of 1915 Model T, 1935 Slant back Ford, and 1955 Thunderbird (source: Ford Motor Company – Company History, 2004)

12.6 Architecture of the 1960s

The 1960s were probably most noted for the continued growth and development of the car engine and the introduction of the “muscle” cars, most notably the Ford Mustang and eventually the GM Camaro (1964 and 1967 respectively) to compete. Transmissions were changing to the standard three-speed with torque convertors, turbo charges were being introduced and used frequently, and even fuel injection was being introduced in some vehicle, frames were moving from the body over frame to the modern monocoque. Figure 87 depicts the automotive architecture of the 1960s.

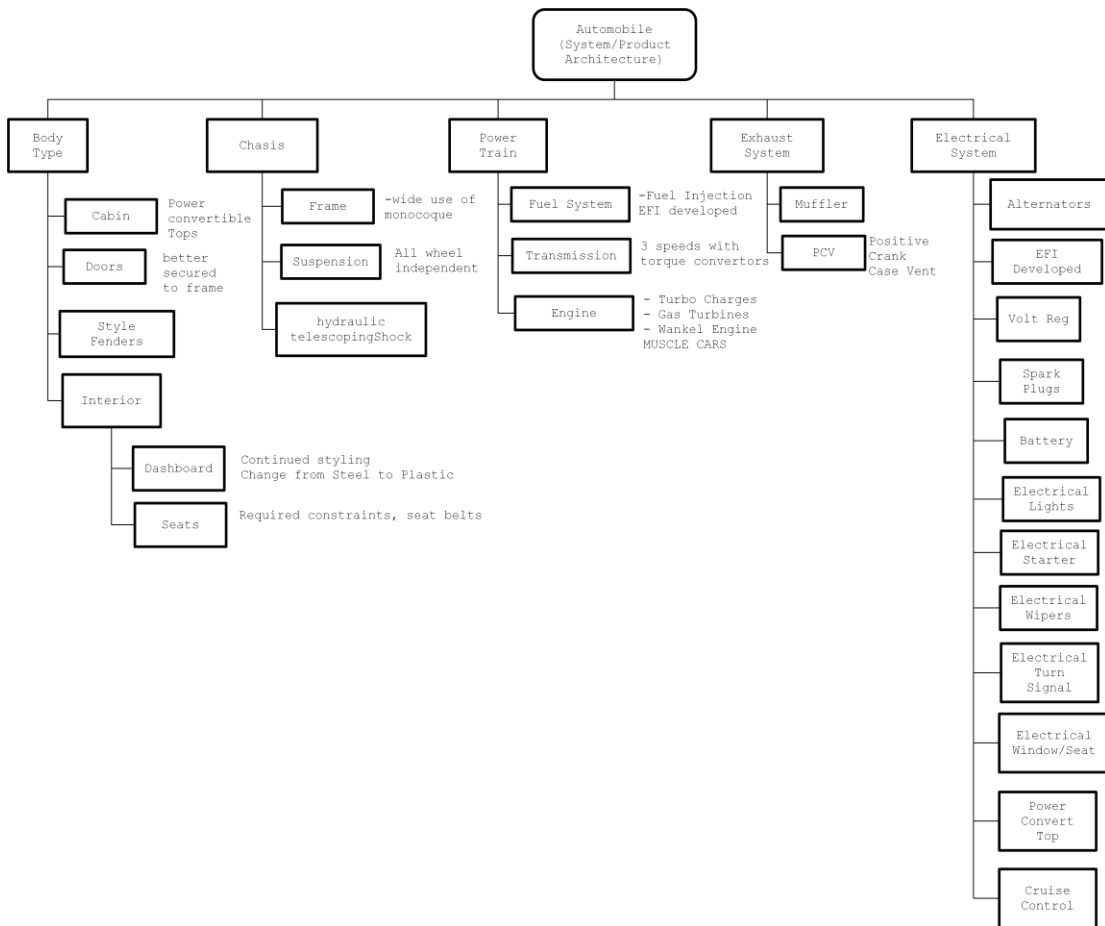


Figure 87 Automotive Architecture 1960s (source: created with data from, Olson & Cabadas, 2002; Banham 2002; Erjavec 2005; Duffy, 2009)

However, three things were occurring or about to occur that would send the automotive industry drastically in a different direction. First, California, among many other states, was complaining about the pollution (smog, or unburned hydrocarbons) being generated by the cars. These complaints of pollution drove the automotive manufacturers to incorporate the positive crank case vent valve (PFC) in California in 1961 and the rest of the nation one year later. This first step was just the beginning of what the automotive industry was to face moving forward.

Secondly, as discussed earlier, Ralph Nader, among other advocates, was gaining the national attention about how unsafe and deadly vehicle crashes can be. His 1965 book, “Unsafe at Any Speed”, and work eventually led Congress to pass the 1966 Traffic and Motor Vehicle Safety Act.

The third just about to occur in the early 1970s was the Oil Embargo, which made gasoline a difficult and expensive (relatively speaking) commodity to obtain. The oil embargo resulted in the demise of the gas guzzling muscle cars of the time and opened the door for strong competition from foreign manufactures producing higher miles per gallon vehicles. As consumers began purchasing Hondas and Toyotas the US population also realize the gap in quality and reliability as discussed in Chapters 10 and 11.

12.7 Automotive Architecture, 1970s - 1980s

The Automotive industry in the 1970s and the 1980s seen a tremendous growth in technologies and system complexity, basically they need to change to comply with the changing environment encompassing their industry. Basically cars had to become safer, get better fuel economy and do it by polluting less. With the introduction of the micro

processor, many opportunities presented themselves for incorporation to answer all of these challenges. Figure 88 depicts a shot of what the automotive architecture resembles in the 1970s and 1980s.

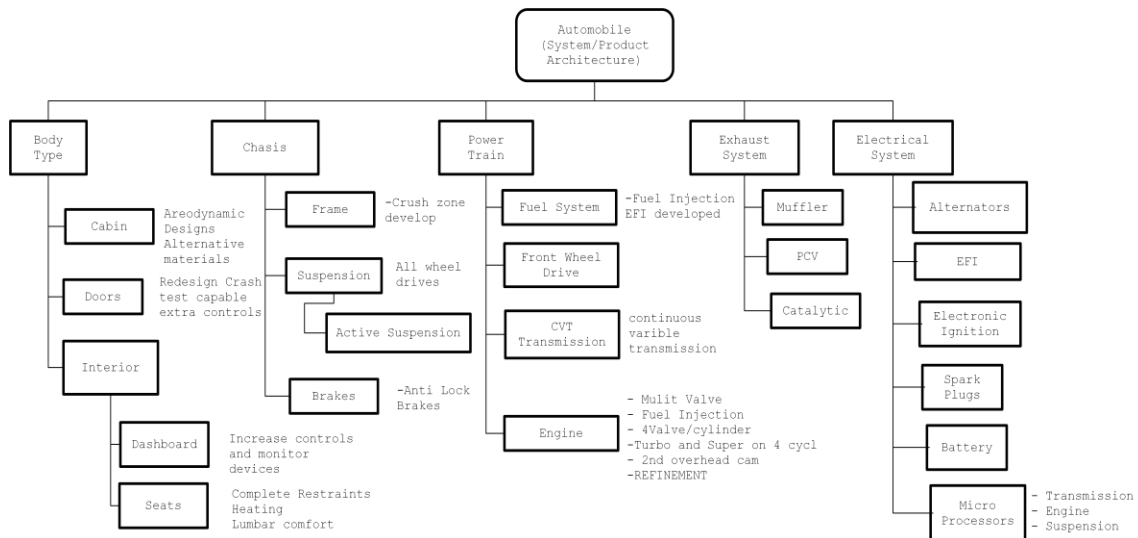


Figure 88 Automotive Architecture 1970s through 1980s (source: created with data from, Olson & Cabadas, 2002; Banham 2002; Erjavec 2005; Duffy 2009)

As can be seen from the above figure, the complexity of the automobile is increasing through the use of “smart” systems by the advent and incorporation of the micro processors. To even further detail this complexity and the necessity of the different modules needing to communicate, and work together, Figure 89 depicts the anti-lock braking system and Figure 90 depicts the active suspension system from a 1989 Chrysler.

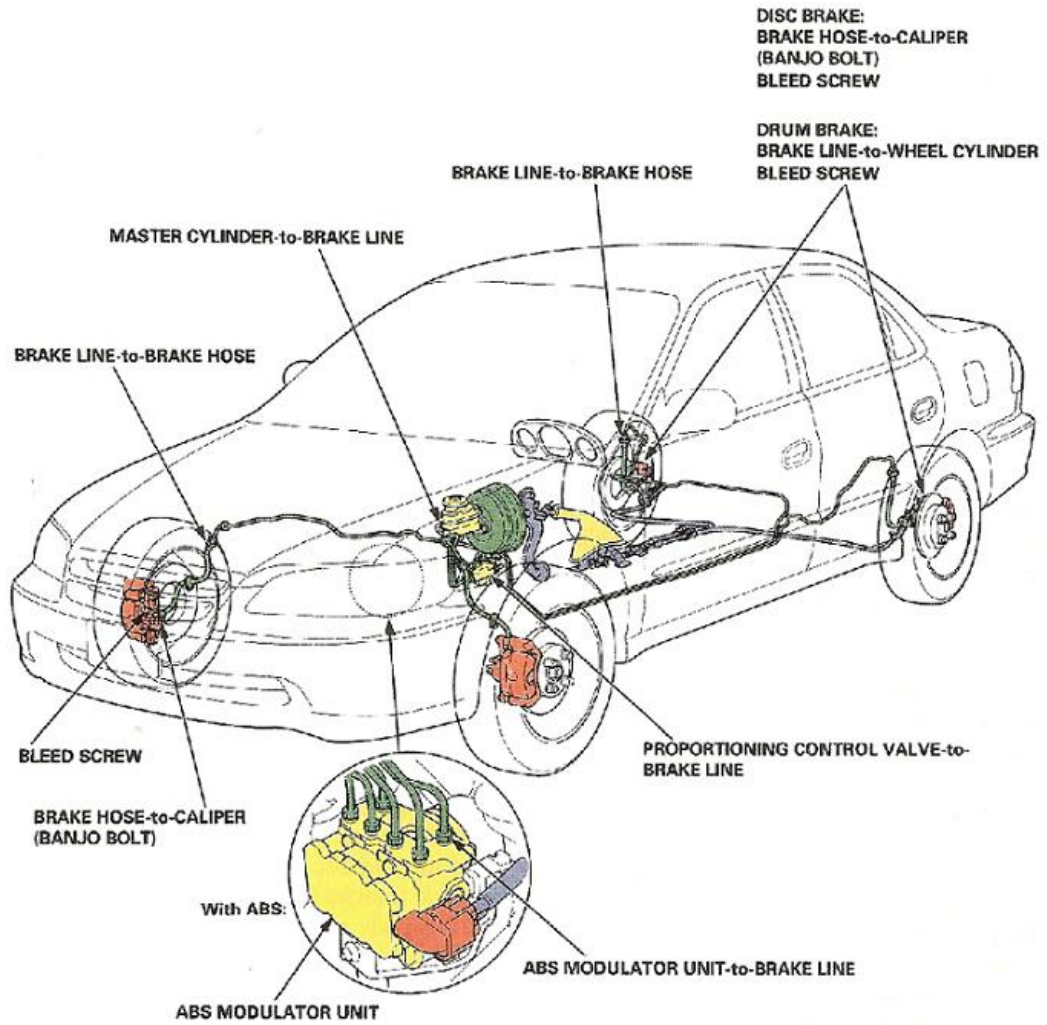


Figure 89 Anti Lock Brakes System (Source: Erjavec, 2005)

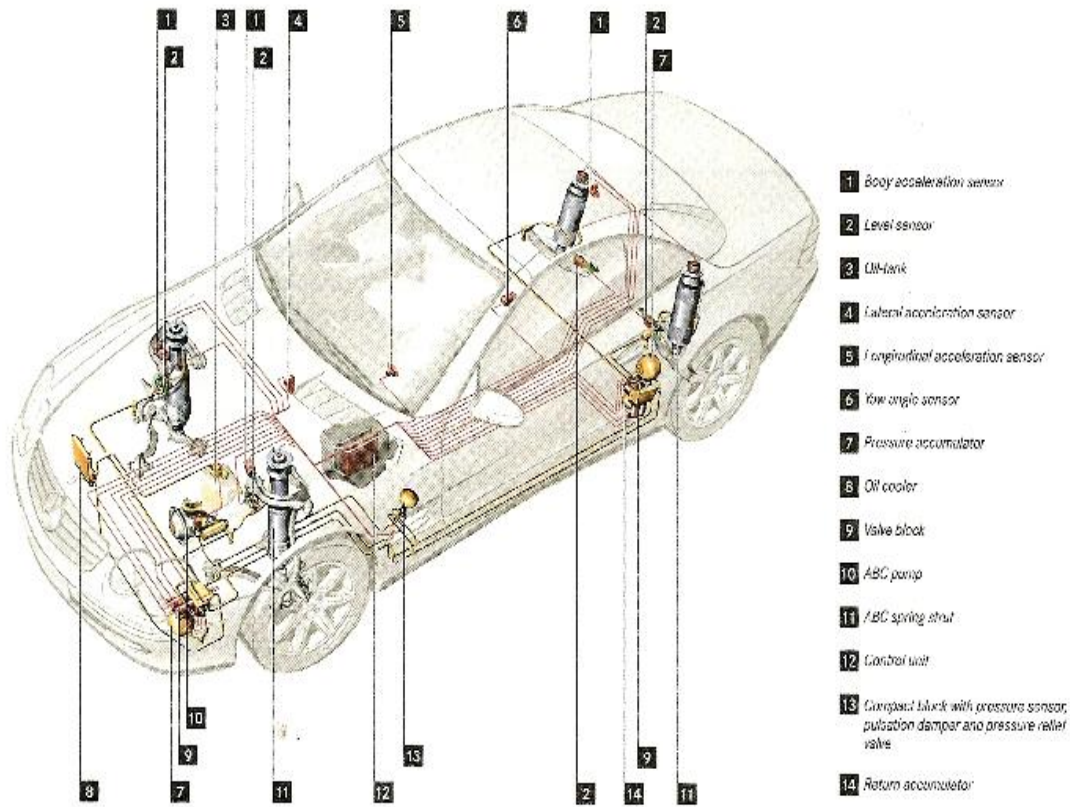


Figure 90 Active Suspension System (Source: Erjavec, 2005)

12.8 Automotive Architecture, 1990s to Present

The 1990s through present can be easily compared with the period of 1960 through 1980. First, the United States witness the drop in crude oil price, see Chapter 13, that gave birth the big, profitable gas guzzling sports utility vehicle (SUV). Then gasoline price exceeded \$4/gallon, while at the same time, global warming issues came to light; similar to the activities of the 1970s. Safety also became a critical issue with Ford's roll over issue.

The SUVs were built on the light truck platform, which exempt the "Big 3" from meeting the CAFÉ standards. As environmental issues rose due to the global warming

issues, mainly due to carbon dioxide from burning of fossil fuels, the “Big 3” began tweaking their SUVs so that it could classify as multi-fuel source (able to consume ethanol), which resulted as a easy way to get dollar credits from the government (McCarthy, 2007). Figure 91 represents the automotive architecture of the 1990s through present.

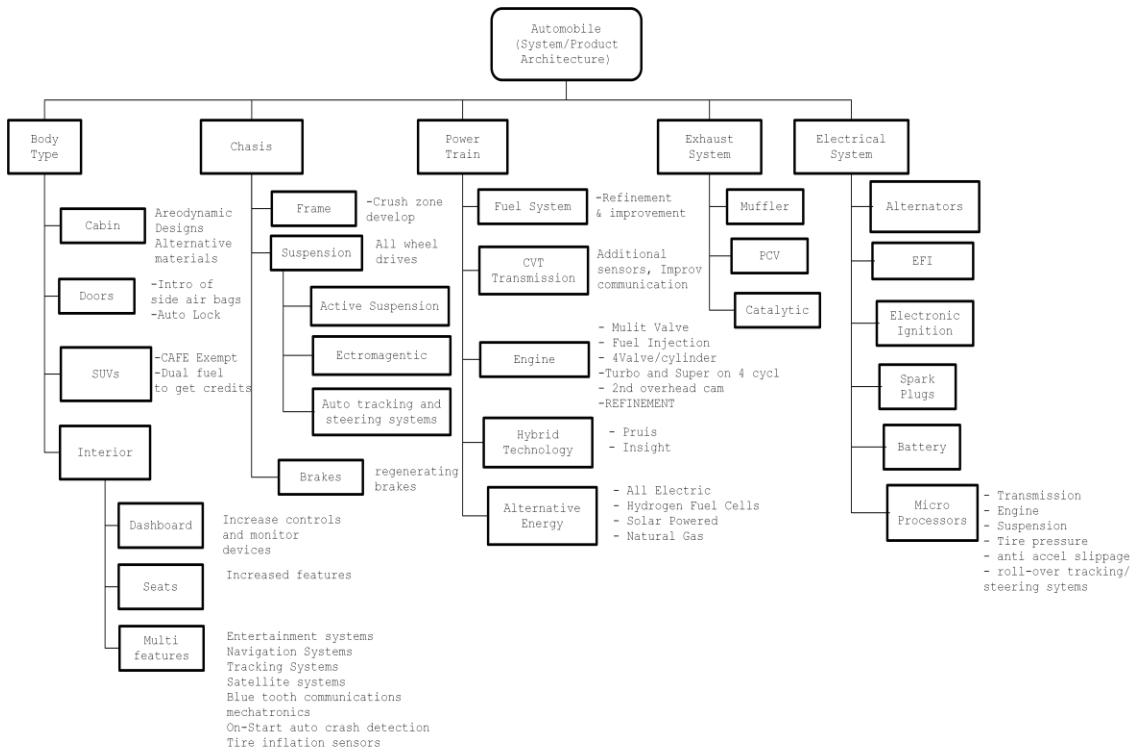


Figure 91 Automotive Architecture 1990s – present (Source: created with data from, Olson & Cabadas, 2002; Banham 2002; Erjavec 2005; Duffy 2009)

As can be seen from Figure 91, the system is fairly complex with many of these items interfacing with each other. To further Illustrate the complexity of everything the automobile is now monitoring to ensure proper operation, Table VIII provides a simple list of different sensors that are employed on the automobile. Each of these evolving

various electronic subsystem networks, in general, were mostly separate wiring (harnesses) connecting only their separate components; even when they began to become microprocessor based, and connected by optical fiber (improved communication speed) wiring.

Table VIII Automobile Sensors

Adaptive suspension	Camshaft reference	Engine speed
Air bag	Crank shaft timing	Fuel injection
Air conditioning	Disc pad wear	Hall-effect
Audible	EGR valve position	Ignition system
Barometric pressure	Engine position	Manifold abs pressure
Mass airflow	Temperature -air	Vacuum
Metal detection	Temperature - coolant	Variable resistor
Oxygen	Throttle Position	Vehicle speed
Photoelectric	Tire pressure	Wheel Speed

(source: Erjavec 2005)

Another good example of component complexity is a snap shot of something as basic as a seat that been around longer then the automobile itself. It now comes with message units, heating units, lumbar support systems, 6 (or more) adjustment directions, and head rest adjustments (all electric). Figure 92 depicts a typical seat with multi-function options.

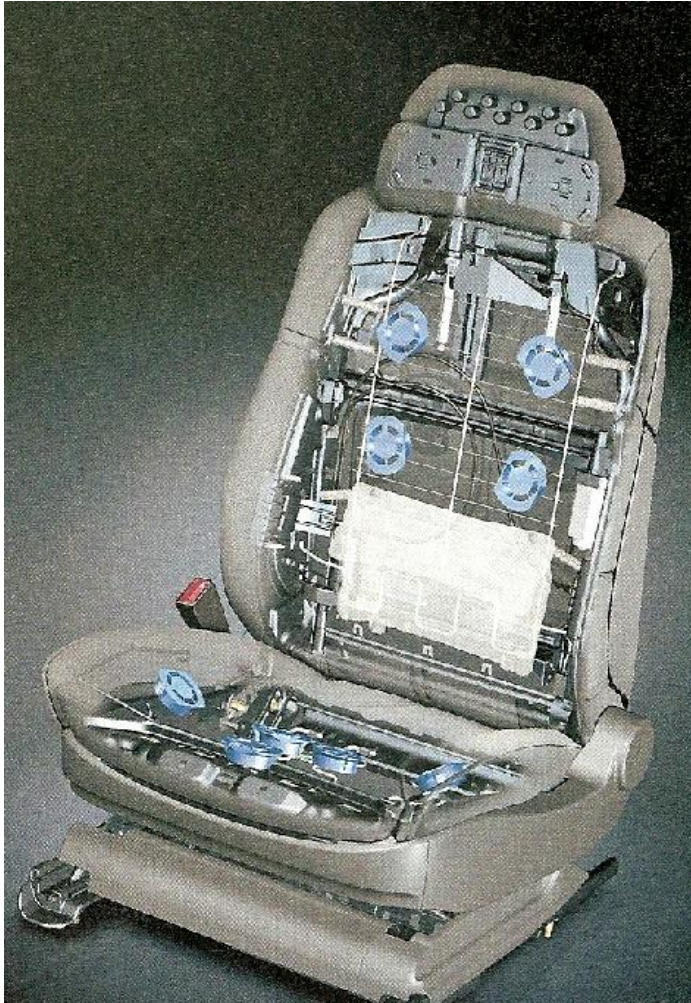


Figure 92 High Option Seat (Source: Erjavec, 2005)

12.9 Additional Role of Electronics

The automobile is a fairly large investment for the average wage earning American and of that cost it is estimated that the electronic on board of the average automobile accounts for roughly twenty percent of the total cost (Sullivan, & Winkowski, 2006).

Some of the functions that electronics play on the automobile today and will be discussed include:

1. Electronic engines control for minimizing exhaust emissions and maximizing fuel efficiency (more or less mandated the tough emissions standards starting in the 1970s and expected to become even tougher as global warming increases),
2. Instrumentation for measuring vehicle performance and for diagnosis of on-board systems malfunctions. This will be talked about in greater detail later in after market and service chapter,
3. Drive line control,
4. Vehicle motion control,
5. Safety and convenience, and
6. Entertainment, communications and navigation

Some more interesting usages and facts about electronics are pointed out by Erjavec (2005) are follows:

- Approximately eight percent of the vehicle's functions are controlled by electronics,
- Due to safety regulations and performance, anti brakes that were once an option of vehicles are now standard equipment,
- Adaptive control suspensions,
- Many computers are used to control the engines, transmissions, security systems, instrumentation, and climate control,

- Vehicle diagnostic systems predict breakdowns and contact emergency roadside services and guide technicians. On-Star, Blue Tooth are some examples,
- Brake lights vary in size and brightness according to pressure applied to the brake pedal,
- Headlights have moveable reflectors that allow the lights to follow the curves of the road,
- Vehicles are now available with an infrared system that provides improved vision at night and in bad weather,
- Sensors and video cameras are now being added to vehicles to remove hidden/blind spots, and
- Intelligent cruise control devices combine speed control with braking. The vehicle's brakes will be applied automatically to maintain safe distances between moving vehicles.

These added features, either for comfort or to address social and environmental issues, are made possible by the incorporation of electronics. As result, however, the automobile electronic components, system suppliers and the acid battery suppliers have all been working on moving from a 12 volt to a 48 volt system. But the similar size, weight and reliability of the 48 volt battery has been a lot harder to develop than expected.

12.10 Tire Example

One of the most basic items and most recognizable features on the car has gone through tremendous change in the 100+ year history of the automotive industry. And in fact, the tire, or wheel, it predates the automotive vehicle by many years. Figure 93 depicts the basic history of the automotive tire while Figure 94 pictorially represents the bias ply (early type), the bias ply belted (used predominately in the late 1960s to mid 1970s) and the current tire in use, radial ply belted.

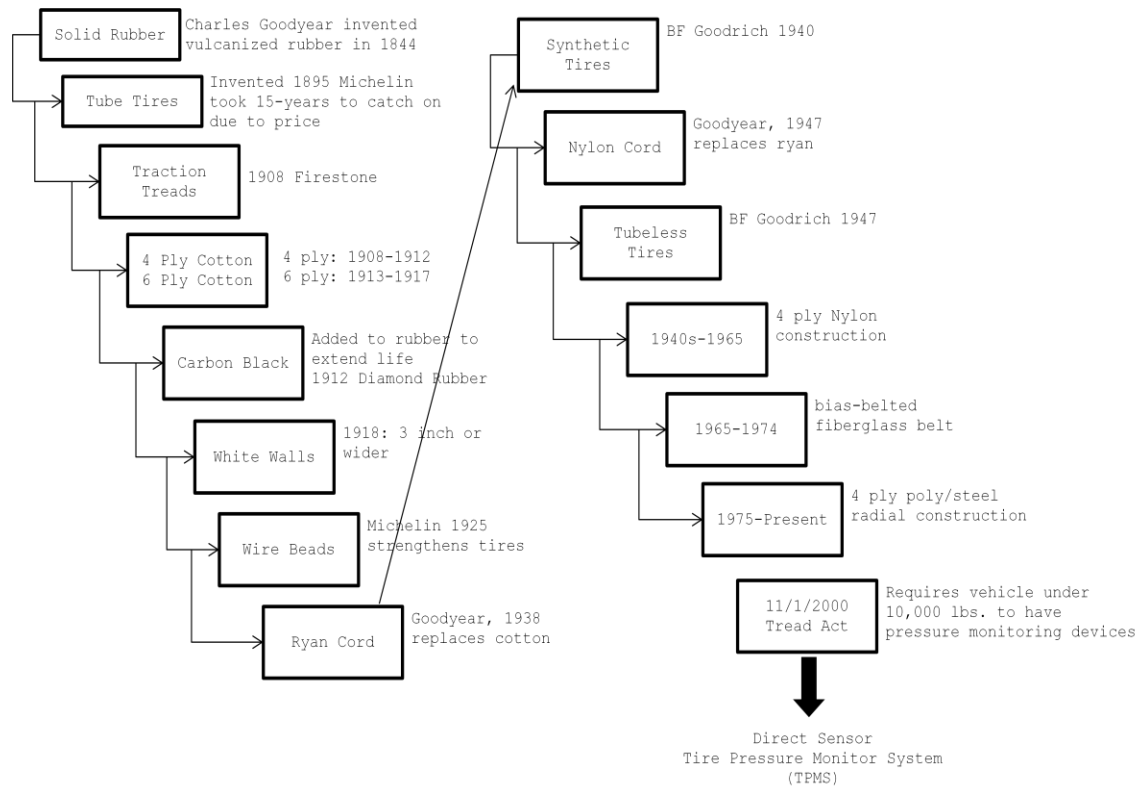


Figure 93 Basic Automotive Tire History (source: created with data from Bellis, 2004)

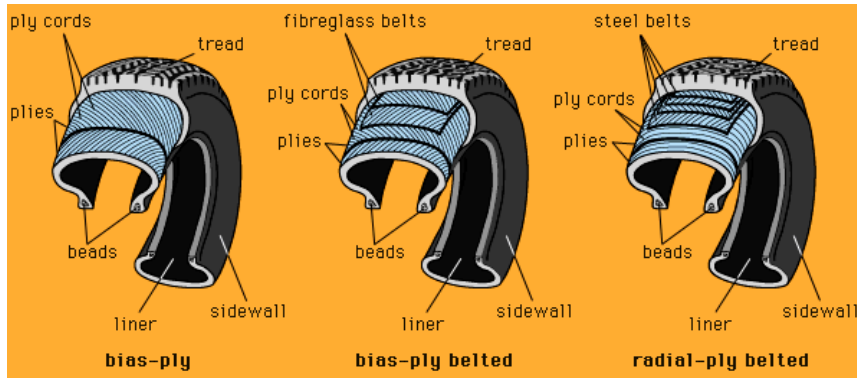


Figure 94 Bias vs Bias Belted vs Radial (source: Erjavec, 2005)

As can be seen from the figures, tires have undergone many changes over the last century. But basically the tire is the point of contact between the automobile and the road surface. Its main purpose or function is to provide traction for acceleration and braking and limits the transmission of road vibrations to the automobile. So most of the above changes to the tire have been to satisfy those basic functions; to make the tire last longer and enhance performance while providing stronger, quicker turning response, comfort (limiting vibration and road noise), while, providing better traction/adherence to the road. Automotive tire design and most importantly tread design play major roles in this challenge. Figure 95 give a more detail make up of the tire, while figure 96 gives some sense of the amount of different tread designs are produced.



Figure 95 Modern Tire Design (source: Automobile Tires, 2007)

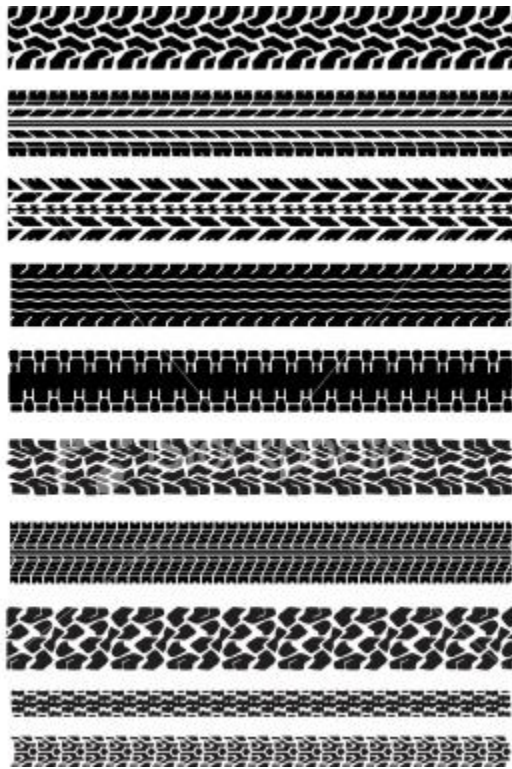


Figure 96 Various Tread Designs (source: Automobile Tires, 2007)

Figure 96 shows how complex the tire can become just by attempting to produce a tire that can remove water (prevent hydroplaning), snow, mud and maintain performance, control, safety and comfort.

Perhaps the most complex addition to the tires was the recent addition of the wireless tire pressuring monitoring system (TPMS). As a response to the Ford Explorer roll-over problem, congress passed the Tread Act on November 1, 2000. This Act basically requires continuous automatic monitoring of air pressure on all vehicles less than 10,000 pounds.

In summary, this chapter identified how complex the automobile has become, and identified some of the major factors to purchase their products. Chapter 21 will provide some perspective of the continuing growth of this complexity.

CHAPTER 13
INCREASED OIL CONSUMPTION AND IMPORTED OIL DEPENDENCY
(Recent History)

13.1 Introduction

America's oil supplies were cut off on October 17th, 1973 by Saudi Arabia and several of its oil-rich neighbors. Within a couple of days, Libya raised the price of a barrel of oil from \$4.90 to \$8.25 to other countries that it supplied and cut America off of its oil. Within four days, other Arab nations, including Dubai, Qatar, Bahrain and Kuwait, in frustration to Israel's military victory that month (Yom Kippur War), cut America off as well. These countries are part of the Organization of Petroleum Exporting Countries (OPEC) founded in 1960 in Iraq, to promote the interests of producer nations. OPEC was originally made up of Iran, Iraq, Kuwait, Saudi Arabia and Venezuela and grew in 1971 grew larger to include Qatar, Indonesia, Libya, United Arab Emirates, Algeria and Nigeria.

Saudi Arabia alone controls roughly twenty-five percent of the estimated oil reserves and coupled with its four neighbors, those percentages increases to two-thirds of the known world reserves, (source, Energy Information Administration, retrieved 7/6/09).

This chapter will look at the ever increasing dependence of foreign oil and offer a perspective of how of the last twenty five years of interruptions have reshaped the American Auto Industry or how this dependence becomes a deficiency and an economic (and environmental) challenge.

13.2 U.S. Oil Production Capability & Refinement

In 1973, the year of the first oil embargo, the United States produced roughly 3,360,903,000 barrels of oils, thirty-four years later, in 2007, the annual crude oil production fell drastically, to a level of production of 1,848,450,000 barrels. Figure 97 graphically represents United States crude oil production from 1970 to 2007.

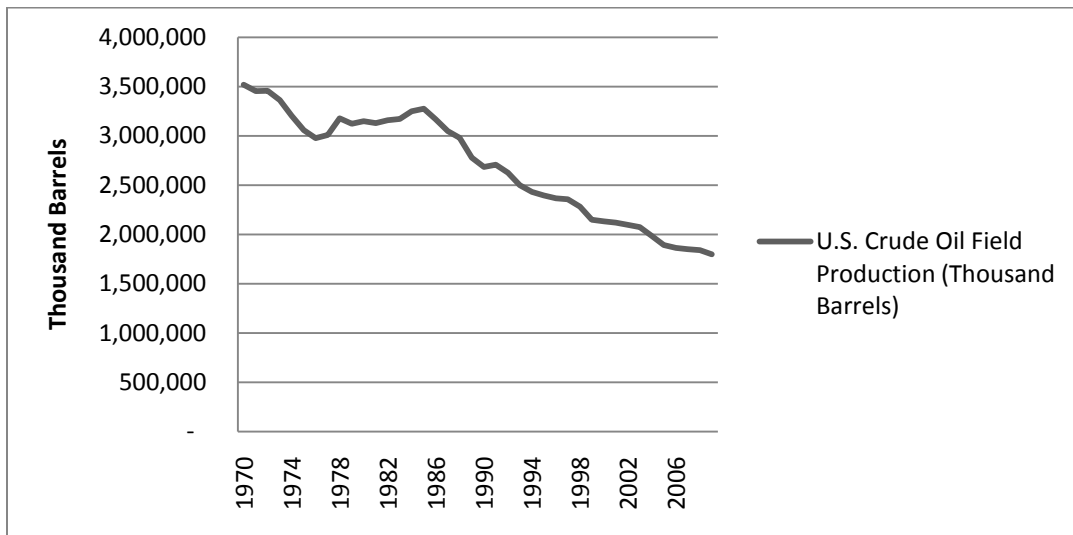


Figure 97 US Crude Oil Field Production (source: Energy Information Administration, 2009)

As can be seen from Figure 97, United States crude oil production has been in decline for many reasons, since several environmental studies performed starting in the late 1960's and a 1969 triggered by an accident on an Union Oil rig, that produced a large

oil slick off the coast of Santa Barbara, California (Flannery 2005). The government championed the cause of the environment, created the Environmental Protection Agency (EPA) in 1970, and pressured the refining industry and automobile manufacturers to clean up their act. Over the last several decades there has been several such oil spill accidents that have created environmental issues, such as the oil spill from the Valdez off the coast of Alaska in 1989. The *International Tanker Owners Pollution Federation Ltd* has maintained statistics of such spills since 1970 and Figure 98 depicts such statistics:

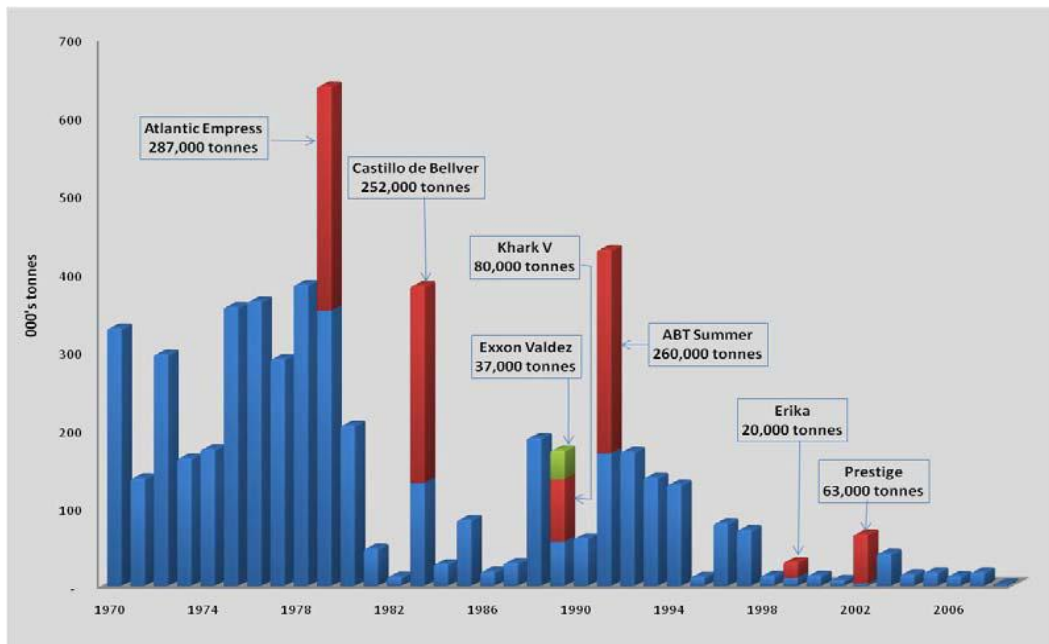


Figure 98 Major Oil Spills (source:oil tanker spill statistics, 2008)

When investigating the number and trends of refineries in the United States, one must consider the environmental issues of operating a refinery. According to the Environmental Protection Agency, (1994), refineries are a significant source of nitrogenoxides (NO) from the boiler, process heaters, fluid catalytic cracking units and

tail gas incinerators. These processes generate approximately 371,800 tons of NO_x annually while having the capability of processing roughly 15 million barrels of crude oil per day. No new refineries have been built in the United States since the refinery in Garyville, Louisiana, was brought on-line in 1976. There are a few reasons why no new refineries have been built. The last attempt to build a refinery was by Energy in the late 1970s near Portsmouth, Virginia; environmental groups and local residents fought the plan and it took almost nine years of battles in court before federal and local state regulators before the company cancelled the project.

Industry officials estimate the cost of building a new refinery would cost between \$2 billion and \$4 billion, this at the time the industry is required to invest close to \$20 billion over a decade to reduce the sulphur content in gasoline. In order to build a refinery, the company could potentially have to obtain 800 different permits, and the industry's long-term rate of return (given the volatility in the market) is only five-percent.

Figure 99 show the number of refineries in the United States from 1982 to current.

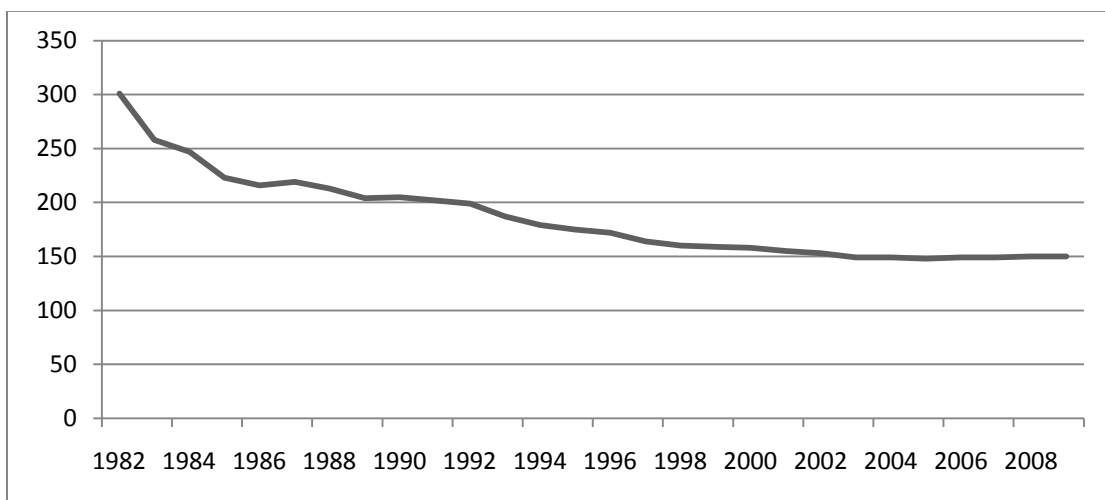


Figure 99 US Number of Operable Refineries (source: Energy Information Administration, 2009)

As can be seen from the above graph, the total number of refineries have been on the decrease over the last several decades from 300 to 150, while gasoline production has increased from approximately 6,000,000 barrels per day to roughly 8,000,000 per day, mostly due to process efficiency improvement introduced at the refineries, however, it can also be seen that these improvements have leveled off, see Figure 100.

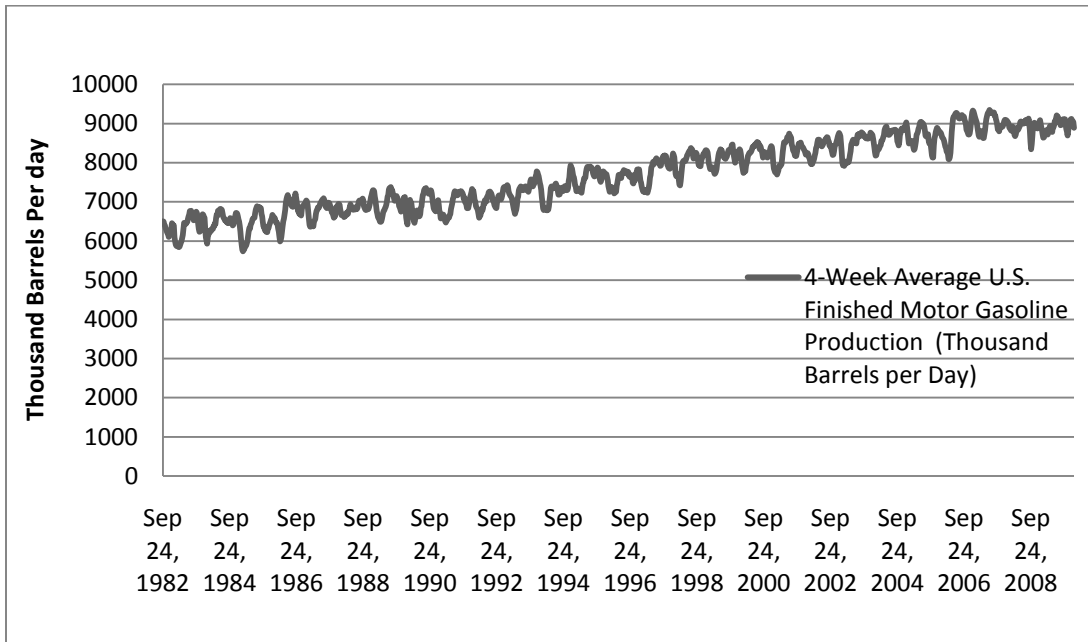


Figure 100 Average Gasoline Prices (Source: Energy Information Administration, 2009)

All though the United State may not be adding additional refineries, the two largest growing countries, China and India, are adding additional capacity to fuel their respective economic growth. According to *Oil & Gas Journal* (OGJ) (2006), China had 6.2 million barrels per day of crude oil refining capacity as of January 2006. Sinopec and CNPC are the two dominant players in China’s oil refining sector. The expansive sector is undergoing modernization and consolidation, with dozens of small refineries shut

down in recent years and larger refineries expanding and upgrading their existing facilities. Domestic price regulations for finished petroleum products have hurt Chinese refiners because of the large difference between current high international oil prices and low domestic rates. According to the BP Statistical Review of World Energy, refinery utilization in China increased from 67 percent in 1998 to 94 percent in 2004. As China seeks to bring additional refining facilities online to meet growing demand for finished petroleum products, BP forecasts that the country will increase refining capacity. Table IX shows the current (2006) refineries and capacities

Table IX Major Chinese Oil Refineries

Major Chinese Oil Refineries	
Refinery	Capacity (bbl/d)
China National Petroleum Corporation (CNPC) /PetroChina	
Dalian	410,000
Lanzhou	250,000
Fushu	200,000
Heilongjiang	160,000 and 120,000
Liaoyang	200,000
Total CNPC/PetroChina: 2,415,000	
China Petroleum and Chemical Corporation (Sinopec)	
Zhenhai	403,000
Ningbo	320,000
Maoming	270,000
Nanjing	270,000
Guangzhou	260,000
Shanghai	226,000 and 176,000
Zibo	210,000
Total Sinopec: 3,095,000	
West Pacific Petrochemical Corporation	
Dalian	160,000
Total China : 6,246,000	
Source: O GJ ; FACTS, Inc. China Oil and Gas Monthly	

(Source: Energy Information Administration, 2009)

India imported a large quantity of refined products through the 1990s, as it lacked the refining capacity to keep up with growing demand. However, in 1999, India's mega refinery hub in Jamnagar construction allowed India to begin increasing capability; by the end of 2004, India had a total of 2.3 million barrels per day in refining capacity, an increase of 1.1 million bbl/d since 1998 (Energy Information Administration, 2009). The largest single addition was Reliance Petroleum's huge Jamnagar refinery, which began operation in 1999. This project was a \$6 billion project and employed 75,000 workers in just four years.

Jamnagar has since, starting in October 2005, went through an additional expansion which was an additional \$6 billion dollars. Jamnagar has reached its full capacity of 660,000 barrels per day and accounts for five-percent of global gasoline production at 1.2 million gallons of gasoline per day. Jamnagar sells its products through three of the state-owned firms, and also has a retail network of its own. Reliance Another major downstream infrastructure development is the construction of pipelines being undertaken by Petronet India, a company created by an agreement in 1998 between India's state-owned refineries. This construction is expected to add 500,000 barrels per day to India's current 325,000 barrels per day capacity for pipeline transportation of refined products. Pipelines between refineries and major urban centers are replacing rail cars as the main mode of transportation in India. Figure 101 depicts the growth of India's oil production and consumption markets:

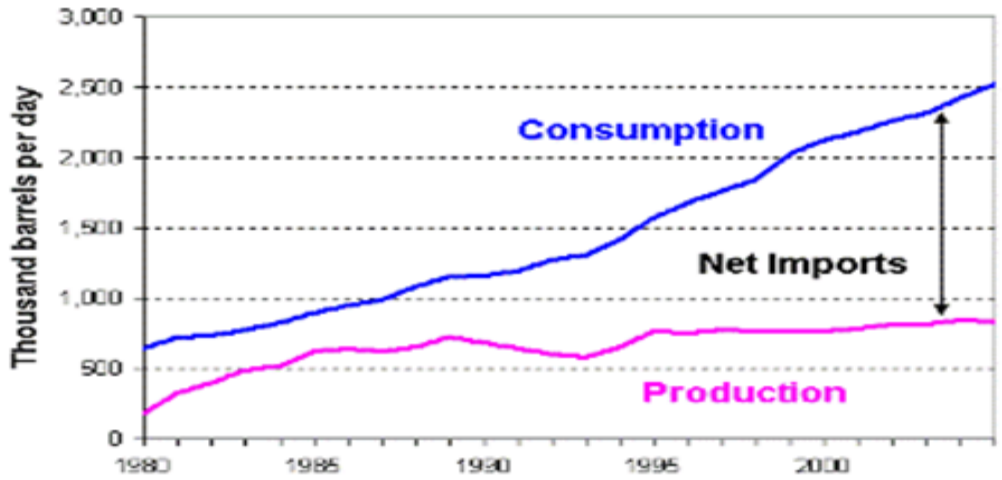


Figure 101 India Oil Production and Consumption (source: Energy Information Administration, 2009)

Figure 102 depicts the growth in demand of China and India in comparison with Japan and the United States:

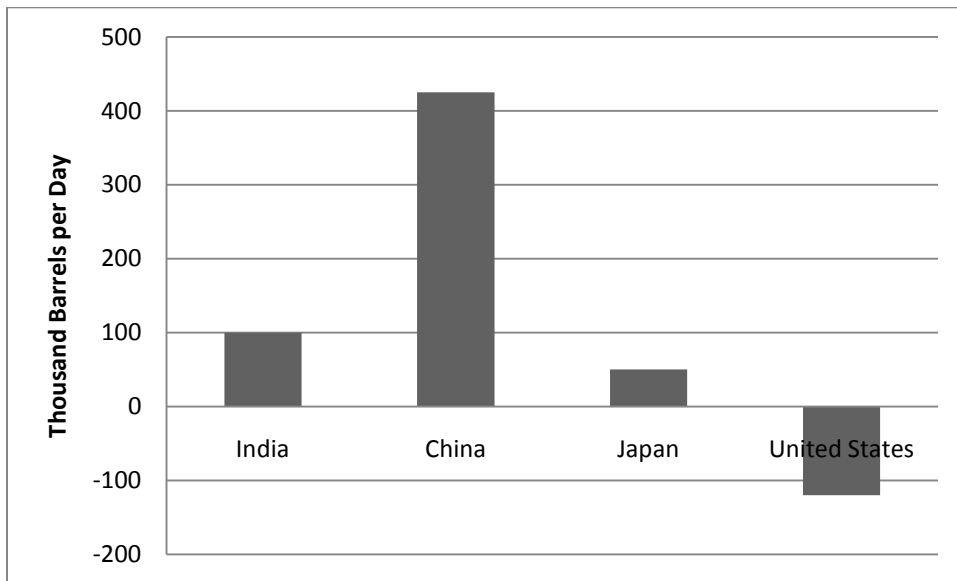


Figure 102 Oil Demand Growth (source: Energy Information Administration, 2009)

13.3 U.S. Demand and Supply

The demand of gasoline to power the automotive industry has continued to grow for over a century now. Figure 103 shows the United States demand from 1970 to 2008, Figure 104 shows the World demand and Figure 105 represents the United States as a percentage to World demand.

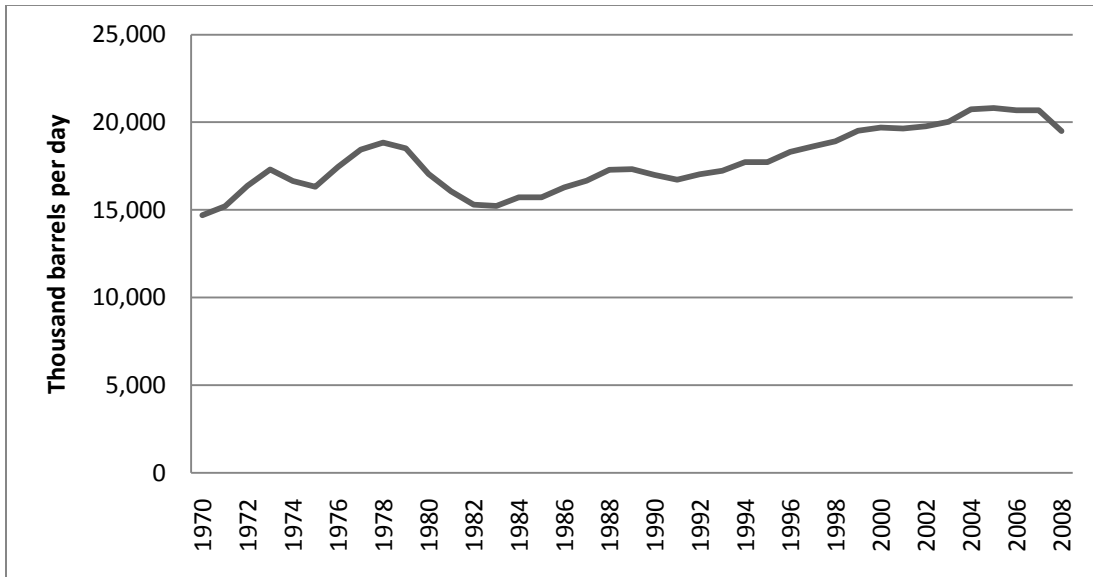


Figure 103 U.S. Crude Oil Demand (source: Energy Information Administration, 2009)

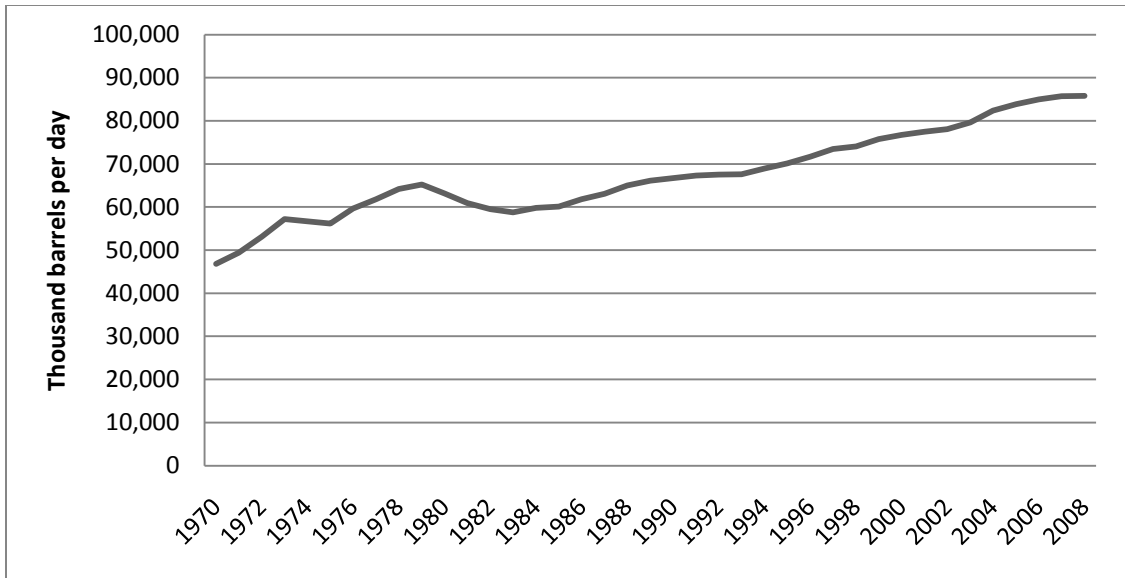


Figure 104 World Crude Oil Demand (Source: Energy Information Administration, 2009)

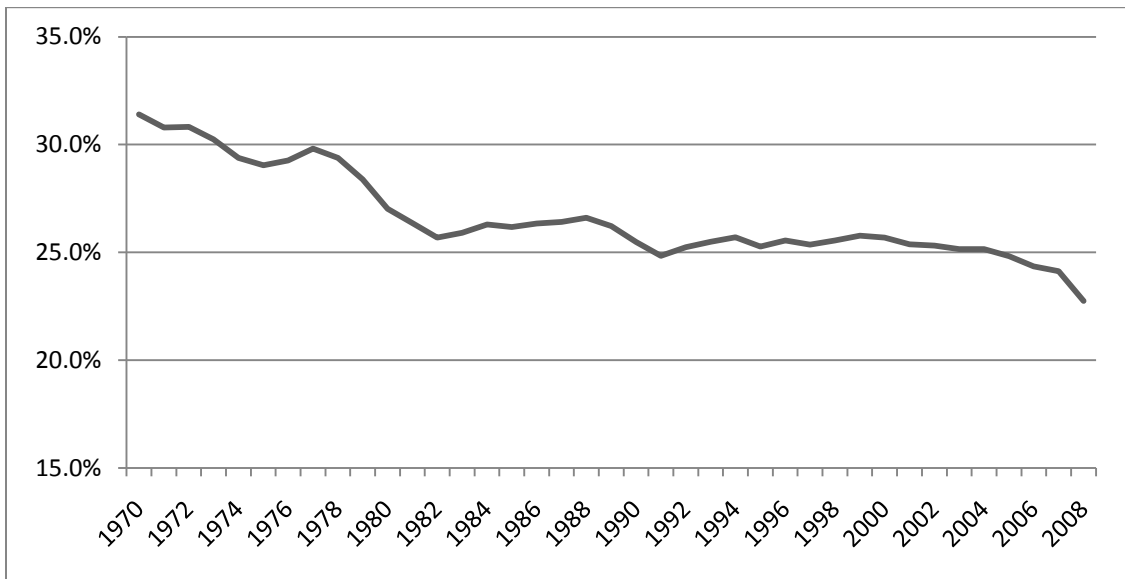


Figure 105 US as % total of World Demand (Source: Energy Information Administration, 2009)

As can be seen in the charts, even though the oil embargo had a small minor blip in the overall demand, it was not lasting. The United States has consistently been the largest user of crude oil; however, in the last several years, the percent of total global

demand has been dropping as other large nations are becoming more industrialized such as China and India.

The next couple of charts show a change in supply, in the early years of sources of crude oil supply, the United States was pretty much self-dependent. However, due to the large changes in demand, and environmental policies that have gone into affect, and the increased costs of extraction, that has changed substantially in recent times. Figure 88 shows the number of barrels imported on an annual bases from 1970 through 2007 and Figure 106 shows the imports as a percentage of consumption, while Figure 107 depicts the world oil reserves.

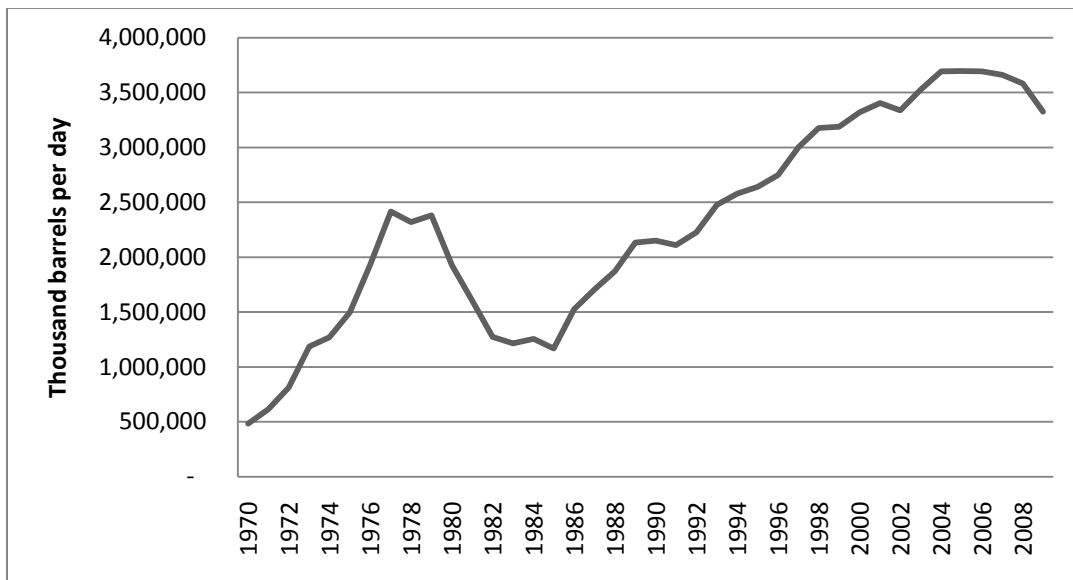


Figure 106 Number of Barrel of US Imported Crude Oil (Source: Energy Information Administration, 2009)

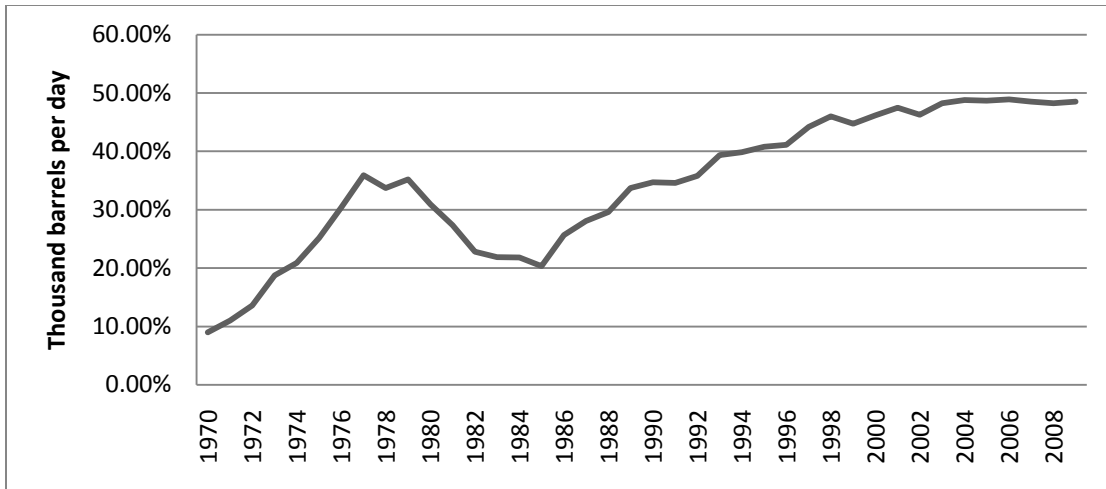


Figure 107 Percentage of Imported Crude Oil of US Consumption (Source: Energy Information Administration, 2009)

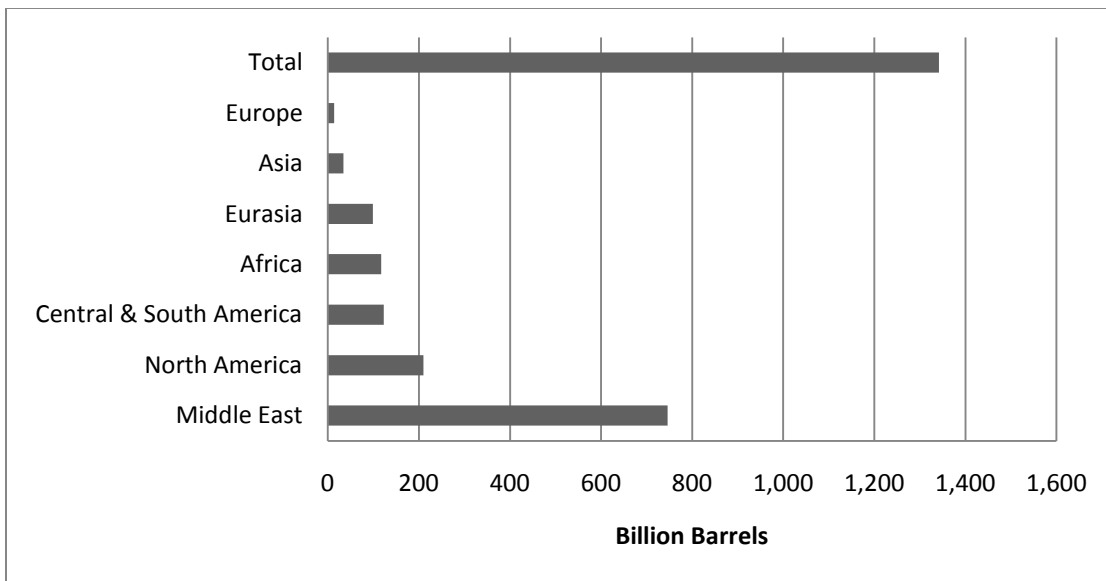


Figure 108 World Oil Reserves (source: Energy Information Administration, 2009)

The first oil embargo, coupled with increase dependence on imported oil, created an era of accelerated increases in the price per barrel of imported crude oil. Figure 109 presents these increases since 1970, while figure 110 looks at the affects of gasoline prices in chosen countries over the last 15 years.

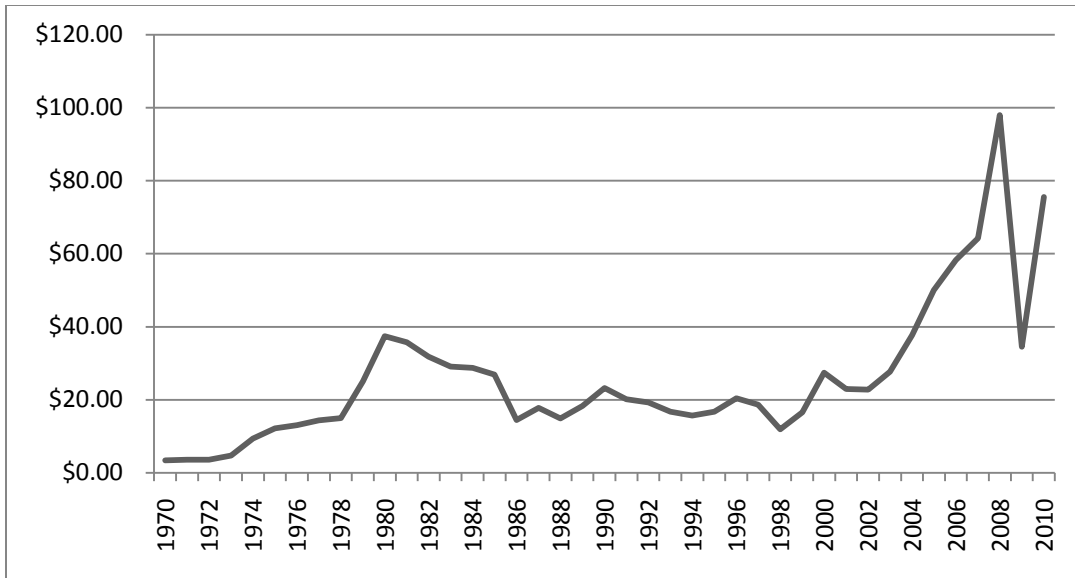


Figure 109 Price(\$)\$ per Barrel per Year of Crude Oil (Source: Energy Information Administration, 2009)

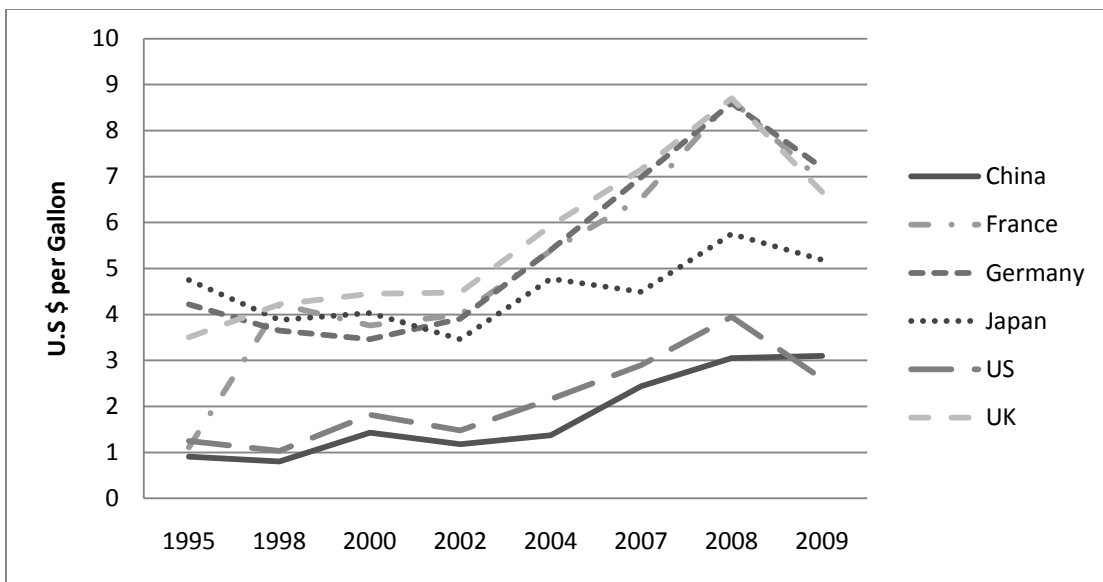


Figure 110 Average Gasoline Prices in Certain Countries (source: World Fact Book, 2009)

As can be seen from these charts on price increases, the first oil embargo led to a quadrupling of crude oil price from 1972 to 1974 (\$3/barrel to \$12/barrel) and the second

oil embargo inflicted by Iran led to another doubling from 1978 to 1981 (\$14/barrel to \$35/barrel). These events led to two major events (McCarthy 2007; Gordon 2009) :

- The development by the United States Government of an Energy Policy;
and
- The US gradual transition to purchasing more smaller, more fuel efficient Japanese made vehicles (As discussed in Chapters 6 and 7)

13.4 An Energy Policy of the 1970s

The 1973 oil crisis made energy a popular topic of discussion in the US. The Federal Department of Energy was started with steps planned toward energy conservation and more modern energy producers (U.S. Department of Energy):

- A National Maximum Speed Limit of 55 mph was imposed to help reduce consumption
- Corporate Average Fuel Economy standards were enacted to stimulate downsizing of automobile categories (reduced size, weight)
- A Maximum price per domestic barrel of oil was established
- Year-round Daylight Saving Time was imposed to better save energy for public, governmental and schools and other associated buildings
- The United States Strategic Petroleum Reserve was created
- The National Energy Act of 1978 was introduced encompassing a:
 - Public Utility Regulatory Policies Act (PURPA) (Pub.L. 95-617)
 - Energy Tax Act (Pub.L. 95-618)

- National Energy Conservation Policy Act (NECPA) (Pub.L. 95-619)
- Power Plant and Industrial Fuel Use Act (Pub.L. 95-620)
- Natural Gas Policy Act (Pub.L. 95-621).
- A pursuit of alternate forms of energy and diversified oil supply resulted

The rapid increase in crude prices from 1973 to 1981 would have been much less, were it not for the United States energy policy during the post Embargo period. The United States imposed price controls on domestically produced oil in an attempt to lessen the impact of the 1973-74 price increase. The obvious result of the price controls was that United States consumers of crude oil paid about 50 percent more for imports than domestic production and United States producers received less than world market price. In effect, the domestic petroleum industry was subsidizing the United States consumer, while losing revenue (and profits) that could have been used to (re) invest in more, new refining facilities incorporating/developing technologies.

In the short term, the recession induced by the 1973-1974 crude oil price raise was less of an effect because U.S. consumers faced lower prices than the rest of the world. In the absence of price controls U.S. companies' exploration and production would certainly have been significantly greater. Higher petroleum prices faced by consumers would have resulted in lower rates of consumption: automobiles would had to achieve higher miles per gallon sooner, homes and commercial buildings would have become better insulated sooner; and larger improvements in industrial energy efficiency would have been forced sooner than they were during this period. As a consequence, the United States would have been less dependent on crude oil imports in 1979-current and

the major price increase in response to Iranian and Iraqi supply interruptions would have been significantly lessened.

The United States derives approximately 84% of its energy from fossil fuels. This energy is used for transport, industry, and domestic use. The remaining portion comes primarily from Hydro and Nuclear stations (See Figure 111). Figure 112 breaks down the oil usage in the United States per sector. Americans constitute less than 5% of the world's population, while consuming 26% of the world's energy. They account for about 25% of the world's petroleum consumption, while producing only 6% of the world's annual petroleum supply and having only 3% of the world's known oil reserves.

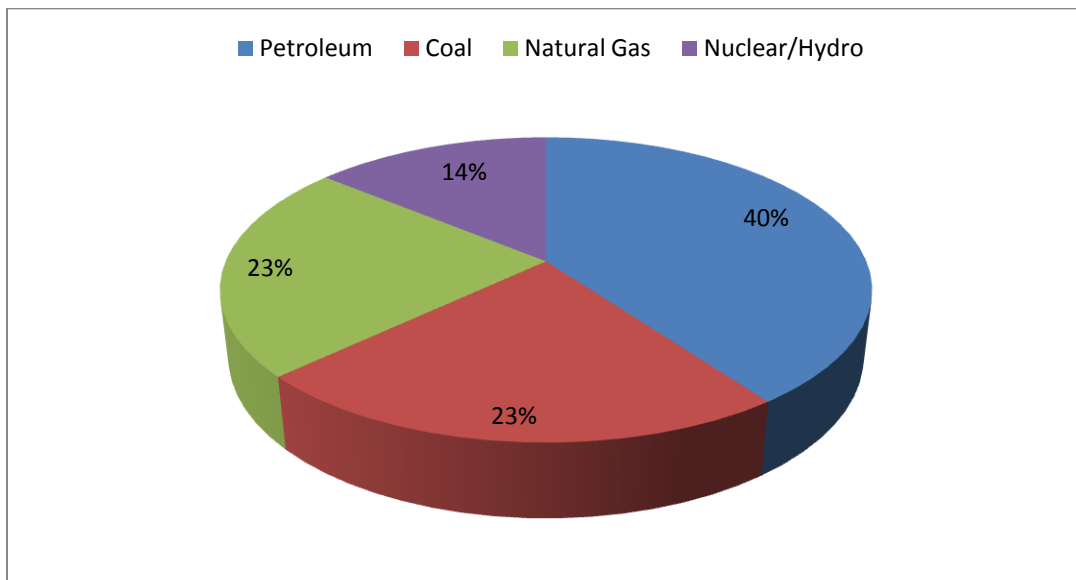


Figure 111 US Type of Energy used by Percentage(Source: Energy Information Administration, 2009)

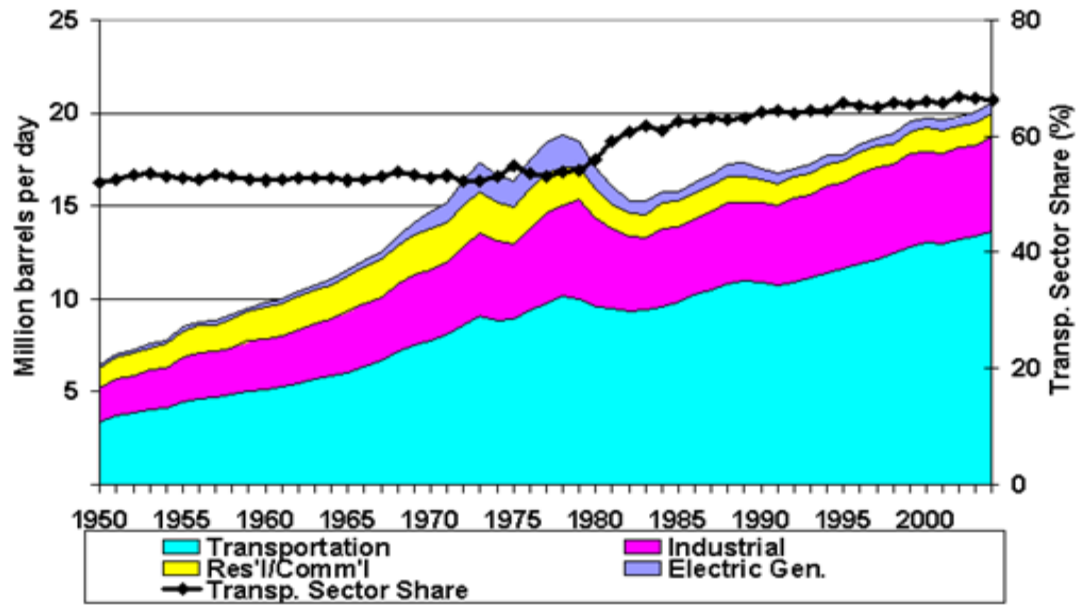


Figure 112 Oil Demand by Sector (Source: Energy Information Administration, 2009)

Figure 113 represents the break down (yield) that the refineries perform, on a volume basis of crude oil as of 2004

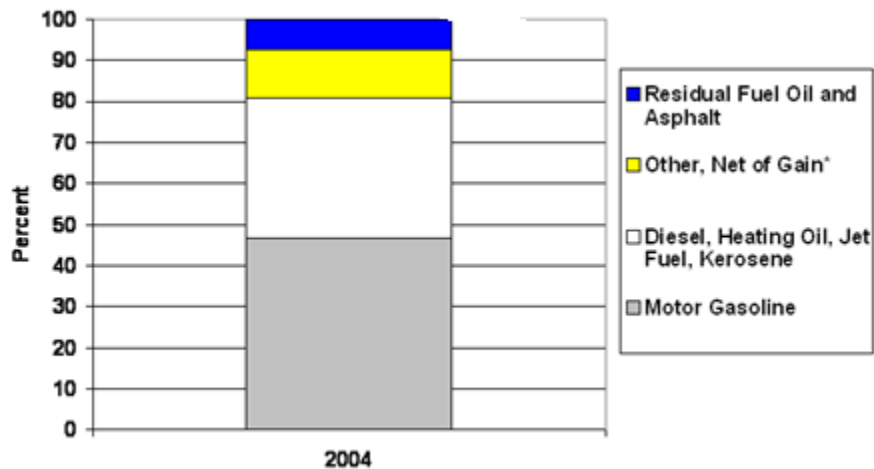


Figure 113 Refinery Yields (Source: Energy Information Administration, 2009)

13.5 Local Spills and Dumping

There are some alarming statistics surrounding the illegal and accidental introduction of used oil and gasoline into the environment. According to the Environmental Protection Agency (2005), there is roughly 400,000 gallons of “used” oil illegally dumped daily into the environment along with approximately 9 million gallons are accidentally spilled by Americans. To put the illegal oil dumping into perspective, the Valdez, in March 1989, gained global recognition for the substantial oil spill of 10.8 million gallons for its destruction of the environment; illegal dumping constitutes roughly 27 Valdez type accidents/spills or roughly once every other week per year.

Used motor oil is a very environmentally damaging substance. Illegally disposed oil can pollute the ground water with contaminants such as lead, magnesium, copper, zinc, chromium, arsenic and polychlorinated biphenyls (PCBs). One quart of oil can pollute 250,000 gallons of drinking water or 40,730 square feet of soil. A single oil change, if disposed of improperly, can ruin a million gallons of fresh water. The EPA also estimates that crankcase oil drainings have been reported to account for more than 40-percent of the total oil pollution of the United States’ harbors and waterways.

13.6 Emerging Markets with Increase Energy Demands

China and India are growing at an incredible pace. China’s car market just 20-years ago produced a mere 30,000 passenger vehicles, in 2009, the estimated production put China’s output at 8.3 million passenger cars; the total sales (trucks, cars, and commercial vehicles) were expected to reach 12.6 million vehicles (Sperling & Gordon, 2009). These figures would make China the world’s largest automotive market. It is

believed that by 2012 the car production market will grow to 9.5 million vehicles with total sales in the realm of 14 million units. This growth is expected to continue given that approximately one-third of the 1.3 billion population in China owned a vehicle in 2009. China has also built, from 2001 to 2005, 15,350 miles of expressway bringing their total up to 25,480 miles. In comparison to the United States, that number is approximately 46,000 miles, however, Chinese officials expect to top that by 2020.

India's market is growing as well, and may even have a jump on China in the number of exports and potential production numbers. In 2009, through September, India's exports topped 292,000 cars which was an increase of 32%. While the same period, China's exports fell 57% to 221,000 vehicles, (Sperling & Gordon, 2009). However, India's potential car market is still felt to be too small to focus on domestic sales, so they are continuing to focus on exports to mostly Europe.

So Globally, as China and India acquire and use more oil-burning technologies to fuel their growing economies the demand for energy will continue to rise, fueling the need for better technologies for crude oil extraction as well as alternative energy sources. It should also be pointed out that with these emerging markets and their need for energy, the United States will no longer be the "largest" buyer of crude oil, so the dependency on foreign oil will only become worse when other countries are in as big or bigger need for oil. This can result in potentially worse swings in the price for gasoline and the end of lower prices (below \$4/gallon). Politics will potentially be a much greater issue in the future than currently especially as countries like China and India are rushing to lock up future and potential oil fields (e.g. contracts with Iraq governments).

13.7 Petroleum Supplies and Technology

As the increasing demand of crude oil from countries like China and India (both expected to by-pass the U.S. in demand), grows, it is becoming increasingly important to develop innovative new technologies to create new oil fields and extend the lives of current oil fields. This creates an environment where new technologies can be developed to extend old oil fields and explore fields where today may not be cost justifiable. The cost of developing these new technologies and exploring difficult areas are decreasing however they are still higher but can be passed on to the consumer because of the increasing demand of the new growing markets such as India and China. Hence not only making new technologies feasible but also providing the necessary catalyst to expedite the alternative fuel development.

Many analyst estimate that only 32-percent of the crude oil reserve within the earth has been used. So the issue is not so much the quantity of crude oil left but how to extract it from difficult areas.

These new technologies are being developed and being used in conjunction with current technologies to improve out put of oil fields (Science Illustrated, Jul/Aug 2009). Some of these technologies include:

- Drilling horizontally to retrieve more oil,
- Injecting steam into the well to loosen up oil and increase the viscosity to improve the ability to extract (heavy oil, containing higher content of sulfur, is thicker and harder to extract, as well as refine into usable products),

- Injecting water or gas into the field to keep pressure up to push more crude oil from the rocks,
- Chemical methods – uses polymers to boost the power of water pressure and loosen trapped oil. Chemicals such as surfactants, make it easier to break oil free from rocks, and
- Carbon dioxide – using waste generate CO₂ from the utility plants (and other generators) into the well to boost pressure in the fields. It also acts to trap CO₂ as well.

Technologies are also being introduced to permit deeper and deeper off shore drilling. Off shore drilling began back in 1896 when Henry Williams built a 300-foot pier off the shore of Santa Barbara and sat a drill on top of it. Now, Shell is expecting to begin extraction of crude oil from its new off-shore rig at Perdido in the Gulf of Mexico which is approximately through 8,000 feet of water.

Also, geologists are now analyzing seismic data in 3-D on computer screens creating a sonogram of the Earth. With this, they can locate reserves of oil and natural gas below the surface and make sensitive electromagnetic measurements that detect if the reservoir contains oil or just seawater. However, all of these new technologies requires continued expensive investments which ultimately translates to higher prices to the consumer.

It is some of these higher costs and difficult extraction that has provided the motivation such as demonstrated by Brazil to develop their own natural resources (sugar cane) to move them from depending on imported, expensive crude oil, to become

completely self-sufficient and move towards a lucrative export business of supplying ethanol to other countries.

Even though some of these technologies are moving forward, most experts believe that a complete replacement of crude oil is very far off (2-3 decades) to circumvent any avoidance of future fuel price spikes and eventual political unrest.

CHAPTER 14

LABOR RELATIONS AND UNIONS

14.1 Introduction

This chapter will take a brief look at the environmental factors that propagated the spread of union membership within the automotive industry. It will also examine the political maneuvers that restricted management's ability to prevent the spread of union membership. Finally, this chapter will investigate specific events and negotiations from the period of the first contractual agreement through the early 2000's.

14.2 Brief History of Unionization in the U.S.

By the mid 1800's labor unions were appearing in localized areas of the country, however, the movement truly gained strength after the Civil War. The first labor organization that was effective was the Knights of Labor, formed and organized in 1869, (Dubofsky, & Dulles, 2004). Unlike previous localized unions who sought basically craftsmen to join their ranks, the Knights of Labor accepted any laborer and anyone who could truly classify themselves as a producer.

A little more than a decade later, in 1881, the American Federation of Labor began, (Zieger, 2002). The American Federation was comprised of different unions with

a goal of encouraging the formation of trade unions and to obtain legislation, such as child labor prohibition, a national eight hour work day and exclusion of foreign contract workers.

In 1886, the American Federation of Labor (AFL) was formed from an agreement between Federation of Organized Trades and Labor Unions, because of bad relations between the Knights of Labor and the trade union movement. Eventually the AFL grew stronger while the Knights of Labor disseminated.

14.3 Conditions Leading to Unionization

Perhaps the greatest single event that eventually led to the unionization of the automotive industry was the advent of the assembly line and the way it was instituted. As discussed earlier, the assembly line wiped out the craft method for producing cars within a few years. Ford, in the early years of assemble line production went from producing 170,000 cars in 1912 to over 500,000 cars in two years (Olsen, & Cabadas, 2002).

With the assembly line, workers capability was transformed. Taylor's scientific management philosophies (*The Principals of Scientific Management*, 1911) were taken to the extreme. The great influx of immigrant workers and ever increasing line speed drove the simplification of each job. Ford stated, "That by his estimates, that 43-percent of the jobs in his plants could be learned in one day, and 85 percent by the end of two weeks (Ford, 2007)". With this, the supervisors became enforcers versus leaders, and they came to recognize that more cars could be produced simply by speeding up the line in turn forcing the employees to work faster. With the work becoming more boring and less

challenging coupled with the supervisors increasing the speed of the conveyors, tensions with the employees began to rise in the Highland Park Ford facility, (Banham, 2002). By the end of 1913 the turnover rate at the Highland Park facility was said to be roughly 400 percent. According to Olsen and Cabadas (2002), Henry Ford was quoted as saying, “We used to hire from 40 to 60 percent of our workforce each month to maintain it. In the year 1913 between 50,000 and 60,000 people passed through the employment office.”

It was clear to Ford that the pressures of the assembly line were driving employees away, so on January 5, 1914, it was announced that Ford Motor Company would go to a five-dollar a day wage coupled with a eight hour workday. The average wage prior to this was \$2.34 for a nine hour day (Ford, 2007).

Another practice Ford instituted that negatively affected the employees was the advent of the Sociological Department. Ford not only felt that he provided good jobs to people he also felt that he had the right and duty to advise them on how to conduct themselves. Sociological Department investigators visited employees’ homes to see if they were living in sin or engaged in other unsavory practices, in which case workers could be disciplined or terminated.

The five-dollar per day was effective at retaining workers; it still could not advert rising tensions among the employees. There were attempts to unionize Ford, however, Henry Ford anti-union sentiments grew. In 1916, Ford hired an ex-prize fighter, Harry Bennett, as head of security. Bennett was eventually promoted to the head of the service department in charge of all of the company’s labor policies. Bennett used this department to gather evidence on union penetration of the workforce. He also had a

network of employee operatives honeycombing the company. Employees involved with or interested in joining a union were typically fired from the company.

14.4 Gaining Momentum, Federal Support

U.S. courts were not very hospitable to union activities during the 1920s; during this decade corporations used twice as many court injunctions against strikes than any comparable period (Zieger, 2002). In addition to these injunctions, the practice of forcing employees to sign yellow-dog contracts that said they would not join the union (or be terminated) was used often.

Many changes were about to take place with the stock market crash of October 1929 followed by a brutal economic crisis which saw unemployment rates in excess of 25-percent. On March 23, 1932, President Herbert Hoover signed what became known as the Norris-La Guardia Act, marking the first of many pro-union bills that Washington would pass in the 1930s. Senator George William Norris from Nebraska and Congressman Fiorello H. LaGuardia from New York City, both progressive Republicans, introduced new labor reform legislation, the Norris-LaGuardia Act. The Norris-La Guardia act would outlaw the practice of yellow dog contracts. Norris-LaGuardia Act marked a profound change in U.S. government oversight over labor relations. It was the most favorable legislation to date for a U.S. labor movement that had always had to fight for its very existence.

With passage of the act, the groundwork was laid for an even more important labor bill, the National Labor Relations Act of 1935, called the Wagner Act. The Wagner Act continued the mission of reforming labor relations. It set out to regulate the nation's

labor relations. It granted unions fundamental rights and powers, including the right of collective bargaining, defined unfair labor practices, and established penalties for violating them. The act granted minimum wage and maximum hours, the most significant passage was, “Employees shall have the right to organize and bargain collectively through representative of their own choosing, and shall be free from the interference, restraint, or coercion of employers”, (Norris-Laguardia act of 1932, retrieved 3/8/2010).

14.5 Unionizing the Automotive Industry

The United Auto Workers union (UAW) was founded in May 1935 under the auspices of the American Federation of Labor. The UAW rapidly found success in organizing with the sit-down strike (UAW website, history, retrieved 3/1/2010). On November 27, 1936, the UAW enacted a sit-down strike at Detroit’s Midland Steel plant, a key supplier to Ford and Chrysler. Unlike previous strikes (picketing the gates of the plants) the workers occupied the inside of the plant and locked police outside. This strike lasted eight days which led to Ford and Chrysler lay off 100,000 workers. Pressure from Ford and Chrysler led Midland to settle. The next UAW target was a brake supplier to Ford, Kelsey-Hayes Wheel Company, later that year in December. Again pressure from Ford to settle led to Kelsey-Hayes settling.

These two sit down strikes led to the 44-day sit-down strike by the UAW on General Motors, beginning December 30, 1936. Soon the sit-down strike involved 10 General Motors plants. On January 11, 1937, General Motors Security and Flint Police tried and failed to forcibly remove the strikers, in what is known as the “Battle of the

Running Bulls”. The Governor, Frank Murphy, ordered the National Guard troops in to separate the police and strikers. The strike continued until February 11 when General Motors became the first automaker to sign a union contract.

The next target was Chrysler, when on March 8, 1937, the UAW pulled a simultaneous sit-down strike on all nine of Chrysler’s plants, involving 17,000 workers. Under pressure from Governor Murphy, Chrysler settled with UAW in April.

The final target was Ford, which proved to be the most difficult and bloody. Ford was intent on not having a union in its organization. Through Bennett’s network of spies within the employee ranks, he discovered that the UAW would be handing out pamphlets on May 26, 1937. There Ford security forces bloodied the two UAW personnel, Frankenstein and Reuther, in front of journalist and photographers. The following day, these bloodied pictures made headline news and was labeled, “Battle of the Overpass.” The National Labor Relations Board subsequently filed an unfair labor practice complaint, and in December 1937, Ford was found in violation of the federal Wagner Act and ordered to stop interfering with the right of Ford employees to organize. Ford appealed and in February 1941 it reached the Supreme Court, which declined to review it. Workers fired for their union activity were rehired and the company, having endured a walkout of 50,000 employees at the Rouge complex in April, finally agreed to negotiate with the UAW. The employees in May, 1941 voted in favor of the union with only 2.7% voting in favor of no union (Banham, 2002).

14.6 Effects of Bargaining

Immediately after World War II, the UAW demanding pay increases for its members; the UAW demanded a thirty-percent increase without raising the price of the automobile. General Motors countered with a 17.5 percent increase (19.5 cents) without raising its price; UAW decided to go on a 113-day strike on November 21, 1945. Ford and Chrysler hourly workers, however, settled for an 18.5 cents-per-hour increase, while allowing the company to raise prices. GM's hourly workers finally settled in March 1946 on an 18 cents-per-hour increase. The UAW discovered that they could not mandate the price of the vehicle that the "Big 3" would just pass on the extra cost onto the price of the car (Zieger, 2002). Figure 114 represents the changes that the UAW made to their benefits in the early period of contract talks (1940s).

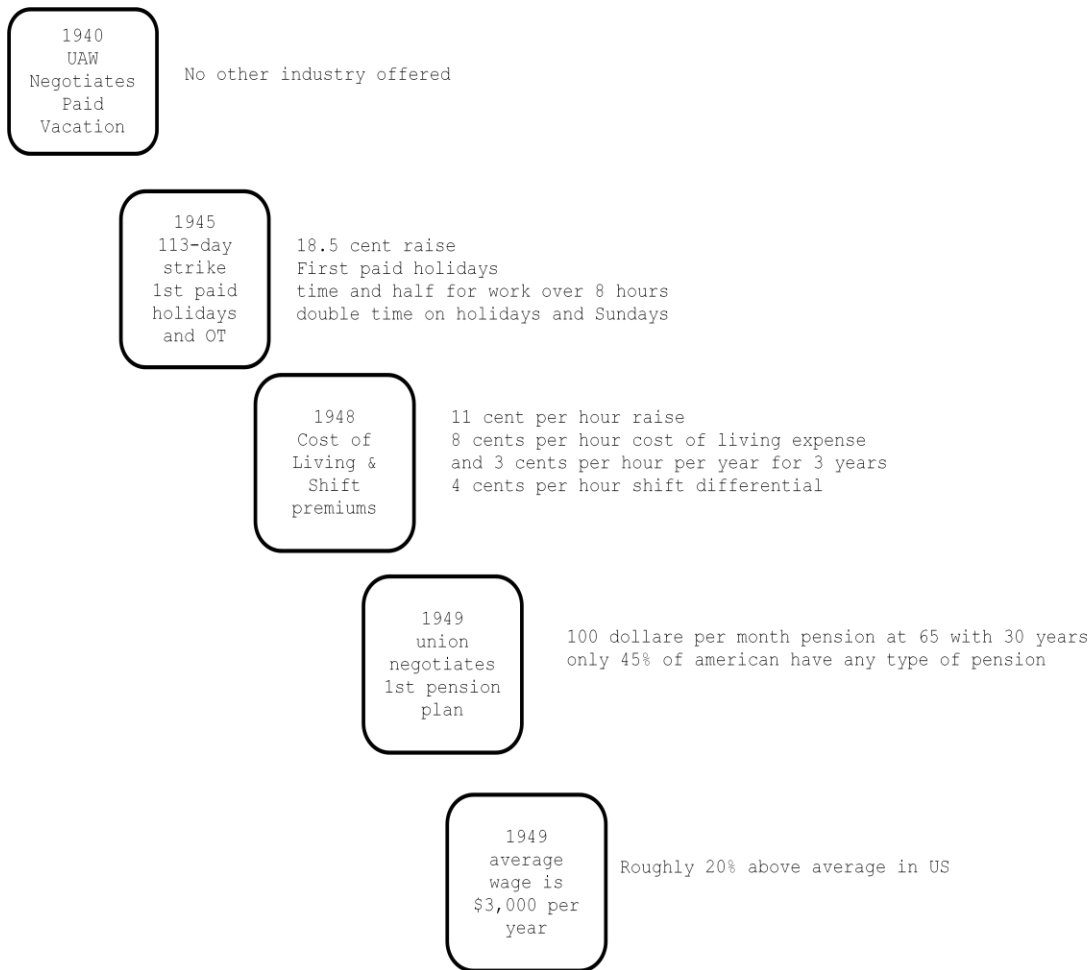


Figure 114 UAW Negotiation Results in the 1940s (source: UAW Website, 2010)

As can be seen from Figure 114, the ground work of increased benefits for the UAW hourly workers was laid nicely, and the response from the “Big 3”, was to pass the cost on; at this point in time, the UAW learned that they could not control the cost of the car, they could only ask for more and more benefits and watch the “Big 3” increase the cost of the automotive to ensure profits, (Banham, 2002; Keller, 1989; Olsen, & Cabadas, 2002). Of course striking is a costly factor for the automotive companies to face, and is used infrequently by the UAW; Figure 115 depicts the historical strike activities. Figure 116 depicts UAW negotiated highlights from the 1960’s to current.

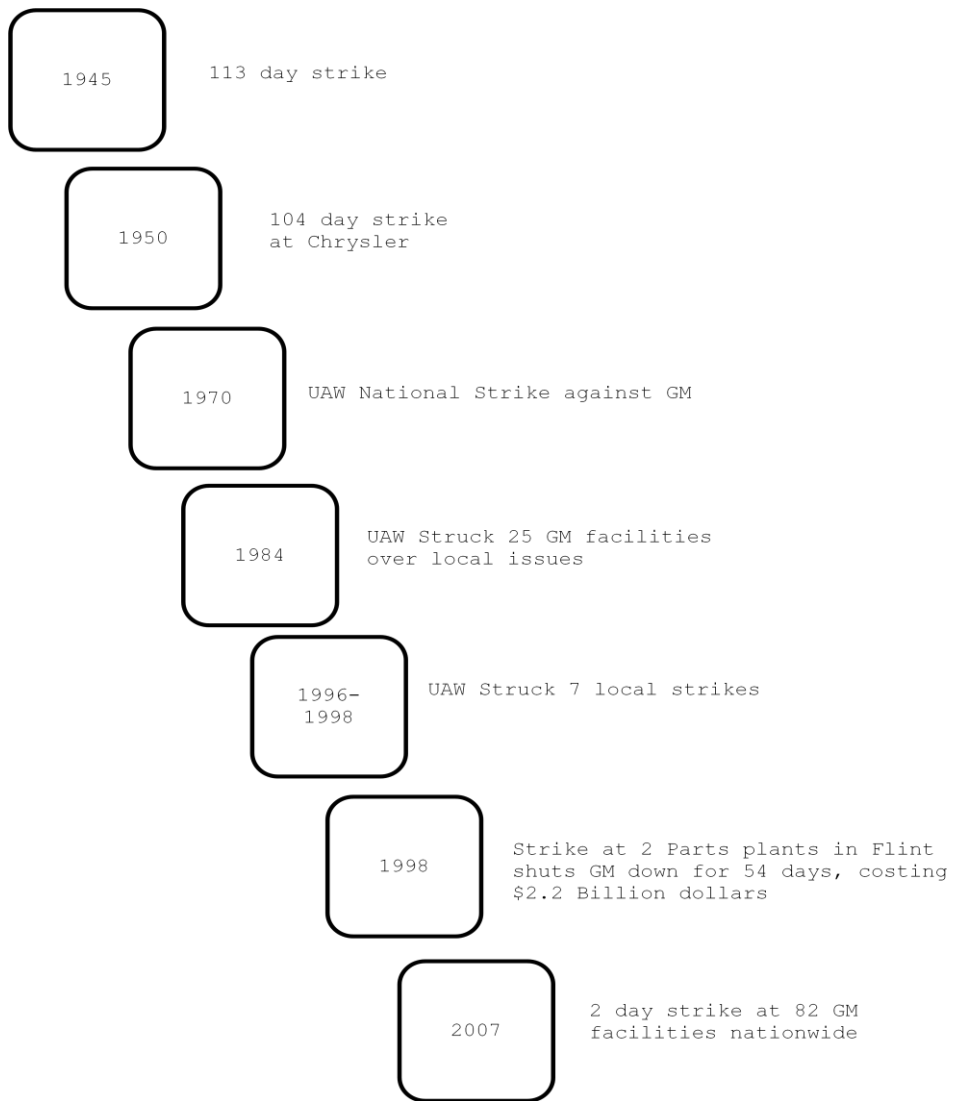


Figure 115 UAW Strikes (source: UAW website, 2010)

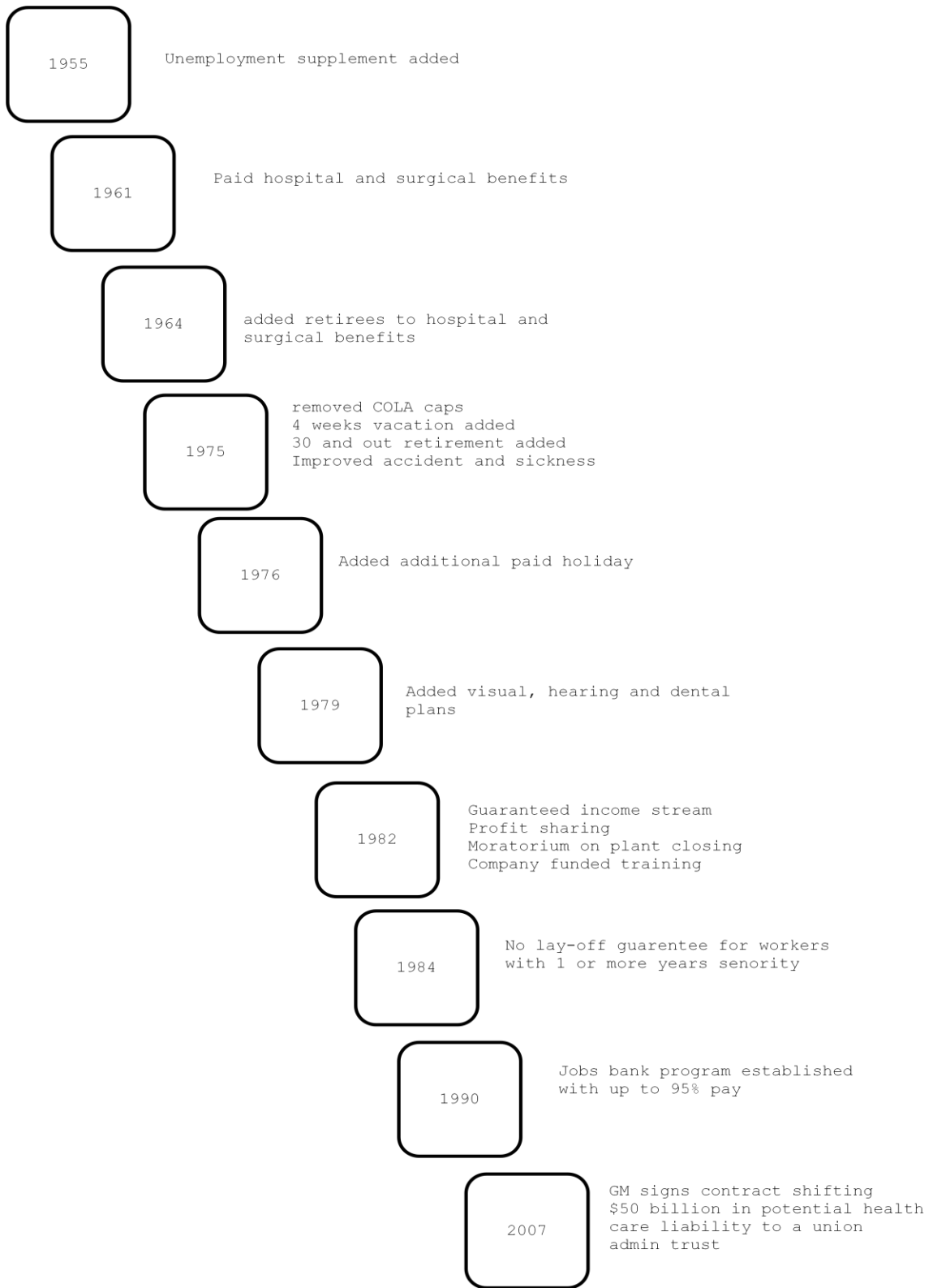


Figure 116 UAW Negotiation Results 1950 to present (source: UAW Website , 2010)

1955 perhaps is the contract period that began to lead to heavy cost burdens that would come to create high tensions in 2008 when it came time to ask congress for loan guarantees. 1995 is when the sub pay was added as a benefit: when an employee was laid off, the company would supplement the unemployment pay so that the employee would obtain 95% of pretax pay for 48 weeks (Schoenberger, 2009; Strumpf, 2008; Langfitt, 2010). Of course, the sub-pay was sufficient until the “Big 3” became challenge by imports (as discussed in earlier chapters). So during the 1984 negotiations, the UAW wants assurances that their jobs were secured and would not be replaced by automation and robots, and the “Big 3” wanting the ability to upgrade their facilities with the latest state-of-the-art technology, agreed to the job security (guarantee)/job banks program.

The jobs bank program was created to make the plants more flexible and automated to compete with the Japanese. As the “Big 3” became more efficient, it did not have a need for as many workers, however the UAW demanded that it keep paying workers displaced by newer technologies; UAW argued that the employees would embrace the newer technologies (making the facilities more efficient and higher quality) if they did not fear losing their jobs. The program kicks in after the employee exhaust their 48 weeks of sub pay coupled with unemployment as discussed above. The job banks programs pays the employee to full wages and benefits regardless if there is work to do or not. The employee could report to work as normal and do nothing, could do community service, or go to school for education (which is paid for as well). This continues until the employee can be placed into a different job, which has to be within 100 miles of current location (Niedermeyer, 2008). When General Motors was seeking the government bailout recently, it was forced to cancel the jobs bank program as a condition. When it

was canceled there were 1,600 workers on the program, most with nothing to do, and costing General Motors \$800 million per year; the program had at one time roughly 7000-8000 workers.

Some other cost items that can be pointed out is the amount of job classifications that are in some of these contracts. Some plants are known to have as many as 183 job classifications (Olsen, & Cabadas, 2002), while, for example, the joint venture between Toyota and General Motors (NUMMI) had only 4. This enormous amount of job classifications leads to inefficiencies and limits the flexibility of the plants. These union restrictions (job classifications negotiations) on job mobility between their different classifications makes it extremely difficult for a worker to move back and forth between jobs a necessary for the business conditions, hence adding extra costs and manufacturing time. According to the 2008 Harbour Report, for example, General Motors averaged roughly 32.29 production hours (engine, transmission, stamping and assembly hours), while Ford averaged 33.83; General Motors' unit sales were 3,866,000 vehicles in North American and Ford was 2,848,000; the number of workers in North America for both General Motors and Ford in 2007 were 145,000 and 100,000 respectively. On the other hand, Toyota averaged 30.37 and Honda averaged 31.33 production hours per vehicle; unit sales for Toyota and Honda in 2007 were 2,942,000 and 1,788,000 in North America; while employee head count for Toyota and Honda were 22,000 and 25,900.

Another heavy expense the "Big 3" endures is the retirement and health care cost benefits. According to the Harbour Report of 2005, health care cost and retirement benefit per vehicle produced by the "Big 3" in North America in 2005 was \$1,525 per vehicle (with changes to contractual language in 2009) puts the figure at \$1,100 for 2011;

while the Japanese companies cost per their vehicles produced in North America was \$1,000 per vehicle.

Figure 117 depicts the average salary earned by UAW hourly workers versus the average in Industry; this chart includes total benefits (e.g. health care, pension, hourly wage).

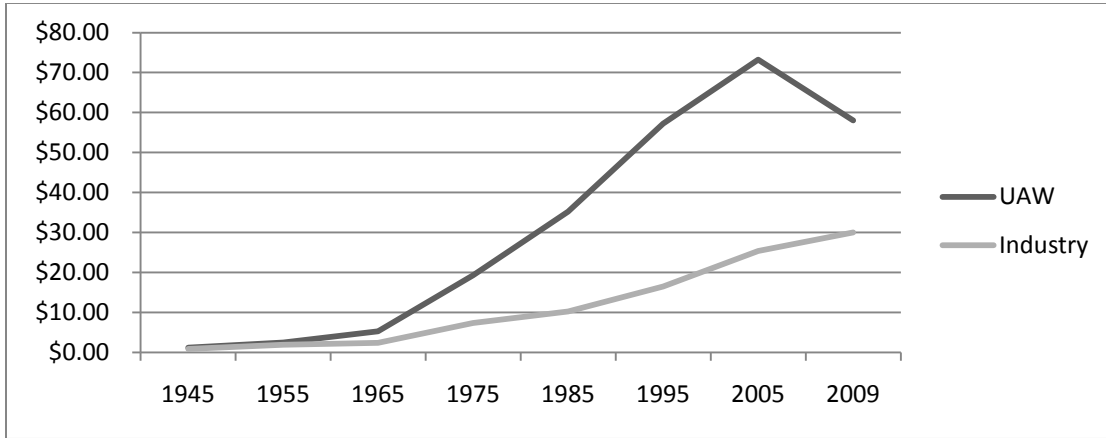


Figure 117 Total Compensation Growth and Comparison (source: created with data from Bureau of Labor Statistics, 2010; UAW website, 2010)

Figure 118 then depicts the growth/decrease of UAW membership over the same period.

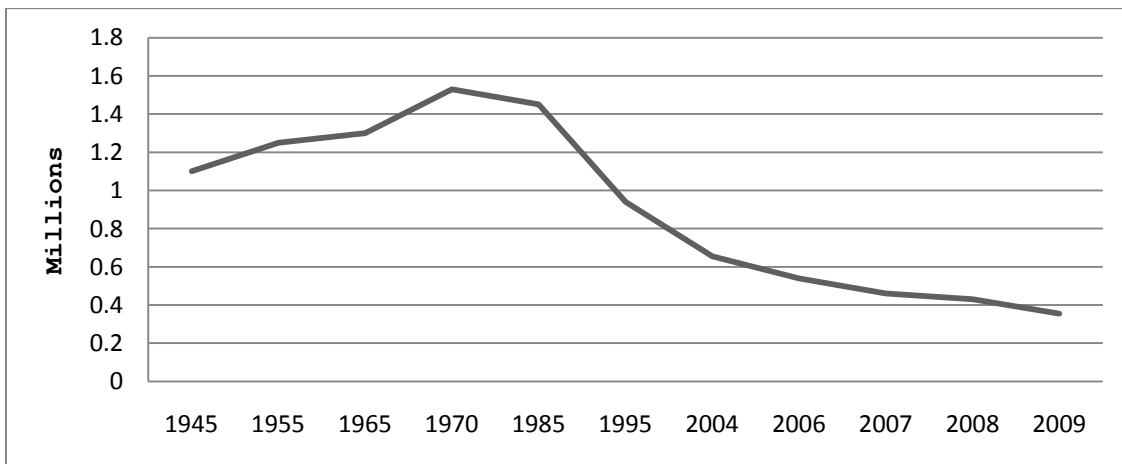


Figure 118 UAW Membership (source: Bureau of Labor Statistics, 2010)

This compensation earned by the UAW membership had grown considerably over the years as compared to the rest of the manufacturing industries. This was accomplished by the UAW by either strikes or the threat of strikes; and with no gains in productivity as resultants. And, in fact, as time progressed contracts became more restrictive through further increases in job classifications (removing flexibility), guarantee jobs (creation of the job banks program) as well as restrictions of plant closures (further adding to excess capacities). It basically took almost a complete failure of the U.S, auto company failures (bankruptcy for General Motors and Chrysler) to reverse this trend moving into 2010 and beyond. This was accomplished basically by:

- Eliminating the jobs bank program,
- Removing restrictions on plant closings,
- Offering buy-outs to expensive senior employees,
- Creating a 2-tier employee system where new hires starting rate was lowered to \$14 per hour, versus \$28 per hour, plus new hires do not get pension or retirement health care benefits, and
- Creating retirement pension trust funds that the UAW must managed
 - With stocks/ownership as part of the payment by the company into the pension fund; in Ford's case it can use stock up to 50% of the 13.2 billion it must pay the union-led trust fund.

CHAPTER 15

MANAGEMENT AND EXECUTIVE COMPENSATION

15.1 Introduction

This chapter will take a brief look at growth and compensation of the executive level of industry; Ford Motor Company will be examined as a representative of the typical historical executive heavy structure (similar to General Motors and Chrysler) of the “Big 3”. It will examine the beginning of Ford Motor Company and the level of executives that Henry Ford believe sufficed, and eventually the level that the Ford Motor Company is currently at. This chapter will finish by looking at some of the compensation these executives have been rewarded with over the last few years and some of the pay structures to remove /retire some executives as well as the pay package used to attract the latest CEO (Alan Mulally) in this dire time in the automotive industry.

15.2 The Beginning Levels

Ford was a very centralized organization from the start. Henry and Edsel Ford took complete ownership of the Ford Motor Company in 1919 when a dispute broke out between the Fords and the other share holders (Banham, 2002). To end this, the Fords

purchased all of the shares from the other share holders. By 1921, the Fords had paid the entire debt off from the banks and the only relationship Henry Ford maintained with the banks was as depositor (Ford, 2007).

Henry Ford had little use for organization structures or charts. He believed in a tightly controlled centralized organization, which gave birth to the roughly 100% vertical integrated Rouge Complex (Banham 2002; Ford 2007). The first challenge to Ford's management structure came with the death of Edsel Ford in 1943. The Ford Motor Company fell into such disarray. Henry Ford lacked the ability/desire to prepare capable managers. Couple with this lack of leadership, Henry Ford also believes in creating a perplexing accounting system in order to confuse the Internal Revenue and to discourage audits, so the accounting was in as much if not worse disarray (Funding Universe, 2004).

Henry Ford, being in such need of help, petitioned the Navy to release his grandson from duty, which the Navy complied. In 1945, Henry Ford II was named president of Ford Motor Company. Henry Ford II then terminated Harry Bennett and Ray Rausch who almost destroyed Ford (Hounshell, 1995). Henry Ford II then hired Ernest Breech who was placed in charge of two groups – a managerial group and a financial group.

15.3 Transition from Central to Decentralized Management

The managerial group was comprised of several managers hired away from General Motors while the financial group was comprised of ten financial experts from the Air Force office of Statistical Control (Funding Universe, 2004). After Henry Ford's death in 1948, this group had complete freedom to implement tight managerial/financial

controls similar to General Motors at the time. Breech's top priority was strict adherence to financial plan with strong profit margins; unfortunately, as previously noted in earlier chapters, this proved to be at the expense of developing automobiles for an increasingly complex market. And by the early 1950's Ford had become known as an imitator versus a pioneer as developed by Henry Ford. Figure 119 depicts the organization structure of Ford in 1946.

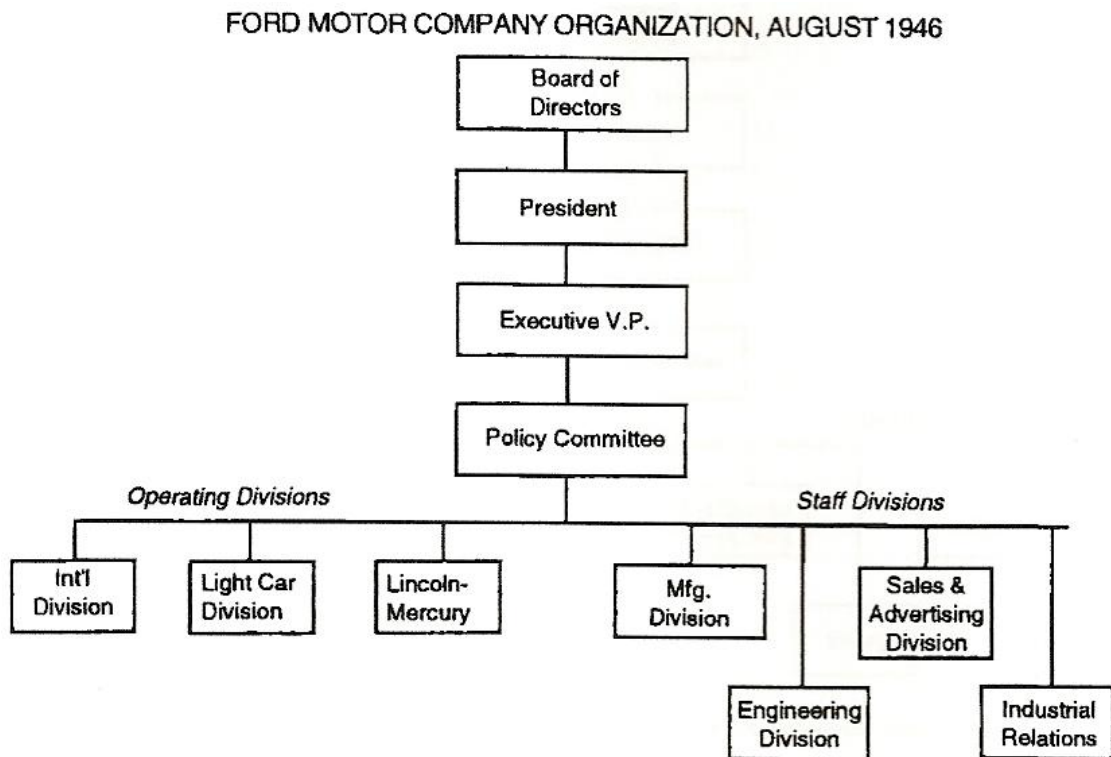


Figure 119 Ford's Organization Structure, 1946 (Source:Hounshell, 1995)

This new management team went to work immediately to decentralize Ford Motor Company. At the time, the goal was to bring the Rouge down to no more than 50-percent of the parts supplier basically due to the on-going labor issues. With this, Ford began to grow managerially and added new positions in departments and divisions. By

1950s the organization chart was much larger. Figure 120 depicts what Ford Motor Company looked like in March 1951.

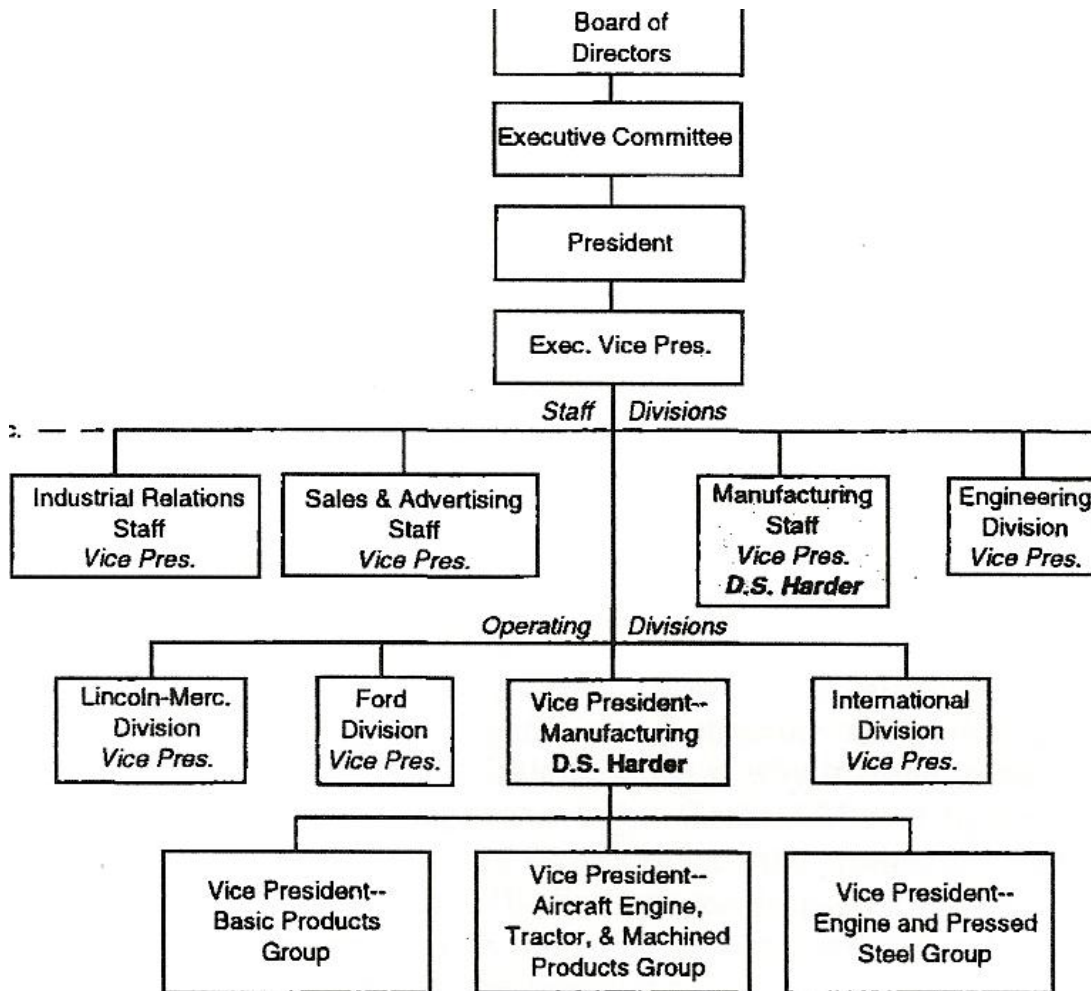


Figure 120 Ford's Organization Structure, 1951 (source: Hounshell, 1995)

These key individuals were also compensated very well. Ernest Breech made Ford Motor Company's first board chairman (another new position), the top eleven officers of the company collected \$2,414,500 in direct compensation, in which Breech made \$321,000 in the time the average autoworker was making around \$5,000 per year.

In addition Ford executive and other key personnel had been given options to buy blocks of the company's stock at \$21 per share versus the expected market price of around \$70. As of December 1, 1955, they had bought 647,100 shares of the new common stock (there are two types of stock at Ford – class B serves for family members and constitutes the controlling 40% voting interest, and the common stock). Stock would not be offered to the public until January 1956. Breech, who purchased 27,000 in 1955, made millions on this deal with only paying capital gains tax.

15.4 Management Changes (1960s and 1970s)

In 1960, Henry Ford II, dissatisfied with his secondary role in the company decision making decided to strip Breech of his authority replacing him with Robert McNamara. However, McNamara left the Ford Motor Company a year later in 1961, which at that time Arjay Miller, who then succeeded the interim president in 1963.

In another move, Henry Ford II dismissed Miller in 1968 and recruited Semon Knudsen as President from General Motors who had been their executive vice-president. However there was constant conflict between Knudsen and Ford, so after 19 months, Ford replaced Knudsen with Lee Iacocca. In April 1977, Henry Ford II reduced Iacocca's power by creating a new executive triumvirate. Iacocca was a member of this, along with Ford and Philip Caldwell. But a year later, Ford added his brother William Clay Ford to the group and relegated Iacocca to a subordinate position. Shortly after that, Henry Ford II terminated Iacocca and placed Caldwell as the president. Henry Ford II was battling stockholder allegations of financial misconduct and bribery at the time and his dismissal of Iacocca made him more unpopular. Iacocca went on to head Chrysler as

their CEO and started what today is the \$1 per year CEO, basically taking stock options (Weinber, 2002), later repeated by Steve Jobs at Apple.

Henry Ford II eventually relinquished his position of Chief Operating Officer in October 1979 to Caldwell and five-months later retired (but retaining his seat on the board of directors) and gave the chair to Caldwell.

15.5 Modern Changes and Current State

Ford Motor company has seen 6 changes in leadership since 1985, all of which seen changes within Ford Motor Company. Figure 121 depicts these changes and the associated timing.

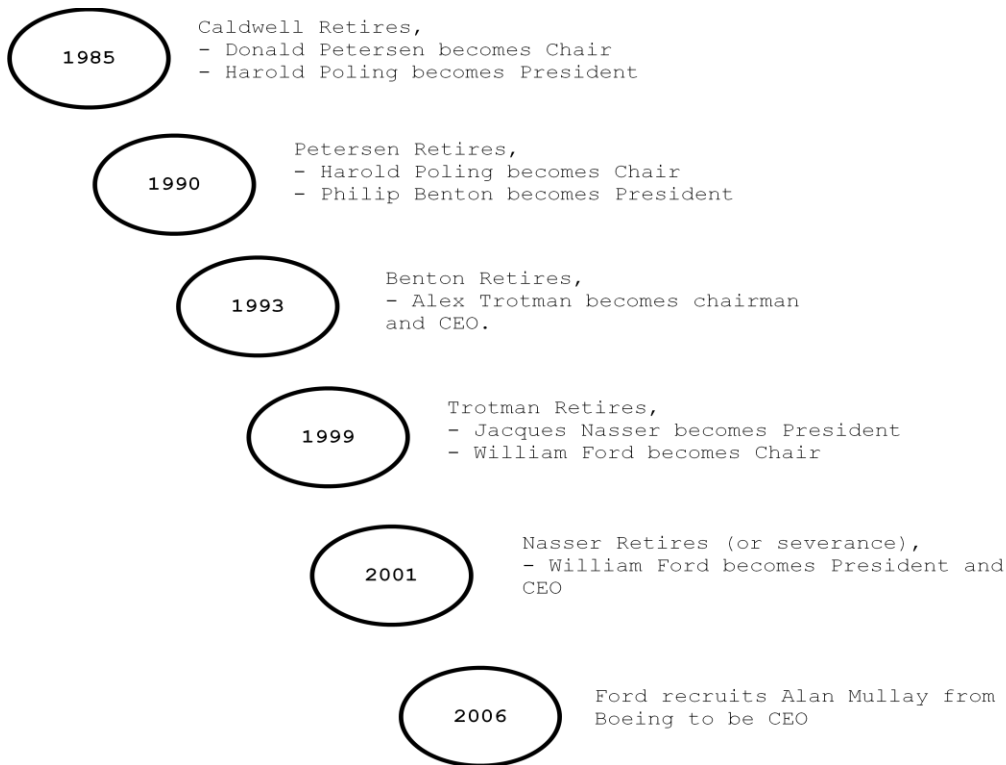


Figure 121 Leadership Changes within Ford (source: created with data from Ford motor Company: Chronology, 2010)

Each of these changes typically resulted in an additional team of management to “help” them implement their respective plan(s) and with this, additional salaries at the executive level and stock options and of course bonus plans that typically have no relation to performance. There has been many article written on the criticism of Ford’s management practices (Kerwin 2002; Taylor, 2010), how for decades the company continued to add staff with no real results oriented compensation; seniority was the basis of moving up the career ladder; poor company performance was a result of the economy with little that management could have done.

The last three CEOs of Ford (Troutman, Nasser and Ford) have taken Ford Motor Company, bought several car firms outside of the United States (as described in Chapter 17) that were losing money; worked to diversify as a more consumer products company (also described in Chapter 17) and introduced Ford as an innovator. While all the time, critics have continuously pointed out that what Ford lacks is the ability to produce cars that people want to buy (Hakim, 2002). Ford over the years, basically went on as business as usual, every once in a while establishing something that would sell; Thunderbird, Mustang, Taurus/Sable, Explorer/F150, while management was rewarding themselves and running with the money. For example, Trotman took the helm in 1993, a year after the record loss (at this point in time) of \$7 billion, five-years later when he left Ford made \$7 billion as the worlds’ most profitable company, strictly due to the sales of the Explorer and F150, just to fail once more by the early 2000s (Taylor, 2005). Over the last several decades executive management has continued to expand management positions and expand their own little empires within the organization, with little or no basis on performance. As Kiley (2009) documents, “executive are more interested in

protecting their turf than working together (p.32).” The next section details some of the compensation that has been awarded to the top executives for lack luster performance

15.6 Management Compensation Discussions

Examining the proxy reports over the last several years, Figure 122 depicts a snapshot at where total compensation has been for the top executives:

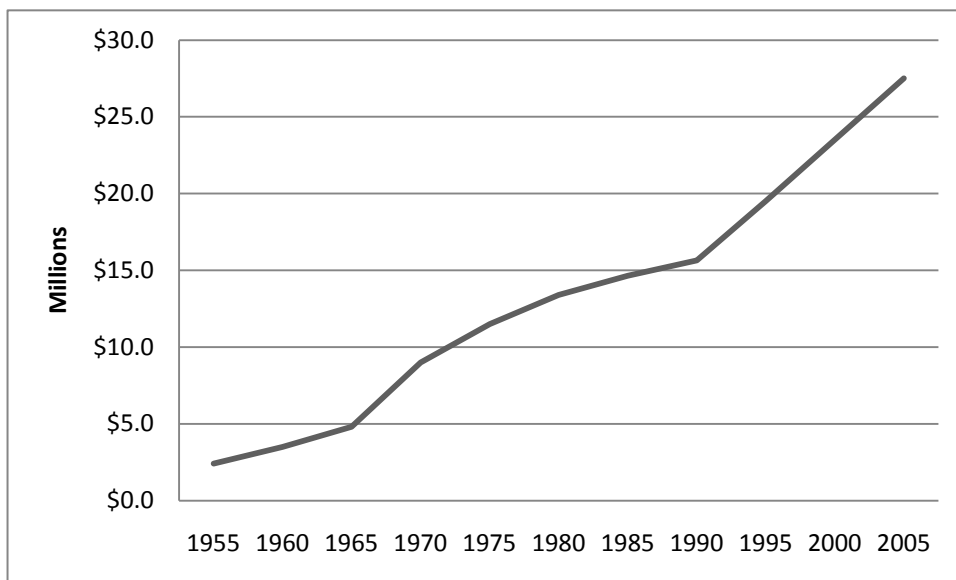


Figure 122 Ford Motor Company Top Executive Compensation (source: created with data from Proxy reports, 1955, 1960, 1965, 1970, 1975, 1980, 1985, 1990, 1995, 2000, 2005)

As can be seen from the figure, and if compared to the profit trends from Chapter 17, one can see that there is no correlation between executive compensation and profit.

And as eluded to in previous section, Ford is no stranger to bigness (and continually increasing bigness) which results in a highly populated organization chart with Chairman, CEO, President Executive Vice Presidents, Vice Presidents, Executive

Directors as well as directors. The most recent pay according to Ford's Proxy statements for the top executives continues to grow and is as follows:

- Alan Mulally, president and chief executive officer, earned \$2,000,000 in salary and received incentive bonus awards of \$7 million. Total 2007 compensation was \$21,670,674, which includes salary, bonuses, the Company-recognized expense for stock options and other stock-based awards as well as all other compensation,
- Don Leclair, executive vice president and chief financial officer, earned \$1,005,633 on salary and received bonus awards of \$3 million. His 2007 compensation totaled \$11,703,127,
- Mark Fields, executive vice president and president, The Americas, earned \$1,255,634 in salary and received incentive bonus awards of \$2,850,000. His 2007 compensation totaled \$8,389,898,
- Lewis Booth, executive vice president, Ford of Europe and Premier Automotive Group, earned \$868,133 in salary and received incentive bonus awards of \$2,250,000. His 2007 compensation totaled \$10,264,463, and
- Mike Bannister, executive vice president and CEO, Ford Motor Credit Company, earned \$708,700 in salary and received incentive bonus awards of \$2,150,000. His 2007 compensation totaled \$8,677,747.

Alan Mulally became the Ford CEO in September 2006 and according to World Socialist Website (Walsh, 2007) had earned a staggering #39.1 million dollars for his first 4 months on the job (proxy statement reported \$28,183,476 including \$666,667 in salary for a 1/3rd of the year, a bonus of \$18.5 million there was also a \$7.5 million hiring bonus

and a \$11 million for forfeited performance and stock option awards at Boeing). Another \$334,433 in ‘other’ compensation includes items such as life insurance premiums toward a policy worth 11 ½ times his salary, tax reimbursements and company contributions to his 401k plan. Mulally’s personal use of Ford aircraft, including his wife, family and guests, was worth \$172,974, and Ford spent \$55,469 for his relocation and temporary housing costs.

This was amongst Ford losing \$12.6 billion dollars in 2006 (the worst year it had in its 103 years) and was in the process of shuttering 16 plants and shedding more than 40,000 hourly and salaried workers. And while asking for lower wages paid to UAW workers, among other give backs.

According to CogMap (2010), Ford Motor Company have 69 executive positions that are entitled to higher pay, larger bonuses and lucrative stock option plans. Figure 123 depicts the Vice Presidents and above.

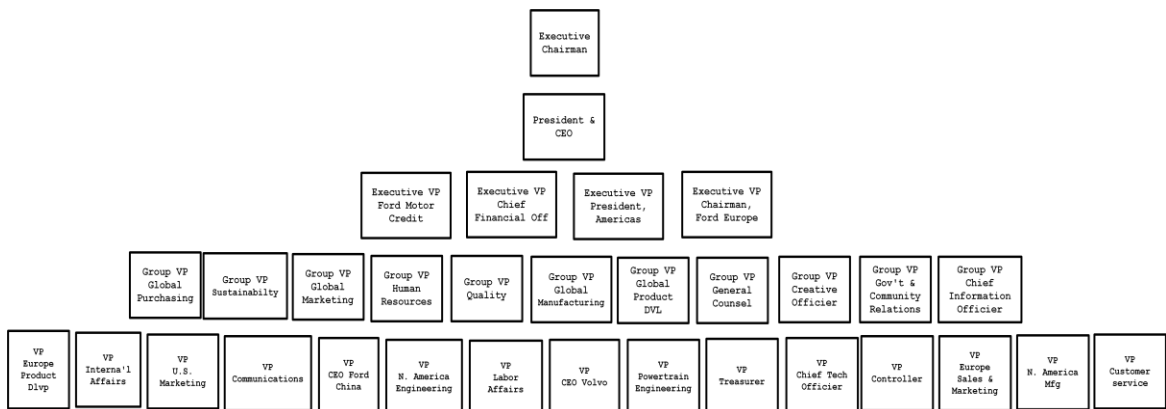


Figure 123 Ford’s Vice Presidents and Above (Source: Data from Ford Media, retrieved 3/17/2010)

Figure 124 depicts a breakdown of the Sales and Marketing organization one level further to further show the expansion of the salary organization.

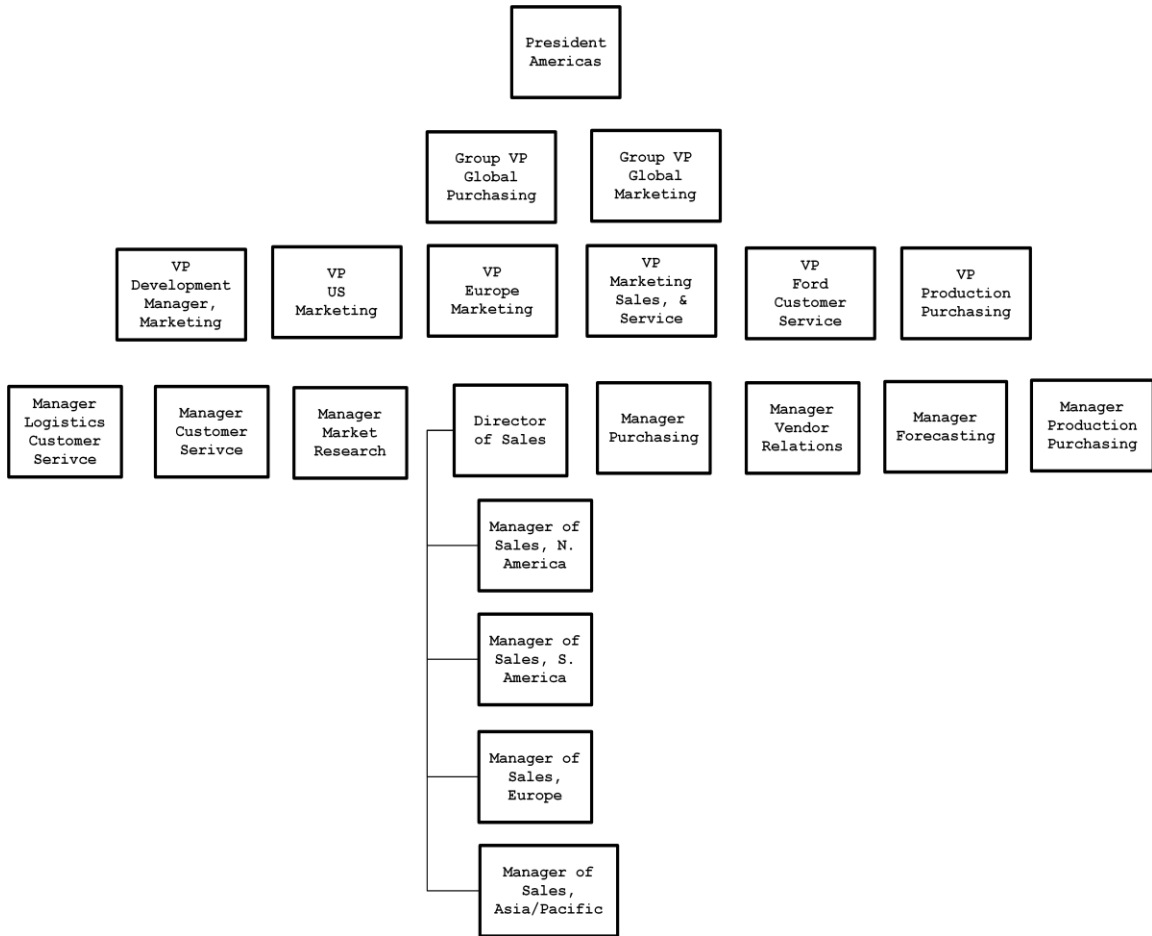


Figure 124 Ford's Sales and Marketing (Source: created with data from Cogmap, retrieved 3/17/2010)

All in told, Ford Motor Company had roughly 35,000 white collar workers as of 2005 (Ellis, 2005), and that number now stands at 21,300 (*Associated Press*, 2009).

Ford is also no stranger to large payouts for leaving current position such as in the case of Nasser. It should also be noted that Nasser's compensation in 2000 (year prior to his separation from Ford), was \$12.1 million dollars which was an increase from 10.2

million in 1999 (High Beam Research, 2001). According to the *New York Times* (Strom, 2001, 2002) Jacques Nasser was paid \$23 million while Ford lost \$5.5 billion in 2001. This can be compared to some of the largest settlements, Charles Watson's \$40 million with Dynergy, Jill Barad's \$50 million from Mattel, or Stephen Hilbert's \$72 million from Conesco.

If Mulally would had left Ford in 2009, his severance package would have been as depicted in Table X (Ford Proxy Report, 2009).

Table X Alan Mulally Benefits Upon Termination

Alan Mulally

(a) Benefits and Payments Upon Termination	(b) Voluntary Termination (\$)	(c) Early Retirement (Rule of 65) (\$)	(d) Normal Retirement (\$)	(e) Involuntary Not for Cause Termination (\$)	(f) For Cause Termination (\$)	(g) Involuntary or Good Reason Termination (CIC) (\$)	(h) Death or Disability (\$)
Compensation:							
Salary (\$2 million) ⁽¹⁾	0	0	0	4,000,000	0	4,000,000	0
Incentive Bonus Plan (175% of Salary) ⁽²⁾	0	0	0	7,000,000	0	7,000,000	0
Restricted Stock Units ⁽³⁾	0	0	0	458,000	0	2,095,877	2,095,877
Performance Units ⁽⁴⁾	0	0	0	0	0	311,451	311,451
Stock Options Unvested and Accelerated ⁽⁵⁾	0	0	0	4,090,200	0	4,090,200	0
Benefits and Perquisites:							
Evaluation Vehicles ⁽⁶⁾	0	0	0	0	0	0	76,526
Life Insurance Proceeds	0	0	0	0	0	0	6,000,000
Total:	0	0	0	15,548,200	0	17,497,528	8,483,854

(source: Ford Proxy Report, 2009)

CHAPTER 16

MANUFACTURING LOCATIONS

16.1 Introduction

This chapter will investigate and summarize the development and operation of automotive manufacturing plants. Figures 125 and 126 depict what has been transpiring over the last three-decades.

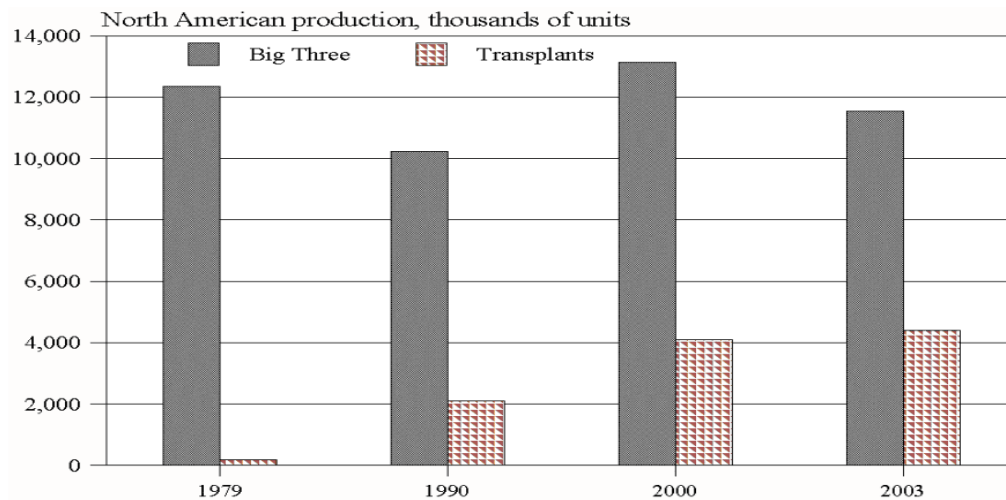


Figure 125 Automotive Production Type (source: Generated with data from Ward's Auto Data, 2010)

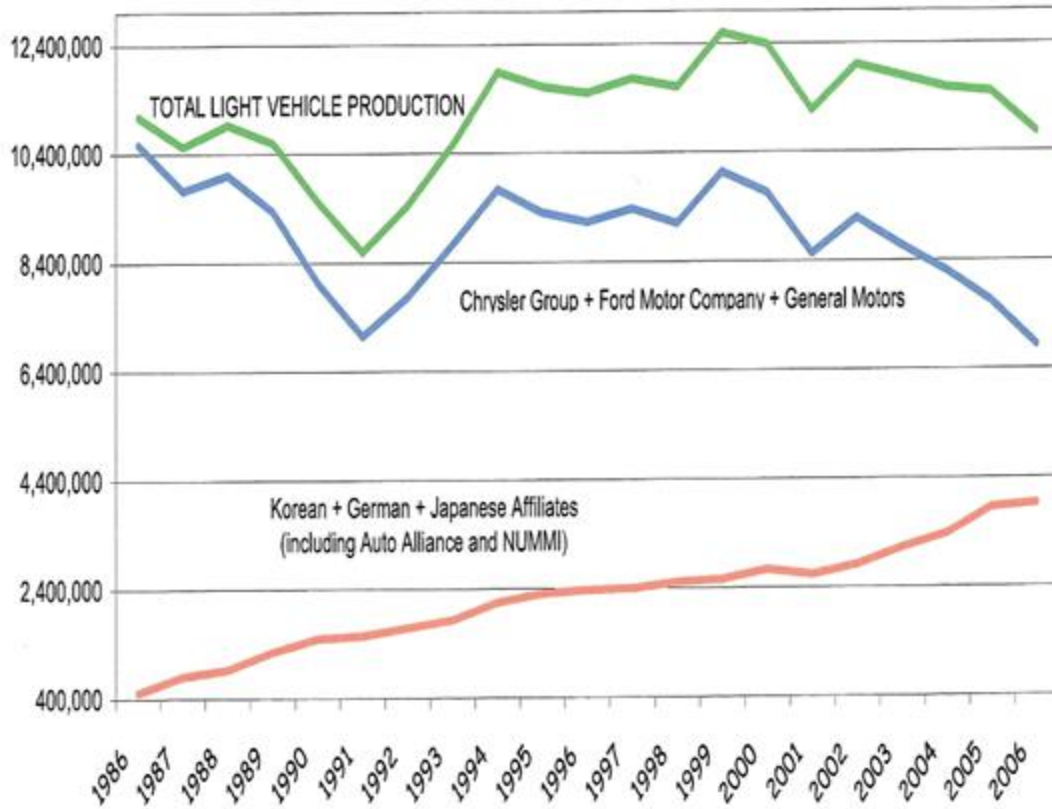


Figure 126 Automotive Production in U.S. (source: International Trade Administration, 2007)

As can be seen in Figures 125 and 126, automotive implants in the United States have continued to grow while the “Big 3” has sustained negative growth.

This chapter will be broken down into three-parts; part one will investigate the establishment of the implants, specifically Honda, Nissan, Toyota, BMW, Mercedes, Volkswagen, Hyundai, and Kia. It will look at the size of the investment and capacity capabilities. Part II will look at the growth of the southern regions of the new automotive belt (Mississippi, Georgia, Alabama, etc), the subsidies offered to attract this big investment, and the type of workforce associated with building these facilities in the South; and Part III will look at the associate plant closings of the “Big 3”.

16.2 PART I Establishment of Foreign Implants

HONDA

Although Honda was not the first implant to begin operation in the United States, they are usually seen as the first (Volkswagen was the first with producing vehicles in 1979 in New Stanton Pennsylvania), (International Trade Administration, 2007). Honda began its U.S. production in 1979 and produced its first automobile in 1982.

Honda has six automotive assembly plants in North America, four in the United States, and one in Canada and one in Mexico. Table XI lists these facilities as well as the location and start-up dates:

Table XI Honda Assemble Plants

<u>Location</u>	<u>Date</u>	<u>Models</u>
Marysville, Oh	1982	Accord, Acura, TL, CL
Alliston, On	1984	Odyssey, Civic, Acura EL, Acura MDX, Pilot
East Liberty, Oh	1989	Accord, Civic, Element
El Salto, Mexico	1995	Accord
Lincoln, Al	2001	Odyssey
Greensburg, IN	2008	Civic

(source: Honda Annual Reports, 1994-2008)

In the three decades of Honda being in North America, they have invested roughly \$9 Billion dollars, employ more than 37,000 associates and have a 1.6 million unit capacity annually; Honda passed the 15 millionth vehicles produced in the United States in May 2009. Honda remains dedicated to design and engineering; they invested in a new advanced design studio in Pasadena in 2006, which focuses on advanced design

concepts and the creation of concept vehicles for future products, (Honda Annual reports, 1994-2008; International Trade Administration, 2007; Maynard, 2006; Cooney, & Yacobucci, 2005).

NISSAN

Nissan Motor Company has two plants in the United States (North America); the first plant opened up in 1982 in Smyrna, TN and the second in 2003 at Canton, MS. The Smyrna produces the Quest, Altima, Maxima, Sentra, Frontier, and the Xterra while the Canton plant produces the Quest, Titan, Pathfinder, Armada and the QX56.

According to Nissan annual reports, the total investment between the two plants was valued at \$4.2 billion and employs over 12,000. The Smyrna plant has an annual capacity of 550,000 vehicles while the Canton facility can produce 400,000. Nissan currently has roughly 1100 dealers nationwide (Nissan Annual Reports, 2009; Barnes, 2008).

TOYOTA

Toyota, being the most cautious of the Japanese companies, began its production in the United States after Honda and Nissan, through a joint venture with General Motors (NUMMI). After that success they built their own facility in Georgetown Kentucky and Cambridge, Ontario Canada four-years later. Table XII outlines Toyota's assembly plants in North America as well as the established dates and models produced:

Table XII Toyota North American Plants

<u>Location</u>	<u>Date</u>	<u>Models</u>
Georgetown, KY	1988	Avalon, Camry, Camry Hybrid, Camry Solara
Cambridge, Canada	1988	Corolla, Matrix, Lexus RX 350
Princeton, IN	1999	Tundra, Sequoia, Sienna
Tijuana, Mexico	2003	Tacoma
San Antonio, TX	2003	Tundra
Blue Springs, Miss	2010?	Highlander, Prius

(source: Toyota Annual reports, 1995-2008; Lawinski 2008)

Also, Toyota invested in the Subaru of Indiana Automotive plant in Lafayette to produce the Camry. In all, Toyota has invested approximately \$21 billion in North America, employs 46,000 people and has an annual capacity of 2 million vehicles. Toyota produces 11 different vehicles in North America and has more than 1,700 dealerships.

BMW

BMW began manufacturing vehicles in the United States in 1994 at its plant near Spartanburg, South Carolina. BMW has an annual capacity of 160,000 vehicles and employs 4,700 people. BMW also is expanding their facility and plans on adding additional capacity upwards of 240,000 vehicles annually and an additional 500 jobs which will bring the total invested by BMW to \$4.1 billion. Also according to a September 2008 study by the Moore School of Business at the University of South Carolina, the BMW plant has added about \$8.8 billion into the State's economy and created about 4.3 jobs statewide for every job at BMW, (Lawinski, 2008).

MERCEDES

Mercedes has one plant in the United States and it is located in Talladega County, Alabama. The plant began operations in 1993; total investment was \$1.1 billion dollars, with an annual capacity of 174,000 vehicles with 3,000 employees. Mercedes assembles the M-class SUV, R-class Grand Sports, and the GL-class luxury SUV (Economic Development Partnership of Alabama, 2006).

VOLKSWAGEN

Volkswagen (VW) was the first foreign automaker to produce vehicles in the United States, and was also the first foreign automotive company (and only) to close a facility in the United States in 1989, eleven years after it opened. The Pennsylvania plant originally produced the VW Rabbit and then the Golf and Jetta (International Trade Administration, 2007). Since 1989, VW has only imported vehicles into the United States.

However, in 2008, VW announced a \$1 billion dollar investment to build a plant in Chattanooga, TN, with plans to employ 2,000 workers with an annual capacity of 150,000 vehicles to start production in 2011 (Poovey, 2008).

HYUNDAI/Kia

Hyundai has one manufacturing/assembly plant in the United States located in Montgomery County, Alabama that began production mid 2005. The total investment was \$1.4 billion, with 3,000 workers and an annual capacity of 300,000 vehicles. Hyundai produces the Santa Fe CUV and the Sonata sedan, at this facility (Barnes, 2008).

KIA announced in 2006 that it would invest \$1.2 billion in its first United States manufacturing facility in West Point Georgia (Ihlwan, 2006). KIA began production in 2010, and the plant is expected to have 2,500 employees and a capacity of 300,000 vehicles annually (Ihlwan, 2006). It is currently producing the Sorento CUV.

Table XIII summarizes these investments, capacities and number of associates:

Table XIII Summary of Investments, Capacity and Associates

	Investment	Capacity (units)	Associates
Honda	\$ 9 Billion	1.6 Million	37,000
Nissan	\$ 4.2 Billion	950,000	12,000
Toyota	\$ 21 Billion	2 Million	46,000
BMW	\$4.1 Billion	240,000	5,200
Mercedes	\$1.1 Billion	174,000	3,000
VW	\$1 Billion	150,000	2,000
Hyundai/Kia	\$2.6 Billion	600,000	5,500

(Source: Author's summary)

16.3 PART II Southern Region Growth

This section will focus on three reasons why the above mentioned foreign implants placed their facilities at the locations. First, large incentives have been offered to attract these companies; second, southern states offer a better opportunity to remain union free; third, wages and worker availability is better.

INCENTIVES

There has been approximately \$3.6 billion dollars in subsidies, mostly by southern states, to lock in foreign investment (Lillis, 2010; Hamser, 2008). There

following is subsidies in the form of land, sales tax exemptions, income tax credits, infrastructure aid, land discounts, and training grants:

- Honda
 - 1980~1987: \$27 million, Ohio
 - 1999: \$248 million, Alabama
 - 2006: \$141 million, Indiana
- Nissan
 - 1980: \$233 million, Tennessee
 - 1995: \$200 million, Tennessee
 - 2000: \$295 million, Mississippi
- Toyota
 - 1985: \$147 million, Kentucky
 - 1995: \$30 million, Indiana
 - 1996: \$15 million, West Virginia
 - 2001: \$30 million, Alabama
 - 2003: \$133 million, Texas
 - 2007: \$300 million, Mississippi
- BMW
 - 1992: \$150 million, North Carolina
- Mercedes
 - 1993: \$258 million, Alabama
- Hyundai
 - 2002: \$252 million, Alabama

- KIA
 - 2006: \$400 million, Georgia
- Volkswagen
 - 2008: \$577 million, Tennessee

SOUTHERN GROWTH AND DEVELOPMENT

The southern region of the United States (also known as the sun-belt), really began to grow and expand during World War II. Many of the military installations and work was being developed in the South because of the more moderate climate. The oil boom, as discussed in Chapter 4, also helped the expansion, most notably in Texas, California and Louisiana.

The Interstate Highway System of the 1950s, the advent of the household air conditioning and passage of the civil rights legislation, lower wages and low level of union involvement created a situation for Industries to move into the south. Industries, in the 1970s, began taking advantage of all of these conditions; and older populations began migrating to the south for retirement to take advantage of the more moderate climate.

Soon, many industries were moving in and large migrations of people from the north to the south were taking place. In the last 30 years higher technology and new economy industries have been major drivers of growth in many areas of the south and west. More than a third of all fortune 500 companies today are based in the sun-belt. Also, two of the largest research parks in the country are located in the south: Research Triangle Park in North Carolina (which is also the world's largest) and the Cummings Research Park in Huntsville, Alabama. This growth has shifted politics as well; since

1970, the southern states have gained 25 electoral votes from the North and Midwest states. So the south was primed to accept the new automotive industry, with the growing network of higher technology, the lower expected pay rates and the more anti-union sediment was conducive the implants moving in.

Table XIV describes the population and population change in specific states (southern states and Ohio and Michigan) while Figure 127 depicts percent changes from 1990 to 2008 and 1970 to 2009:

Table XIV State Population

	2008	2000	1990	1980	1970	1950	% Change '70-'09	% change '90-'09
Alabama	4,627,851	4,447,100	4,040,587	3,893,888	3,444,354	3,061,743	34.4%	14.5%
Arkansas	2,855,390	2,673,400	2,350,725	2,286,435	1,923,322	1,909,511	48.5%	21.5%
Florida	18,328,340	15,982,378	12,937,926	9,746,324	6,791,418	2,771,305	169.9%	41.7%
Georgia	9,685,744	8,186,453	6,478,216	5,463,105	4,587,930	3,444,578	111.1%	49.5%
Kentucky	4,269,245	4,468,976	3,685,296	3,660,777	3,220,711	2,944,806	32.6%	15.8%
Louisiana	4,410,796	4,468,976	4,219,973	4,205,900	3,644,637	2,683,516	21.0%	4.5%
Mississippi	2,938,618	2,844,658	2,573,216	2,520,638	2,216,994	2,178,914	32.5%	14.2%
North Carolina	9,222,414	8,049,313	6,628,637	5,880,095	5,084,411	4,061,929	81.4%	39.1%
South Carolina	4,479,800	4,012,012	3,486,703	3,120,729	2,590,713	2,117,027	72.9%	28.5%
Tennessee	6,214,888	5,689,283	4,877,185	4,591,023	3,926,018	3,291,718	58.3%	27.4%
Texas	24,326,974	20,851,820	16,986,510	14,225,513	11,198,655	7,711,194	117.2%	43.2%
Ohio	11,485,910	11,353,140	10,847,115	10,797,603	10,657,423	7,946,627	7.8%	5.9%
Michigan	10,003,422	9,938,444	9,295,297	9,262,044	8,881,826	6,371,766	12.6%	7.6%

(source:Population Division Table 1 & 4, 2008)

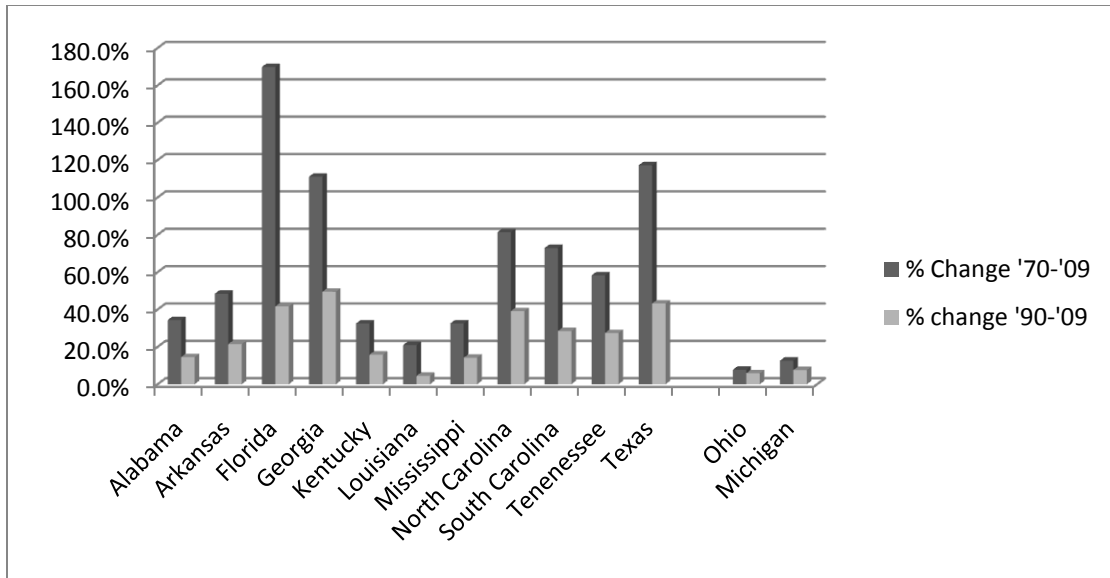


Figure 127 Percent Change in Population (source: Population Division Table 1 & 4, 2008)

As can be seen from the above table and figure, the only southern state that did not grow significantly more than Ohio and Michigan was Louisiana, however, hurricane Katrina contributed to a mass exodus from the state, which offers explanation. Figure 128 shows the growth from 1970 to current of some of the cities in these states:

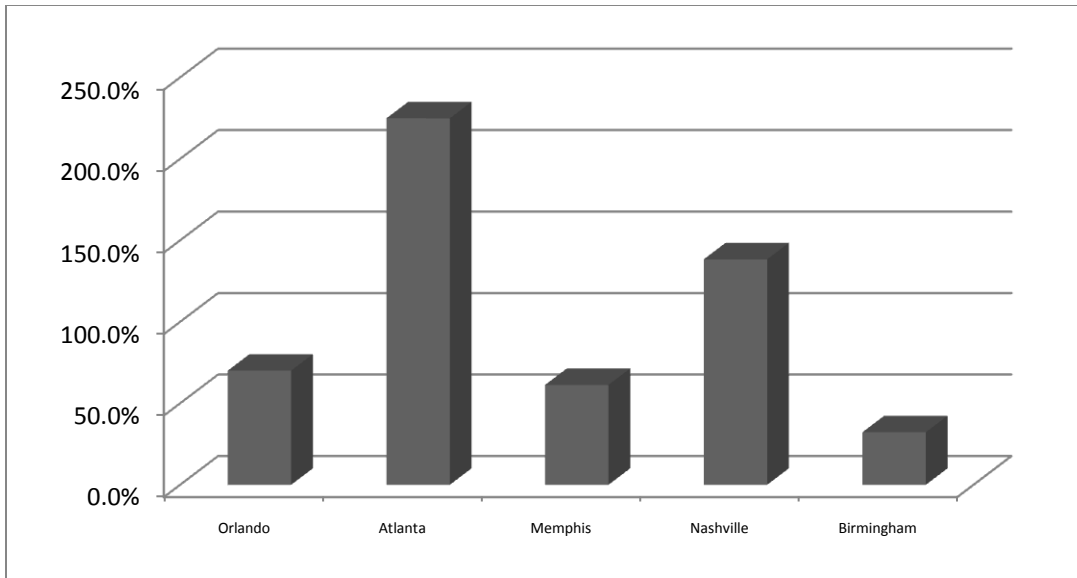


Figure 128 Percent Growth from 1970 to 2008 (source:generated with data from the Population Division Table 1 & 4, 2008)

The age of the population in each of these states do not vary considerable, Table XV summarizes the age demographics:

Table XV Age Demographics

	< 5 years	< 18 year	> 65 years
Arkansas	7.1%	24.6%	14.3%
Florida	6.2%	21.8%	17.4%
Georgia	7.6%	26.3%	10.1%
Kentucky	6.7%	23.6%	13.3%
Louisiana	7.0%	25.1%	12.2%
Mississippi	7.5%	26.1%	12.6%
North Carolina	7.1%	24.3%	12.4%
South Carolina	6.8%	23.8%	13.3%
Tennessee	6.7%	23.8%	13.2%
Texas	8.3%	27.6%	10.2%
Ohio	6.5%	23.8%	13.7%
Michigan	6.3%	23.9%	13.0%

(source: U.S. Census Bureau Data, retrieved 3/31/10)

Florida, as one would expect, does possess a higher population of retire aged people. The United States averages for age over 65 is 12.8%, while under the age of 5 is 6.9% and under the age of 18 stands at 24.3%.

NON-UNION ENVIRONMENT

The majority of the implants are being built in the South, most notably, from South Carolina to Texas, there are 11, either operational or being built, of these implants. All of these states happen to be a right to work state, unlike the northern states. If a union does manage to get a foot hold in one of these plants, they cannot force employees who do not wish to be in a union to join; whereas in Michigan if a plant is unionized all workers must join (Barnes, 2008).

The United Auto Workers union (UAW) has only managed to force three votes since the 1980s in these plants, the first being in 1989 at the Nissan plant that managed to get less than twenty-percent of the vote and a few years later at the same plant and eventually another failure at the Mercedes plant. The south is also known for its suspicion of unions, making it easier for these implants to remain union free, and its ability to work directly with the employees to let their voices be heard without a union being the middleman.

WORKERS and WAGES

According to the U.S. Census Bureau, from the period of 2000 through 2030, the southern population is expected to grow by 43-percent versus the Midwest of ten-percent. Southern states were also known heavily for their in the textile industries as well as the

furniture industry, both of which has moved overseas, most notably to China. So there is variables are aligning to where there is an abundance or potential, both current and future, pool of workers.

Wages are lower as well, some more than others, for example, according to Forbes (Elliott, 2009), Kia's new plant had 43,000 people apply for the 2,300 positions that they had posted, with a starting salary of \$17/hr. When Toyota began operations when Kentucky, they had some 142,000 applicants to fill 3,000 positions. What Toyota then did, was they chose 28,000 people and began a two and a half year weeding down process to ensure that the only hired the "right" people (Austen, 2009). This process includes many hours of class room training to make sure that potential employees learn and understand the cultural/work ethic and operational/manufacturing systems (e.g. Toyota production system) prior to floor manufacturing. It is not uncommon for employees to maintain temporary status for well over a year. The application process is very similar in the other implant plants as well. With this flexibility, lack of the legacy costs, no automatic cost of living increases year over year and pay for performance, it is estimated that it cost approximately \$2,000 less per vehicle in labor costs to build a car in these implants versus UAW plants.

It is not said that these implants are paying on average the same, the fact is that they are paying a higher rate than other industries in their respected states (as in the case of Toyota, they started out \$8 per hour higher), which is another added benefit to keep unions out of their plants. Figure 129 is from the Economic Partnership of Development of Alabama (2009) on their current pay data:

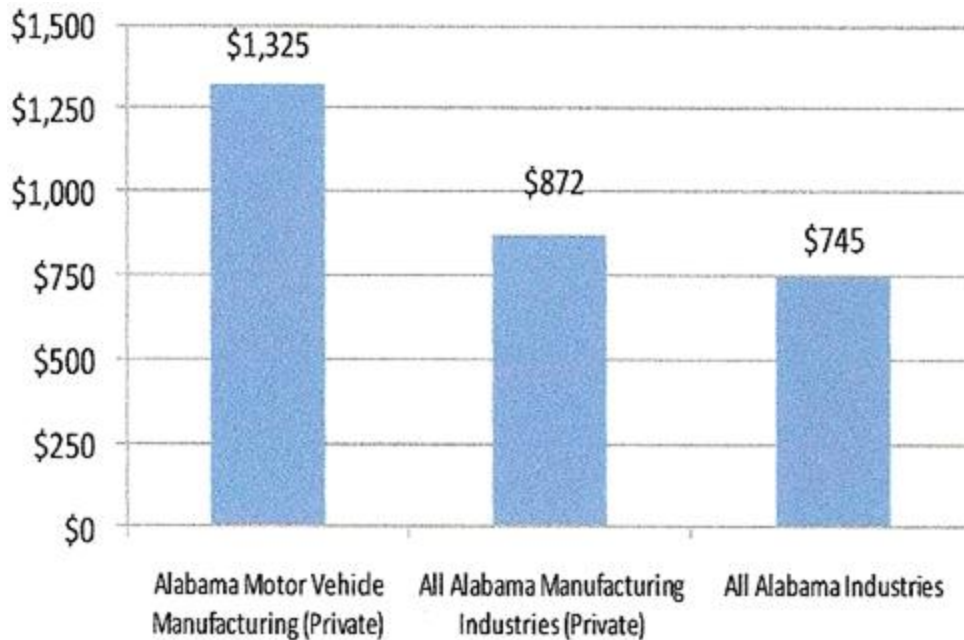


Figure 129 Alabama Average Weekly Salary (source: Economic Partnership of Development of Alabama, 2009)

Implants also initiated their the salaries at the start with pay for performance and profit sharing plans, versus the typical UAW plan for pay for seniority and job description. The implants maintain a very low number of job descriptions to maintain a higher level (or a level of) flexibility versus the “Big 3” plants. If the companies are doing well, then the employees do very well, plus maintain overtime pay.

The implants also have the advantage, by hiring a younger workforce when the plants began production; they are not battling the legacy costs as the “Big 3” is battling. And now that there is an established automotive presence in the south, there is also an established partnership of suppliers that are enjoying the same benefits as the implants are enjoying, with the lower wages, less health care costs and abundance of workers that are suspicious of unions and are sitting up shop in right to work states.

It should be noted though that management in the implants is more worker friendly, forming quality circles, giving the employees a right to voice their opinions and participate in decision making process in the operations. With this, there are no unionized implants, other than the joint ventures that were note discussed in this chapter, regardless of the location. So it can be said that the south is more advantageous because of the lower pay scales needed, the more moderate climate for accessibility and the growth of population, larger pool to pull from, and of course, the better incentives being offered by southern states.

16.4 PART III - Big 3 Plant Closures

As discussed in earlier chapters, there are a significant number of Americans employed by the automotive industry manufacturers; congressional reports place that number at roughly million Americans, (Cooney and Yacobucci, 2005). The industry has changed dramatically since the U.S. “Big Three” motor vehicle corporations produced the overwhelming majority of cars and light trucks sold in the United States. By 2003, most passenger cars sold in the U.S. market were either imported or manufactured by the implants discussed earlier. The Big Three now dominate only in light trucks, and are being challenged there by the foreign brands, see Figure 129. The Big Three have shed about 600,000 U.S. jobs since 1980, while about one-quarter of Americans employed in automotive manufacturing facilities (nearly 300,000) work for foreign-owned companies.

These changes have had major effects on the structure and location of the U.S. motor vehicle industry. Michigan has been the state most directly and adversely affected,

losing about 100,000 auto industry jobs since the late 1970s. Table XVI outlines the plants already closed by the “Big 3” since the 1980s.

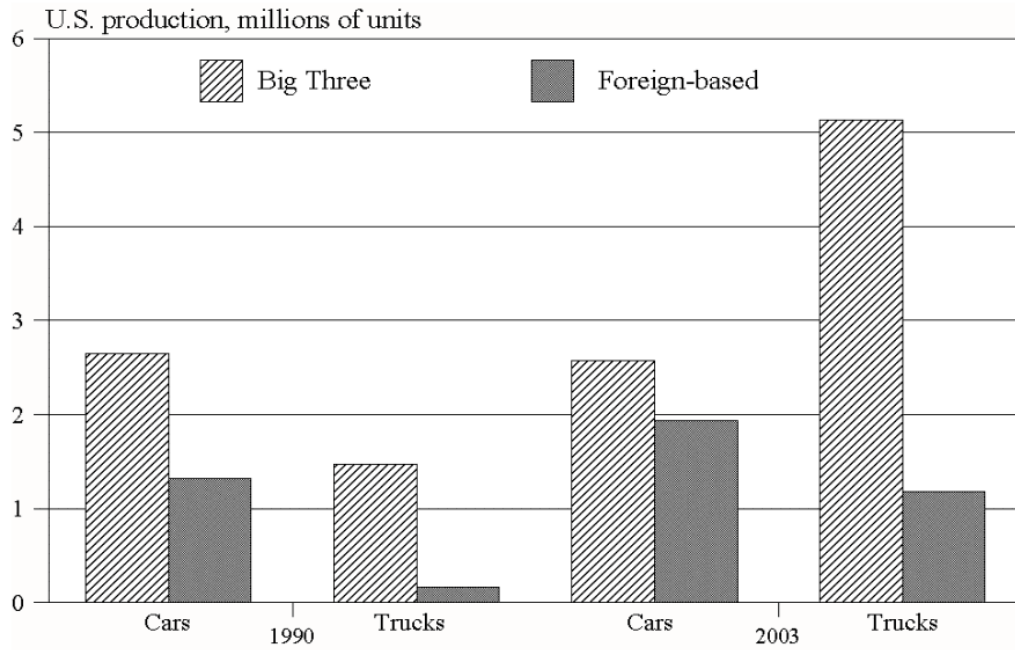


Figure 130 Growth of Implant Truck and SUV production (source: Ward’s Auto Data, 2010)

Table XVI Big 3 Plant Closures

Company	Location	Year Closed
GM	South Gate, CA	1982
GM	Norwood, OH	1987
GM	Detroit, MI	1987
GM	St. Louis, MO	1987
GM	Farminham, Mass	1989
GM	Atlanta, GA	1990
GM	Van Nuys, CA	1992
GM	Ypsilanti, MI	1994
GM	Sleepy Hollow, NY	1996
GM	Linden, NJ	2005
GM	Lansing, MI	2005
GM	Baltimore, MD	2005
GN	Oklahoma City, OK	2006
GM	Lansing, MI	2006
GM	Doraville, GA	2008
GM	Moraine, OH	2008
GM	Janesville, WI	2008
GM	Pontiac, MI	2009
GM	Wilmington, DE	2009
FORD	Pico Rivera, CA	1980
FORD	Mahah, NJ	1980
FORD	Edison, NJ	2004
FORD	Dearborn, MI	2004
FORD	Hapeville, GA	2006
FORD	Wixom, MI	2007
CHRY	Hamtrack, MI	1980
CHRY	Kenosha, WI	1988
CHRY	Newark, DE	2008

(source: GM annual reports, 1994-2009; Ford annual reports, 1994-2009; Cooney and Yacobucci, 2005)

Coupled with the above list, it is unsure of which plants Chrysler will look at closing in the future due to the recent (2009) activities with the sale of Chrysler and 67% ownership by the union.

Also, with General Motors bankruptcy filing and government assisted bailout, there can potentially be further reductions, more specifically, two plant idling can turn into closures as market share and economic conditions dictate (Orion, Michigan and Spring Hill Tennessee). Ford also has plans to decrease payroll by 25,000 employees and

plan 14 plant closures by 2012 (Speer, 2006). Ford's business plan as submitted to congress in 2008 included the following on plant closures:

- Plans two additional plant closures in 2008 and four additional plant closures between 2009 and 2011. The company also has announced its intent to close or sell what will be four remaining ACH plants. The company said it will continue to aggressively match manufacturing capacity to real demand.

CHAPTER 17

FORD MOTOR COMPANY

17.1 Introduction

For many past decades (1930s~1970s) the automotive industry in the United States operated as an oligopoly with General Motors setting the tone of the industry business/marketing product development to add features and options, establish the direct and indirect costs, markup the profit margin and set the price and then all others will follow, with the combined “Big Three” market share exceeded 90% in the 1950s. However, this began to change as the oil embargos took hold in the 1970s (see chapter 12); Figures 131 and 132 depicts the recent volume of vehicle sales in the U.S. and market share captured in the U.S. by the “Big Three”:

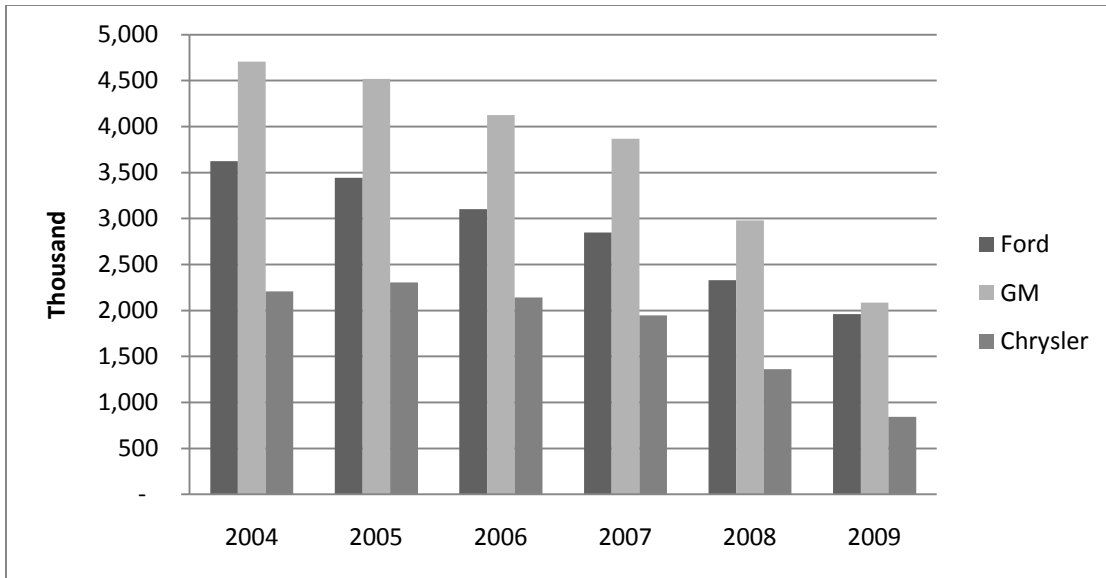


Figure 131 Big Three U.S. unit sales (source: Ward's Auto Data, 2010)

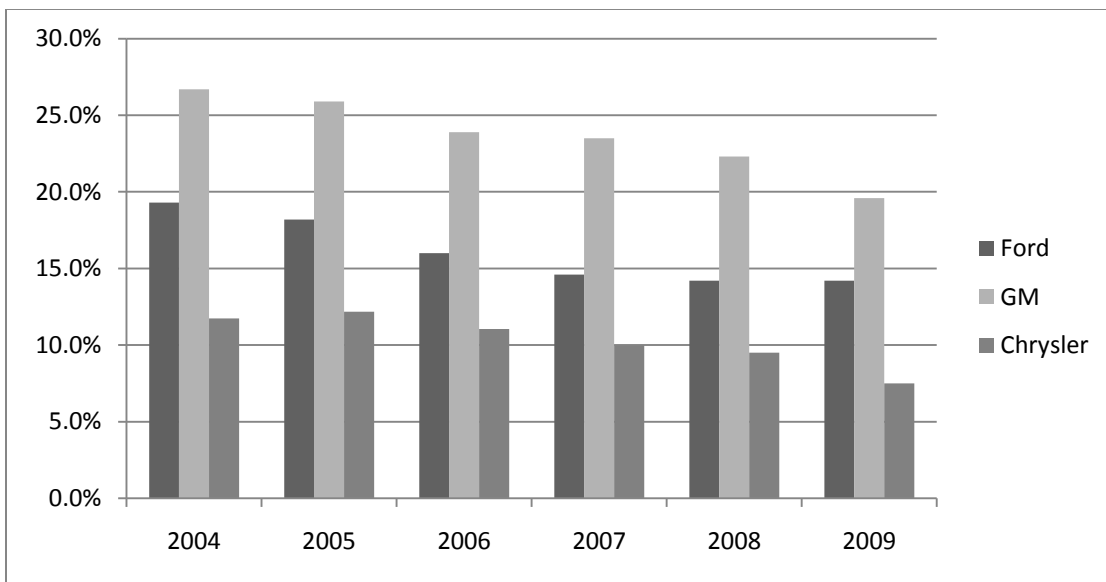


Figure 132 Big Three U.S. Market Share (source: Ward's Auto Data, 2010)

2009 was a year that saw the combined market share of the U.S. drop below 50 percent.

Figure 133 depicts the gross income earned (lost) on these unit sales:

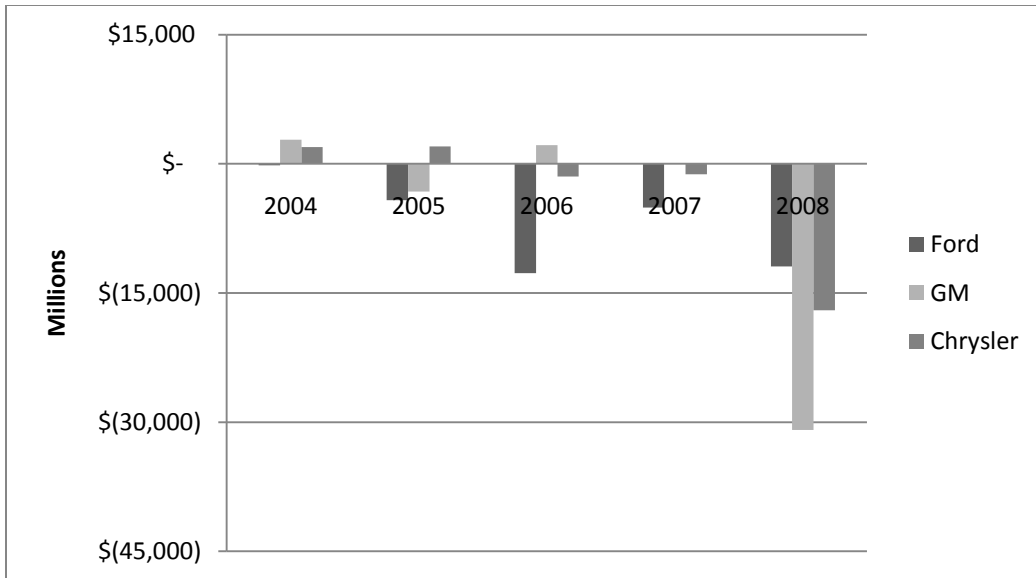


Figure 133 Big Three U.S. Net Income (source: Annual Reports, 2004-2008)

Figure 134 depicts the gross revenue of Ford and General Motors over this same time period (Chrysler is now privately owned with Fiat's stake of twenty-percent and consistent gross revenues could not be obtained):

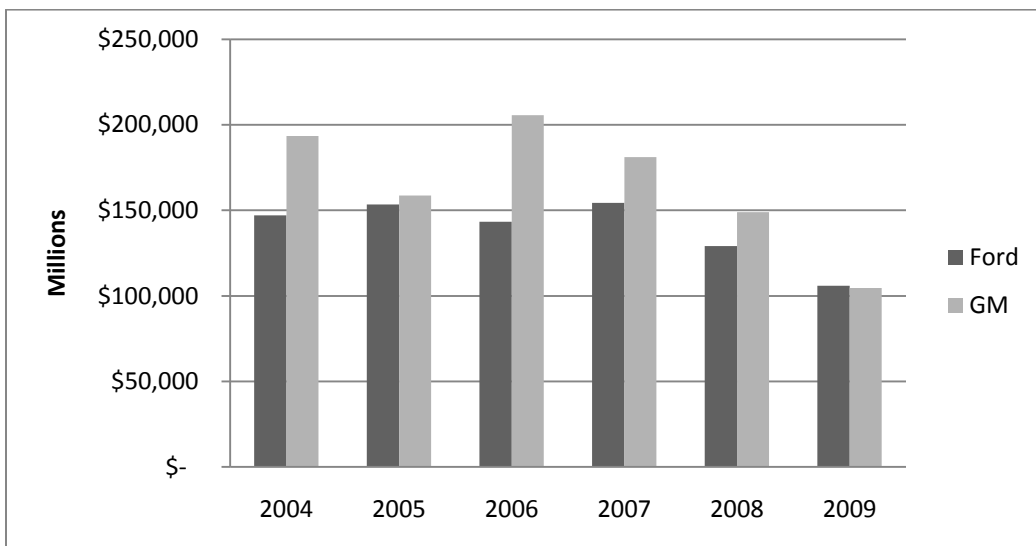


Figure 134 Ford and GM Revenue (source: Annual Reports, 2004-2009)

From a research and development standpoint, through this time period Ford has had the highest R&D budget of the automotive manufacturers while General Motors has the second highest budget (Toyota was second); Figure 135 depict their respective spending:

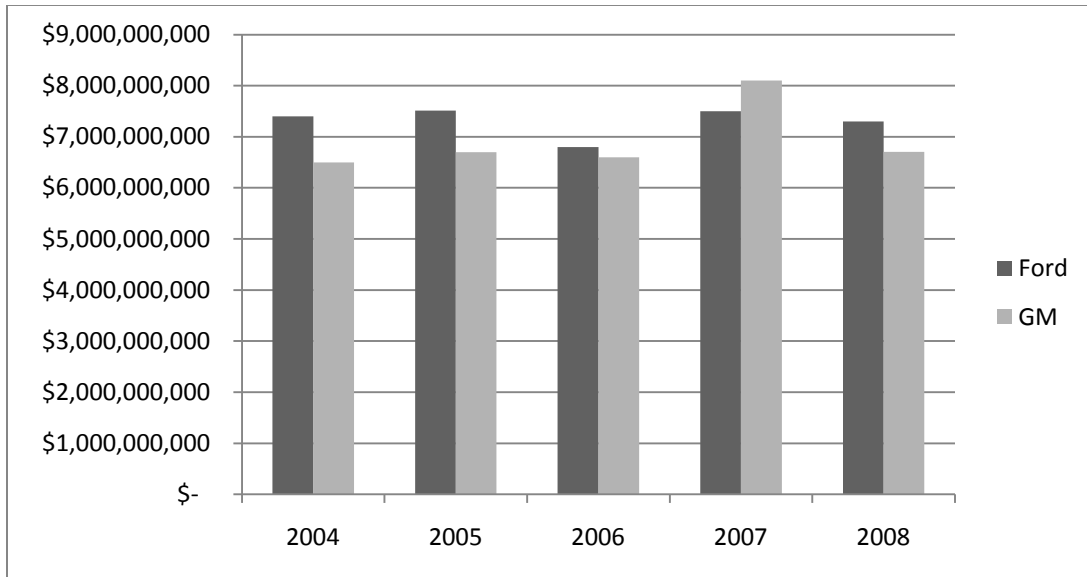


Figure 135 Ford and GM R&D Expenditure (source: Annual Reports, 2004-2008)

Both General Motors and Chrysler ended up filing for bankruptcy and sought Government bailout. Chrysler, as part of Fiat, is teaming with Fiat currently for exchange of small engine technology, while GM has downsized the number of brands, eliminating Saturn, Pontiac, and Hummer and selling off international units, in hopes to “right size”(down size) into profitability and long time survival.

17.2 Chapter Structure

This chapter examines several characteristics of the Ford Motor Company. The chapter is divided up into six parts: part one looks at the diversification of Ford Motor

Company, in both automotive and nonautomotive industries; part two presents the previous sixteen-year trends in an assortment of characteristics and comparisons; part 3 examines Ford dealerships – number of dealerships and examination of profit source; part four looks at vehicle prices of small and midsize cars from 1979 to present taking 4-5 year samples ; part five investigates recent recall issues, cost associated with these recalls and adds some perspective of how Ford has handled safety and environmental concerns; and part 6 examines current management, efforts and technology commitments and presents a brief perspective and historical backgrounds of past management leaders.

Figure 136 outlines the current vehicle structure and offering of Ford Motor Company.

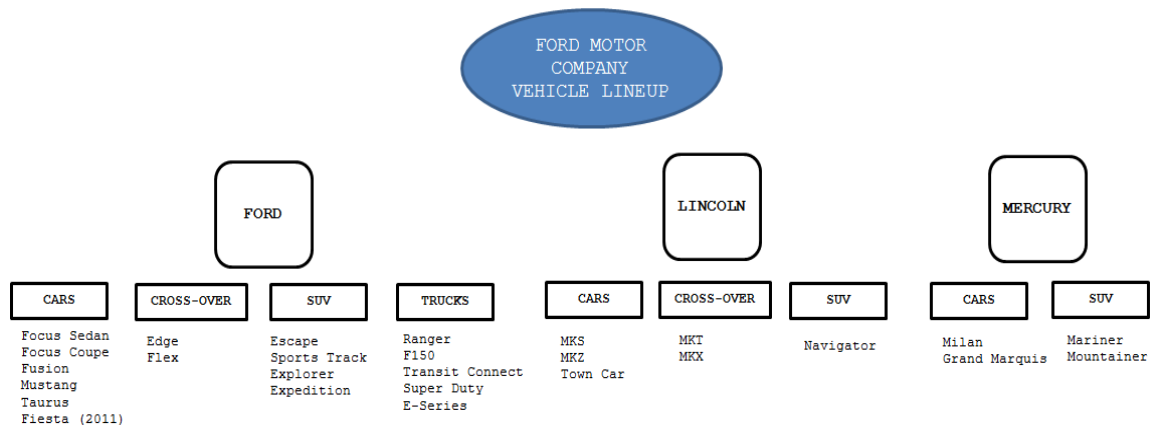


Figure 136 Ford Motor Company Vehicle Lineup (Source: Ford Annual Report, 2009)

17.3 Part I – Diversification

According to Angus Mackenzie (2009), the American auto manufacturers, “Big 3”, had an overwhelming advantage after World War II. The United States remained unscathed during the war while England, France, Germany, Italy and Japan were devastated; their factories and physical and political infrastructure was destroyed, middle

class and their income were nonexistent. By 1955, the “Big 3” oligopoly had 95-percent of the U.S. market. Moreover, one thing that remained constant was that the automotive industry mirrored the gross domestic product (see Figure 137); therefore at the time diversification seemed to be a logical step for more significant revenue growth

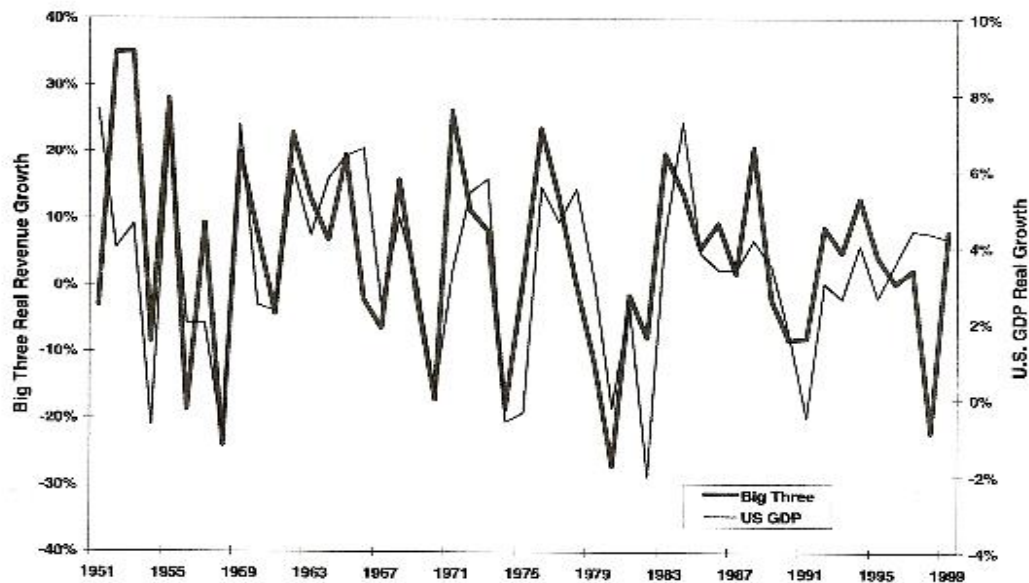


Figure 137 Big 3 Revenue and U.S. GDP (source: Perold, 2002)

One of the first and most notable early diversification of products not associated with the automotive industry was Ford Motor Company’s purchase of Philco in late 1961. With this Ford Motor Company not only produced automobiles (and associated items through their vertical integration previously discussed in Chapter 3) they were now quickly producing the following items:

- Car Radios,
- Air conditioners,

- Refrigerators and home freezers,
- Consumer electronics, televisions,
- Electric ranges,
- Home washers and dryers, and
- Philco 2000 model 212 computers for governmental use

In 1963, Ford merged their Aeronutronic, defense and space related division, with Philco to subsequently create the Philco Aeronutronic Company. Among the highlights of this company were that it then became NASA's primary communications equipment vendor during the 1960s, also building the consoles in the Manned Spacecraft Center in Houston (Ford motor company: Chronology, 2010).

However, after the first oil embargo (see Chapter 12), Ford became money strapped due to their inability/desire to create and produce smaller higher miles per gallon competitive cars (see Chapters 7 and 8), and began selling parts of Philco in 1974. First was the sell-off of everything except the aerospace/defense portion in 1974 to General Telephone. The remaining portion was renamed Ford Aerospace and Communications Corporation in 1976, and then again to Ford Aerospace Corporation in January 1988. Eventually, continually struggling, Ford sold the remaining portion to Loral Corporation in 1990 for \$715 million.

As discussed in Chapter 15, there were many changes in Ford's executive management 1980s through to the current company team. With these changes brought a fierce outreach to growth by acquiring other assets; automotive, nonautomotive and automotive related. A list of the more worthy for discussion is as follows:

- Diversification into financial services
 - \$5.5 Billion spent in the last half of the 1980s including \$3.4 billion for The Associates, a Dallas based finance company,
- 1990 acquisition of Jaguar Motor Company,
- 1991 creation of a Quality Care and Customer Care system to meet the diverse “after sales” needs of Ford owners and dealerships,
- 1991 Joint venture with Volkswagen in “AutoEuropa”, an organization which will produce multipurpose vehicles at Setuba, Portugal,
- 1992 50% stake of Mazda,,
- 1993 efforts of Troutman for globalization of Ford
 - First formal dealerships in China,
- 1994 Acquires Hertz Rent-a-Car,
- 1997 Creation of Visteon, out of its internal components unit, only to be made independent later by Nasser, in 2000,
- 1999 start of an automotive e-business integrated supply chain,
- 1999 51% interest in Norway’s PIVCO Industries,
- \$6.45 billion purchase of Volvo,
- 1999 Purchase of Kwik-Fit and Junk Yard, and
- 2000 officially purchased and took ownership of Land Rover

Jaguar and Land Rover

Ford Motor Company acquired Jaguar in 1989 for \$2.5 billion and Land Rover in 2000 for \$2.7 billion. Both of these companies were struggling with costs and quality

prior to Ford taking over. Ford, over the period they owned these two companies invested roughly \$10 billion in product development costs, losses and quality improvement initiatives (Associated Press, 2008).

Ford's plan with Jaguar was to improved quality (serious issue), expand manufacturing capabilities and introduce a lower cost Jaguar, the X-type (or Baby Jag) to compete with the BMW-3 series. However, 18 months late in development and with a host of reliability issues, pushing them down 17 notches in the JP Powers and Associates ratings to 19th place was the end result (Kerwin, 2002). Worse yet, the higher end XKE Jaguar also displayed similar problems/effects; in 2004, Jaguar had a rebate of \$5,000 dollars versus \$464 for Lexus and \$552 for Mercedes and none for BMW; the only luxury car that fared worse for rebates and resale value was the Land Rover (Kerwin, 2004).

Ford, in order to raise capital for their "Way Forward", a reorganization plan to reduce costs and improve profits that was submitted to and accepted by the board at the December 7, 2005 board meeting and later expedited by Mulally (to be discussed later), sold Jaguar and Land Rover to Tata Motors Ltd., netting \$1.7 billion, a far cry of the over \$15 billion spent. In the end, Jaguar's quality improved marginally and Land Rover ranked last in JD Powers and Associates rankings of initial quality and dependability in 2007.

Volvo

Volvo faired a little better then Jaguar and Land Rover. Ford gained safety performance and engineering of safety from Volvo. Volvo contributed slightly to the

bottom, mostly breaking even or at a slight profit. Ford Motor Company purchased Volvo in 1999 for \$6.45 billion, invested an additional \$2 billion in product development and manufacturing development and sold Volvo in 2010 to Geely in China for a reported \$1.8 billion.

Visteon

Visteon was created by and became a subsidiary of Ford Motor Company in 1997 and is one of the world's largest automotive suppliers dealing in vehicle electronics, systems, modules, & components. Ford created Visteon from its internal parts supplier division (a result of long time vertical integration); its premise was to make them perform in a competitive environment to earn bids for subsystems and components against other outside independent suppliers of similar components. Visteon's historical problem was its high labor and benefits cost (as being part of Ford's unionized labor force, as described in Chapter 15) which made many smaller components and modules very expensive for the small value added. Ford then made Visteon independent in 2000 because the lower margins (earned because of the competitive nature of the parts business). Ford did maintain some legacy associated costs with current (under Ford ownership) Visteon employees. Visteon went into bankruptcy in 2009.

Kwik-Fit and Junk Yard

Jacques Nasser wanted to transform Ford into a service provider. He felt that the average amount spent on ownership of a vehicle was roughly \$64,000 dollars over the lifetime (Feast, 2002); therefore, he wanted to collect the "other" revenues (aftermarket

parts, non-warranty replacement parts, personalized modifications) associated with the sale of the car. Ford purchased Kwik-Fit in 1999 for \$1.5 billion and a little over two years later sold it for \$505 million.

17.4 PART II Key Indicator Trends

Maxton and Wormald (1995) collected and published some very interesting automotive industry data; world estimates in vehicles owned are at 450 million with 75 percent being in the United States and Europe at the time. Though no numbers exist on the number of automobiles being retired each year, there are an estimated 50 million additional automobiles being produced each year. World production of vehicles consumes roughly 15 percent of the steel produced, 25 percent of glass and almost half of the world's rubber. In industrialized "rich" countries the automotive industry accounts for almost 10 percent of gross domestic products.

Maxton and Wormald (1995) estimates put the new automobile production economy at \$1,000 billion dollars. Their estimates are based on their estimates that there are 10,000+ parts per vehicle made by specialized plants or a total of 500+ billion parts on an average of \$20,000 per vehicle. The estimate of this economy is low; it does not take into account after-market sales, investments in infrastructure (e.g. highways, bridges, and parking lots), petroleum refinement, sales, service and after market customization. Even though of this large economy, according to an article in *The Economist*, perpetual motion (2004), it references a study completed by the Deutsche Bank in 2002, that showed the car industry in Europe represented just 1.6 percent of its stock market

capitalization versus 3.6 percent two decades earlier and in the America's the automotive industry represents 0.6 percent versus four percent two decades ago.

Along with the decay in market capitalization, there has been a steady decay in profits seen by the original equipment manufacturers. In the 1920s in the beginning the automotive manufacturers saw profits in the 20 percent range, a few decades later in the 1960s the profit decreased to roughly 10 percent; today the average is roughly five percent, with some of the manufacturers actually losing money. So despite the role the automotive industry represents in employment, importance in modern economics, and political influence, it has all but disappeared in importance in equity markets and has continually shrunk as a percentage of GDP.

80 percent of travel today in the United States is required using a car, e.g. work, shopping, while the remainder of travel by car is for recreational purposes. Coupled with this, travel to work has increased 60 percent over the last 20 years as people are living further and further from work and commuting from their expanding suburbs.

Market Share, Unit Sales and Employee Headcounts

Ford, even though not the inventor of the automobile, is truly the father of the car industry. By adapting the moving assembly line that Henry Ford observed in the Chicago slaughter house, he gave birth to mass production. Even though having a significant lead in market share at the start, Ford lost much ground to General Motors in the 1920s and fell to second place. Ford managed to maintain this status until Toyota passed them in 2008 making Ford number three.

Ford's market share in 1994 stood at 25.5 percent and decreased by 44 percent to 14 percent by 2009. Much of Ford's demise can be directly related to the increase of market share that foreign implant makers, such as Honda and Toyota, gained in the North American automotive market. Even worse for Ford, competition in the larger truck and SUV markets no longer just come from GM and Dodge, and instability of gas prices topping out last year at over \$4 per gallon have created lower large vehicle demands (see Chapter 12 for gas price trends). Ford has been noted as making less than \$1,000 in each of their car sales, however, making in excess of \$10,000 per vehicle for their F150 trucks and SUVs, where the F150 truck has been the number one seller over the past 15 years in all categories (Ball 2003). Figure 138 represents Ford's trend in total market share in North America and Figure 139 shows market share of cars and Light Trucks/SUVs separately:

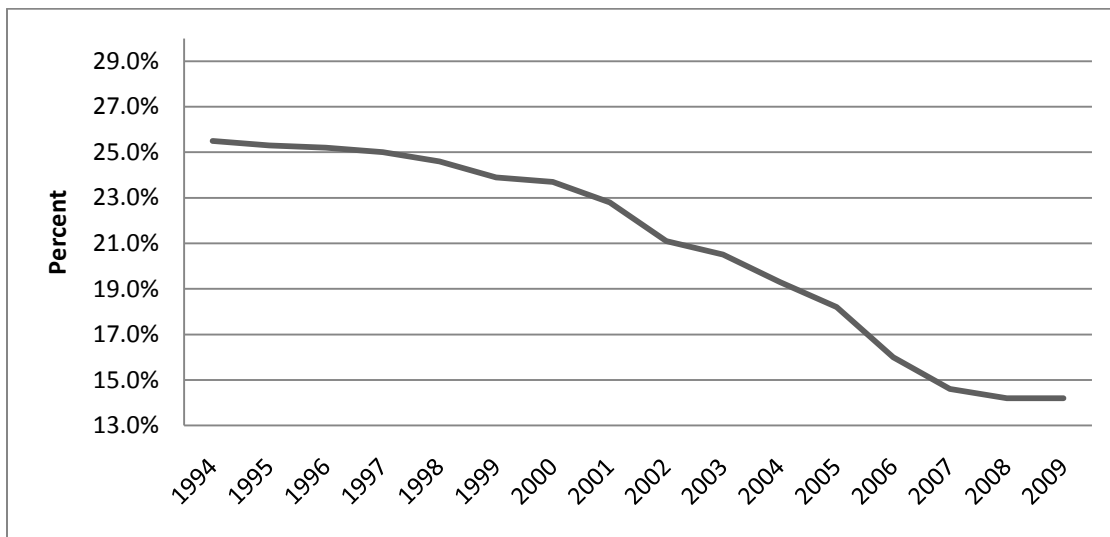


Figure 138 Ford Total Market Share, NA (source: created with data from annual reports, 1994-2009)

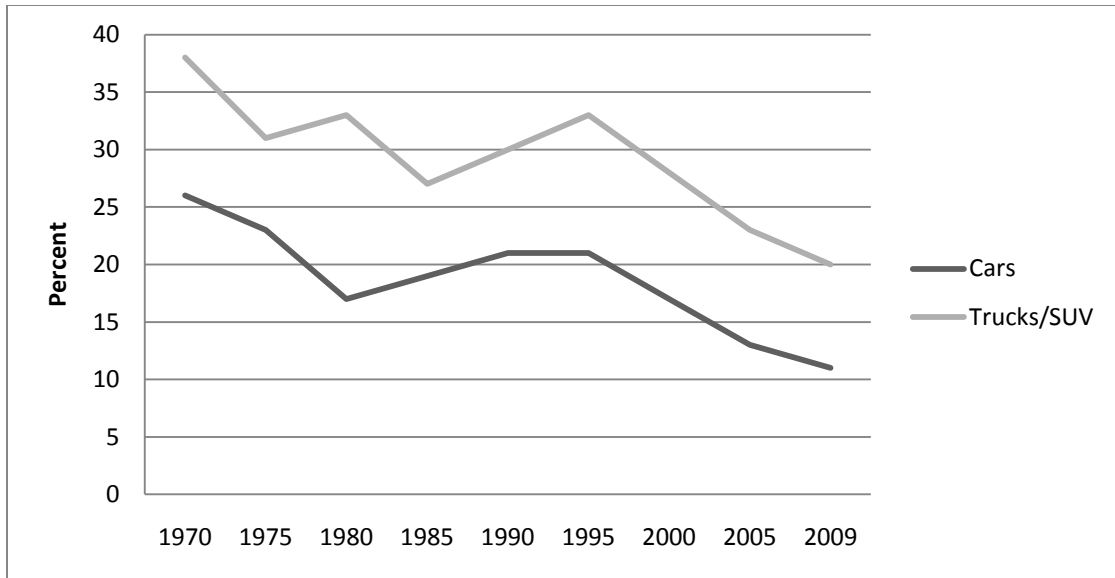


Figure 139 Ford Truck and Car Market Share, NA (source: Ward’s Auto Data, 2010)

An alternative to the examination of market share is the raw number of vehicles produced/sold and the gross revenue generated by the sale of these vehicles. Keys (1995 and 1998) argues that the domestic manufacturers have been producing vehicles with old financial (budget) models investing instead of in newer technologies and leading in the management of technologies, but into the development of heavier more feature addition vehicles (cars, trucks and SUVs). Keys contradicts some studies of vehicle weight reductions, but instead makes an argument that overall vehicles are weighing more, which supports the theory that Ford, for example, was beefing up on heavy vehicles, weight (counting heavily on larger sports utility vehicle and trucks) and adding more features (increasing weight) and raising prices for these vehicles. Keys contend that since around the 1930s the automotive industry, until the last decade or so, has operated in an oligopoly. General Motors has set the tone of leading the industry business/marketing product development cycle/process “to add features and options establish the direct and

indirect costs, markup the profit margin and then set the price”; and then the others (Ford and Chrysler) will follow. As Keys states, “somewhere along the way, the automobile companies lost the effectiveness-efficiency paradigm of Henry Ford - a dynamic growth period characteristic of more value for less money (p.268).”

When examining Ford’s performance over the last sixteen years we can see that Ford sold 4,218,000 vehicles in 1994 and that has decreased by 53.6 percent to a level of 1,959,000 vehicles in 2009. Ford’s major revenue and profit center is mostly composed of the sales of their sports utility vehicles and pickup trucks. These markets are expected to take even a harder hit as prices for fuel increase (drastically fluctuate and drives fear of even higher gas price), more foreign implant competition arrives; and public awareness to pollution most notably carbon dioxide (CO₂) and other (NO_x and SO_x) green house gases cause speculation of its contribution to global temperature rise. Figure 140 shows the decrease in vehicle sales that has haunted Ford over the past several years. Over this period Ford has relied heavily on Truck and truck plat-form SUVs, representing some 60-68 percent of total vehicle sales of the Figure 140 unit sales; again because they are less restricted by the CAFÉ standards.

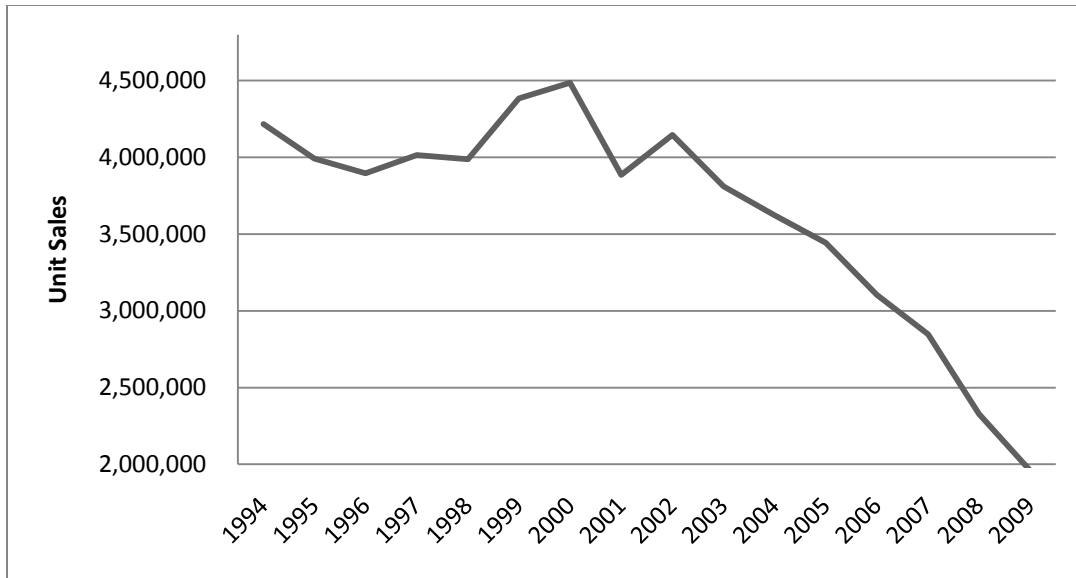


Figure 140 Ford Unit Sales, NA (source: created with data from annual reports, 1994-2009)

Market share growth and number of vehicles produced are good indicators of how an organization is contributing to the surrounding community and the job creation through either growing itself or creating further jobs at the suppliers supplying product. When examining Ford's level of employment we can see that in the same period, Ford in 1994 employed 180,861 and dropped by 59.1% to a level of 74,000 employees in 2009. Ford's reductions are coming from restricting plans to make capacities match their market share; two plans in general outlined these reductions, plan 2000 and way forward plan that is currently being implemented (Ford annual report, 2009). Both of these plans operated through natural attrition with no replacements and buyouts to all hourly people.

Reduction in the number employees can be seen as a way to reduce costs, and increase efficiencies and flexibilities. However, upwards of twenty five percent of the vehicles sold by Ford are purchased by its employees (Perpetual Motion, 2004). Ford has

had a number of plant closures over the last several years and had announce further reductions in their *Way Forward Plan*; starting in 2004 Ford closed the following assembly plants: Edison NJ, Dearborn MI, Hapeville GA, Wixom MI from 2004 through 2007 along with a number of support plants; all together Ford intends to close seven assembly plants in North America and an additional seven other factories (transmission plants, engine plants, stamping). Detroit was once the epitome of an industrial boomtown. From 1900 to 1930, it was the fastest growing city in the world. Now, ravaged by recession and a plummeting population, the city is shrinking.

As recently as 1950, Detroit was a strong manufacturing city, with 1.9 million residents and thousands of workers at a dozen auto companies, not to mention the industries, shops and stores that sprang up to service them. Today, the population of the former Motor City is just over 800,000 and falling. Since the start of 2008, the greater metropolitan area has lost nearly a quarter of its manufacturing jobs, and as of April 2010, Michigan has an unemployment rate of 14.1 percent versus the national average of 9.7 percent and Detroit is approximately 25 percent unemployment; 2006 mean income of Detroit was \$28,730 versus the average in the United States of \$35,499 (U.S. Census Bureau data, 2010).

Ford's decreasing employee head count trend in North America from 1994 to 2009 is depicted in Figure 141.

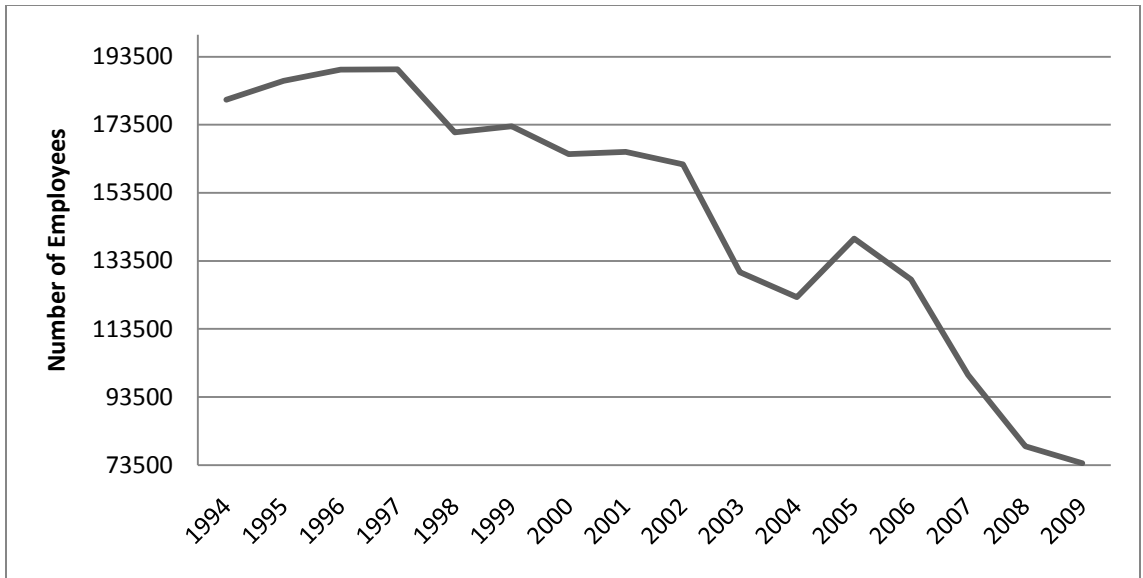


Figure 141 Ford Number of Employees, NA (source: created with data from annual reports, 1994-2009)

Financial Results

We examined the number of vehicles that Ford produced year by year over the last 16 years, obviously one would expect that with an increase/decrease in the number of vehicles sold the net sales of the originating manufacturer would follow the same trend, granted that average cost per vehicle remained stable or varied only slightly. Figure 142 depicts Fords net sales over from 1994 through 2009:

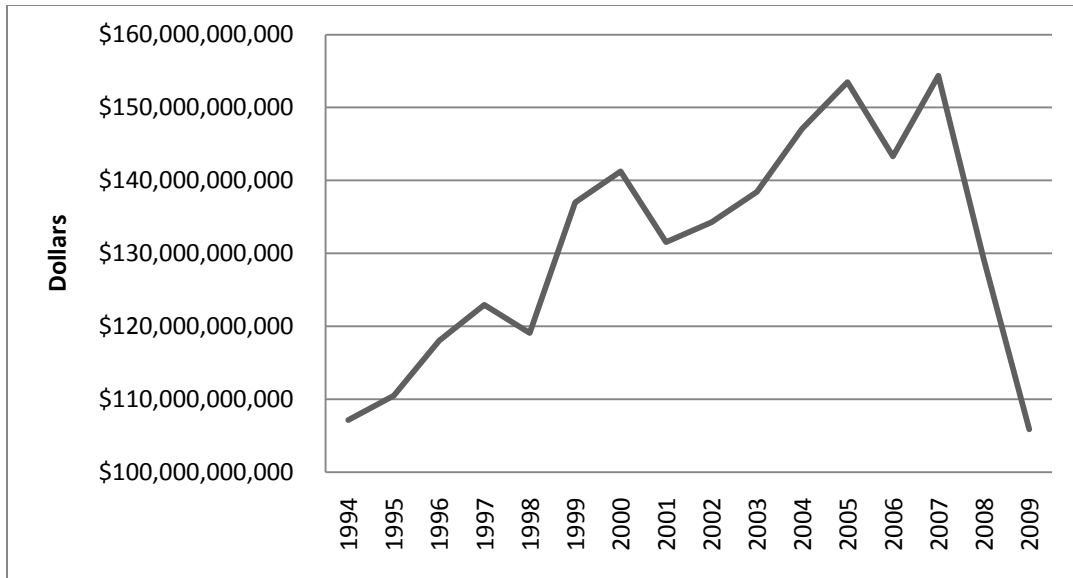


Figure 142 Ford Net Sales (source: created with data from annual reports, 1994-2009)

Ford's major revenue and profit center is mostly composed of the sales of their sports utility vehicles and pickup trucks. It can be seen that Ford is relying more on larger higher dollar vehicles (sport utility vehicles and pickup trucks) to make up their total sales number. This evidence strongly supports the views earlier offered that Ford is devoting energies and monies into the added features of their larger, heavier vehicles and listing them at higher prices.

Net sales is a nice characteristic to examine, however, when it comes to the shareholder, it is all about profit. Figures 143 and 144 charts Ford's performance in terms of operating profit and net income over the last several years:

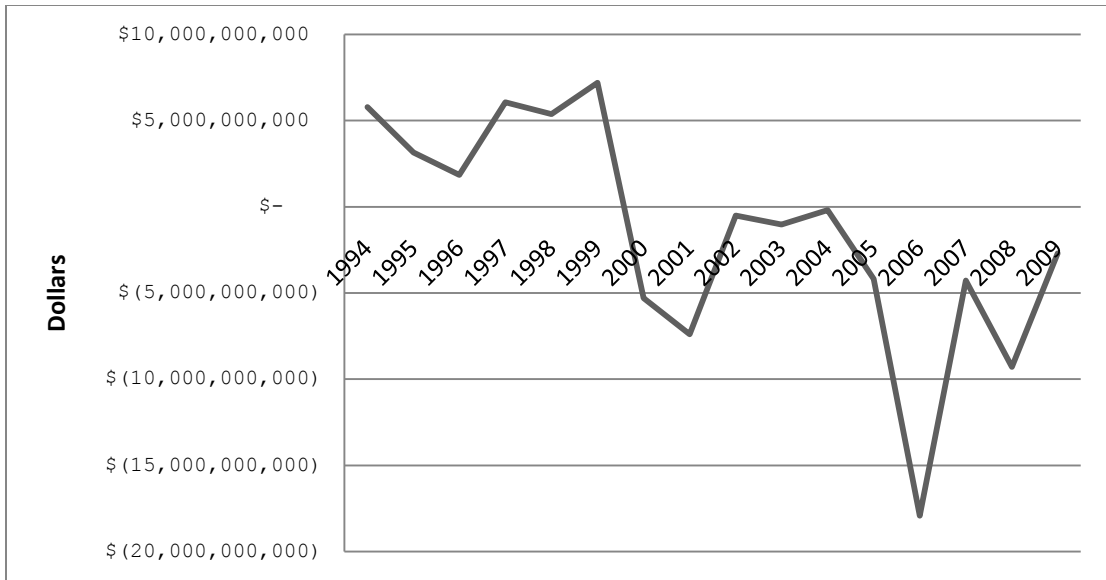


Figure 143 Ford Operating Profit (source: created with data from annual reports, 1994-2010)

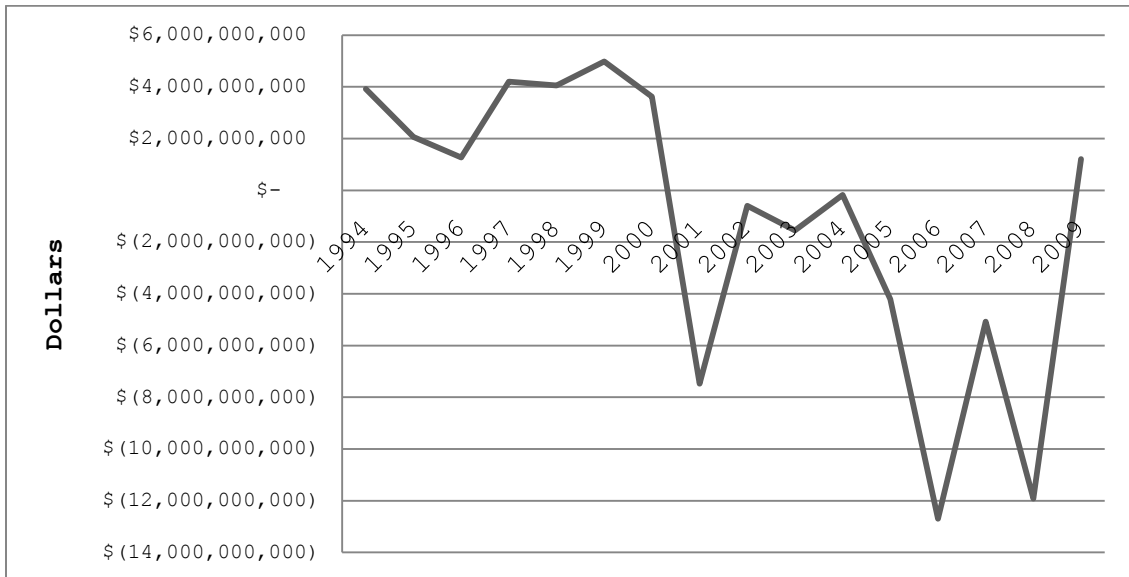


Figure 144 Ford Net Income (source: created with data from annual reports, 1994-2009)

Figure 145 shows the 10-year trend of stock prices up through April 20, 2010:



Figure 145 Ford Stock Price (source: Ycharts, retrieved 5/15/2010)

Along with the stock price, we want to take a look at Ford’s ability to raise money, or their credit ratings. Since earlier in the decade, Ford’s credit rating has been very poor; Moody’s (2010) has had Ford’s rating at the B level for the past eight years, and recently, March 2010, Ford’s rating was bumped up due to higher market shares, volume and profit to a level of B2 from B3 (the fifth level below investment grade. Prior to this raise, Ford’s \$1.8 billion of 7.45 percent notes due on 2031 were traded at 15.4 cents on the dollar in 2008. Mulally needs to retire \$10.5 billion in revolving debt that comes due in December 2011, so the future credit rating and stock price is imperative for Ford’s ability to raise cash for future model releases, advertisement and R&D. Ford’s secured credit is currently rated at Ba3 while its unsecured debt rating it at B3.

Another interesting characteristic to look at especially with the level of headcounts that Ford had to maintain through the years because of such programs as the jobs bank program is the revenue dollars per employee head, and more importantly the automotive operating income per employee head, these are shown in Figure 146 and 147.

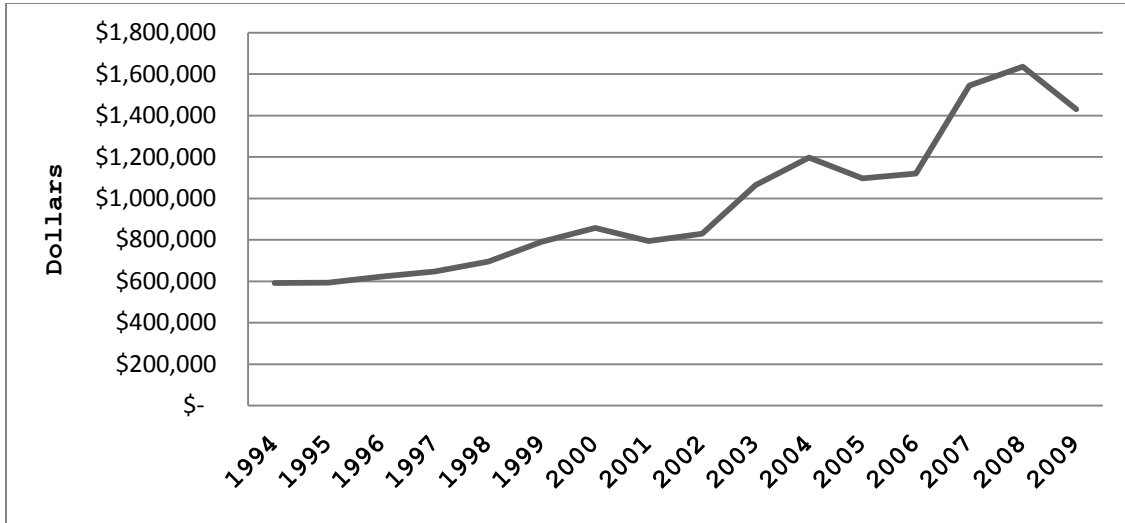


Figure 146 Ford Net Sales per Employee (source: created with data from annual reports, 1994-2009)

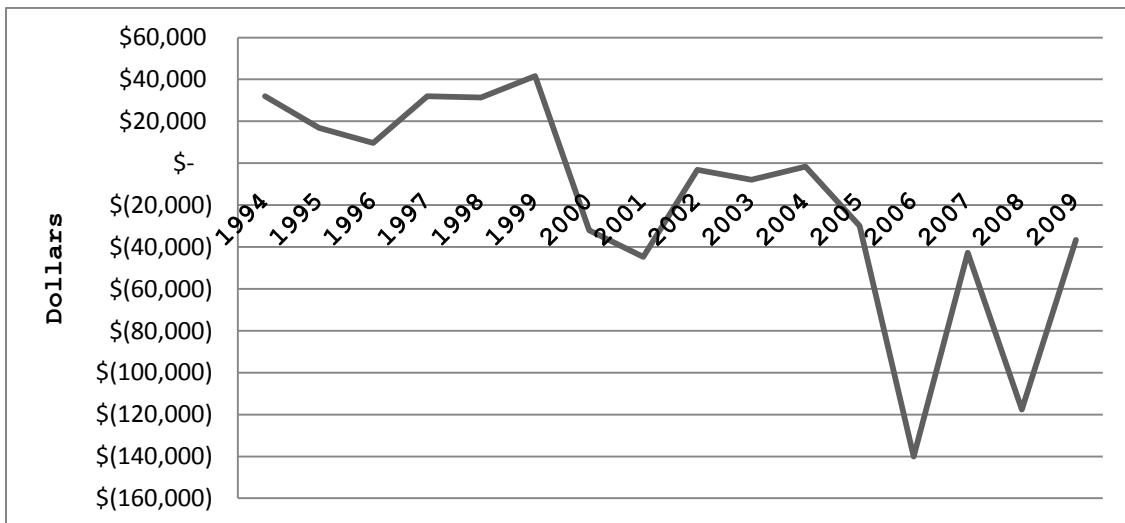


Figure 147 Ford Automotive Operating Income per Employee (source: created with data from annual reports, 1994-2009)

Investments in Research and Design

Keys (1995) argues that the United States domestic automotive manufacturers have historically invested dollars into added features and functions not into core systems improvement technologies; while the same investments done by the Japanese have been spent more for improved quality and reliability or in other words investing in the core systems technologies and addressing actual customer expectations and desires. Caravatti (1992) argues that while the strategic interaction of competing firms does play a role, the composition of spending between product and process innovation has a significant impact on the trade balance. Caravatti studied the difference between the United States and Japan in research and development investments in respect to products and process.

It was discovered that the firms in the United States heavily favored investment in new products, where 81% of research and development dollars were spent, while focusing on improved process development was less important, where only 19% of research and development dollars were spent. In contrast to the United States, 26% of the Japanese firms were investing research and development dollars into manufacturing processes, 17% were investing into new product development, and the majority of the firms were focusing on incorporating technologies developed by others.

Caravatti further discovers that in research and development that each dollar spent is at least three times more effective in developing international trade in Japan versus the United States. Keys (1993) also offered a comparison between investment as a percentage against revenue of the Japanese firms versus the United States firms and the effects of accrued expenses, other liabilities and principally warranty costs (percent allowances versus net sales).

There is an abundant amount of publications centered on research and development dollars for providing better efficiencies and flexibility (Womack, Jones and Roos, 1990; Keys, 1993; Halberstam, 1986). Keys (1993) suggests that there has been no signs of real price benefits passed to the customer, that the automotive industry is not investing research and development monies properly to gain real net wealth and added consumer benefits. Betz et al (1995) suggests, "paradigm" shifts must occur for which the productive enterprise is managed. On the same lines, Keys (1997) contends that the automotive industry has not made the leap from one technology S-curve (which has been in play for approximately the 1930s) to the next technology S-curve. Keys draws haunting comparisons between the automotive industry and past industries (copier industry, consumer electronics industry, etc.).

A new S-curve (creating a discontinuity) can be defined as anticipating consumer tastes by; using new technologies to build flexible plants capable of several vehicles in one location, build to order vehicles versus stocking show room floors in anticipation of a "hot seller", anticipate and act on government regulations (safety and environmental), develop brand new technologies to improve performance and add value. Transforming from internal combustions engines and heavy vehicles to newer light weight built out of lighter stronger materials increasingly powered by electricity is a new technology system typical transformation S-curve. Researchers have indicated that a successful technology based company mostly approves a higher part of its sales into research and design, typically 5-10+ percent (e.g. Microsoft, Intel, Google, CISCO). While this can often be true, it implies that the research and development efforts go into producing increased sales, revenue and profits within a reasonable, one-three years, time frame. That is where

the business risk is greatest during the discontinuity process of transitioning from one s-curve to the next s-curve.

Ford Motor Company's average investment over recent years in research and development is surprisingly higher than any other automotive company; Figure 148 depicts Ford's investment dollars over the last several years.

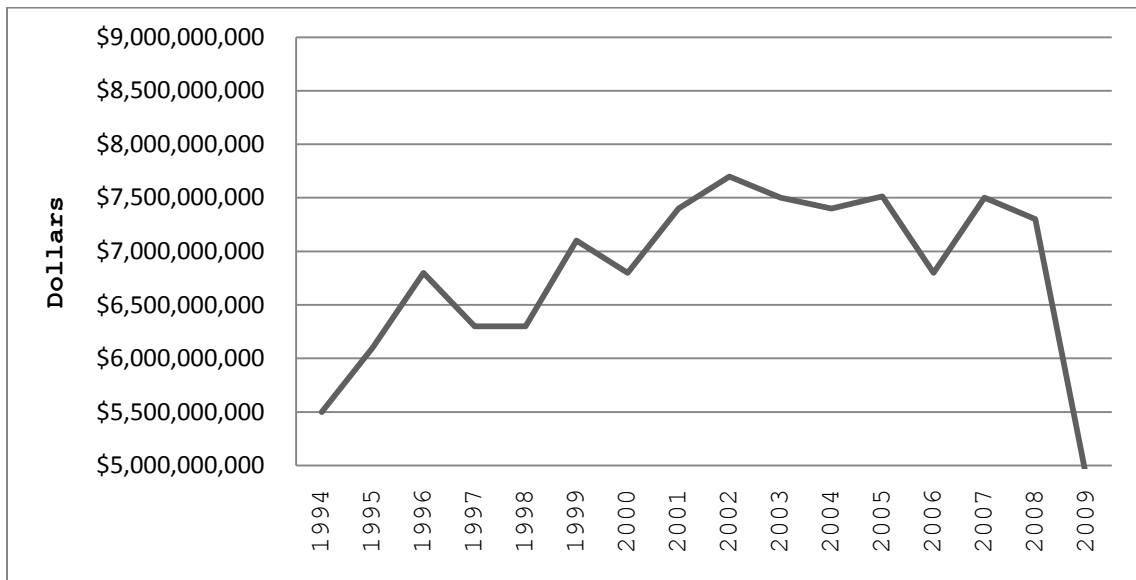


Figure 148 Ford R&D Dollars (source: created with data from annual reports, 1994-2009)

When examining Ford's investment in research and development with respect to net sales, Ford's investment practice has varied approximately 26-percent from a high of 5.8 percent in 1996 to a low of 4.6 percent in 2009, where Ford was under tremendous economic and survival pressures to create new attractable products, reduce capacities and costs. Figure 149 shows the 16-year trend of Ford's research and design investment as a function of net sales.

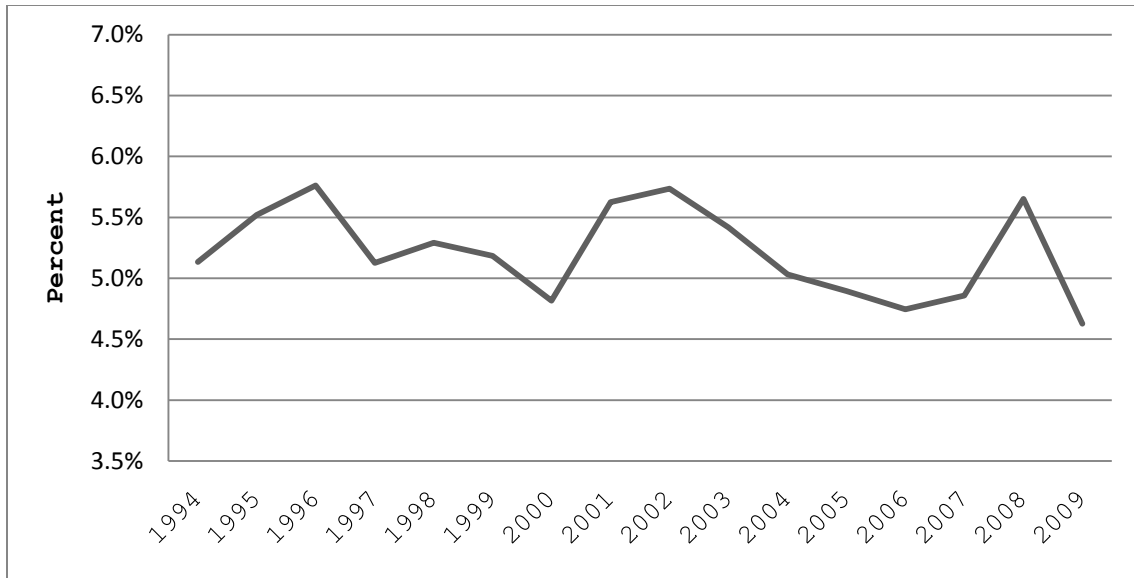


Figure 149 Ford R&D vs Net Sales (source: created with data from annual reports, 1994-2009)

Allowances, Claims, and Incentives

As stated previously, Keys (1995) argues that investments into research and design differ between the United States manufacturers and the Japanese counterparts in the automotive industry, and by Cavetti (1992) in general research and design dollars between U.S. and Japan. As Keys argue, the United States is more interested in investing time, monies and effort into additives and features while the Japanese are more interested in investing in new technologies to improve “system” efficiencies, effectiveness, performance, quality and reliability. When considering return on investment benefits, perhaps quality and reliability are good indicators of overall performance (see Chapters 10 and 11 for discussions/definitions on quality and reliability). Here we will investigate the amount of dollars paid out for warranties, deal claims and incentives by Ford. Figure

150 represents the dollars reserved in dealer allowances and claims over the last 16-year period.

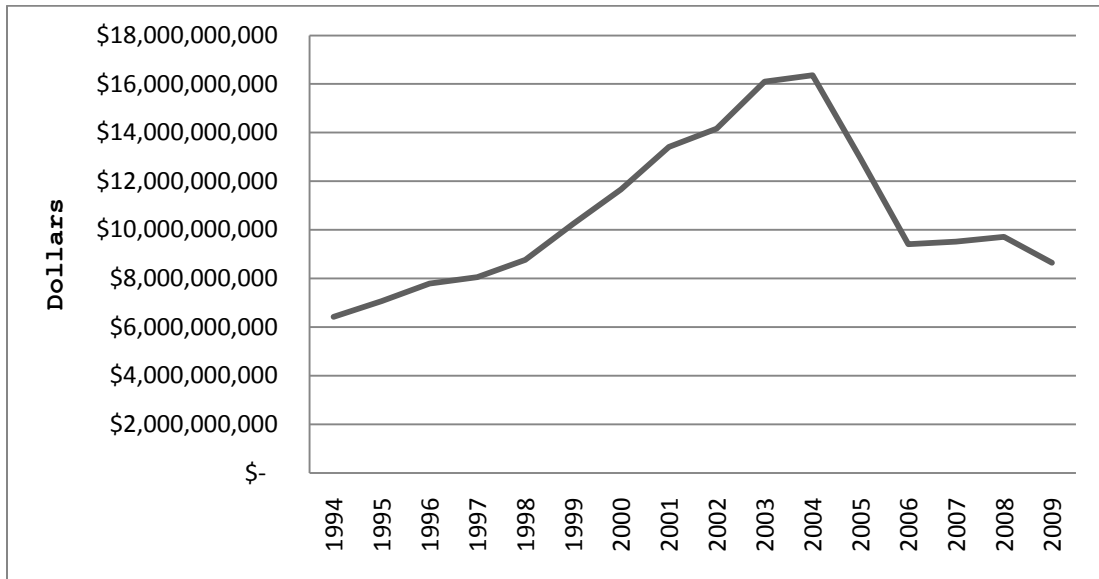


Figure 150 Ford Dealer Claims (source: created with data from annual reports, 1994-2009)

It is interesting to note that Ford's annual dealer allowances and claims paid significantly exceed the amount of dollars invested in research and design, see Figure 151.

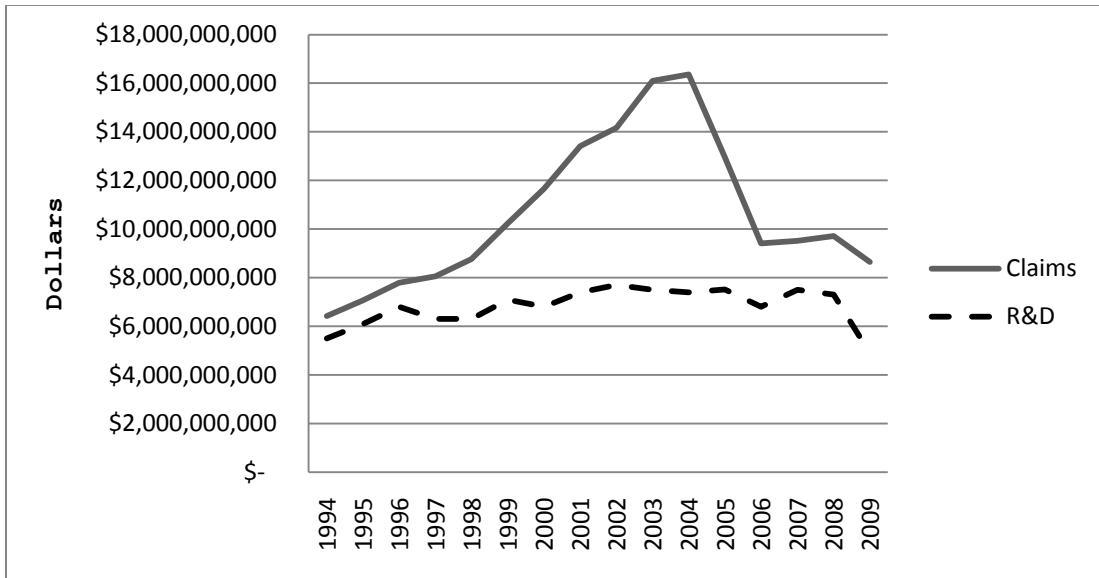


Figure 151 Ford Dealer Claims and R&D (source: created with data from annual reports, 1994-2009)

Another interesting result surrounding dealer allowances and claims is the ratio of dollars paid versus net income. Ford's ratio in 2009 was 8.2 percent, down from a high of 11.6 percent in 2003, and 11.1 percent in 2004. Figure 152 represent how the ratio of claims, warranties and incentives versus net sales has varied over the last several years at Ford, showing an inconsistency/uncontrollable situation.

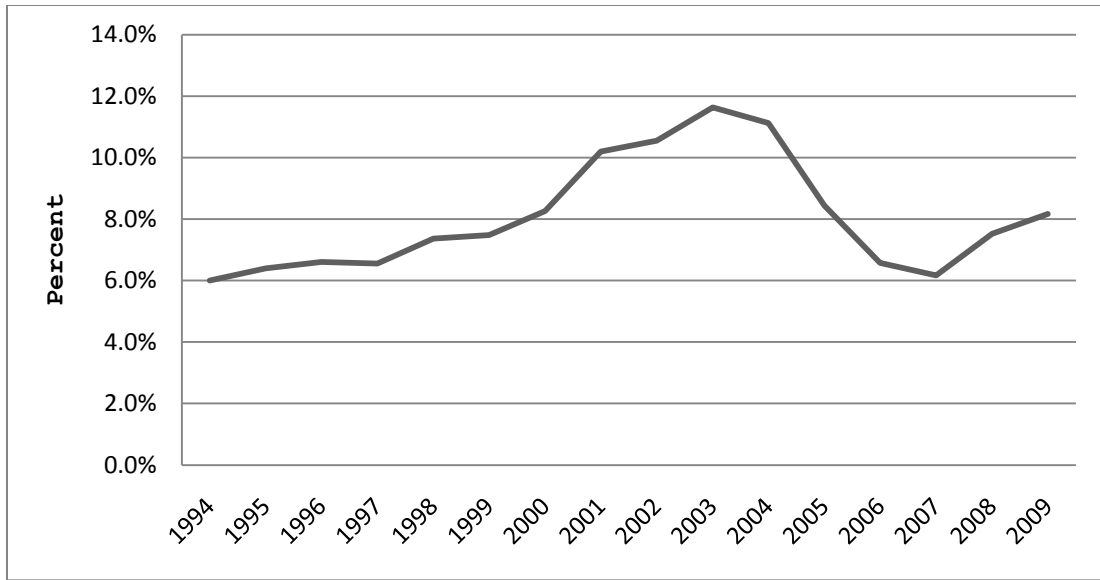


Figure 152 Ford Dealer Claims vs Net Sales (source: created with data from annual reports, 1994-2009)

Advertisement

The last factor being investigated is the amount of dollars invested into advertisement and ratio of dollars invested in advertisement to net sales.

Ford's investment into advertisement had been growing by roughly 60 percent, perhaps to battle the negative press being received from the past issues, most specifically the Explorer roll-over-issue and car fires, but recently had decreased (along with profits) but advertisement versus net sales has increased from two-percent to over three-percent in the last three years. Figure 153 depicts Ford's advertisement expenditures, while Figure 154 depicts advertisement versus net sales.

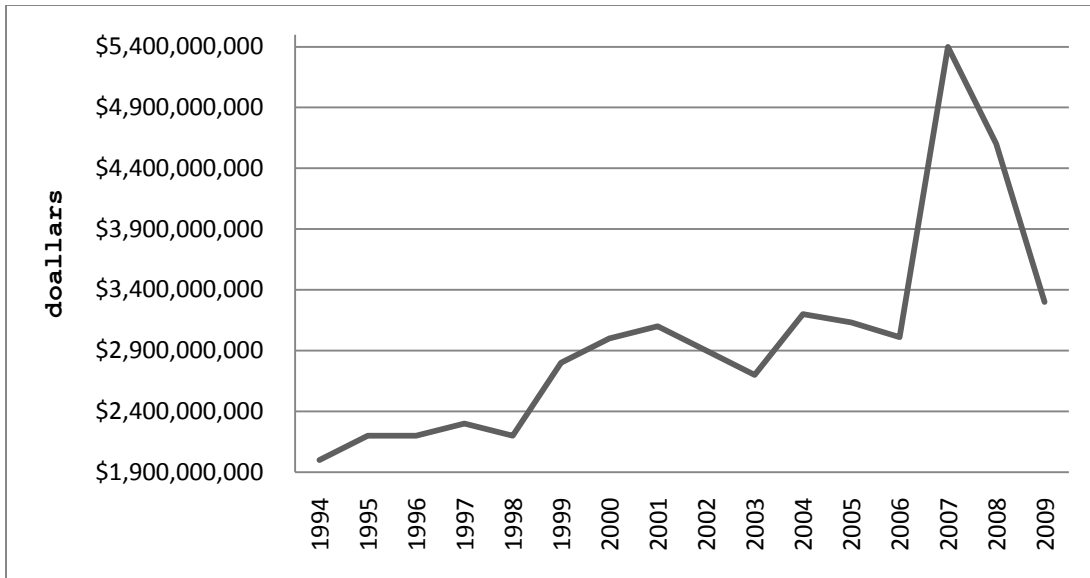


Figure 153 Ford Advertisement Dollars (source: created with data from annual reports, 1994-2009)

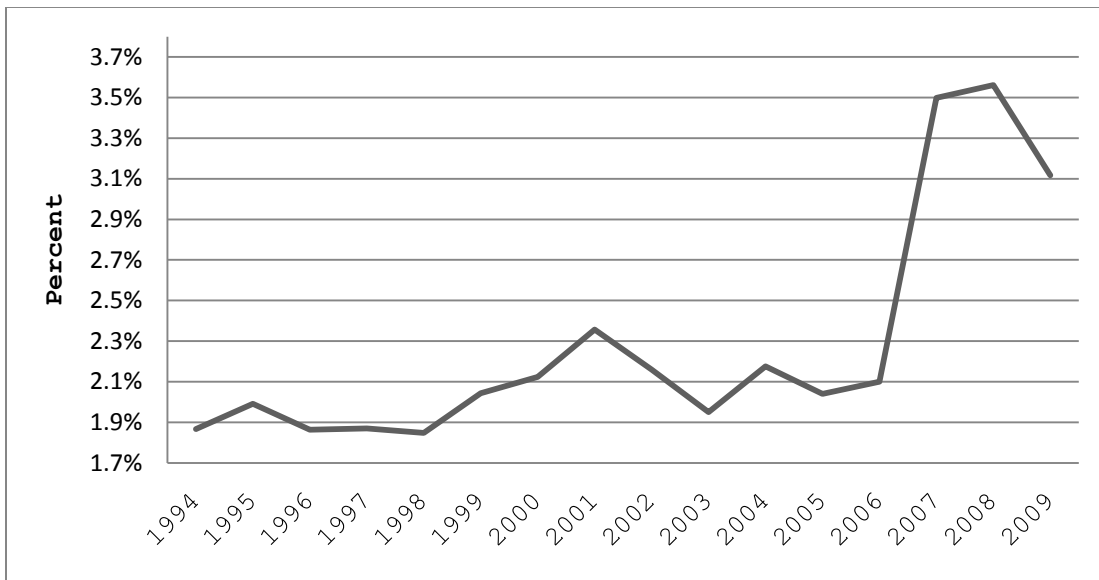


Figure 154 Ford Advertisement Dollars vs Net Sales (source: created with data from annual reports, 1994-2009)

While these figures are only representing what Ford invests into advertisement the actual total advertisement cost is very difficult to determine, and perhaps in itself would

be an area of future research work. For example, the *Economist*, Perpetual Motion (2004) estimates that during the car buying process, a high figure estimate is that seven in ten potential purchasers will visit the internet for information. Some noteworthy sites would consist of consumer reports.com, Edmunds.com, reviewing JD Powers and Associates, Road and Track evaluations, and other.

17.5 PART III - Dealer Network

Ford has had a long history with their dealerships and also a long relationship of changing them. This section will look at the past 15-years of Ford's efforts to change the dealerships; look at the revenue, on average, for dealerships; and look at where the dealerships actually make their profits.

Alex Trotman, CEO of Ford, in 1995 announced the dealership consolidation effort, Ford Retail Networks, that he was initiating (Connelly, 1998). Trotman stated that, "Ford wants its new retail networks to end rivalry among its dealerships and to slash advertising, administrative and other costs. The consolidations also would improve customer convenience via multi-brand superstores and quick service centers." These consolidated stores aim to cultivate good will with non-negotiable prices and salaried salespeople. Ultimately, Ford wanted a larger voice in how its vehicles are sold to improve customer satisfaction. By 1998 Ford had consolidated dealerships in five U.S. markets; Tulsa, Oklahoma City, San Diego, Salt Lake City and Rochester.

As time passed by, aggressions developed between Ford Dealerships and Ford, most namely Nasser. By April 2002, Ford was selling its last dealerships in the Retail

Network back to private owners, commenting that Ford needed to focus on manufacturing and leave the retailing to the dealerships.

In 2000, Ford maintained roughly 23.7 percent market share with approximately 4,800 dealers and averaged 934 new vehicle sales per dealer. By 2006 only 385 dealers closed during the time that Ford's market share slid almost eight percentage points to 16.7 percent. This math equates to roughly 605 unit sales (roughly a 35 percent drop) per dealer. The Ford Dealer Alliance, a New Jersey-based group that represents 1,500 of these dealers, estimates that 36-percent of them are operating at a loss (Hoffman 2006). However, the dealerships combined profit from 2001 through 2003 was roughly \$1.6 Billion, 2004 was at \$1.2 billion and by 2009 the combined profit was approximately \$1.2 billion with the number of dealers is approximately 3,700 Nationwide (Ford Annual Report, 2009).

So as the competition becomes ever increasing and sales continue drop, the dealerships must rely on other avenues in order to create revenue and profits. The following are the revenue generating areas of a dealership:

- Front End – Revenue made from customers on the sale of the vehicle
- Back End – Revenue made from brokering the deal
- Service Department – revenue generated by the maintaining, repair/warranty work, recall repairs of the vehicle over its life time

There are several ways the dealerships generate their profits, here are 6 key ways:

1. Profit from the sale of the new car its self: However, according to Paul Taylor, the chief economist for the National Auto Dealers Associations (NADA), the average profit off of new cars sales was actually barely a break even ordeal in

2007 with up to \$500-\$1000 for luxury cars and larger trucks/SUVs (Eldridge, 2008). Estimates put the profit from the sales of new cars at about five-percent of the total profit for the dealership.

2. **Extra and Fees:** After the sale is complete the dealers will then offer other items such as paint or fabric protection, alarm systems, upgraded sound systems, other comfort devices, detailing. It is estimated that the profit from these sources account for approximately 10-15 percent of the total profit.
3. **Extended Warranties:** Extended warranties are approximated at roughly twenty percent of the total profit of a dealership.
4. **Financing:** When dealerships provide the assistance in finding finance for the buyer, they typically have agreements with finance companies and the dealers will tack on an additional $\frac{1}{4}$ point on top of the “best available rate”. Estimates put this profit contribution at one-five percent of the total.
5. **Trade-In Used Car Sales:** The typical annual sales of used cars averages between 10 million and 12 million units. Dealerships average roughly 10 percent of their total profit. However several items can affect the resale value of used cars. The amount of vehicles sold to rental companies, namely for Ford case Hertz, can have a negative effect on used car values; the leasing agreements becoming due; reliability performance as defined by evaluators such as Consumer Reports. In all, Ford’s average car only maintains 39 percent of its original value after one-year, and less the twenty percent after three-years (Welch, 2002).
6. **Service:** This is the most profitable center of the dealership. It accounts for only 10-15 percent of the revenues, it accounts for close to 40-45 percent of the profit,

and at some dealerships, even higher. Estimates put service at roughly at \$300 billion. This comes from parts and service from regular customer maintenance intervals; normal wear and tear over the life cycle of the car; and warranty, out of warranty and recalls. So the dealer makes money here from warranty and recall work from the parent manufacturer (in this case Ford) even if it costs the manufacturing money, or even a loss. One can see how the move to a five year, 100,000 warranty with the improvement in quality and reliability is ultimately going to reduce an important part of the dealers' revenue but more importantly the net profit.

For these reasons, the "Big 3" has been attempting to consolidate and reduce the total number of dealerships. It is not easy for Ford, or General Motors and Chrysler to reduce the number of dealerships; each state has their own individual franchise laws, the "Big 3" have to pay for the dealers to close (Welch, 2009). When the auto companies attempt to phase out a brand, it could also mean big payouts as well; for example, when GM phased out the Oldsmobile brand, the dealers sued and GM paid out \$2 billion dollars.

17.6 PART IV - Price, Reliability and MPG

This section will take a brief look at the typical historical cost structure/price range of cars meant to be competitive against the foreign fuel efficient brands. It will start with the 1979 year models and progress roughly every five-years to review and trends occurring over time Figures 155 plots the small car price range over these years

(Pinto/Escort/Focus) while Figure 156 shows plots for the family midsize car, Taurus. It will also look at the durability results as provide by Consumer Reports of the same time period and be presented at the end of this section as Figure 157. Also presented at the end of this section will be mile per gallon ratings as published in the EPA historical database, Figure 158.

1979

Two cars were examined in this time period, Pinto and Fairmont. The Pinto's price range started at \$3,829 for a 2-door hatchback and progressed up to \$4,248 for the 2-door wagon. Consumer reports rated these as "old designs", somewhat heavy and poor fuel efficiency (See Figure 157). Automatic transmission was offered for \$307 dollars. The Fairmont, a slightly smaller car, was still heavier than other foreign small cars, also had poor fuel efficiency and same options as the Pinto and was priced from \$3,880 to \$4,211.

1985

The Escort replaced the Pinto so it will now be investigated and the newly released Tempo and Taurus are also examined. The Tempo being slightly larger than the Escort had a base price of \$7,160 and the Escort was based at \$5,876 and the Taurus being the largest of the three had a base of \$9,645. Several options were available on both vehicles:

- Diesel Engine - \$478
- Auto Transmission - \$363

- Power Steering - \$223
- Air Conditioning - \$743
- Power Windows - \$272
- Power Locks - \$254
- Cruise Control - \$176
- Tinted Glass - \$110
- Stereo AM/FM Cassette - \$109
- Rear-window Defrost - \$140
- Remote-control mirror - \$93

The Escort fully loaded (Turbo GT) priced for \$8,680, the Taurus at \$13,860 and the Tempo at \$8,253.

1990

The Escort's base price in 1990 was \$7,402; with the major options, as defined by Consumer Reports as being:

- Auto Transmission - \$539
- Air Conditioning - \$744
- Power Steering - \$235

Consumer Reports overview stated, "Ford Escort is a model with few strengths and many weaknesses, the Escort lacks the roominess and sophistication of the higher-rated small cars." The Taurus becoming a hot seller priced from \$11,778 to \$16,524 while the Tempo priced \$9,057 to \$10,860.

1995

The base price was \$17,585 and with all options went to \$21,010. The major option for this period was the electric power seats. The Escort priced \$9,680 to \$12,820 while the Tempo priced \$13,310 to \$15,695 followed by the Taurus at \$17,585 to \$21,010.

2000

In 2000 the Escort's price range was \$11,975 to \$12,000, with no major additions to options. As Consumer Reports states, "the Escort remains adequate, no more no less. The ride feels stiff and choppy but it's composed in bumpy turns." The Escort is being replaced by Ford's new Focus which is selling from a price range of \$11,960 to \$15,380. The Taurus ranged from \$17,790 to \$20,990 while the Tempo went from \$16,940 to \$22,810.

2005

The Focus (replaces Escort) price range in 2005 was \$12,965 to \$19,330. The car now comes standard with front airbags. Options include 6 speed manual transmission (versus the standard 5 speed) and the 4-speed automatic. ABS breaking and Traction control are also options. The Taurus prices \$19,830 to \$23,775. The Tempo is now discontinued.

2009

The Ford Focus in 2009 priced from \$14,995 - \$17,970. The most significant difference in options from 2005 was the addition of Ford's SYNC Infotainment that links all data and information (news, video, navigation) for the driver. The Taurus starts at \$25,170 and goes to \$32,520; the super high output (SHO) Taurus for 2010 model year will debut with a price of \$43,300.

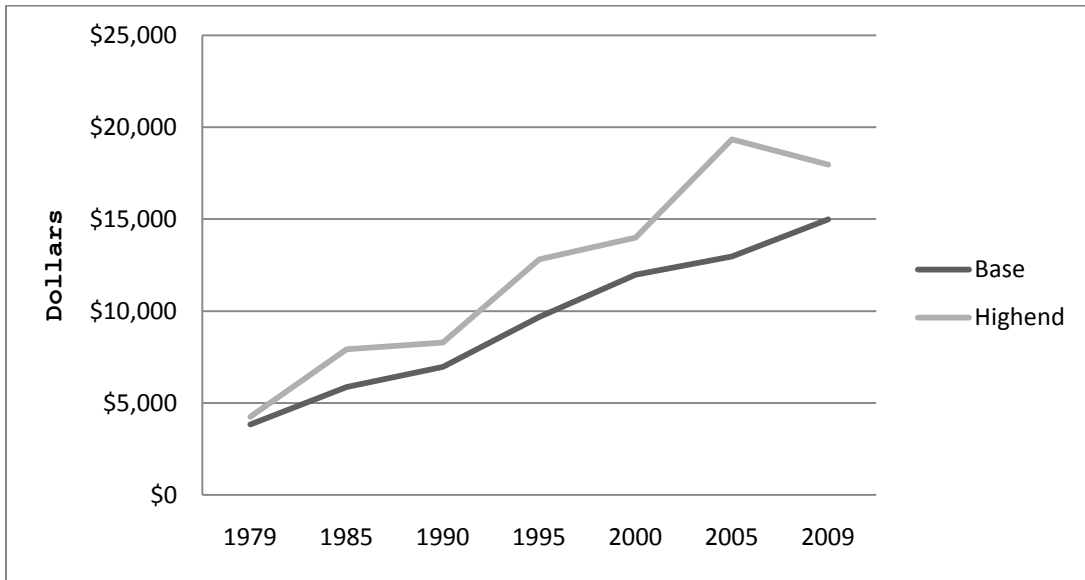


Figure 155 Small Car Selling Price (source: Consumer April Automotive Issue, 1979, 1985, 1990, 1995, 2000, 2005, 2009)

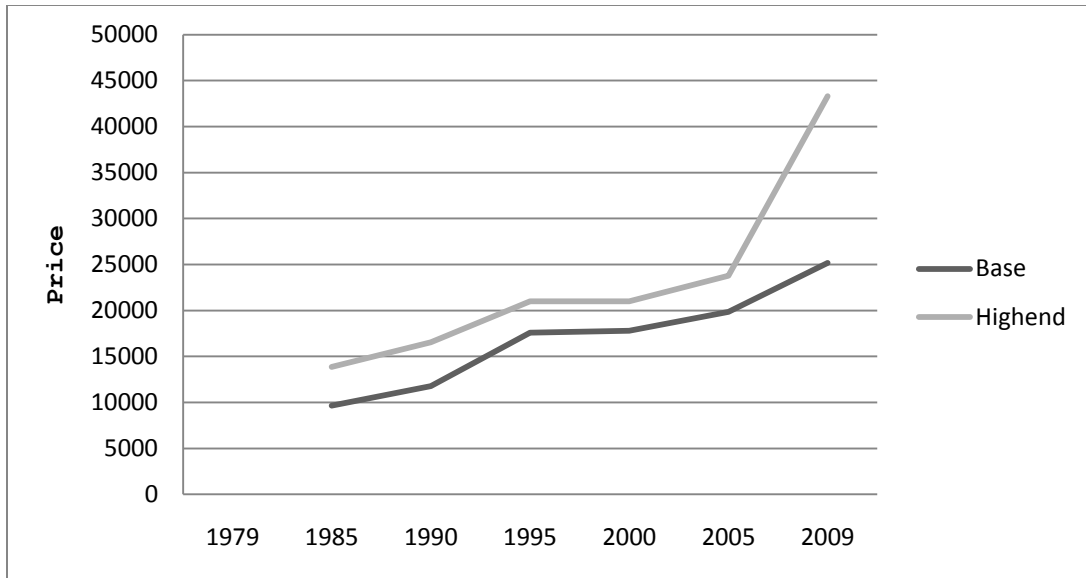


Figure 156 Taurus, Midsize Selling Price (source: Consumer April Automotive Issue, 1979, 1985, 1990, 1995, 2000, 2005, 2009)

Reliability Rankings

Figure 156 rates the reliability of the vehicle. Consumer Reports uses Much Better Than Average, Better Than Average, Average, Worse than Average and Much Worse Than Average. Figure 157 assigns a numerical number of five to one to Consumer Reports ratings and plots of the averages of the small cars and Taurus over the period analyzed.

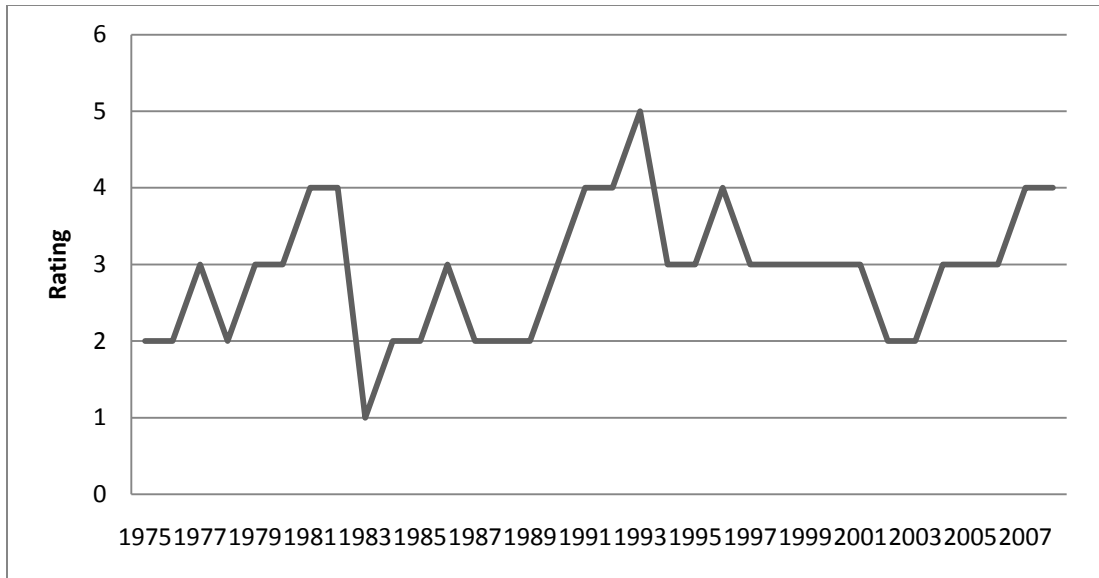


Figure 157 Ford Reliability Rating (source: created with data from Consumer Reports, April 1979, March 1985, April 1990, 1995, 2000, 2005, 2009)

Miles per Gallon

Figure 158 presents the Ford miles per gallon for a variety of vehicle classes over the past 34 year period. In 2009 Ford corporate average fuel efficiency finished at 25.15 mile per gallon, which is comparable to the Model T. Recently, President B. Obama announced that the CAFÉ standards for cars will increase from 27.5 mpg required today to 39 mpg in the year 2016; light trucks will also see a requirement changed from where it is today, 22.5 mph, to a 30m mpg by 2016.

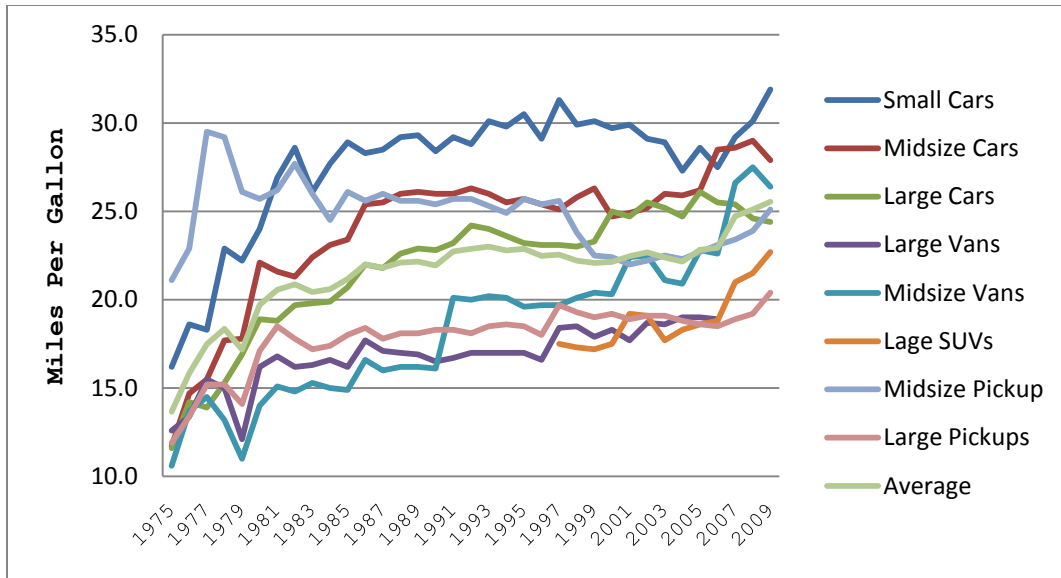


Figure 158 Ford Miles per Gallon (source: created with data from Environment Protection Agency – Fuel Efficiency, 2010)

17.7 PART V- Recalls

This section will review Ford Motor Company’s recalls in the past several years, attempt to assign a dollar figure associated with these recalls (not all legal suite settlements are disclosed to the public) and look at how Ford handled recalls over the past several years.

Over the past 40 years, Ford has management to own 4 of the top eleven recalls in the United States (not including the Explorer recalls). This top list includes:

- 2008 Ford Recall – 14.3 million cars, cruise control switch catching fire when parked
- 1996 Ford Recall – 8.6 million vehicles, ignition switch fires
- 1971 Ford recall – 4.1 million vehicles, seat belt shoulder harness failure
- 1987 Ford recall – 3.6 million vehicles, engine compartment fires

Figure 159 breaks down the number of recalls that each model year Ford vehicle had since the 1990 model year:

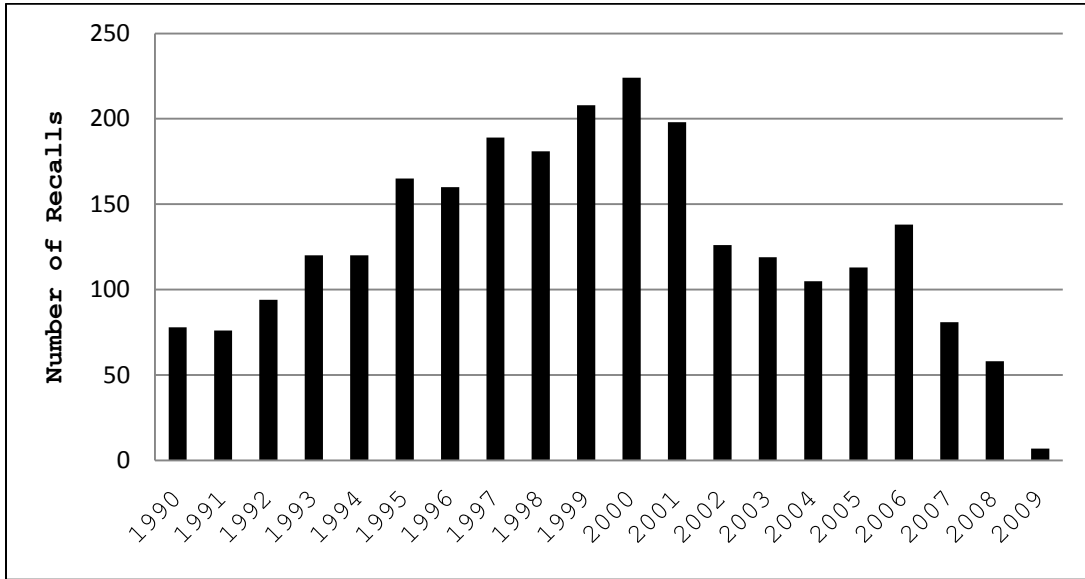


Figure 159 Ford Model Year Recall (Source: National Highway Traffic Safety Administration, 2010)

Ford has experienced several large recalls (excess of 100,000 per recall) over the last 30-years. Table XVII highlights these recalls for discussion.

Table XVII Ford Larger, +100,000, Recalls

Model Year (s)	Model (s)	Number recalled	Defect	Results
1992-2003	Winstar minivans/Ford, Mercury, Lincoln SUVs and trucks	14,300,000	Speed control switch causing fires	2 deaths, 1,170 fire
1993-1995	Various	8,600,000	Ignition switch fires	265, 21 fires
1983-1985	Various	3,600,000	Engine Compartment fires caused by faulty ignition switch	30 fires
1986-1995	Taurus/Sable/Continental	2,700,000	rust on lower subframe could cause body mounts supporting engine and transmission to fail	565
2000-2001	Focus/Taurus/Expedition/Excursion/F-Series/Continental/Town Car/Navigator/Sable	1,100,000	Wiper switch causing fires	40 fires
2000-2003	Taurus/Sable	1,030,000	brake light failures; switch and wiring problem	150
2000	Explorer/Mountaineer	810,000	Link in stabilizer bar could fracture making vehicle more difficult to control	212 complaints, 2 crashes, 2 injuries
1997	F150/F250	670,509	Holes in the fuel line	131 claims
2000-2001	Focus	446,569	Bolts in lower control arm can loosen, front suspension collapse, crash	2 crashes
2000-2003	Taurus/Sable	418,000	air filters can catch fire	2 fires
2000-2001	Taurus/Sable	400,000	Adjustable pedal put the brake and accelerator to close together	18 accidents/2 injuries
2003-2004	Ford Trucks	384,000	Power Stroke Diesel Engine failure	58 lawsuits
2001-2003	Escape	363,440	Duratec 3liter V6 may stall at certain speeds	8 accidents
2000-2002	Focus	358,857	Rear passenger doors may not latch properly	33
2000	Focus	351,000	Roof pillar not to standard, not enough impact protection in crash	
2000-2001	Focus	291,854	loosen or broken battery attachments, insulation damage, can lead to failure or fire	164
1993	F-Series Pickup	291,733	Fuel pressure regulator, may lead to fuel leaks/fires	15
2000-2001	Focus	203,700	Rear wheel hub retaining nuts work loose, left rear wheel loss	20
2005-2006	Five Hundred/Montego/Freestar	133,000	Door latches may allow water to enter causing them to freeze	100

(source: National Highway Traffic Safety Administration, 2010)

On top of the dealership warranty, claims and incentives list above, Ford also has legal obligation that can be part of these above listed recalls. And the above list is not a complete list relative to what Ford has to address. For example, the Ford Explorer roll over incident is not listed above since the federal government ruled it a Firestone tire issue which ultimately led to 13 million tires being recalled. However, Ford spent \$3

billion dollars replacing tires in order to maintain their image (or attempt to develop their image) as customer focused.

This Explorer rollover situation sustained by the Explorer can be tracked back even further to its first generation vehicle the Bronco II. Like the Explorer the Bronco II, in order to give it an economical efficiency measure, was a stout SUV body placed on the chassis and suspension of the Ford Ranger truck. But to take even a further step back, Ford's design plan or its developmental point of reference for the Bronco II was modified from the Jeep CJ-7. At this time Ford was aware of the CJ-7 and its predecessor, the CJ-5 had a rollover propensity significantly higher than other vehicles in their class. This propensity of rollover was so bad that the traffic safety administration had advised the Army in a September 1971 letter not to sell 6,000 surplus Jeeps to the public, even with warning labels. Also, in a February 1980 study, the University of Michigan's Highway Safety Research Institute found that a Jeep CJ was three times more likely to be in a fatal rollover than a standard size SUV. An internal Ford slide presentation made the same point in 1982.

Ford Engineers raised concerns about the vehicle's high center of gravity and narrow track. Five proposals were submitted to correct the problem, where three of the five would have significantly widened the vehicle's track and lowered the center of gravity (and would also add significant expense and delay production). Ford management, in a high-stakes race with Chevrolet, which was ready to release the S-10 Blazer, chose a proposal that only slightly widened the track and slightly lowered the center of gravity.

A 1987 analysis by the traffic safety administration found that the Bronco II had a fatality rate for its first-event rollovers three times higher than that of the Suzuki Samurai, a vehicle known for its instability. A 1988 Ford memo stated that the Bronco II had a higher fatality rate than the Jeep CJ-5/CJ-7 in the early and mid-1980s. Also a 1989 test by Consumer Union, the Bronco II showed 2-wheel lift off at 42 miles per hour, and while comparing it to the S-10 Blazer, it showed no lift off.

Ford gave the go ahead in 1986 to develop and bring into production its next sports utility vehicle, the Explorer. Like the Bronco II, the Explorer for economic reasons (same production lines, parts, and manufacturing robots) would use the Ranger Chassis and suspension. However, by 1989, as stated earlier with the above testing and studies, as well as a early 1989 report from Consumer Reports stating that the Bronco II had a high potential for roll over at high speed turns proves Ford was completely aware of the rollover issue that was facing the Explorer's design. However, any major changes to the design would set the Explorer back by years costing a lot of money and loss share in the lucrative SUV emerging market. So three solutions were devised:

- Shorter suspension springs could be used to lower the front end by half an inch and the back by one inch,
- Use lower tire pressure, 26 pounds per square inch (PSI) versus the 35 PSI used on the Ranger, and/or
- Redesign entire vehicle and mount the wheel two inches further back (would not be able to produce on the same assembly line as the Ranger then)

Ford ultimately chose the first two solutions. The decision making shows how they weighed costs and benefits, and ultimately were hemmed in by the original design as they tried to make the rollover/tippy truck into a safer family vehicle.

Another trade-off that was known to be a potential problem was Ford chose the same size tire/type (Firestone Wilderness AT) it had long used on the Ranger. Those tires had the lowest possible rating for withstanding high temperatures. And when the company lowered the recommended tire pressure from 35 PSI to 26 PSI as a solution to the rollover issue, it also further reduced the tire's ability to carry weight without overheating.

With these records, reports, studies stating that the engineers at Ford were aware of the roll over issue as early as 1993 (Fisk, 2005), and Ford also chose not to reinforce Explorer roof supports to prevent collapses in a rollover as recommended by engineers (Fisk and Koeing, 2004). Ford eventually lost a court order on roof reinforcement; Ford wanted records showing that they knew of alternative roof designs that would prevent roof collapse sealed because they contained trade secrets.

When all the issues began appearing with the tread separation, Ford chose to let the blame fall completely on Firestone. So much so Nasser, then CEO of Ford, originally refused to appear before Congress. Eventually under pressure he did so (Muller, 2001). Ultimately it was Congress who had to act by passing the Tread Act in November 2000, as discussed in Chapter 12, just as they had to handle the automotive industry in the past in concerns of safety by passing the 1966 Traffic and Motor Safety Act. Safety should not be treated as an economical trade for profit.

On top of the Explorer issue, there was also an issue of police Crown Victorian vehicles' gas tanks rupturing during crashes leading to fires. In all, there were 26 fires reported, 16 deaths and 11 injuries. The Federal Government performed an eleven month investigation and found that the Crown Victorians exceeded federal standards and closed the investigation with no fault to Ford. However, Ford did spend \$50 million dollars to install gas tank shields on over 350,000 police cars. There are also a number of law suits against Ford. Table XVIII summarizes a number of items/costs associated with these types of issues.

Table XVIII Ford Additional Costs for Safety Issues

Issue	Action
Explorer Tire Issue	\$3 billion in Tire Replacement \$590 Million in legal settlements
Bronco Rollover	\$2.4 Billion in Legal Class Action
Police Car Fires	\$50 million installing gas shield 17 law suites
Power Stroke Engine	58 Law suites, Ford declines to estimate cost to fix
Cruise Control Switch	\$50 per vehicle, \$750 Million 2 wrongful death suites
Ignition Switch	\$4 billion
Premature cracking on exhaust manifold	\$735 per vehicle, 1.8 million vehicles, \$1.3 billion

(source: Associated Press, 2001; Koenig, 2001; Brezosky, 2001; Annual Reports, 1994-2009)

Ford has been criticized over the years for their responses to issues such as listed above. It can be traced back to as early as the Pinto case when Ford denied any issue with the gas tank explosion, but later it surfaced that they had knowledge of the issue prior to any investigation starting. The ignition switch issue Ford's first response was to

first refuse any issue with the switch and then perform 4 selected recalls over seven years (Peters, 2006). When the major Firestone tire/Explorer rollover issue first arose, Nasser, then CEO of Ford, first refused to appear in front of Congress, and then only after being prodded did he testify. Nasser then chose to place the blame solely of Firestone igniting a blame game between the two companies, or between Nasser and Lampe (Muller, 2001). This issue created over 1400 roll-overs and 88 deaths in total.

On top of this denial, Ford has also chosen to walk away from other safety related issues; for example, a Federal study of impact deaths conducted from data from 1991-1997 showed that the Explorer was more deadly on impacts with automobiles than any other light trucks and SUVs (National Highway Traffic Safety Administration, 2010). The Explorer killed 10 drivers per 1,000 crashes when impacting cars, while the other light trucks and SUVs averaged five to seven. A car on car had a kill rate of 0.6 per 1000. The study also confirmed that weight was not the factor since large passenger cars weigh as much as the Explorer. With these results, the auto industry agreed to create voluntary testing standards in order to reduce this death rate and deaths due to rollovers. Bill Ford, in 2005, decided to disband this effort due to the reasoning that it would be too expensive to create.

17.8 PART VI -Management and Strategic Philosophies

Over the past few decades Ford has continue to engage in status quo type behavior – product development is guided by MBA thinking of budgetary setting, delivering new products that lack style, have poor quality, low fuel efficiency, over budget and late (Taylor, 2009; Welch, 2009). One of the more successful product

development projects (or so stated by Ford) was the first generation Taurus placed into production in 1986. Realistically, the Taurus was seven years in the product development process, and a cost of approximately three-billion dollars and promoted the incorporation of new technology that had been use by the Japanese for years (Keys, 1997). The release of the then newly redesigned Ford Explorer (2002) was over one year late and had five recalls in its first year. The Thunderbird came out in 2002 a full year late; so much time had passed from the unveiling of the show car to the release of production models that the buying public had lost some its enthusiasm. Quality was also a problem. The plastic top (for winter) scratched the body, and Ford dealers got an early reputation for ripping off customers by overcharging for the car. Although the car's exterior was beautiful, the interior was a bit of a letdown, especially for a car with a \$40,000 price tag. Ford figured it could sell 25,000 Thunderbirds a year at \$40,000 apiece, but in 2002 it moved only 19,000 cars. In 2003 only 6,000 were sold (Flint, 2003).

The past five leaders, looking back to 1985 (see Chapter 15), were all home grown Ford employees, all possessing a MBA and most being financially experienced individuals (except Peterson). This has been true until the recent (September 2006), recruitment of Alan Mulally.

Alan Mulally began his career and worked as an engineer with the Boeing Company, until 2006 when he began his tenure as Ford Chief Executive Officer. He is the first outsider to come in and run the Ford Motor Company. He brings with him the knowledge and ability to design and integrate and bring on-line the latest technologies

available, as he demonstrated when he over saw, as the chief engineer, during the design of the Boeing 777.

Mulally brings that dedication to product design and development as well as the fundamental philosophy of focusing on core business (or nameplate) through investing for future and taking gambles on products. He also brings with him the drive to communicate and ensure that everyone understands every aspect of the business and business plan (Kiley, 2009). Within the first three months on the job, Mulally accomplished the following items (Taylor, 2009):

- Created the Business Plan Review Meeting – Meant to bring all organization functions together in unity and operational discipline. All four profit centers must present their plans and where they are at within those plans (including charts and postings for all to review). And then the 12 functional areas must do the same (from product development, human resources, manufacturing, IT.),
- Mortgaged Ford’s Assets and borrowed \$23.6 billion – Mulally realizing a recession, wanted to raise money to weather the recession. Managed to mortgage assets to get the higher value before the entire financial crisis came to bare. Which ultimately circumvented the necessity to have the government bail them out as in the case for Chrysler and GM (and which the government is playing a decision making role in those companies), and
- Created Global Heads of Manufacturing, marketing, and product development and announces the company will consolidate under the rubric of One Ford. Meant to break down the barriers of executives being defensive of their “turf” and forcing a more team oriented environment to feed off of the synergies.

Mulally has also been more successful at reaching agreements, or negotiating than past leaders. He managed to convince Bill Ford of the necessity to offload the failed luxury brands, as discussed earlier, to better focus on the Ford brand and effect the focus on improving manufacturing operations and cutting capacities and heads, as defined by the Way Forward Plan. Mulally also plans to go from 97 nameplates in 2006 down to 40 worldwide by 2013, leveraging on the European designed small cars and selling them in North America. He also negotiated, successfully, with the UAW to make hourly labor costs competitive with Toyota beginning this year (see Chapter 14 for past failures). These negotiations include the concessions of pay, benefits, reduction in work force, and the closures of facilities (see Chapter 15 for assembly plant closure list).

Also under Mulally's leadership Ford's focus on quality is returning benefit in the resale value of its vehicles; according to Ford's news release, resale value grew 23 percent in the past year alone, outpacing the industry average by four percentage points. Ford also reported that warranty repair rates on its vehicles have declined by an average of more than 40 percent globally in the past three years. For example, on average, the redesigned 2010 Ford Taurus is selling 50 percent higher at auction than the 2009 Taurus after one year in service. Similarly, the 2010 Fusion V6 was up 26 percent at auction than the 2009 model after one year in service.

Mulally's product development experience is playing a role as well in reshaping Ford Motor Company. As Taylor (2009, 2010), described, Mulally, within his first week as CEO approached the product development team and wanted to review the product line up. When he found that the Ford Taurus was discontinued because of the past failed attempts to redesign it into a top seller and failing to assure quality and reliability it was

decided by Ford to be discontinued the Taurus. Mulally felt that there was billions of dollars sunk into the brand loyalty and that it needed to be redesigned such that it could once be a top seller, the redesigned car is due out this year.

Mulally believes that Ford's future lies in the development on high efficient cars, versus relying on trucks and in a product development time compressed manner. Mulally is also set on now eliminating the V8 engine in order to meet new tighter government mileage standards and also to be in line with his mandate to produce smaller higher mileage cars at a profit. Even the Explorer is being retro fitted.

The 2011 model will use the same engineering platform as the Ford Taurus, rather than a truck chassis; and reducing over 150 pounds off of the body with lighter-weight steel. Most of the Explorers will be produced with a new eco-boost engine, which uses direct injection and turbo charging, plus sophisticated software, to get maximum horsepower. This will all add a slight premium to price, however, instead of using the current 4.6 liter V-8 engine, the new SUVs will run on a 2 liter, 4-cylinder design, producing 275 horsepower (Allen, 2009).

Mulally has been involved with the latest development in technologies, most notably, engine technology. He has been instrumental with Ford's drive to catch up with the Japanese companies, namely Honda, in terms of advanced engine design, and has been involved with the three cars that have been named in Motor Trend: Taurus, Focus and Fusion; Ford Fusion being named as the car of the year for 2010 ended an eight year drought of missing this title for Ford.

The engine technology being driven by Mulally and Ford is the new EcoBoost Engine technology (Lassa, 2009; Automotive Engineering, 2010). EcoBoost is a family

of turbocharged and direct injected six-cylinder and four-cylinder gasoline engines. The EcoBoost recently was awarded the Popular Mechanics Breakthrough Award in October 2009; some of the more notably aspects of this engine include:

- Gas Direct Injection – Highly pressurized fuel injected directly into the combustion chamber of each cylinder rather than traditional mixing with the incoming air in the inlet port
- Turbo Power – Energy from the exhaust is used to rotate turbine fan which is coupled to a compressor that pressurizes the output per liter of the engine. The lag of the turbo charger is offset significantly by the direct injection
- Upgraded lightweight die cast aluminum block
- Four valves per cylinder
- Electronic Wastegate control – improved performance, drivability and boost system (noise, vibration and harshness)
- EcoBoost I-4 includes Twin-Independent Variable Cam Timing

First EcoBoost engine produced in production was in May 2009 at the Cleveland engine plant. The 3.5L EcoBoost V6 is obtaining equal horse power (365) and torque (350 ft Lb) as the 6.0 Liter V8 with up to a twenty-percent improvement in fuel efficiency and a reduction of up to fifteen-percent reduction in CO₂ emissions. The 2.0 liter EcoBoost I-4 is rated at 200 horsepower with 222 foot pound of torque.

Leading up to the EcoBoost, is the Duratec Engine. The Duratec replaced the SOHC two-valves-per-cylinder architecture and cast-iron block that was uncompetitive in performance, emissions and overall mass (Brooke, 2010). The original Duratec was the

2.5 L V6 introduced with the Ford Contour in 1994. When the 2000 Mondeo was introduced, the 1.8 L and 2.0 L engines became Duratecs as well. Now there are engines multiple sizes of the Duratec engine. In North America, Ford uses the Duratec name on all its dual overhead cam 4 and 6 cylinder engines. The four-cylinder Duratec is a very fuel efficient powerful engine with the following modifications:

- The Duratec 20 is a 2.0 L found in the Ford Focus. This aluminum block engine and aluminum DOHC cylinder heads offers 136 hp producing 136 ft lb of torque. The Ford Focus sold in the clean air states of CA, NY, MA, VT and ME come PZEV (Partial Zero Emission Vehicle) equipped, which is also an option for any vehicles sold in borders states.
- The Duratec 23 is a 2.3 L version of the Duratec 20. Just like the Duratec 20, it has an aluminum engine block, lined with cast iron and aluminum DOHC cylinder heads.
 - The Duratec 23EW is a Mexican-built engine used on the Focus up until and through 2007. It offers 151 hp with 154 ft lb of torque. A variation on this engine is used for the Mazda MAZDA6, Ford Fusion, and the Mercury Milan. This Duratec 23EW is found in the 2003-2007 Ford Focus.
 - Duratec 23NS is a variation of the Duratec 23 with California PZEV emissions and can be found in the 2003-2007 Ford Ranger and Mazda B-Series. It offers 143 hp with 154 ft lb.

- The Duratec 25 offers more power at 171 hp and producing 171 ft lb of torque. There is also a Hybrid Duratec 25 that is going to be replaced soon with the Hybrid Duratec 23 version.
- As well, Ford is replacing the 2.3 L engine with a 2.5L which is to go into the 2009 Ford Escape, 2009 Ford Fusion, and 2009 Mercury Milan.
- The Duratec SCI (Smart Charge Injection) is a 1.8 L engine that first appeared in the 2003 Mondeo. Today it is available on the 2.0L engine. The SCI engines are designed in German but built in Spain. They are matched to a special six-speed manual transmission.

Even though Ford has made some positive changes in the past few years, there remain many challenges for them in order to remain competitive and survive. First they must deal with the large debt burden that they undertook in order to raise cash and which ultimately kept them from the need to receive a bailout from the US government.

Secondly, they must still address the over capacity issue with further plant closings and employee buyouts. They must also deal with the amount of dealers dedicated to Ford and the cost associated with those. Even though Ford has won some recognition from Motor Trend and Consumer Reports recently, can they overcome their past issue with one-three year reliability performance (for example, Ford just announced a recall of 33,000 vehicles, including the Fusion for seat flaw; front seats and head rest may collapse back during a crash), (Kean 2010).

Thirdly, Ford, like General Motors and Chrysler must still deal (albeit less than before) with the legacy retirement pension cost and retirement benefit costs; in Ford's case, it must pay the Union managed trust fund \$13.2 billion. Lastly, even though they

made good strides at reducing their overall labor costs, it was still accomplished with the necessity of survival; the union knew they had to give concessions. What will happen when Ford begins to show competitive returns? Will the union want to renegotiate back what they lost? Ford is still not completely in line with Honda/Toyota in labor costs per vehicle (\$97 difference per vehicle) nor in the assembly time per vehicle (Figure 160, labor hours per assembly and Figure 161, labor dollars per vehicle depicts these factors). So these challenges still remain for Ford to address in the near term.

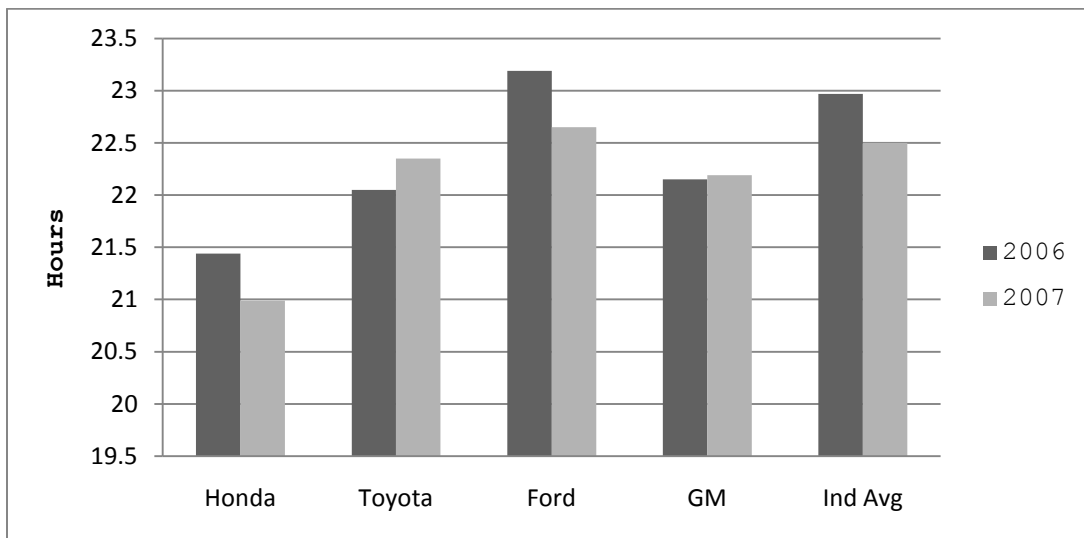


Figure 160 Assembly Labor Hours per Vehicle (source: Harbour Reports, 2008)

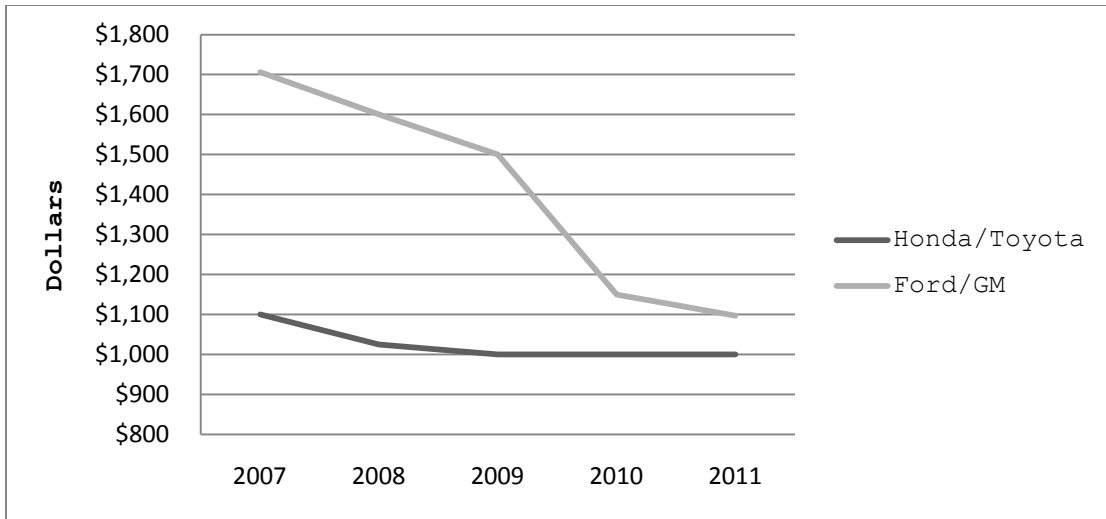


Figure 161 Labor cost per Vehicle (source: Harbour Reports, 2008)

CHAPTER 18

HONDA MOTOR COMPANY

18.1 Introduction

Honda Motor Company began motorbike production in late 1949 with its first ones being available for sale in 1950 (see Chapter 8). Not long after becoming number one in motorcycle sales in the Japanese market, Honda decided to begin dealer operations in the United States with the advent of Honda American Motors (HAM) in 1958 in Los Angeles. Soon after that, Honda decided to get into the automotive industry with the advent of the N-series car in 1968. However, success was not achieved until the design and release of the Honda Civic in 1973 (discussed in detail in Chapter 8). At which time, Honda also began building their own automotive dealer network (not very successful using their current motorcycle network) and continued to expand their automotive lineup; Figure 162 depicts Honda Motor Company's current vehicle lineup:

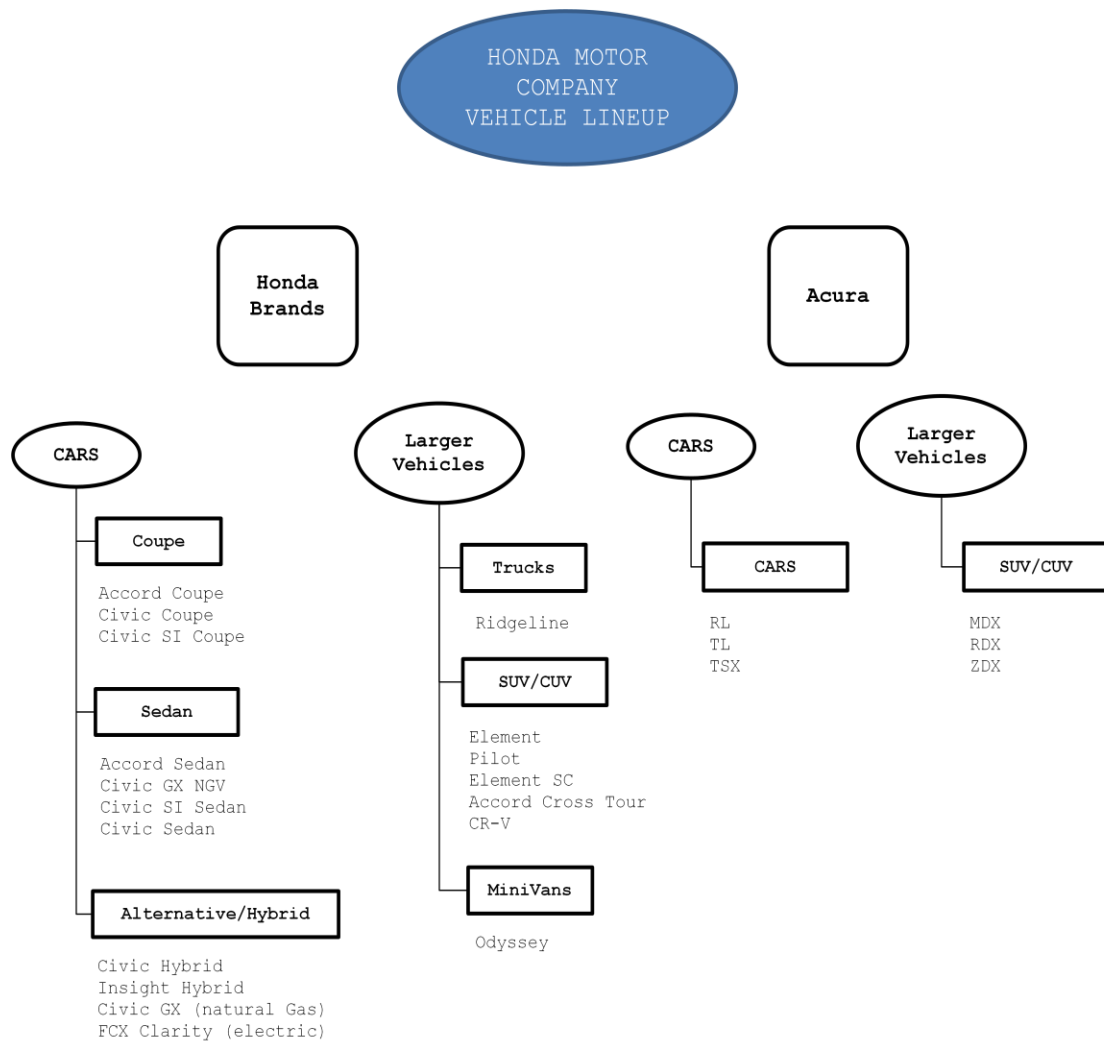


Figure 162 Honda Motor Company Available Vehicles (source: created from Honda annual report, 2009)

This chapter examines several characteristics of the Honda Motor Company, similar to Chapter 17. The chapter is divided up into five parts: part one looks at the business model diversification of Honda Motor Company, in both automotive and nonautomotive industries; part two presents the previous sixteen-year trends in an assortment of characteristics and comparisons; part 3 examines Honda dealerships; Part IV investigates the historical sales price and reliability rating of the Honda civic and Accord starting in 1979 and every 4-5 years thereafter; part five looks at recent recall

issues, cost associated with these recalls; and Part VI looks at some of Honda's applied technology (engine design, manufacturing flexibility) as a follow up from Chapter 8 and follow up on environmental commitment.

18.2 Part I - Diversification

Honda, unlike its American car company competitors, has not aggressively pursued going out and purchasing other companies in order to diversify their business. Honda's diversification, although limited, has come basically from growth within, building on their superior engine and engine technology; originally designed and developed from their very successful motorcycle business. Honda is currently comprised of: (1) Motorcycle business, (2) automotive business (3) financial services, (4) power products and (5) HA-420 HondaJet aircraft business (part of the power products division). In all of these businesses (except financial services) the technologies were not purchased but developed internally from Honda's research and development budget and efforts. Perhaps the biggest driving force behind not going out and acquiring is that Honda is and always has been founded in engineering and design and as an organization has always been led by an engineer; it considers itself the Japanese BMW.

Honda's engineers in research and development insist on devising their own solutions and shuns outside alliances (Taylor, 2008). Honda's R&D, a wholly owned subsidiary of Honda Motor Company, has produced every CEO of Honda since 1948 (Taylor, 2008).

Perhaps Honda's two furthest areas of diversification from their core motorcycle and automotive industry are their power products unit and their new aircraft unit.

Power Products

Honda entered the power products business in order to fulfill the wishes of Soichiro Honda, the founder, to utilize superior engine technology to help people perform jobs at work and home, and improve the quality of life (Honda annual report, 2009). The Power Products unit accounts for 3.4-percent of net sales according to Honda's 2009 annual report.

Honda's power products division first starting producing engines for power products in 1953 to introduced into common items (lawn mowers, roto-tillers). Honda now produces general purposes engines (for sale as stand-alone power), generators, roto-tillers, lawnmowers, industrial mowers, trimmers, water pumps, snow blowers, power carriers, sprayers, electric scooters, outboard marine engines and compact household cogeneration units (back up generation). The interesting about the compact household cogeneration unit is that it is combining the GE160V world's smallest gas engine with unique Honda sine-wave inverter technology and a high-efficiency heat exchanger with integrated catalyst, has enabled the development of a compact household cogeneration unit for the first time in the world.

Honda Aircraft

At first, Aircraft manufacture may seem a far different business then manufacture of automobiles, however, Dr. Masaaki Kato, President and CEO of Honda Research and Development, and Frank Paluch, Vice President of Automotive design, both contend that it is only a matter of time that these two converge. Honda devotes much time and effort to the analysis and understanding of motion so that they can understand and predict future

technologies and continue to build on their core business. Honda constructed its 215,000 square foot manufacturing facility in Greensboro North Carolina and plans to enter into production on the Honda HA-420 HondaJet VLJ sometime in early 2011 (Honda annual report, 2009). Within three months of the \$3.65 million jet's launch in October 2006, more than 100 customer orders had been placed. Popular Science magazine even selected Honda-Jet as the winner of its Best of What's New Award in the aviation and space category.

18.3 PART II - Key Indicator Trends

Market Share, Units Sold and Head Count

Since the oil embargo, as discussed in Chapter 13, Honda's ability to consistently deliver fuel efficient, high performing, environmentally friendly and highly reliable vehicles has led to a continually increasing market share. Honda has increased market share from 5.1-percent in 1994 up to 10.5-percent in 2009, an increase of over 100 percent. Figure 163 depicts this growth and trend over the last 16 years:

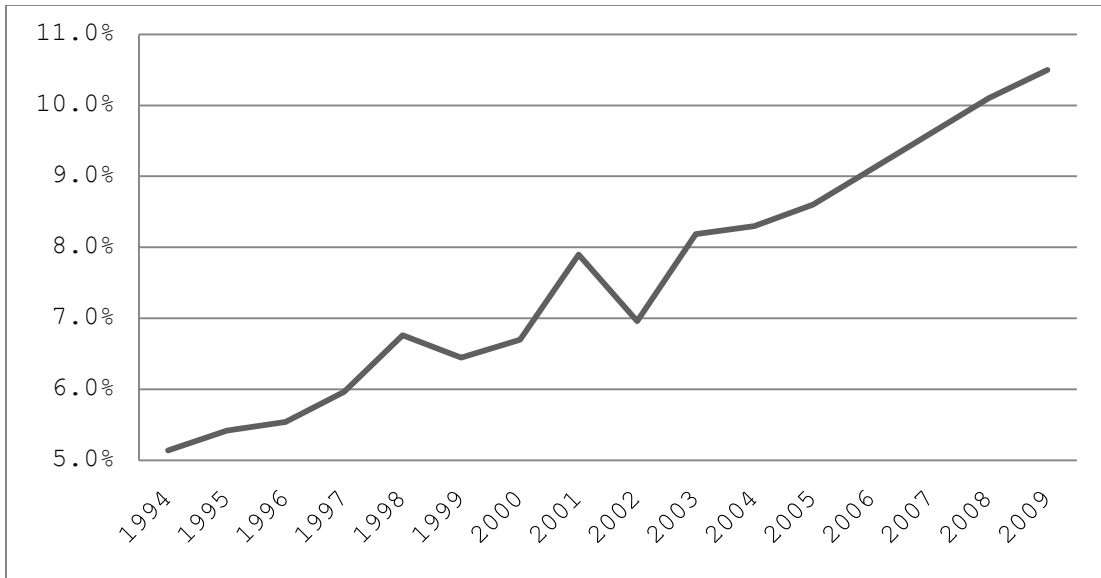


Figure 163 Honda Market Share, NA (source: created with data from Honda Annual Reports, 1994-2009)

Figure 164 now represents the total unit sales that Honda had to sale in North America to capture that level of market share:

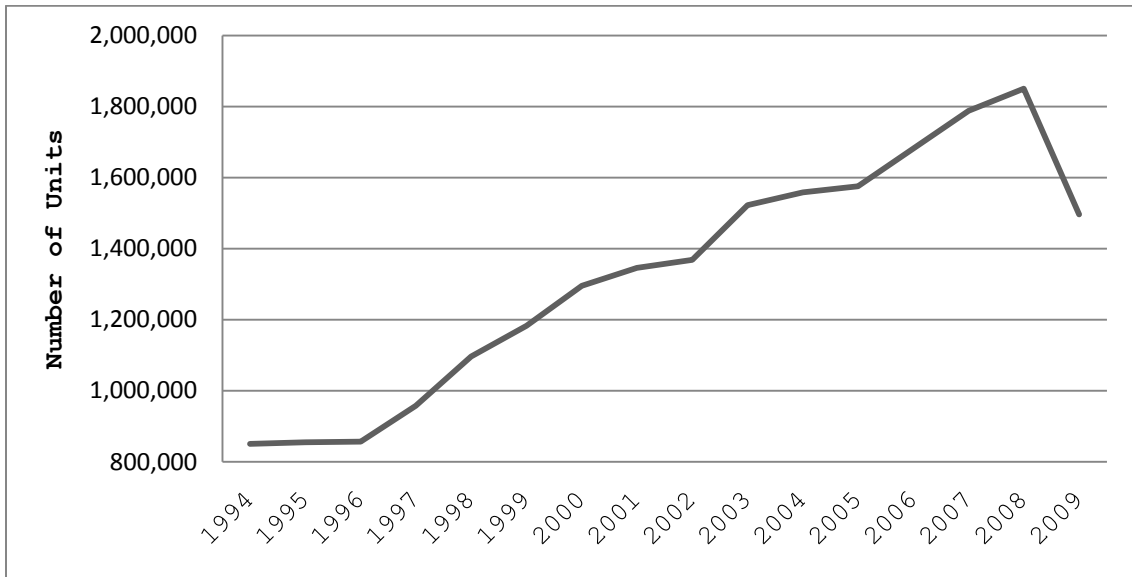


Figure 164 Honda Vehicle Unit Sales, NA (source: created with data from Honda Annual Reports, 1994-2009)

With this growth in unit sales, and expansion of facilities as discussed in Chapter 16, head count in North America has expanded as well as depicted in Figure 165:

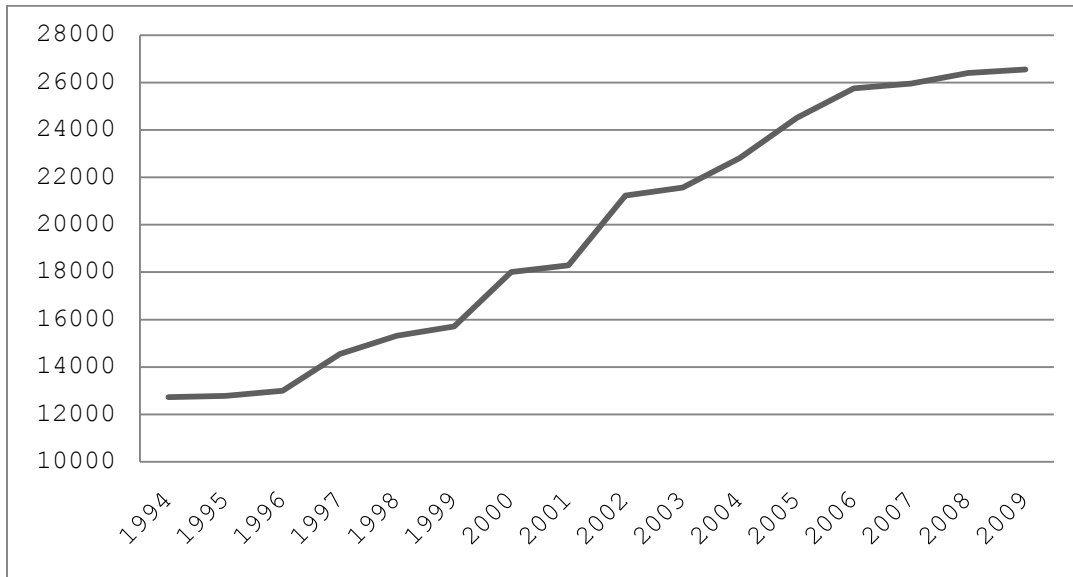


Figure 165 Honda Head Count, NA (source: created with data from Honda Annual Reports, 1994-2009)

Honda has had an advantage with its hourly workforce, in that they have avoided facility unionizing, despite establishing their early facilities in central Ohio (Barnes 2008; Elliot 2009). Honda had the advantage, by locating in more rural areas (where there exist a more independent minded potential workforce) and being able to scrutinize every aspect of potential employees; first that would prescreen the employee, hire them once they past the prescreening as “under evaluation”; and send them through a series of education and training (Honda received millions of dollars from local and state officials, mostly for training and training facilities as follows:

- 1980~1987: \$27 million, Ohio
- 1999: \$248 million, Alabama

- 2006: \$141 million, Indiana

Honda has avoided unions basically because they have paid employees on the same level, wage wise, as the “Big 3” hourly employees. Honda has also introduced pay for performance bonuses that are very lucrative, and has traditionally understaffed so that they could ramp up with overtime, which further increases the potential annual wages to its employees.

Another benefit that Honda has enjoyed is the absence of the legacy costs, however, with their manufacturing facilities in Ohio now reaching 30 years + in age that benefit is not quite so great. However, being nonunionized facilities; Honda has greater flexibility to make changes to the employee benefit plants to ease the financial burden and can offer buyouts to its North American work force at anytime the need arises, such as the poor economic conditions of 2008/2009; And in this case Honda has cut employee pay from top executives to blue collar (Associated Press, 2009).

Honda has also aggressively worked to ensure that they do not get unions in their facilities when building in the more “traditional” union states. When Honda announced in 2006 that it was building a new plant in Indiana, it also announced that it would limit the number of counties that could apply for employment; only 20 of the state’s 92 counties were eligible (Boudette, 2007). This restriction excluded regions where most of the state’s thousands of unionized lay-off workers. The practice of preemptive hampering unionization in the foreign implants is quite effective; of the 33 auto, engine and transmission plants in the United States that are wholly owned by foreign companies, none have been organized by the United Auto Workers union.

Productivity efficiencies and total employee cost per vehicle can be seen in Figures 160 and 161 in Chapter 17.

Financial Performance

Unlike other companies in the automotive industry, Honda has remained stable and somewhat predictable. Honda has remained focused on their core automobile, and engine technology and environmental/mileage vehicles (including dominating the world in motorcycle sells). They have also been a leader at introducing global vehicles and flexible manufacturing facilities (discussed in detail in part VI). This focus has provided them an avenue for continual growth and profitability, continuing and through 2009, while others have stumbled badly. Figure 166 represents net sales in North America while Figure 167 depicts Honda worldwide net sales:

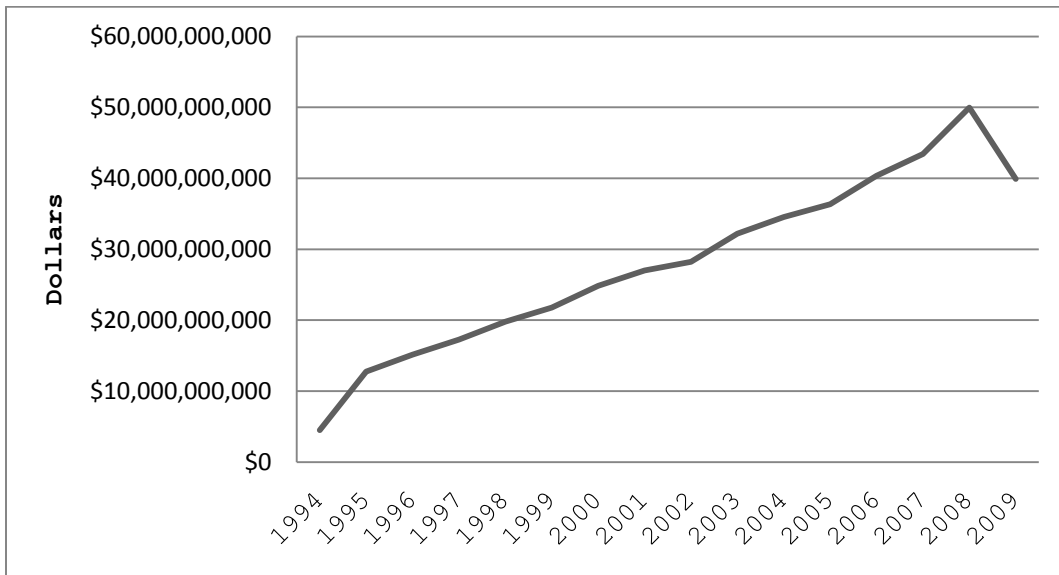


Figure 166 Honda Net Sales, NA (source: created with data from Honda Annual Reports, 1994-2009)

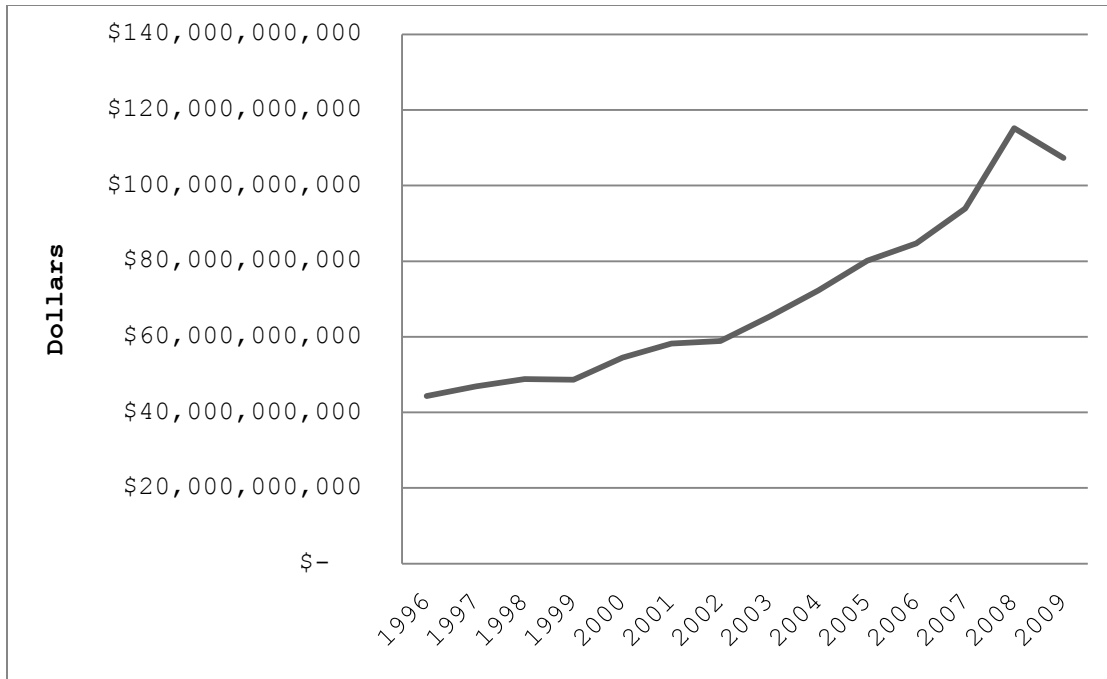


Figure 167 Honda Net Sales, World Wide (source: created with data from Honda Annual Reports, 1994-2009)

Obviously, net sales are not the core judgment factor on the health of an organization; the ability of an entity to also produce a profit will far outweigh how much revenue an organization can generate. Figure 168 represents Honda's net income while Figure 169 depicts operating income. Lastly, some important comparison figures are Figure 170 trends the profit percentage per net sales, Figure 171 looks at Net Sales per employee and Figure 172 examines operation income per employee.

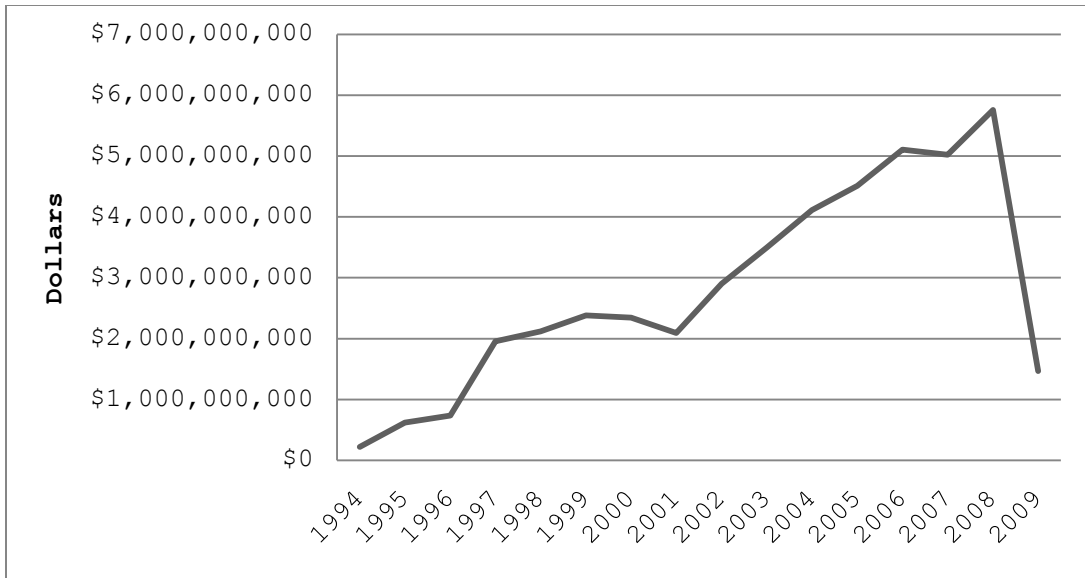


Figure 168 Honda Net Income (source: created with data from Honda Annual Reports, 1994-2009)

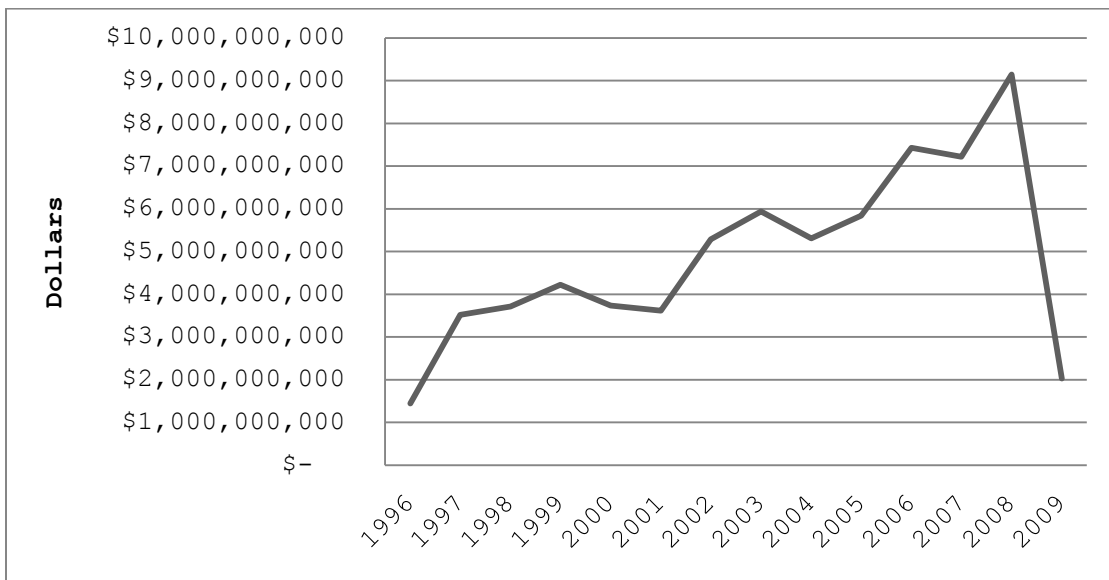


Figure 169 Honda Operating Income (source: created with data from Honda Annual Reports, 1994-2009)

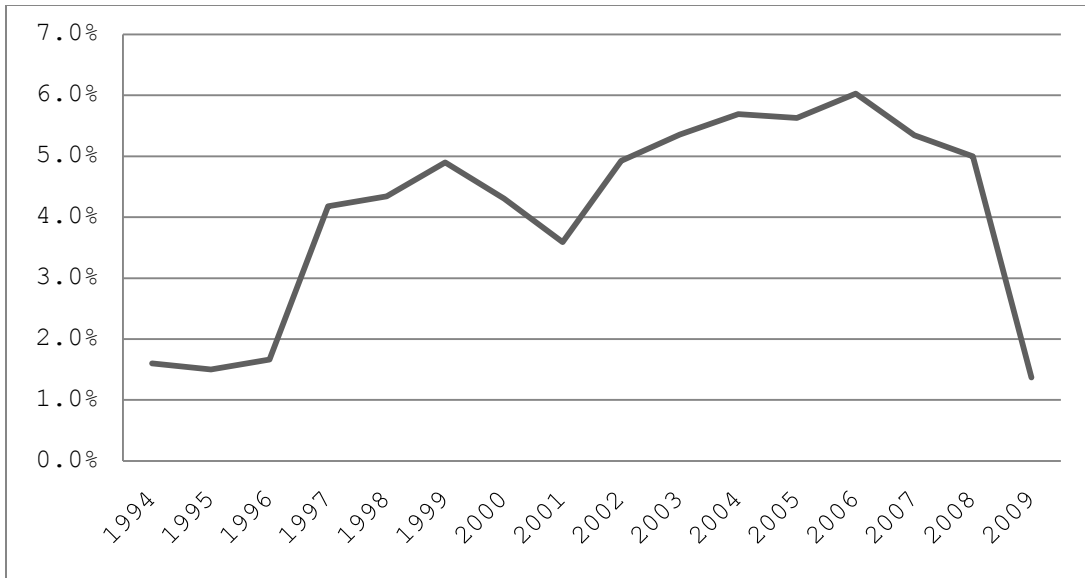


Figure 170 Honda Net Income vs Net Sales (source: created with data from Honda Annual Reports, 1994-2009)

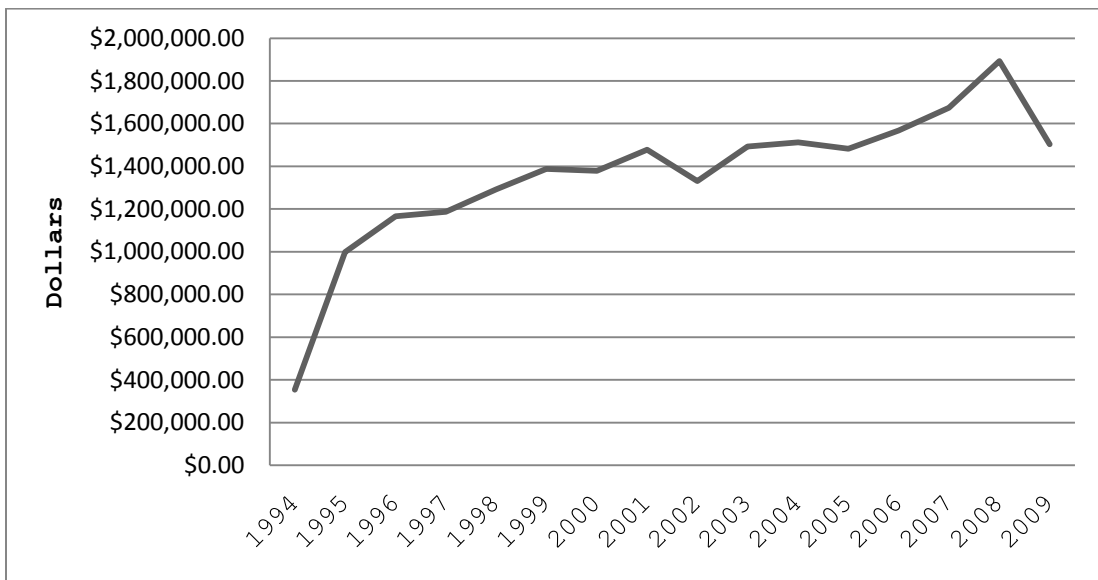


Figure 171 Honda Net Sales per Employee – North America (source: created with data from Honda Annual Reports, 1994-2009)

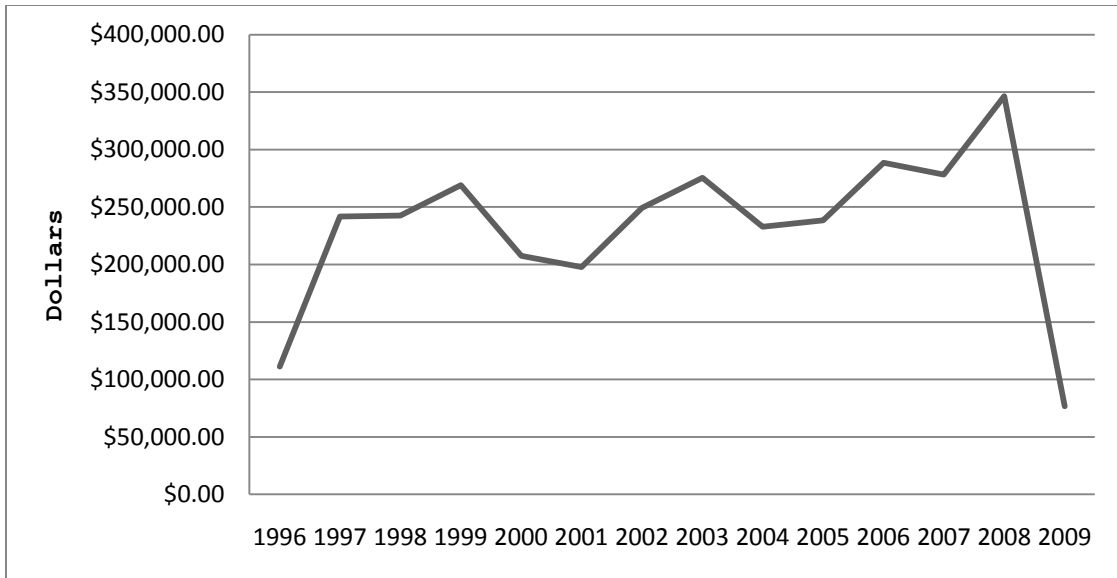


Figure 172 Honda Operating Income per Employee – North America (source: created with data from Honda Annual Reports, 1994-2009)

Of course, one of the more important resultant of the financial performance is the reaction of the movement of the stock price. Figure 173 represents the last 11 years of stock prices (stock split 1/9/02, adjusted price \$19.45):

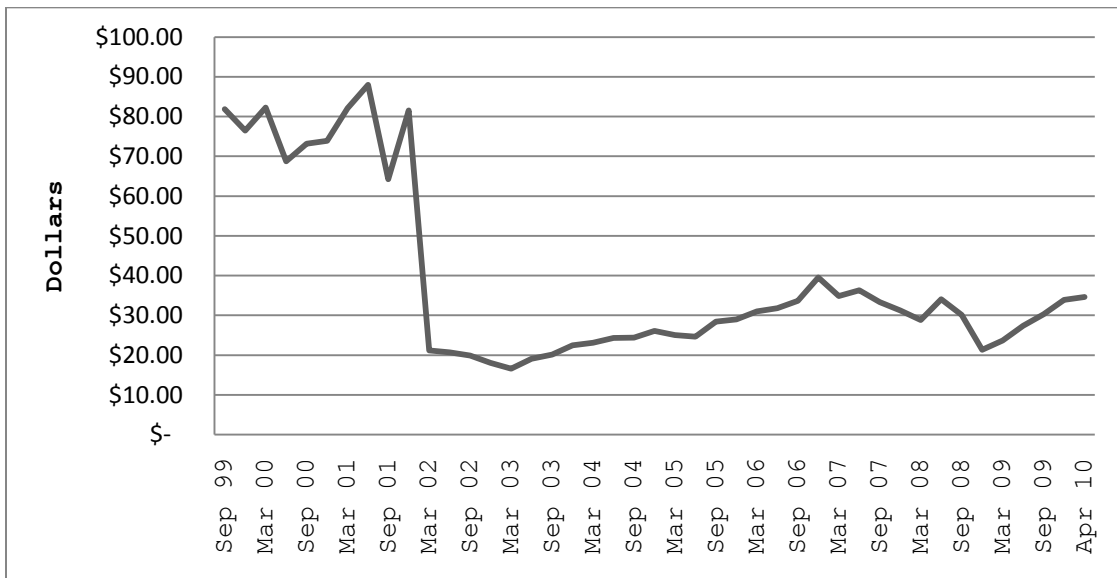


Figure 173 Honda Stock Price - NYSE (source: Ycharts, retrieved 5/15/10)

So while Honda has not escaped the effects of the recent economic downturn, it had remained financially healthy and profitable. The only issue from the down turn (car demand falling) would be the latest downgrade of Honda credit rating in 2009 from Aa3 to A1 by Moody's Investor Service. A1 rating the fifth-highest rating, had little effect on cost of borrowing for Honda.

Investments in Research and Design

Honda's annual budget for research and design has grown from an annual dollar amount of \$1.75 billion to \$6 billion or an increase of close to 245% from 1994 through 2009. Honda's investment strategy has been geared towards innovative technologies addressing environmental concerns (e.g. California's tougher standards and industrialized nations response to green house gas discharges, KOYOTO); understanding all aspects of mobility as discussed above, and incorporating these technologies together. Honda has made great strides in developing engine technologies to improve miles per gallon and meet tougher environmental standards with minimizing the adverse effect of horsepower, as well as investments into hybrids as well as alternative fuel sources (natural gas, electric and fuel cell pilot vehicles), (Yamaguchi, 2008) . Honda has also taken a hard stance (industry leadership) on safety, in their program "safety for everyone", designing technology to protect pedestrians as well as occupants of the vehicles. Honda's investment trend in research and development is depicted in Figure 174 and R&D against net sales is depicted as a percentage in Figure 175.

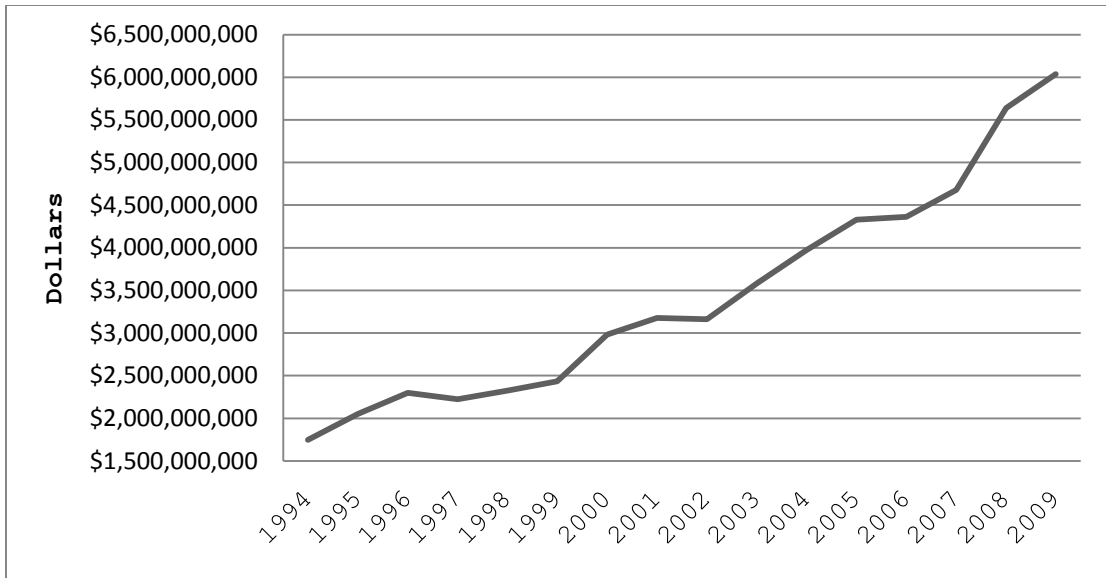


Figure 174 Honda R&D Expenditure (source: created with data from Honda Annual Reports, 1994-2009)

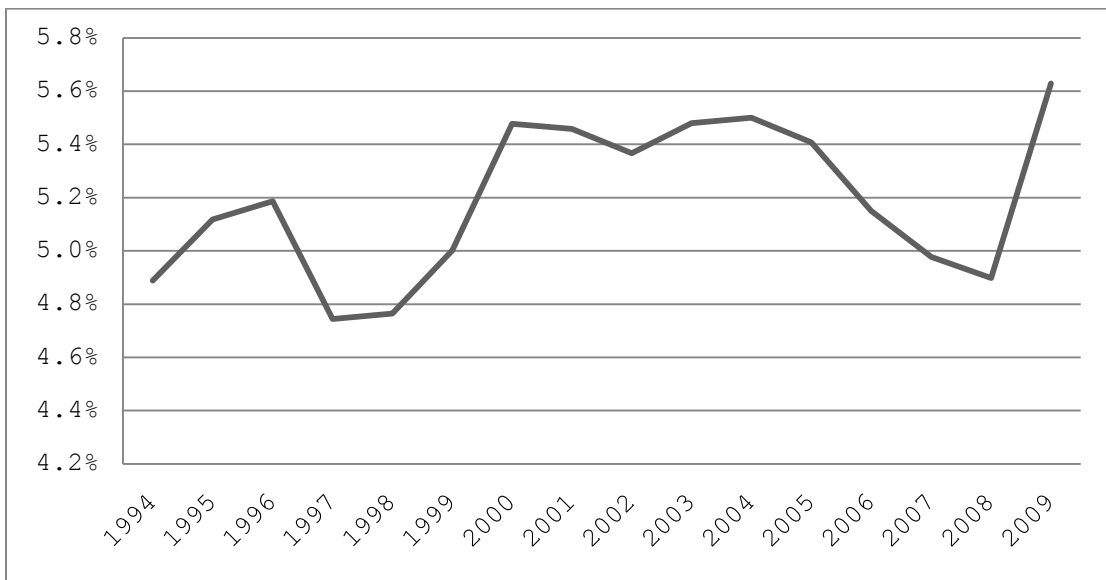


Figure 175 Honda R&D Expenditure vs Net Sales (source: created with data from Honda Annual Reports, 1994-2009)

Advertisement

Advertisement for Honda has varied from a low of \$1 billion in 1994 to a high of \$3 billion in 2008 over the last 16 years with a percentage against net sales of a high of 3.4 percent in 1999 to a low of 2.5 percent in 2009. Figures 176 and 177 depicts the advertisement dollars and advertisement dollars again net sales respectively:

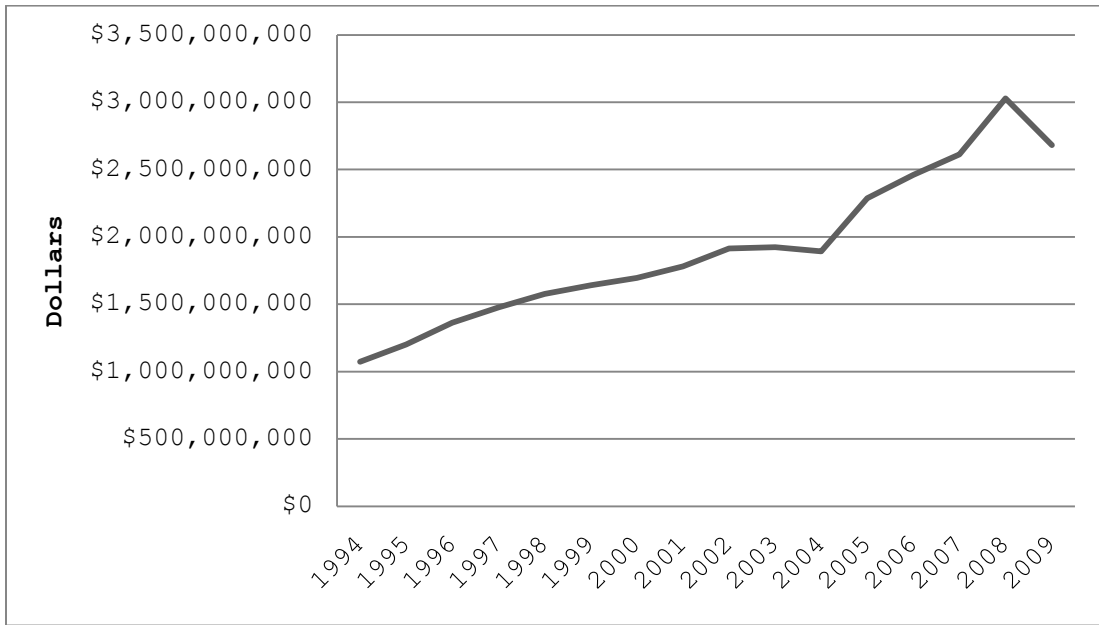


Figure 176 Honda Advertisement Expenditures (source: created with data from Honda Annual Reports, 1994-2008)

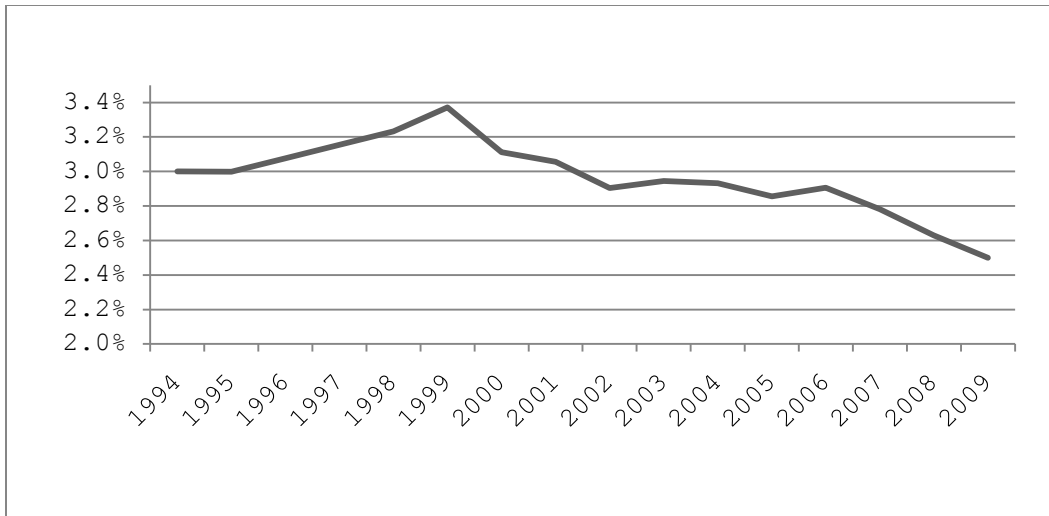


Figure 177 Honda Advertisement Expenditure vs Net Sales (source: created with data from Honda Annual Reports, 1994-2008)

Warranties

Figure 178 depicts the warranty cost associated with Honda while Figure 179 depicts warrant cost against net sales as a percentage.

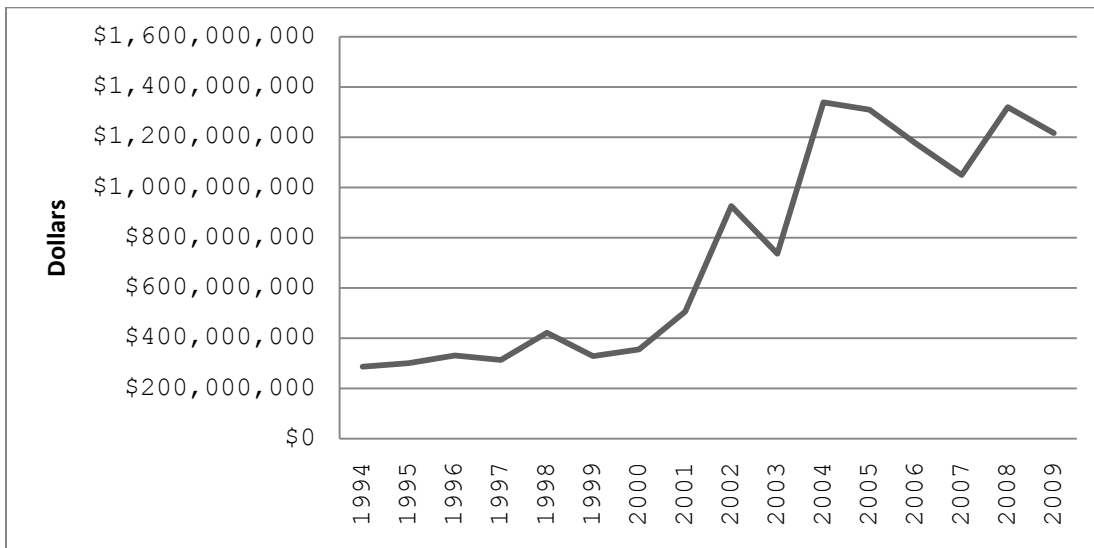


Figure 178 Honda Warranty Expenditure (source: created with data from Honda Annual Reports, 1994-2009)

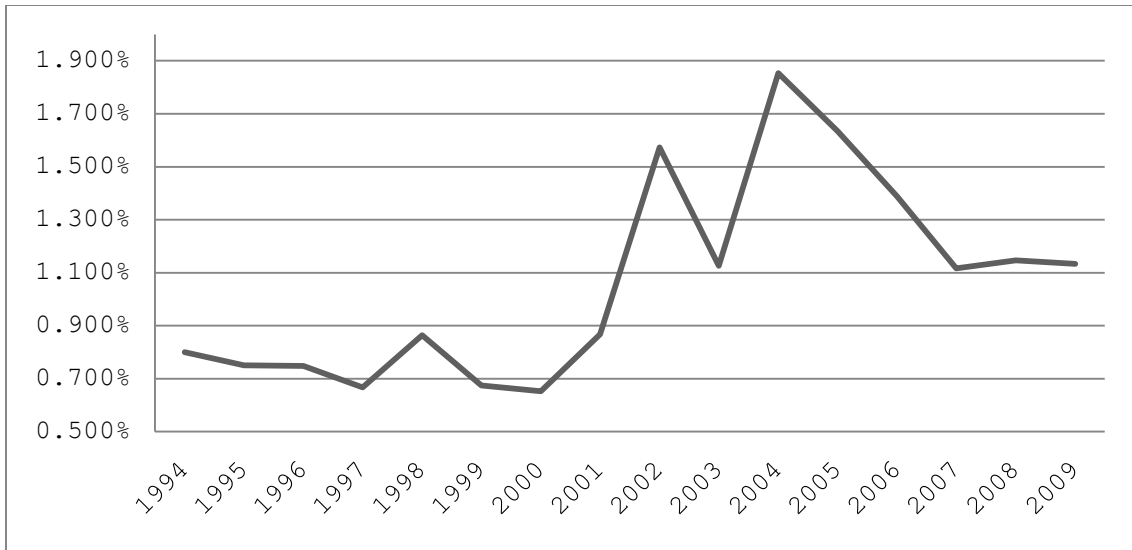


Figure 179 Honda Warranty Expenditures against Net Sales (source: created with data from Honda Annual Reports, 1994-2009)

Figure 180 examines the warranty costs versus the amount of dollars spent on research and design:

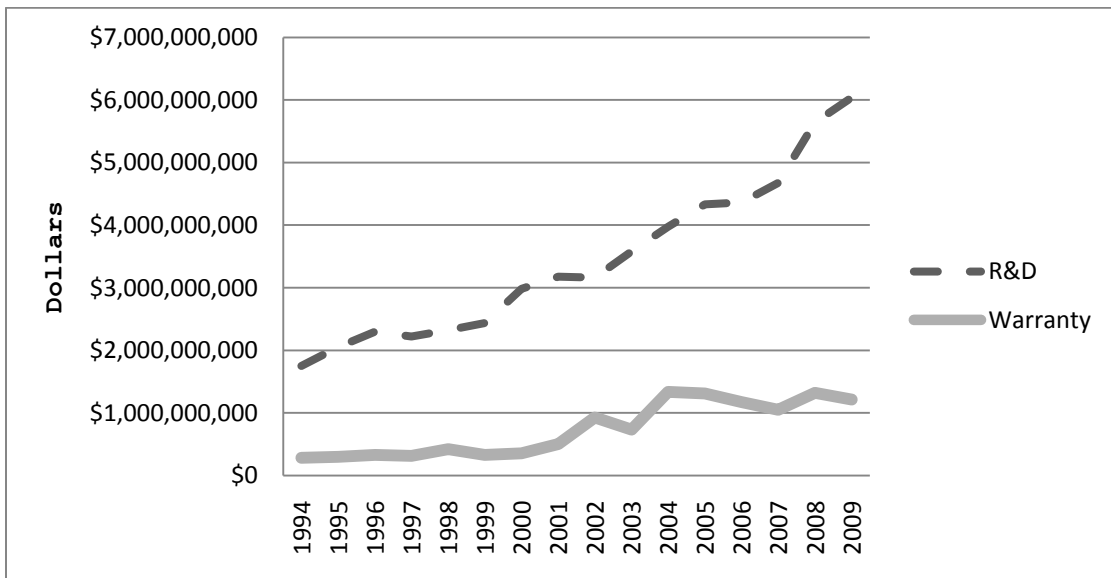


Figure 180 Honda – R&D and Warranty Expenditures (source: created with data from Honda Annual Reports, 1994-2009)

Warranties appear to have grown recently, but that could be attributed to the introduction of many new models, specifically their new class of SUV/CUVs, and all totally new generations of the Civic and Accord, however, as they have progressed through the learning curve, it can be seen that as a percentage of net sales, warranties are again leveling out or heading downward.

18.4 PART III -Dealer Network

Honda has roughly 1,000 Honda dealerships and about 200 Acura dealerships in North America (Honda annual report, 2009). Average unit sales of new cars per dealership average roughly 1,300 units with an average profit range of 10%, accounting for roughly 25% of their total profit. Honda repair and maintenance and warranty work accounts for approximately thirty-percent of total profit. Used car sales accounts for approximately twenty-percent, and financial services and extra warranties account for the remainder. With the used car sales, Honda is much better positioned; Honda's depreciation of new cars is the lowest, overall, of any other manufacturer, maintain 75% of their value after 1 year and 65% after 3 years (Durben, 2007).

18.5 PART IV- Price, Reliability and MPG

This section will review the price variation of the Honda Civic and Accord over the last several years starting in 1979 and moving forward every 4-5 years. Figure 181 is presented of the reliability rating as tested and presented by Consumer Reports for Honda as an average, while Figure 182 depicts the total mile per gallon (mpg) as tested by Consumer Reports for the civic and Figure 183 depicts Honda's total fleet, per vehicle

type, miles per gallon. And last, Figures 184 and 185 graphically summarizes the Civic and Accord price changes over the last 30 years.

1979

In 1979 the Honda Civic priced from \$3,999 for a 2-door, up to \$4,849 for a fully loaded 2-door hatchback. The 4-door wagon sold for \$4759. The Accord base model priced at \$5,799 and topped out at \$6,799

1985

In 1985, the Civic now priced for base 2-door hatchback for \$5,399, and for a Si series, including air conditioning, automatic transmission, cruise, power windows/locks priced at \$7,295. A 4-door wagon priced at \$7,195. While the Accord now priced from \$7,895 to 12,945.

1990

The Accord in 1990 Consumer Reports was priced at \$11,230 from the base and went to \$15,920. The Civic based at \$6,635 with the fully loaded Si going for \$10,245. The 4-door LX version priced at \$12,410. Consumer Reports rates the climate controls at excellent with road noise being very well. Controls and displays were rated as excellent.

1995

The Honda Civic prices from \$9,750 for the base model up to the fully loaded model at \$16,950. Consumer Reports is still rating the climate controls as excellent as

well as the handling and braking as excellent. Interior is classified as roomy and appealing. The Accord being highly recognized by Consumer Reports has the car listed from \$14,800 to \$22,090.

2000

In 2000, the Civic now priced at \$10,750 and tops out at \$17,545. Consumer Reports is rating the Civic as one of the best cars on the market. They state it rides relatively well and handles very well. Honda overall is getting the highest marks for reliability and highest marks for resell value; the Accord prices from \$15,350 to \$24,550.

2005

The base model of the Civic is \$13,010 and for the higher trim lines, goes to \$19,650 while the Accord is \$15,900-\$26,500. The Civic and Accord scored very well on the crash tests. However, Consumer Reports says that the Civic is nimble but not quite as agile as the Ford Focus. The ride is a bit firm with pronounced road noise.

2009

The Civic price range was \$14,113 to \$23,747 and the Accord is listed from \$20,905 to \$31,055. On road test, Consumer Reports rated the Civic 78 and Accord a 79. Overall Honda score in 2009 was 78, which is calculated from the carmaker's average test score and average predicted-reliability rating. The average test score is based on individual scores for all vehicles tested. Reliability rating is based on how models for which there was sufficient reliability data to compare with all other models. Honda again

had the highest overall score of all of the manufacturers in 2009, and in fact, all of the consumer reports used to create Figure 181 rated Honda as the highest reliability rating overall.

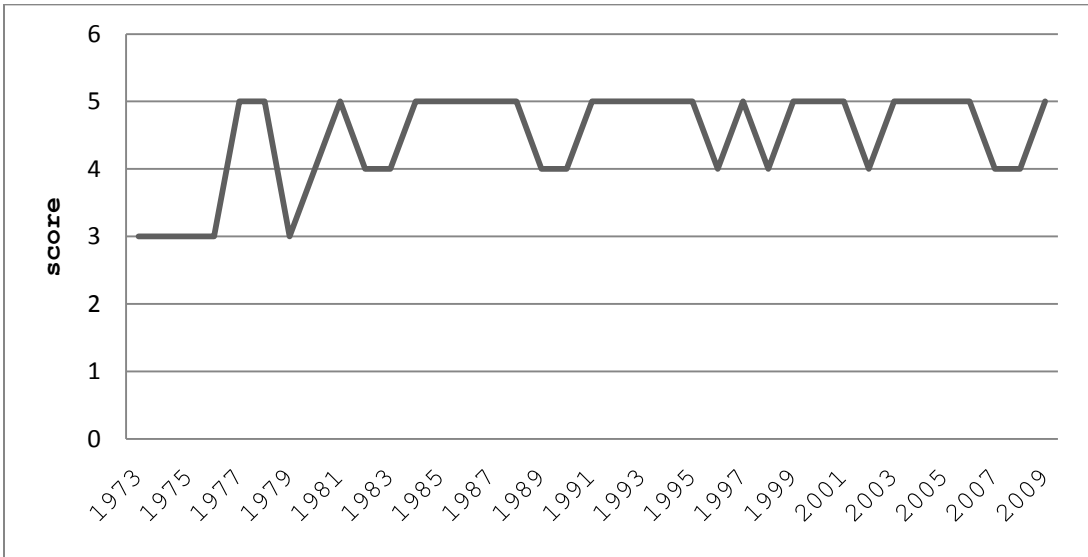


Figure 181 Honda Reliability Rating (source: Consumer April Automotive Issue, 1979, 1985, 1990, 1995, 2000, 2005, 2009)

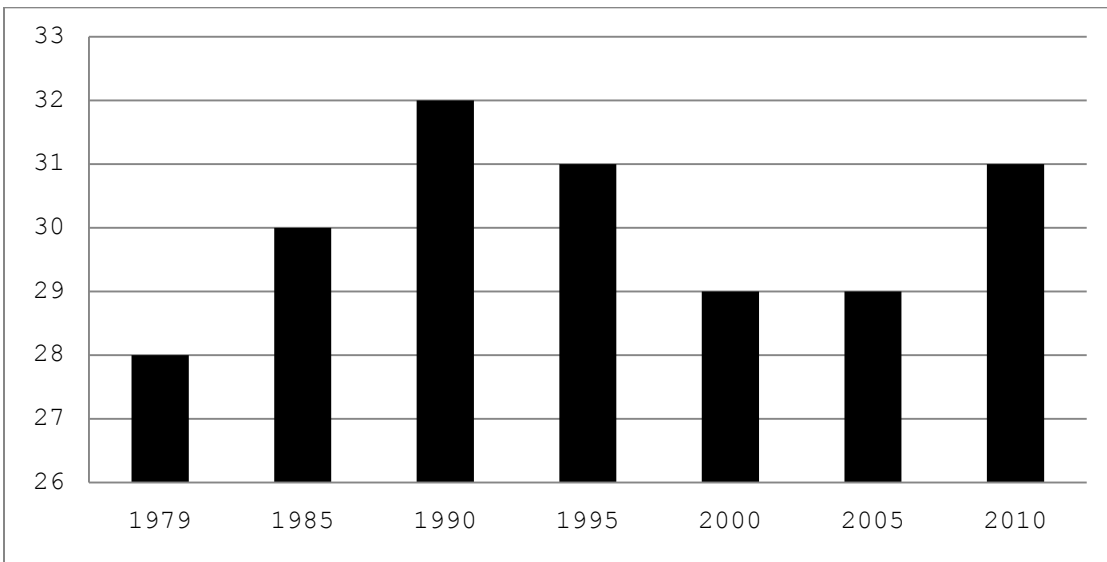


Figure 182 Honda Miles Per Gallon, Civic (source: Consumer April Automotive Issue, 1979, 1985, 1990, 1995, 2000, 2005, 2009)

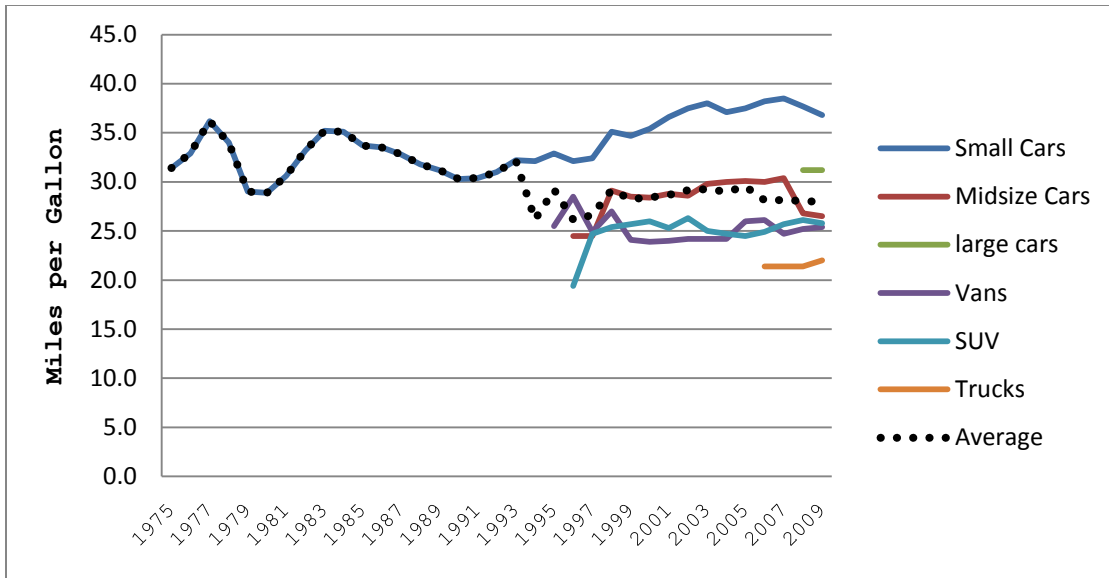


Figure 183 Honda Miles Per Gallon, Fleet (source: created with data from Environment Protection Agency – Fuel Efficiency, 2010)

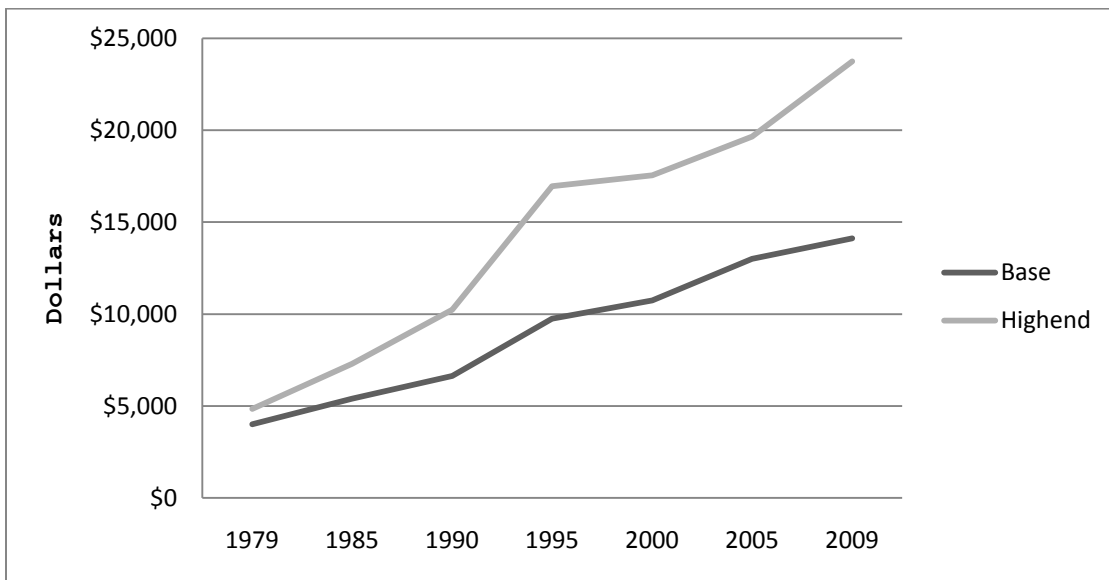


Figure 184 Honda Civic Price (source: Consumer April Automotive Issue, 1979, 1985, 1990, 1995, 2000, 2005, 2009)

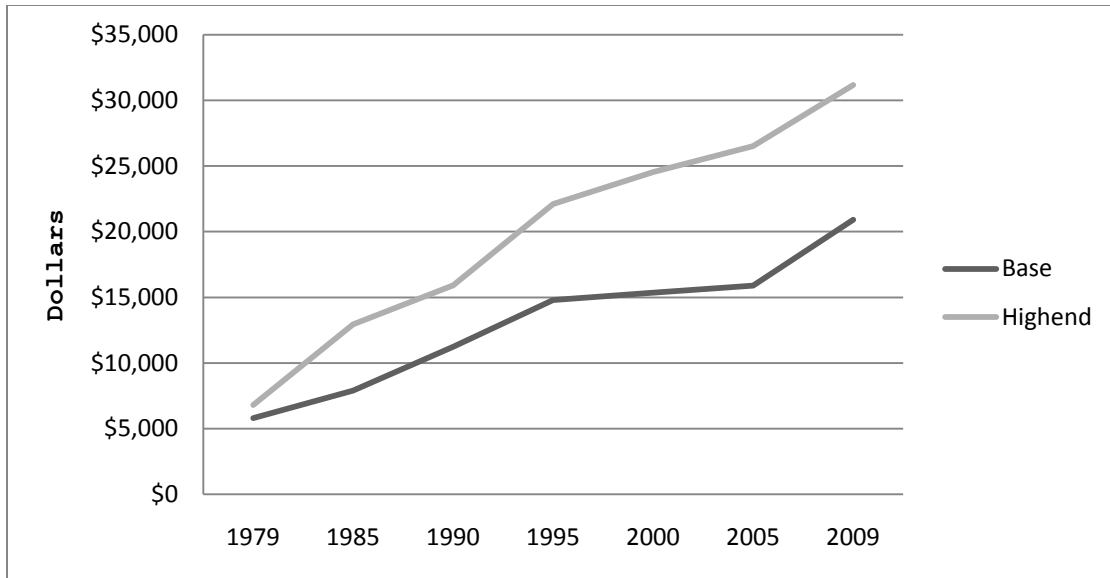


Figure 185 Honda Accord Price (source: Consumer April Automotive Issue, 1979, 1985, 1990, 1995, 2000, 2005, 2009)

18.6 PART V- Recalls

Honda has only made the headlines on a few occasions for recalls. The first recall to make head line news was in 1995 for a seatbelt sticking problem. Honda recalled 3.7 million vehicles, seat belt failures causing release and sticking after accidents. Honda reacted quickly and put a fix in place. The next large recall to gain attention is an issue with Airbags. Honda began a recall effort in 2008 with 4,000 vehicles and eventually expanded to cover an additional 510,000 vehicles in 2009. The problem is that the airbags can over inflate causing them to burst spraying potentially deadly metal shards. This fault has been traced to 11 injuries and 1 fatality.

Most recently Honda has had two recalls; the first being the 2010 Hoyota recall of 646,000 vehicles with a faulty window switch that can over heat when exposed to liquid causing smoke and potential fire, no injuries are reports; second recall involves 410,000

Odysseys and Elements that have a softening brake issue, the pedals or braking sensitivity can become soft over time.

Figure 186 depicts the total number of recalls (mostly minor) per model year over time:

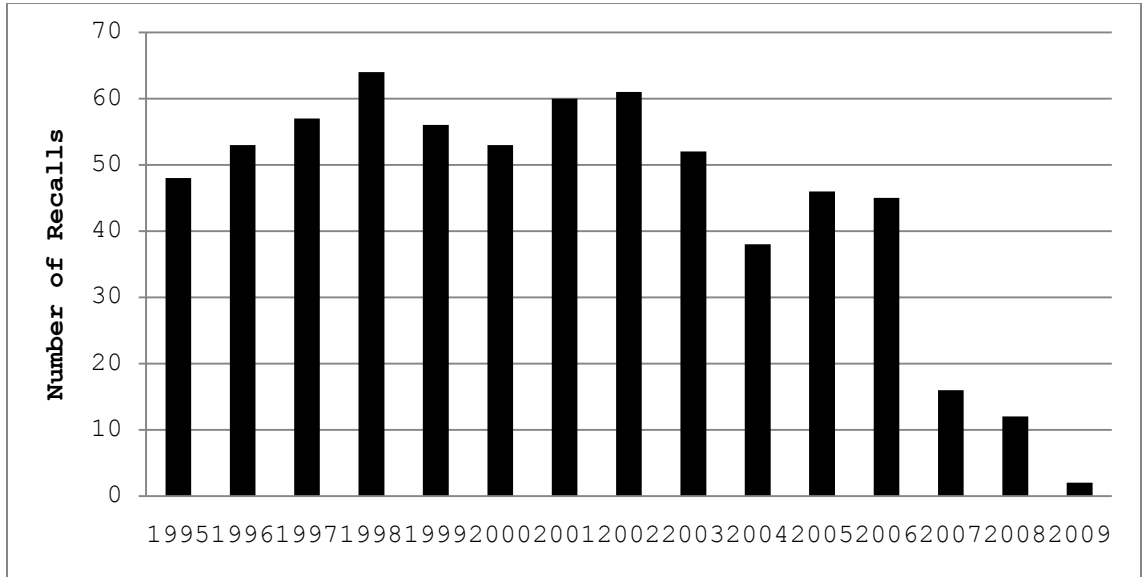


Figure 186 Honda Recalls by Model Year (source: National Highway Traffic Safety Administration, 2010)

18.7 PART VI - Management & Strategic Philosophies

Flexibility and Globalization

A portion of Honda's research and development dollars are spent to ensure that their manufacturing facilities are flexible; capable of producing more than one type of vehicle depending on current consumer preference/market demand. The manufacturing dexterity of Honda's plants, which is rated as the most flexible plants in North America by Harbour, is emerging as a key strategic advantage for Honda. For example, when gas

prices were hitting record highs and the market all but shut down for trucks, Honda transferred their Ridgeline factory over to a better selling vehicle (Linebaugh, 2008). And it is not like there is a large time frame needed to do this.

Linebaugh writes that she recently witnessed Honda producing 129 Civics one morning, shut the line down, specialists came to the line, spent five minutes switching the hands over on the line robots and began producing the CR-V cross over. Honda's plants are also set up to manufacturing a higher demand vehicle (such as the Accord) as well as other less-in-demand vehicles (e.g. Element and Acura RDX) (Vlassic, 2008). So in the event that market tastes change, Honda can react immediately (versus laying people off, or like in the past enter into the unproductive job banks program).

Honda also believes that focusing on its core and globalization of their small car markets builds the necessary economy of scale. No other manufacturer has the global vehicle line up. Ford failed miserably with the "global" Monedo platform, which actually evolved into 5 different versions in attempts to sell in other counties and in North American from Portugal. Even though more money can theoretically be made on larger cars (and Trucks/SUVs) Honda finds economy of scale by concentrating on four key models – the Fit compact, Civic, and Accord sedans and the CR-V small SUV – in large quantities; with a presence in the premium market with the Acura product line. World-wide, each sell more than 500,000 annually, and together they account for more than three-quarters of unit sells (Rowley, 2009).

Engine Technology, and Electronic Control

Honda has led the industry in the study of electronic, interfacing and incorporation of electronic control systems (mechatronics) in vehicles (Taylor, 2008). One of the achievements Honda has demonstrated at integrating several technologies is the advent of their robot, Asimo (advanced step in innovative technology). Honda began researching and developing Asimo in 1986 and the first prototype was displayed in 2000. It is now the most advanced robot on the planet. Asimo is the only robot capable of walking up and down stairs and just balancing on one foot requires the monitoring, synching and adjusting of 34 small electric motors. This type of experience and research has led to the many engine developments and improvements.

As previously discussed in Chapter 8, Honda revolutionized the small engine design and was the first to pass the new environmental standards of the time (without a catalytic convertor), with the release of their 1974 electronic vortex combustion chamber engine (CVCC) also being a pioneer in electronic engine management systems. However, Honda abandoned the CVCC in 1984 as more stringent EPA standards required a different approach and also now required the use of a catalytic convertor.

In the 1980s Honda had some improvements in engine design with their early single overhead camshaft (SOHC) and later their double overhead camshaft engines (DOHC). Honda has also incorporated light weight designs into their engine from technology that they developed/improved such as the aluminum block. The Honda F-Series engine was Honda's "big block" SOHC inline four, though lower production DOHC versions of the F-series were built in the late 1980's. It features an aluminum

open deck cast iron sleeved block and aluminum/magnesium cylinder head. Honda's F22B1 Engine won a spot on the Ward's 10 Best Engines List in 1995 and 1996.

In SOHC, the camshaft is situated in the cylinder head, above the valves. The valves are opened and closed either directly with a shim between the cam lobe and the valve stem, or via a rocker arm. SOHC engine valve configurations typically have 2 or 3 valves per cylinder. It is also possible to have 4 valves per cylinder using SOHC but this translates into a complicated combination of rocker arms and cam lobe shapes. The DOHC arrangement uses two camshafts in each cylinder head. Two cams per cylinder head mean that a DOHC V engine has 4 camshafts because it has 2 banks of cylinder heads. This allows the manufacturer to easily implement a 4 valve per cylinder setup; it also allows the engine to rev higher. It also allows better placement of the valves in an optimized setup that gives you maximum performance. But the disadvantage of such a setup is more weight, more cost and more complexity. It takes more stuff to drive two camshafts. The main reason to use DOHC is to drive more valves per cylinder. If a SOHC setup can allow 4 valves per cylinder, having a DOHC engine will not bring that much benefits over SOHC and the additional weight becomes a burden instead. DOHC engines also allow the spark plug to be placed right in the middle of the combustion chamber. This promotes efficient combustion. With SOHC, the camshaft is usually in the middle of the head because it has to drive both the intake and exhaust valves, robbing the sparkplug of its optimal location.

A major break in technology (and manufacturing requirements) came with the release of the breakthrough was variable-valve-timing and electronic lift control (DOHC VTEC) engine - With an electronically-controlled variable valve timing and lift

mechanism, this “super sports” engine delivered high performance in all areas; delivering the performance of a turbo charged engine without the turbo charger. Honda’s engineers, pursuing high RPMs and high output on a par with racing engines, developed the incredibly high-powered DOHC VTEC engine, taking both high-speed and low-speed performance to a new level.

VTEC uses two camshaft profiles; one with lower duration for good low speed torque, and one with longer duration and valve lift for good high speed torque. The electronic computer system switches camshafts at about half engine speed to combine the best features of each camshaft. The resulting torque curve is M shaped - it has a torque peak for the low speed camshaft (at about 3500 rpm) and a torque peak for the high speed camshaft (at about 7000-8000). The part of the torque curve in between the low and high speed camshaft peaks, has a torque dip because the low speed camshaft torque is dropping off and the high speed camshaft torque is picking up. During the camshaft, the engine is at the lowest point of engine torque (Kerr, 2001).

However, with the higher RPM performance tighter tolerance was required. Honda has been refining machining operations for years, in order to get the performance first out of their engine designs from motorcycles and then carrying that same discipline for automobiles. The higher the rpm on a vehicle the more stress. Going from 6,800 RPMs to the 8,000 RPMs to get the desirable performance, an additional 40-percent inertial force is placed on various engine parts (Honda history, retrieved 2009). For example, Honda went from a cast crank shaft, typical of industry, to a forged crankshaft; this change tightens the tolerances which allows the use of a smaller bearing journals

which reduces friction, and it also builds a stronger bottom end so that more RPMs can be obtained for more power (Jordan, 2000).

The 2003, all new generation product system, Accord super low emissions vehicle (SULEV) was fitted with a mass airflow meter and a larger catalytic convertor that in comparison to the 1982 (two years prior to the use of the catalytic convertor and using the CVCC engine), it would take 40 2003 accords to produce the same amount of emissions that the 1982 Accord produced (Bornhop, 2000). In the V6 version of the 2003 Accord, Honda incorporated the aluminum cylinder heads with the tuned ports of the exhaust manifolds into their castings. This permits the catalytic convertor to move further upstream for quicker light-off and reduced emissions also reduces some, assembly and manufacturing steps which leads to increased reliability through fewer assembly steps and fewer gasket interfaces (potential leaks). Table XIX outlines typical Honda I4 and V6 engines used in the Civic, Accord and Acura from 2001 to present:

Table XIX Honda Engine Types and Power Information

K20A	2.157	260 @ 8250	175 @ 6750	01-06 Civic Muger
K20A	1.998	240 @ 8400	159 @ 7000	01-06 Civic
K20A2	1.998	200 @ 7400	142 @ 5600	02-04 Civic
K20A3	1.998	160 @ 6500	141 @ 4000	02-05 Civic, 02-06 Accord
K24A3	2.354	189 @ 6800	164 @ 4500	03-08 Accord
K24A4	2.354	160 @ 5500	161 @ 4500	08-present Accord
J30A1	2.997	200 @ 5500	195 @ 4700	03-05 Accord
J30A5	2.997	244 @ 5500	211 @ 4800	06-07 Accord
J35	3.471	240 @ 5800	253 @ 4400	01-08 Acura
J35Z2	3.471	271 @ 6200	254 @ 5000	08 - present Accord
J37	3.66	300 @ 6000	275 @ 5000	07- present Acura

(source: Honda Engine Types, 2010)

Although, since the release of the 2003 all new designed Accord, Honda has not made drastic changes to the internal combustion engine. While General Motors and Ford have both pursued direct injection technology and turbo charging to boost horse power while simultaneously improving mileage, Honda has not pursued direct injection and only recently introduced turbo charging in its I4, 2.4 liter, 240 horsepower engine in their new small RDX SUV.

In an October 2009 interview CEO Takanobu Ito was asked about when Honda was going to introduce direct injection technology and whether he thinks that Honda has lost its competitive lead in engine technology, his response to the question was, “We have limited resources, and we are concentrating on Hybrids. We want to build the optimal engines for hybrids. And if we’re going to talk about hybrids, we have to talk about the costs for the consumer. Hybrids are very expensive” (Niedermeyer, 2009).

Environmental Leadership

In a letter from Nobuhiko Kawamoto dated June 27, 1997 in the Honda Motor Company’s annual report, he states, “One of the most important global issues facing automakers today is environmental protection.” Kawamoto goes onto say, “since the number of motor vehicles in the world is increasing, we believe that the ideal evolution of motorization is impossible unless it is fully harmonized with the environment.” Honda has been a leader in the development of low-emissions, ultra-low, super-low emissions and zero-emission vehicles, and has historically seen this leadership as a competitive advantage and as a corporate culture. Honda refuses to incorporate V8 engines into their

line-up and refuses to incorporate large body-over-frame large SUVs and trucks into their lineups (Rowley, 2009).

Based on this strategy with regards to the environment, Honda has aggressively devoted resources to improve their internal combustion engine technology, develop alternative energy vehicles, recycled bumpers and other components and reducing factory waste. Honda's goal, as stated by Kawamoto is, "to create innovative solutions that are not restricted by current concepts." Also in 1997, Honda began marketing low-emissions vehicles globally, which, in the United States included the Honda Civic, which met the demanding standards set by the State of California.

Honda's Civic also was the first vehicle to meet the then newly created U.S. Clean Air Act of 1974 which placed strict regulations on tail pipe emissions and also placed first in fuel efficiency tests conducted by the U.S. Environmental Protection Agency in 1974 . In 1997, Honda also began marketing the Civic equipped with a compressed natural gas engine that met even tougher standards of an ultra-low emissions vehicle.

In Japan, Honda began sales of low-emission vehicles that only produce one-tenth the carbon monoxide, hydrocarbon, and NOx emissions allowed by the current standards. In 1995, Honda introduced the first gasoline-powered vehicle to meet ultra-low-emissions standards, this following their first introduction in 1993 of Honda's power product engines being the first to meet California emission regulations.

Fuel cells have been aggressively pursued by Honda since the 1999 announcement of Honda's vehicle FCX-V1 and FCX-V2. This followed by the 2000 announcement of the FCX-V3 and 2001 FCX-V4 prototype vehicle. In 2002, the Honda

FCX fuel cell vehicle was the first prototype fuel cell vehicle delivered and was delivered in both Japan and the United States. 2004, Honda FC stack, a next generation fuel cell stack capable of cold starts and operation at temperatures as low as minus twenty degrees Celsius was developed.

In 1998, the Union of Concerned Scientists began ranking six automotive manufacturers (which accounts for ninety percent of total industry output) in terms of relative contribution to smog and global warming. The environmental performance of car companies uses governmental data to provide a quantitative analysis of automakers' environmental performance; the results of 1998 ranking of 1997 model year placed Honda as the cleanest automotive manufacture and Honda has not lost that ranking (union of concerned scientists, www.uscusa.org, as viewed 4/15/2010). Overall Honda's vehicles produce less than half the pollution of the fleet average.

Safety Leadership

Honda utilizes their "Safety for Everyone" concept to improve safety; which Honda defines it as a comprehensive approach to vehicle safety that seeks to provide top-level occupant protection for all Honda and Acura vehicles regardless of size and price, along with reduced aggressivity toward other vehicles and improved safety for pedestrians (Honda annual report 2009). Honda's research and testing facilities include the omni-directional vehicle-to-vehicle crash test facility at the Tochigi research and development center, which opened in 2001 and is the world's first indoor all-weather facility. And in 2003 Honda added an automotive safety and research facility at their Honda R&D center in the Americas, which features seven advanced testing laboratories,

including the world's most sophisticated crash barrier block and the world's first pitching crash test simulator. The pitching motion simulates the lifting of a vehicle's rear end in a frontal collision, allowing engineers to gather data on the performance of safety systems such as airbags and seatbelts that more closely reflect real world performance.

Honda is also working on an advanced safety vehicle technology program. This particular program is broken down into three phases. The first of the three phases features a navigation system with intelligent predictive and preventative safety functions. Phase two applies radar-based collision avoidance technology. The final of the three-phase program incorporates pedestrian protection. These efforts have resulted in the development of Honda's Intelligent Driver Support system, which is designed to help vehicles maintain lane integrity and proper vehicle distance.

Honda has also committed heavily to a driver education program to train potential and current drivers on proper driving techniques. As a result of Honda's safety program, they have obtained an industry leading safety rating by the United States federal government by having 5 models in the Five Star crash rating system for driver and front passenger in front-impact and front and rear seat passenger in side impact testing. This includes the Civic Coupe which is the only compact class vehicle to ever earn the government's highest crash safety rating. To put this in perspective, only 22 vehicles in the entire industry have achieved this level of safety performance.

Management Structure

Honda is probably best known as the company run by engineers; every CEO of Honda has been produced by the Honda Research and Development subsidiary of Honda

(Taylor, 2008). A differentiating characteristic (as compared to other automotive manufacturers) is that Honda is relatively un-hierarchical and forgoes many of the trappings of corporate success (Rowley, 2009). Honda believes that the organization need to be flat, as CEO Takeo Fukui in 2006 said, "If management oversight is too strong, then it's difficult to innovate (Honda annual report, 2006)." Figure 187 depicts how Honda's organization is set up:

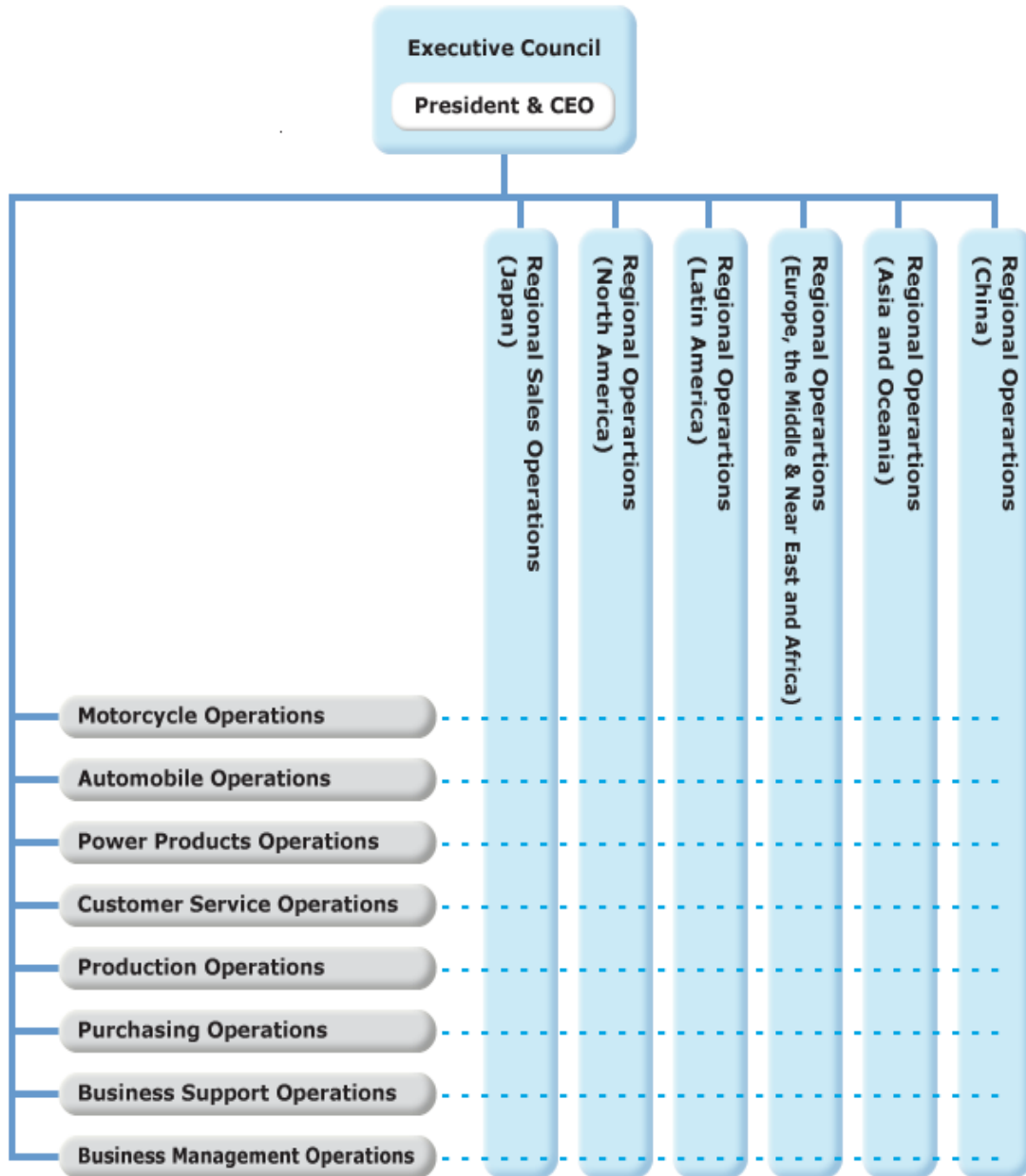


Figure 187 Honda Organization Structure (source: Honda Annual Report, 2009)

Along with the CEO (past and present) most top executives are engineers and appear to be more interested about technology than discussing finance.

Compensation for Japanese companies, from a management standpoint, is much lower than that of their U.S. counterparts; rarely is a CEO compensated over \$1 million

dollars (Carty 2007). Japanese companies are not required to break each of their executive's pay out individually, but instead lumps all of their pay together. According to filings with the Securities and Exchange Commission an U.K. firm Manifest Information Services, which analyzes proxy information, estimates Honda paid out \$11.1 million, combined, for its top 21 executives in 2006; that number includes salaries and bonuses paid. And the sum of salaries and bonuses that the CEO shares with 36 board members was \$13 million (Fahey, and Kelly, 2006). It should also be noted that "perks" (houses, club memberships, and chauffeurs) are not included.

While Honda has performed very well over the past few decades in North America, they too have many challenges. While their competition has evolved and added additional features and comfort technologies in their typical family cars, Honda has not always followed. For example, most manufacturers have added/upgraded to six speed automatic transmissions (some have even moved to seven and eight speed automatics) and bumping horse power up to over 300 horse power for the last 2-3 years. Honda has finally just introduced its first six-speed automatic transmission on its new Acura ZDX performance sedan along with the new 300 horsepower 3.7 liter V6. The ZDX is the Acura version of the Accord Crosstour, which still has the past five plus year old 271 HP, 3.5 liter V6 with a five speed automatic. As Honda considers itself a more value added, economical version of the BMW, the Crosstour competes with the BMW 5 Series Gran Turismo; and the Acura ZDX competes with the BMW X6M.

From an engine design standpoint, Honda's response to the direct injection engine was that they are focusing on Hybrid technology. And looking at Hybrid technology, Honda re-launched its Insight hybrid in 2009 with much hype about its lower cost,

however, in comparison to the Toyota Prius, through the first quarter of 2010 Honda only sold 5,000 units while the Prius has sold six-times that amount. In March of 2010, Ford's Fusion hybrid sold 1,670 units to Honda's Insight unit sales of 1,652 (Welch, 2010).

CHAPTER 19

PAST INDUSTRIES, AND MANAGEMENT OF TECHNOLOGY

19.1 Introduction

This chapter examines a number different industries in the United States and how adaptation, or their lack of, and proper investment in research and design to develop, and incorporation of new technologies, and not effectively leading the progression down one Sigmoid Function-curve, learning-curve, (old generation), and preparing for investing in the next new S-curve (new generation) of products, eventually led to their business loss or significant loss in industry leadership (Foster, 1986). Betz et al. (1995) identifies several paradigm shifts over the last couple of centuries in management. He begins with the industrial revolution and follows through with interchangeable parts, accounting practices of direct and indirect labor, scientific management, through mass production and lean production. Betz talks about an eighth paradigm shift occurring since the last half of the twentieth century consisting of the conscious creation and leading of technological change and innovation.

As Betz describes that prior to the Second World War, the economic benefits of technological innovation could be captured nationally as the new technology more slowly

diffused throughout the world. In countries like Germany and Japan, their national policies changed significantly after World War II to require the deliberate borrowing (licensing) and developing of critical technologies on a national scale. As a result the pace of technology diffusion in the world has increased dramatically, resulting in a globalization of technology, production and markets. The recent rise of technology advancements in China, India, and South Korea with their developing markets has added dramatically to this globalization of markets and growth of new innovative high technology business.

19.2 Management of Technology (MOT)

Today's products involve systems of multiple technologies (sub-systems) acquired from all over the world in both the design and production. Betz makes a distinction between regular or mature technology and a critical technology. A mature technology is one that has been around for some time and slowly evolves, or continues to improve; a critical technology is one which paces the rate of obsolescence of either the product or how it is manufactured. Historically, products and the method of producing were managed by the speed of change of a signal critical technology.

To explain this more clearly, Betz offers the following example: machine tools have traditionally depended on two critical core technologies, metallurgy and mechanical machinery. A third critical technology, electronic control, now has been added. Where the core historical technologies have slowly and incrementally changed the electronic controls have exploded in change, hence controlling the direction of machine tools. On top of this, electronic sensors have been added for closed loop computer controlled

systems, introducing the term mechatronics (Keys, 1995, 1997); with real-time built in quality control/assurance systems.

Therefore, it is now necessary to have the ability to simultaneously manage new product and process technologies change due to the complexity of multi-critical technologies. Betz, et al. (1995) identifies several principals which can help focus management in a new paradigm to deal with both changes and:

- Value creation,
- Quality and reliability (see Chapters 10 and 11),
- Responsiveness
 - Time to market
 - Time cost of money to do it,
- Agility,
- Innovation,
- Integration (see Chapter 9),
- Teaming, and
- Fairness

Modern products, at least most modern products, and services for that fact, require a system of many technologies which must be integrated are core to the design, development and the manufacturing of these products, ergo system engineering; an organization must have the capability to staff, develop and/or obtain and integrate the organization around these technologies. As stated earlier, the pace of the change in product lifetimes is dominated by that technology or subsystem of technologies that are changing the most rapidly. An organization cannot continually dominate their respective

market without having the ability to continually trade, manage and integrate these rapidly changing critical core technologies, especially those products that have the rapid product cycles (e.g. PC workstations, high definition televisions, cell phones, etc). Therefore, Betz identifies two technologies that must be integrated: (1) the technologies of products; and (2) production of the enterprise and the technologies by which the enterprise is managed.

19.3 Management of S-Curves, Discontinuity and Change

Foster (1986) was one of the early pioneers of understanding the S-curve and the challenges of passing from one S-curve through the discontinuities period (a discontinuity) to the next evolving S-curve. In his *Innovation: The Attacker's Advantage* book, he cites many examples of companies' failure to navigate from one such curve to the next.

Often (usually) a company that is successful in the initial s-curve is not successful in subsequent new technology evolving s-curve(s). Foster presents, as an example, a table that depicts a number of companies that did not successfully make the transition from vacuum tubes to solid state semiconductor device manufacture. He also presents a number of other examples in the tire, chemical industry as well.

Relevant to this dissertation is his early perspective on the U.S. automobile industry inability after the 1930s to generate a very positive future revenue return on its research and design (R&D) investment; and how the imports were able to (obtaining a much more favorable return from R&D investment) grow their market share from close

to zero to approximately 18 percent from 1950 to 1975, as an indicator of the business organization weakness (see Figure 188):

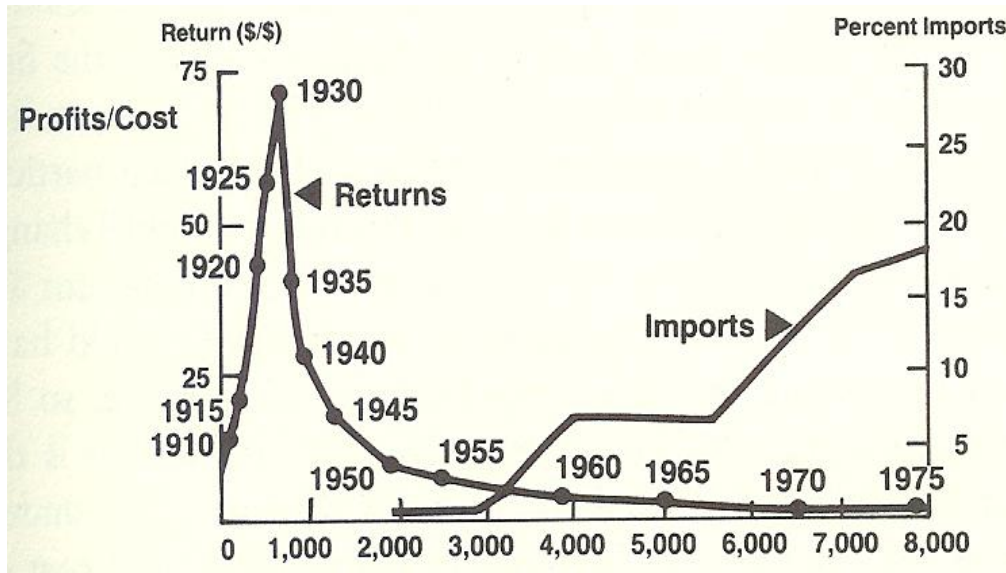


Figure 188 R&D Payoff in the U.S. Auto Industry (source: Foster, 1986)

Also relevant to this dissertation and as a follow up to the tire example used in Chapter 13, Foster also outlines the changes in the tire industry and how an unknown, Michelin, became a major player with the development of the steel belted radial tire and also the manufacturing process to produce this tire economically that upset the bias ply tire (shift of S-curves) rather quickly in the early 1970s; allowing them to gain a major market segment against the U.S. leaders of Goodyear, Firestone and Goodrich. Figure 189 depicts this transition:

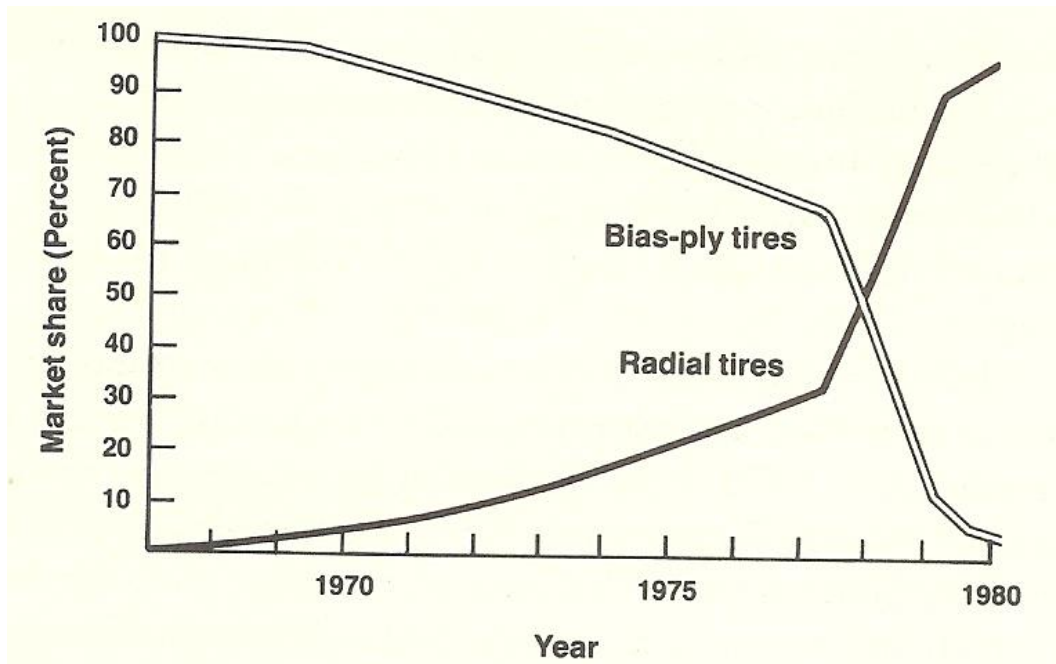


Figure 189 S-Curve Shift, Bias-ply to Radial Tires (source: Foster, 1986)

As has been documented in the previous chapters on systems engineering, project management, reliability (warranties) and quality presented by Keys, this period of growth in revenues and volume of units shipped was due from about 1950 on by a post World War II U.S. economic boom. During this time frame the U.S. companies in general were growing and expanding their organizations vertically to respond to the increase number and variety market segment of new and more complex products to stimulate and respond to the buying power of this new self generating economy. As these companies grew, they increasingly became more horizontally disconnected which led to communication problems, and a transfer of product and process problems from/through one part of the organization to another (next in sequence); this is where the isolation of “silos” originated.

The Silo is the evolving management system where the focus is an inward and information vertical communication to the various segment leaders. Silos have individual

segment managers that serve as information gatekeepers (buffers, decision bottlenecks); making timely coordination and communication across/between departments difficult to achieve; and seamless interoperability within and between external parties impractical and very time consuming. Silos tend to limit productivity in practically all organizations, provide greater opportunity for security lapses, internal power games, privacy breaches, and frustrate consumers who increasingly expect promised product information to be immediately available, complete and on-time. Figure 190 presents a basic depiction of the silo concept:

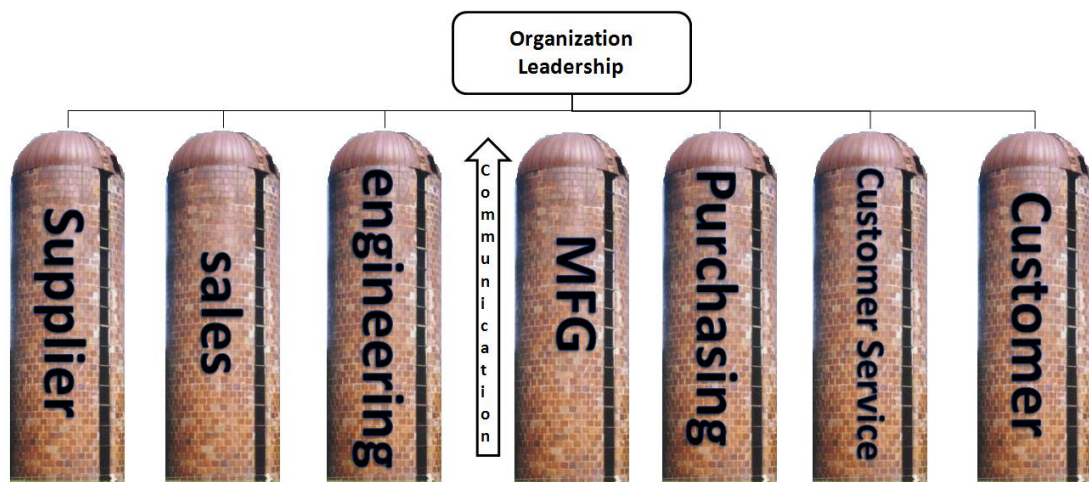


Figure 190 Organization Silo Depiction (source: author's depiction)

This became a real concern (major problem) with various industrial companies' leaders as new product development times increased, reliability went down, warranty (overall life cycle) costs went up and the quality continued to become increasingly worse.

From the 1970s on, to try to reduce this silo affect, a number of new industrial programs and initiatives were created including; simultaneous engineering,

project/program management, total quality management, six-sigma, concurrent/collaborative engineering, and system engineering are a few of them more significant efforts that were developed to combat this problem. Despite all these new management tools, many U.S. companies still did not fully adopt and implement these tools aggressively; which ultimately resulted in the decline of many of these organizations.

Despite being very successful many companies in the consumer electronics industry (amongst others), such as RCA, Magnavox, Xerox, IBM (PCs), American Motors, Westinghouse, Hoover, and others which disappeared, were sold to foreign interests or operate today less significantly with a smaller market share in their specific industry/products they once dominated. So these companies either: 1) struggled to get new products from engineering in to production and to the consumer or 2) struggled even more to get (usually unsuccessfully) new s-curve technology products out of R&D into engineering for development and eventually manufacturing to provide to the consumer base. Figure 191 depicts another perspective on the S-curve definitions moving along the curve:

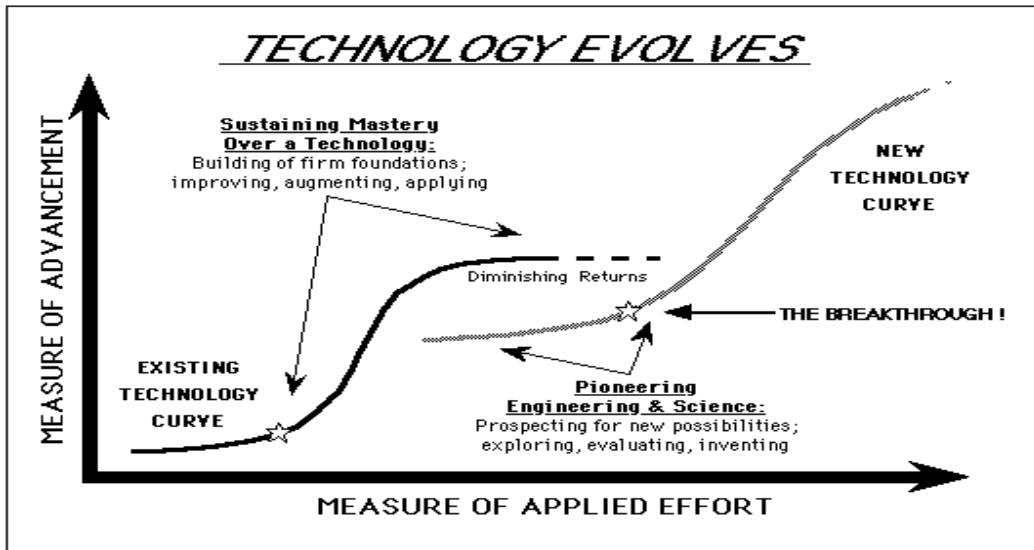


Figure 191 S-Curve Definitions (source: Scott, 2008)

19.4 The Movement of Technology Along the S-curve

The sigmoid curve, or the S-curve, as Handy (1994) puts it, “sums up the story of life itself. We start slowly, experimentally, and falteringly; (grown in knowledge and then) we wax and then we wane.” With the accelerating pace of change gets smaller the size of the S-curve shrinks as well. The key to continual success (customary to continually building knowledge) is to realize when one curve is nearing the end of life to transition onto another curve. Figure 192, inserted again, depicts the movement from one S-curve to another. While the depiction is simple, the execution of it can be traumatic and deadly for the initial S-curve pursuer; and handsomely rewarding for the emerging new S-curve.

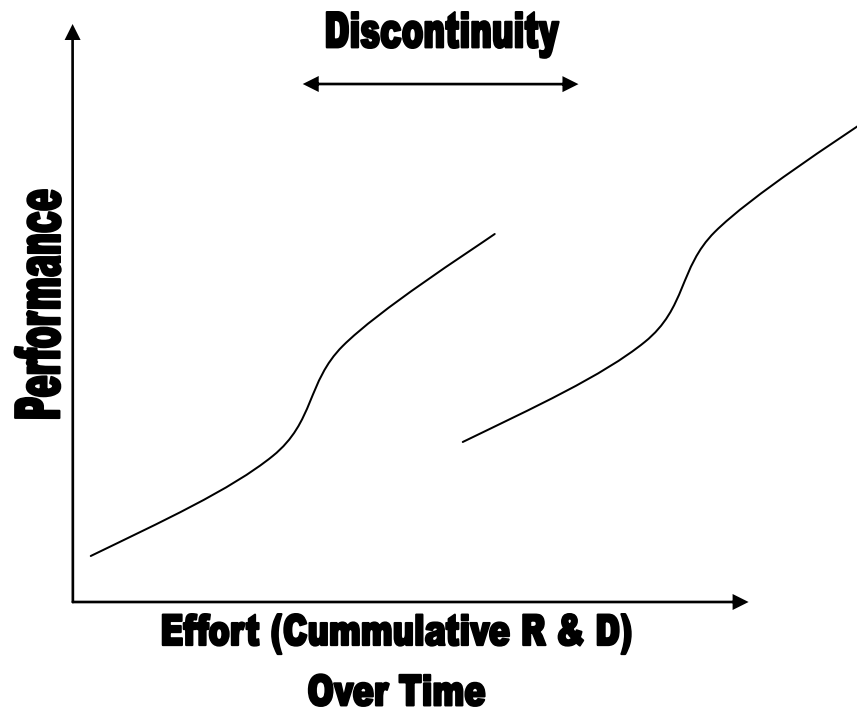


Figure 192 S-Curves and Discontinuity (Source: Keys, 1994)

Timing the move from one S-curve to the next is typically the challenge. A simple concept, Sidorowicz (1998), is to determine an appropriate unit of time measurement and where you are now on the curve, and the expected course is clear. Sidorowicz identifies some key issues to deal with that makes this somewhat a difficult task:

- The compression of time,
- An accelerated wave frequency, and
- The paradox of change

The compression of time is where the life cycle of products/processes once used to take a decade or more; now the time frames today have shrunk dramatically

(depending on the industry to 3-5 years or 1-3 years) and this accelerated pace of change affects all activities. In product development terms, the speed to market is critical to stay globally competitive, therefore, reducing the S-curve. Often in many significant markets, market share can be lost by just a few months delay in product launch; also, a company can potentially lose a year's worth of revenue by this same delay. The natural inertia of many individuals and organizations can also create a significant lag in reaction and response time. As both Sidorowicz (1998) and Handy (1994) describe that you are usually never where you believe you are on the curve, and in fact, you are always much further along then you will want to acknowledge. With the accelerated wave frequency it is now how much and how fast something is changing.

The most difficult is probably the paradox of change. Figure 193 identifies the most logical mathematical point at which time to start a new S-curve (which is always pretty obvious with 20/20 hindsight):

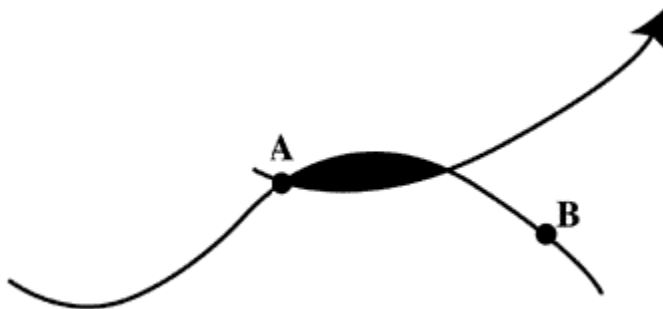


Figure 193, New S-Curve Start (source: Handy, 1994)

The obvious point to start a new S-curve is on the plateau (A) prior to the decline, this is where you have the time and energy and resources to get through the early stages of exploration and adjustment before the curve heads south. The paradox, being that the company's cash cow providing all of the revenues/profits/bonuses/management promotions is about to go away without foreseeable warning, is that it is also at this exact point (peak) that all historical indicators are telling the organization that it is poised for continued growth and success (financial accounting methodology and thinking). It is difficult to change (from a cultural and power position) from what is and has been working so well. The problem that then arises is that by the time the curve transitions from point A to point B occurs, there is now a real impetus to suddenly try and change course when the downslide is well underway and the organization is faced with real disaster; but does not have the revenues available to address it. Handy (1994) and Sidorowicz (1998) identify the following as a list of items as potential happenings at/by this "B" point in time:

- It is very difficult to make significant changes at this point;
- Resources and energy are increasingly depleted as the cycle runs its course down hill;
- The credibility of leaders is diminished as they are perceived as having led the organization downhill.

Figure 194 depicts how the current market becomes saturated with competition with figure 195 depicting with a "bell-shaped" curve along with the S-curve of saturation depicting the inflection point of change:

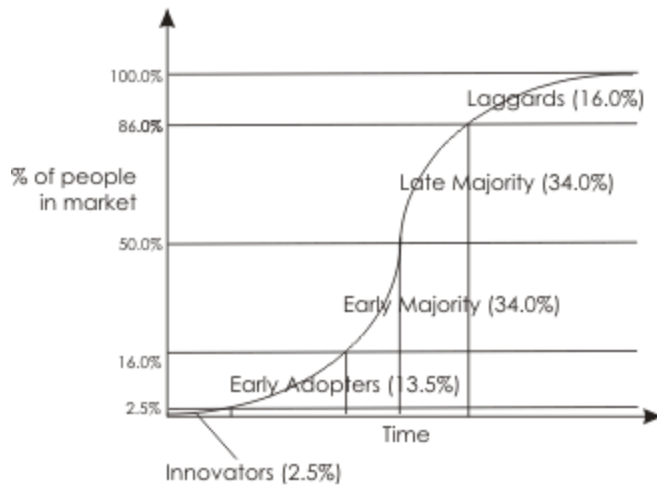


Figure 194 Entrants into the Market (source: Handy, 1994)

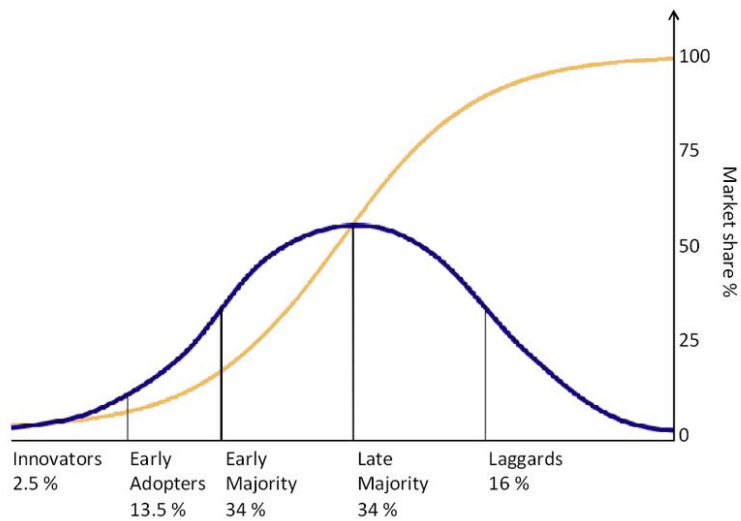


Figure 195 Bell Shaped Curve Representing Market Movement (source: Author depiction)

19.5 Reasons for Failure

Keys (1997) comments that many organizations over the past thirty to forty-years, cannot or will not, make the commitment to create the leap from one S-curve to the next. Some of these organizations will be discussed later on in this chapter. But first, some of the issues that prevent organizations from leaping from one curve to the next curve will be discussed. It is like being an ice skater in a hockey game and try to determine when to gently shift one's weight from one skate to the other to make a dramatic change in direction to score the goal.

First, Handy (1994) points out what Schumacher called curvilinear logic: the conviction that there is a sigmoid curve, that everything has its ups and its downs, and that everything has a life cycle. An example of this is just-in-time manufacturing. Ohno, a chief engineer with Toyota, developed a new way to coordinate the flow of parts within the supply system, where the idea was to simply convert a vast group of suppliers and parts plants into one large coordinated synchronized machine, by dictating that parts would only be produced at each previous step to supply the immediate demand of the next step (Womack et al., 1990).

This idea was brilliant; make the supplier carry/manage the inventory to get away from facility's carrying costs and inventory costs. However, this idea became too popular and then trucks began traffic jams on Japanese roads, especially around "Toyota City"; and these costs and delays soon outweighed the just-in-time savings and even forced items to be delivered too late, let alone the unmeasured pollution damage to the environment (Handy, 1994).

Second, the first S-curve may lead to a secondary service operation that assumes the profit center of the original organization that blinds them from making a jump from one S-curve to the next S-curve. One example of this that will be talked about later in this chapter and paper, includes, RCA's economic dependence of its consumer electronics business on revenues from the replacement tube business; or companies to expand/diversify into financing (e.g. Ford and GM) and expect to make their revenue/profits off of this; often forgetting that these extra revenues are building upon, and leveraging, keeping a healthy, consumer interested, competitive product line base.

Third, the organization may develop the new technology, but lack the ability to recognize, by its need for continual and expanded investments, the importance or timing of controlling the implementation. A good example of this is Motorola, who created the CB and cell phone products, business and owned the Market for years. They delayed in developing their digital cellular phone products; thinking that it was too early and continued to develop its next generation cellular phones as analog, believing that they could stay competitive, remain in control of the market (at least short-term) by cost savings (process improvements) through the pioneering use of six-sigma. Their business, profit center leaders could not see cannibalizing their own analog business with new digital products; even though Motorola was also one of the leaders in CMOS semiconductor microprocessor technology of the time. The later is the core of a modern digital cell phone as well as other most important modern digital products. Ultimately analog could not compete with the features, at a lower operational power requirement and lower cost, that digital potentially could and did offer, and a small unknown company, Nokia, came from nowhere to capture the majority of the cell phone business which still

leads today; Motorola eventually separated its cell phone business and has attempted for many years to off load it all together. Figure 196 depicts the cell phone industry in 2009:

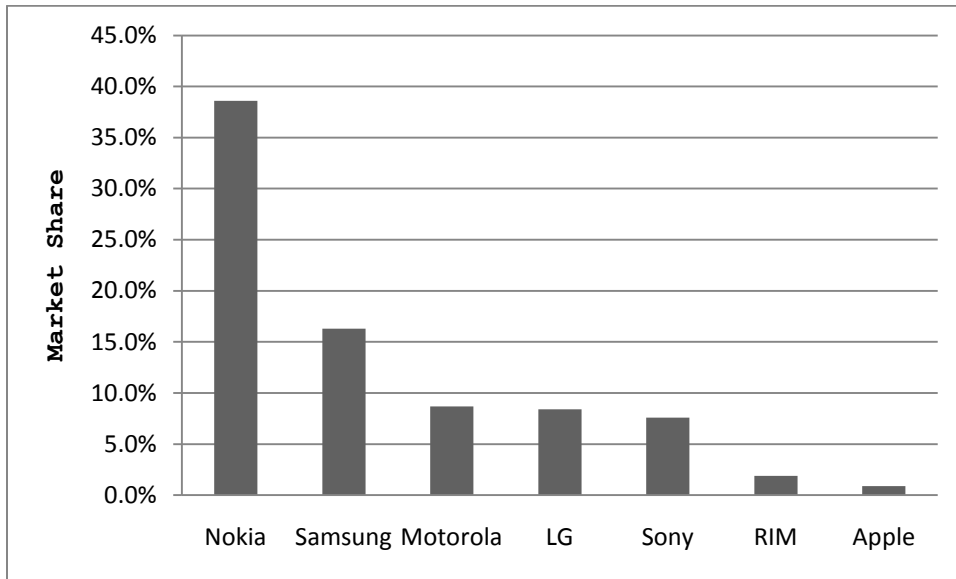


Figure 196 Cell Phone Market (source: Silver, 2010)

And probably the most famous example cited by most experts is the Swiss, who led in the development of precise fine mechanical watches for centuries, and who developed the digital watch and then selling the patent technology to Texas Instruments thinking that no one would want to purchase a digital watch, and that they were also selling style and image; also, Xerox's Parc development of the pre-cursor to the Apple Computers, the mouse, Ethernet, multi-task (multiple windows) type software as well as an oriented graphic personal computer interface is just another example, at one time Xerox had a network of almost 1,000 such system in its user R&D labs.

19.6 Past Industries

This section will briefly reflect on some of the past industries leaders in the United States (or potential leaders/innovators) and how those leaders failed to recognize the importance of these new technologies and or failure to react or lead the innovation. We will first take a brief look at the consumer electronics industry in general terms and then look at past leaders in those among several other industries.

Consumer Electronics

Perhaps the best example of American companies and industries failure to move from old technologies (transition from one S-curve to the next) is the American consumer electronics business, which it pioneered. Like other industries in the United States, global competition was not an issue (due basically from the complete destruction that World War I and II had on Europe and World War II had on Italy and Japan), and post World War II returning GIs creating a long period of economic prosperity. A few industries and companies grew into oligopolies; a big one was the U.S. consumer electronics industry led by RCA, Magnavox, Zenith, GE, Quasar and Sylvania.

Success from the 1940's to late 1960s with the tube-based televisions was great and eventually led these companies to expand their sets into a more all inclusive entertainment type console/cabinet systems. RCA created the system engineering architecture of the tube-based television and then Zenith, Magnavox and others then grew it into this more "furniture based, entertainment console systems", with better sound system, styling, and grand scale cabinet work.

This transition led to an organization expansion as well; the company as a result of its success grew into subsections/elements or silos. Marketing staff grew to market these new entertainment systems; engineering grew in order to design and develop more modules and larger tubes than color; manufacturing increased in size to build these larger number of more complex modules and sets. Each of these silos grew in complexity and independency, making it more difficult to communicate and organize across departments, ultimately leading to increased costs; subsequently passed onto the final customers (the industry being an oligopoly permitted this to take place).

The development of color television expanded this complexity even further. Color also offered new engineering challenges, manufacturing time expansion (long manufacturing times through the process, lower inventory turns and higher prices as a result), and with this extra complexity brought higher warranty/quality issues; so cost to the final user, or the overall life cycle cost is much higher and continuing to increase.

These changes, moving to larger television (CRT) black and white tube sets to the early small color picture television tube sets and then to the larger (25-27") color television tubes and television consuls with improved sound entertainment functions, meant that the vacuum tubes required to support these changes, along with needed better performance requirements; caused the tubes to become much more complex, powerful and consume more energy (requiring bigger different power supplies) resulting in higher initial product costs (and profits) and, generating higher replacement vacuum tube aftermarket service costs business. Vacuum tubes work by conducting electrons across a vacuum, which results in a vacuum tube having a high resistance. Therefore, as these tubes became more complex the resultant was a need for higher power from the higher

(and more filaments) filament resistance, which ultimately led to reliability issues, overheating and in many cases, house fires.

The consumer electronics companies (customer service organizations), distributors and dealers did love the resulting increase revenues and profits from the aftermarket tube business. American consumer electronics was very similar to the American automotive industry; pushing more and more features and larger units, more options, while incrementally having reliability waning; and at the same time, as in the case of dealerships, making maintenance/repair a very lucrative profit business for the company's service center. And also like the American automotive industry, much of the sales were coming from smaller, multiple family owned shops, similar to all of the dealerships for the "Big 3" automotive companies.

It was not the issue that a company like RCA did not have the necessary technologies in house to make a transition from the vacuum tube S-curve to the solid state S-curve; RCA had many labs dedicated to solid state development and had government/military contracts supplying, and developing state-of-the-art CMOS solid state devices. According to Foster (1986) RCA was, by far, the most successful of the leading tube makers in pursuing crossing the discontinuity to solid state, but even RCA was plagued by the difficult choices of which solid state technologies to back. It had to face questions like "why should we cannibalize out profitable tube business for uncertain profits from a rapidly changing solid state business?" These types of questions led to indecisiveness on the part of the leadership of RCA.

RCA had organized a group to develop solid-state devices, primarily for hearing aids, transistor radios and military devices, however, this group's reporting structure had

it answering to the business manager of the vacuum tube division. Of course, to protect cash flow (bonuses, promotions, etc) of the tube business it made no sense to cannibalize a proven source of income. So this new initiative did not get much leadership support to strengthen this business opportunity. Eventually RCA recognized this problem and changed the reporting structure to where this group now answered to a senior executive on the head office staff. However, the negative cash flows, quick pace and wholly strange technical ideas were too much for RCA general executives, so they transferred the solid state group back under the vacuum tube division. All of these changes, resulting from the frustration of trying to defend old technology and the old S-curve that provided the revenue took their tolls; and occurring during the A-B period decision making period (the Paradox decision region).

With each one of these reorganizations the strategic direction of the group changed; engineers were continuously asked to start and stop projects prior to completion driving down morale and esteem. Instead of recognizing the necessity to migrate to the next S-curve (solid state based) that they were developing technology for, RCA decided to diversify to build revenues/profits, more quickly very similar to activities taking place in the automotive industry, see Chapter 17 for Ford's efforts on diversification.

Early in the development stage of single transistors, needed for the possible future generation color televisions, there was a transitional period in which hybrid modules (composed of multiple single solid state devices) that were designed and developed to help bridge this transition.

Several problems got in the way of this "transition phase" thus preventing a smooth transition. One of these problems was that the rate of improvement in creating

the desired increase in performance needed a more complex new system architecture/answer (solid state) for the television; it needed much more complex electronics. These new solid state semiconductor ICS functional requirements outpaced the development rate of getting the transitional hybrid generation of not as economically producible, hybrids into production; and at a lower volume cost; and with better reliability; e.g. solid state device continuing performance improvement moved progressively faster than one could get the first generation of the hybrid into volume production.

The second major problem was that the higher powered higher voltage component analogue tube based television console system had an entirely different and incompatible system architecture than the evolving low voltage and current analogue (active transistor) solid state device based system architecture being required and developed in parallel for the next (and needed) all solid state television. The attempt to blend the two different architecture interfaces into a “hybrid” system ended up being done on a slow, limited module/function by module/function equivalent basis, that ended up being very expensive, time consuming and ultimately not very successful. RCA even spent millions of dollars to construct a volume hybrid circuits manufacturing facility outside of Indianapolis to build its 90% hybrid television that never went into production. Shortly after (months) its opening dedication it was shut down without ever getting more than a modest volume of some limited sets out the door; when a new general manager of the operation appeared.

The Japanese Penetration into Consumer Electronics

The consumer electronics was the first industry the Japanese entered into after World War II. The Japanese were introduced to quality and system thinking from the likes of Deming and Juran (see Chapters 7 and 11) and with this process, they observed all of the consumer complaints from the US companies and built better reliability to circumvent those potential issues. Japanese first enters into the U.S. market with the tube based simple black and white televisions, using this total life cycle cost, total quality system thinking improving reliability and quality. The Japanese started in the solid state business in the early 1950s, and just like the United States, their group of original transistor makers had representatives from both established receiving-tube manufacturers and from new entrants. However, in the early 1950s the Japanese electronics industry was small and lacked an indigenous technical base.

Like Toyota coming to America in the early twentieth century (see Chapter 7), the Japanese electronics companies went looking for technology in the United States. While in the United States the major tube-based companies that also worked with solid state viewed solid state as mixed (could not decide whether to cannibalize their own products) this was not the case in Japan.

The Japanese recognized, as did many in the US, the advantages of solid state began developing items to develop their knowledge base (e.g. walkmans, small radios and black and white televisions). The Japanese used its approach to build value on cost and performance basis to build higher valued consumer products and realized the benefits of:

- Reduction of power requirements of solid state
- Significantly better reliability

- Life cycle total cost
 - And less hassles to the customer (e.g. replacement tubes)
- Importance of volume to drive down overall costs (Henry Ford model) and substantially reduce learning curve (driving costs further down)
- Being able to add new features and functions through integration while driving costs down

However, attacking the color television required a major longer (investment of time) complete redesign and system engineering redevelopment.

It took the Japanese competitor companies continuous research and development investment over some ten-years to finally design, develop and produce the first generation solid state consumer electronics television. The Japanese also developed in parallel the highly automated (for that time period) manufacturing process to economically produce these solid state television sets in volume.

This eventually created the opportunity, i.e., opened the door, for the Japanese companies to bring a new generation of more reliable solid state (purchased from AT&T) based television and other consumer electronics products to market in the 1970s.

The Japanese, in order to penetrate the American Market, began supplying the large box stores (Sears, Montgomery Ward's) with their own individual name brands. This was never permitted by the US companies; they believed that their own name commanded a higher premium, thus more profits. The Japanese also discounted for large volume purchases and also provided assurance by initially offering 90 day warranties.

With the solid state technology and the newer complex high efficient and repeatable manufacturing systems, the Japanese realized that they could supply large

quantities of consumer products at a lower price because of their higher level of reliability/dependability. The soon began extending their warranties from 90 days to a year, and when the US companies followed suit, the Japanese extended to two years; with the product life cycle model, dedication to refinement and repeatability, their televisions had no issues performing without reliability problem over this period of time and in most cases for a much longer period of time (10 years plus). The US companies, being organized in functional silos, could not understand the disastrous consequences of extending these warranties; within a few years the profitable aftermarket vacuum tube business became a very large liability.

This once profitable but now large liability began eating at the market share and revenues. At the pearl of its success, the finance MBA driven American consumer electronics business, not respecting the budding S-curve, did not see the importance of aggressive research and development investment into solid state but seen more importance in growing revenues/profits. While Japanese electronics companies were producing more reliable, better picture quality and cheaper solid state equipment, RCA was caught in the profit center in tube replacement sales, and also had short term quick revenue creating diversification plane purchasing frozen foods, rental cars, real estate, carpet manufacturers, etc. (Keys, 1997). RCA was then purchased by General Electric (GE) co.; the RCA and GE consumer electronics merged and then was resold to the French consumer electronics company, Thompson CSF, ultimately ending in selling off in pieces all of the RCA stakes and even their name.

Consumer electronics companies were not the only ones caught in the above described issues, the next few companies stand as examples of other industry leaders who fell into the same trap:

Ampex Corporation

Ampex Corporation was formed in 1944 by Alexander M. Poniatoff (Ampex History, 2008). Ampex is known for magnetic tape drives used for tape delay radio broadcasts back shortly after World War II. In 1956, Ampex releases the Ampex VRX-1000 video tape recorder and introduces it at the National Association of Radio and Television Broadcasters in Chicago in March of that year. This is the world's first practical videotape recorder and is hailed as a major technological breakthrough.

Even though Ampex created the first working video cassette recorder in 1956, it was their lack of follow, it has become common knowledge that the Japanese have become very good at taking innovation and turning it into a marketable product; after which improving the product both in reliability and cost of manufacture. Twenty years following the invention of the video recorder, the Japanese have become so superior, due to the U.S. electronics manufacturers (Ampex, RCA, General Electric) lack of innovative leadership, that none of the U.S. companies manufacturer video cassette recorders, that they just purchase off of the Japanese and slap their name on the machines for resale.

Xerox

Chester Carlson, a patent attorney and part-time inventor, made the first xerographic image in his makeshift laboratory in Astoria, Queens, in New York City, on

Oct. 22, 1938. He spent years trying to sell his invention without success. Business executives and entrepreneurs did not believe there was a market for a copier when carbon paper worked just fine. And the prototype for the copier was unwieldy and messy. Some 20 companies, IBM and General Electric among them, met his invention with what Carlson called an enthusiastic lack of interest.

Finally in 1944, the Battelle Memorial Institute in Columbus, Ohio, contracted with Carlson to refine his new process, which Carlson called electro photography. Three years later, the Haloid Company, a maker of photographic paper in Rochester, N.Y., approached Battelle and obtained a license to develop and market a copying machine based on Carlson's technology; Haloid later obtained all rights to Carlson's invention. Carlson and Haloid agreed the word "electro photography" was too cumbersome; a professor of classical languages at Ohio State University suggested "xerography," derived from the Greek words for "dry" and "writing."

Haloid coined the word "Xerox" for the new copiers, and in 1948, the word Xerox was trademarked. Inspired by the early, modest success of its Xerox copiers, Haloid changed its name in 1958 to Haloid Xerox Inc. The company became Xerox Corporation in 1961 after wide acceptance of the Xerox 914, the first automatic office copier to use ordinary paper, (Xerox history, 2008).

Xerox created Palo Alto Research Center (PARC) in 1970 as part of Xerox research and development process. PARC engineers and scientists created technologies such as laser printing, Ethernet, the graphical user interface, and ubiquitous computing. The path of the personal computer was created there (Smith and Alexander, 1988). However, Keys (1997) has documented that Xerox failed to capitalize on this invention

because of the increasingly finance management (MBAs) dominated business organization which believed that it can manage the old technology by the numbers and forecast the future. They never saw the potential of this new technology; not only that but Xerox did not see the blending/merging of the copier and printer products.

The copier business has seen several entrants entering into the market capitalizing on this new technology, to the point that, even though coping is synonymous with the Xerox name, Xerox by now only maintains roughly 10-percent of the market share. Figure 197 represents what the market looked like in the early 1990s showing where Xerox placed within the market: The copier/printer market is not significantly different in members except HP has now become a major new player in the past ten years.

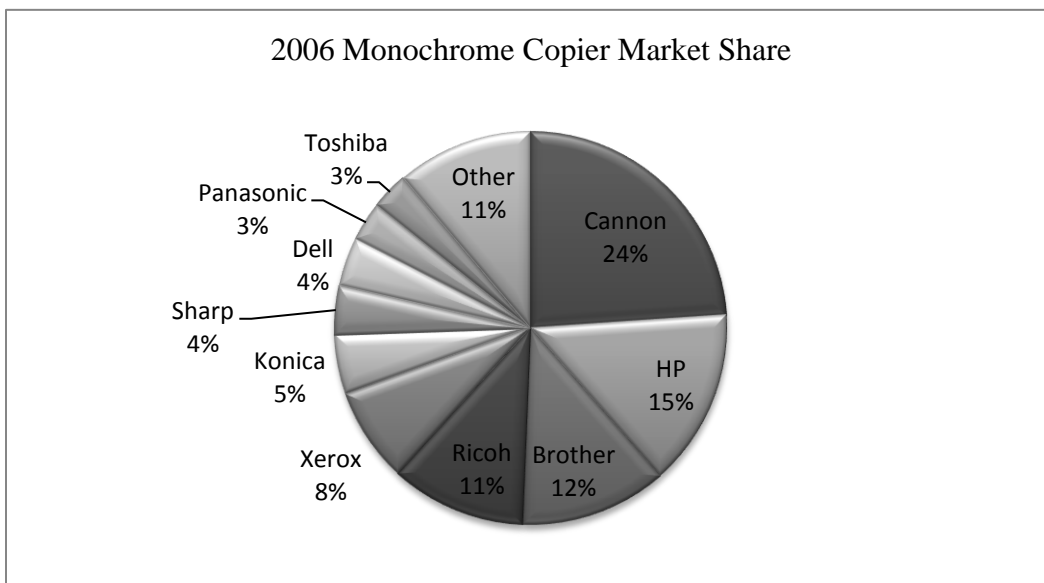


Figure 197 Copier Industry Market Share (source: Gartner Data, 2007)

Intel has driven Motorola out of the semi-conductor (microprocessor) business and kept AMD a minor player in the business by pursuing an aggressive expansion growth sequence of new devices or the S-curve Pentium family evolution.

Three local examples of this discontinuity effects are; (1) the demise of the Akron based Hoover Company. Primarily driven (out of nowhere similar to Michelin and the time example) by the revolutionary “Cyclone” (bag less) unique new product, technology system design by an English entrepreneurial electrical creative designer, James Dyson, who now leads the U.S. market and market share; (2) the Strongsville company Van Dorn Company, a leader in pneumatic, hydraulic injection molding machines. They were overtaken and purchased in 1993 by the German company, Demag, who were among the leader introducing the game changing, discontinuity, new electronic, mechatronics screw injection molding machine. Subsequently VanDorn/Demag was then purchased in 2003 in such mechatronic screw-machine drives injection molding company, Sumitomo who has only sales/service support center in Strongsville,; (3) the Firestone Company was absorbed by Bridgestone, who subsequently, based on a number of process/product issues, removed the name all together.

19.7 Current Innovation Leaders

Boeing Example

Boeing presents an example of complex systems multiple technologies system products that have gone through several major S-curve transitions successfully; transitioning from the piston engine to the jet engine and understanding the interactions between the engine and the rest of the plane led to Boeing’s dominations of commercial

aircraft production (Baseden, 2004). Boeing incorporated several major technology changes in order to develop their new, 300-400 passenger, wide 777 twin jet fuselage aircraft: (1) management style changes, (2) development involvement changes (reducing normal/historical development time from ten years to less than five), (3) development technologies and (4) technologies.

Phil Condit, then the Executive Vice President and General Manager of the new Boeing 777, and V.P. and Chief Engineer, Alan Mulally (eventually promoted to General Manager of 777 program), realized how Boeing had grown into the Silo type organization as discussed earlier and decided change was necessary (Snyder and Sanker, 1998). The 777 project shifted from this Silo type organization to a strong team orientation (concurrent, collaborative engineering) with the use of cross functional teams; this led to cost based design at the outset rather than those things being imposed on the design in the classic linear fashion. The organization also shifted from strong orientation to the individual to knowledge-sharing; thus, eliminating the “knowledge is power” mentality. This meant that each of the 238 design-build teams responsible for designing all aspects of the aircraft (parts, components, and subsystems) included at least one person from the information systems department to provide the computing tools so that the team of technical people can solve complex problems.

Along with the management organization changes, outside influences were also sought after to change the development involvement structure. In January 1990, Boeing asked eight world-class airlines to help define the 777's configuration and mission (Norris, 1995). These airline representatives contributed more than 1,000 design changes (Cook, 1994). These revisions made the 777 cheaper to build and operate, more

appealing to passengers and easier and faster to service; thus reducing overall life-cycle costs. Along with the potential customers of the 777, Boeing also requested that their global suppliers responsible for different parts/components be part of the design team as well from start to finish.

From a development technology standpoint, the 777 was the first product design completely paperless; Boeing used a 3D design software package, Catia. Catia was credited with eliminating 65 percent of the errors and reworks, and savings from not having to build expensive mock ups of the aircraft to make sure that all components fit and work together; through Catia's 3D modeling, parts can be tested on the computer to make sure that there are no interferences between parts. Boeing's design engineers also went through every previous product developments to categorize every issue that occurred in order to prevent reoccurrences on the 777 project. Automating the design process by using Catia reduced development time by 91 percent and labor costs by 71 percents when comparing the design process of earlier aircraft including the 757 and 767 (Norris, 2005). This process also eliminated over 3,000 assembly interfaces without prototyping, and gave designer more ability to standardize parts among similar components (Boeing estimated over one million in savings by standardizing their doors).

The new technologies utilized on the 777 (transitioning from one S-curve to the next) included a unique fuselage cross sections; first commercial use of fly-by-wire application; advanced technology glass deck with five liquid crystal displays; a large scale use of composites, ten-percent by weight; and extremely powerful and efficient new engines, at the time being the only twin engine aircraft permitted for transatlantic flights. The 777 program General Manager, Alan Mulally, who successfully led the 777 airplane

into production is the same person who was named Ford's President and CEO on September 5, 2006.

New product design and development is more often than not a crucial factor in the survival of a company. Innovative companies will typically be working on new innovations (products) that will eventually replace the old ones (shortening the discontinuity), and even a generation past the next. In an industry that is fast changing, firms must continually revise their design and range of products. This is necessary due to continuous technology change and development as well as other competitors and the changing preference of customers.

A system driven by marketing is one that puts the customer needs first, and only produces goods that are known to sell. Market research is carried out, which establishes what is needed. If the development is technology driven then it is a matter of selling what it is possible to make. The product range is developed so that production processes are as efficient as possible and the products are technically superior, hence possessing a natural advantage in the market place.

Some of the more innovative and heavier research & development investors (as a percentage against revenue) include Apple, Intel, Microsoft, Google, Cisco, Nokia, and Oracle. These companies have outperformed the S&P 500 by over 10 times over the last 5 years. Figure 198 depicts the investment of these companies as a percentage of revenues while Figure 199 depicts the dollar value of the R&D investments and finally Figure 200 depicts total revenue:

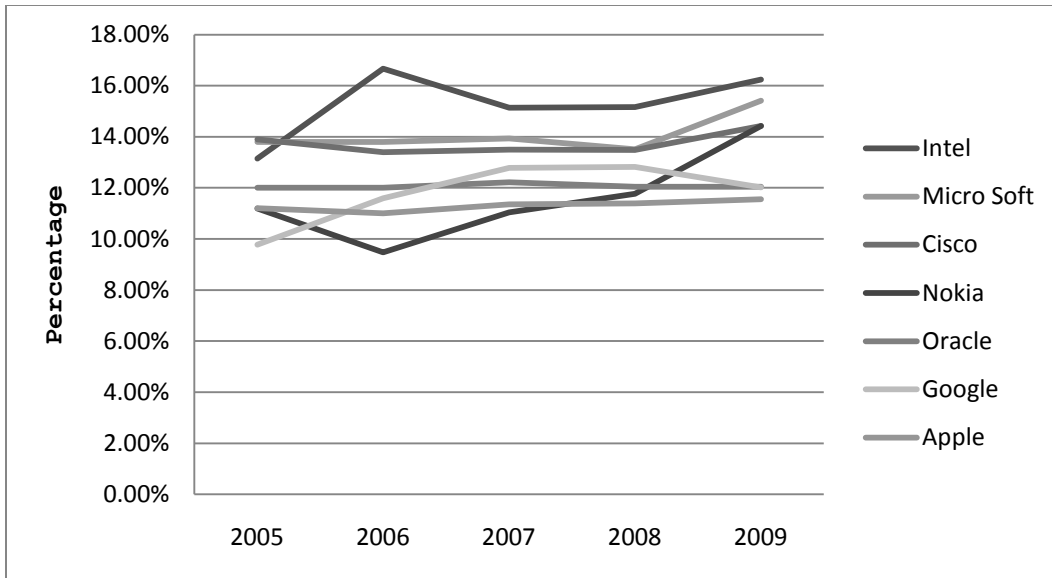


Figure 198 R&D as a percentage of Revenue (source: created with data from the individuals company's annual report, 2005-2009)

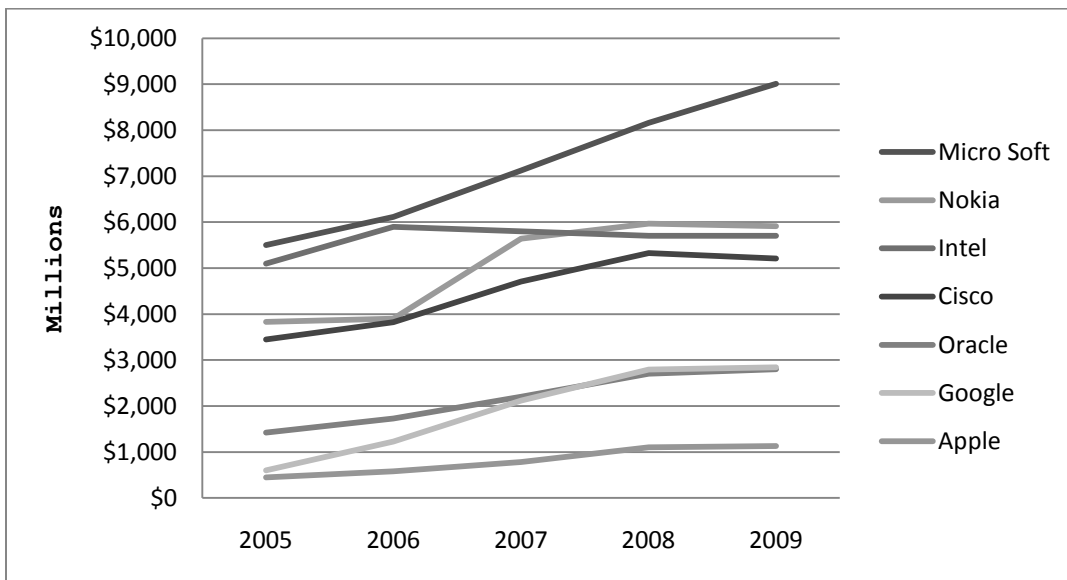


Figure 199 R&D Expenditures (source: created with data from the individuals company's annual report, 2005-2009)

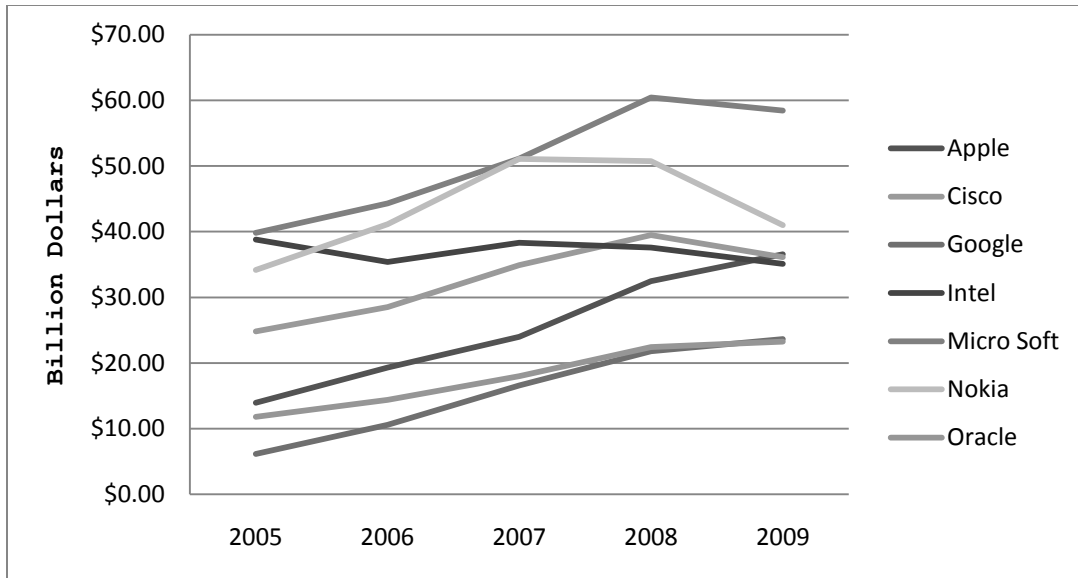


Figure 200 Total Revenue (source: created with data from the individuals company's annual report, 2005-2009)

These companies are continuing to be very successful through the practice of “living in the paradox of change. Living the paradox requires the foresight to have major investment in research and design to build the future while at the same time maintaining and extending the present. Intel for example continually has three generations of past present and future technologies based products/processes in its business pipeline at any point in time. It is continually improving its process technologies by introducing more improved generations. The pathway through paradox is managing simultaneous opposites, confusing and chaos – the conflict of the visible success of the old (or current) and the unfelt immediacy of the new and different. The above company's leaders are living beyond the curve, and are gaining a shared understanding of the paradox very early in the life cycle and actively create the next wave with a clear vision and sense of purpose.

The following depictions are from various companies that at one time possessed leadership in their given industry lost it but managed to stay in business and become successful once again. Figures 201, 202, 203 and 204 depict Net Sales, Net Profit, investment in research and development and investment in research and development as ratio again net sales:

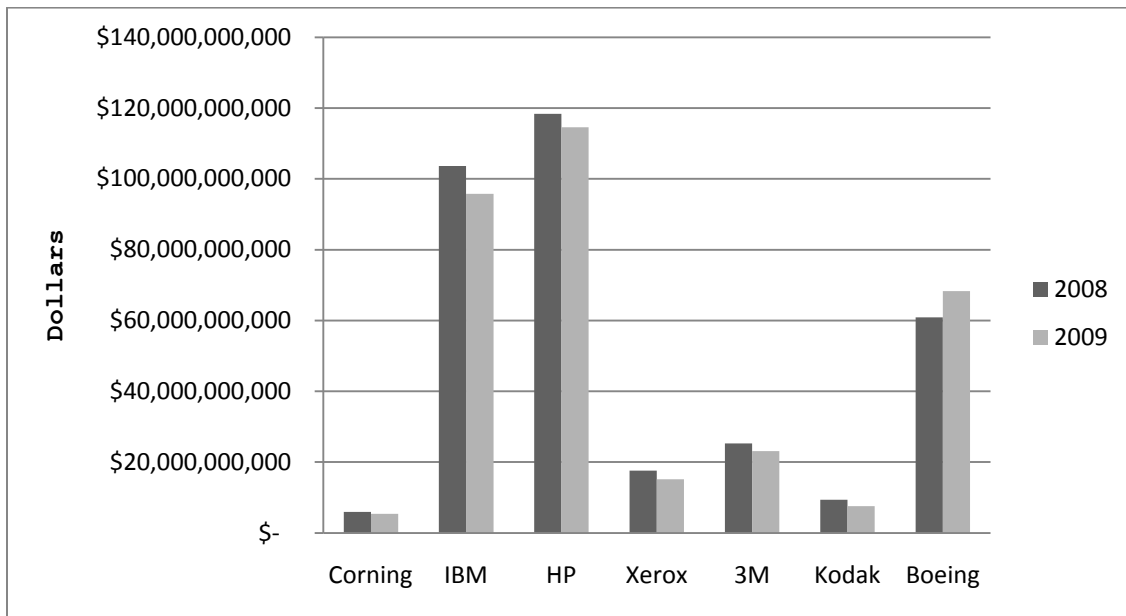


Figure 201 Net Sales (source: created with data from individual companies' annual report, 2009)

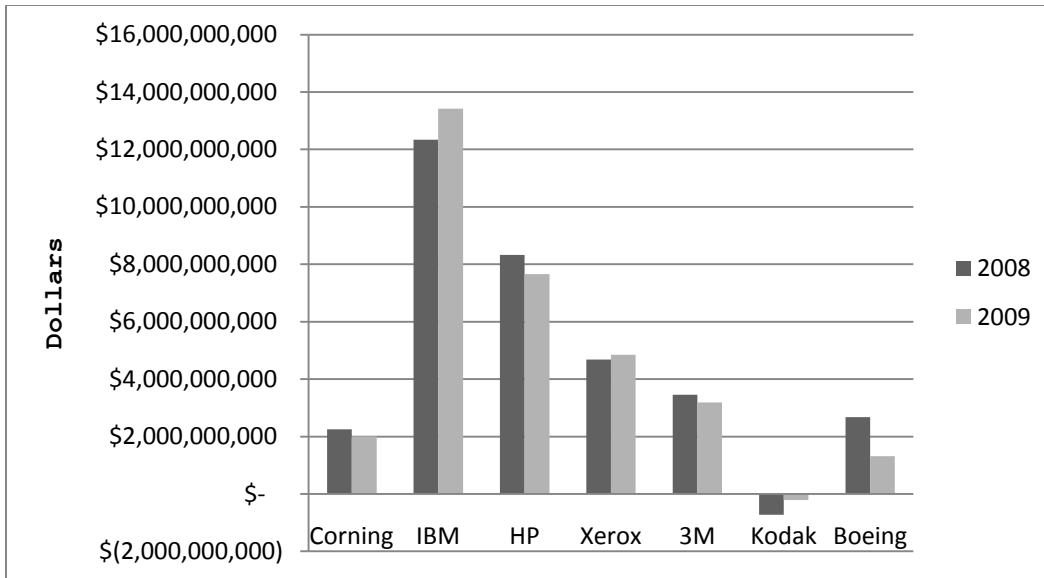


Figure 202 Net Profit (source: created with data from individual companies' annual report, 2009)

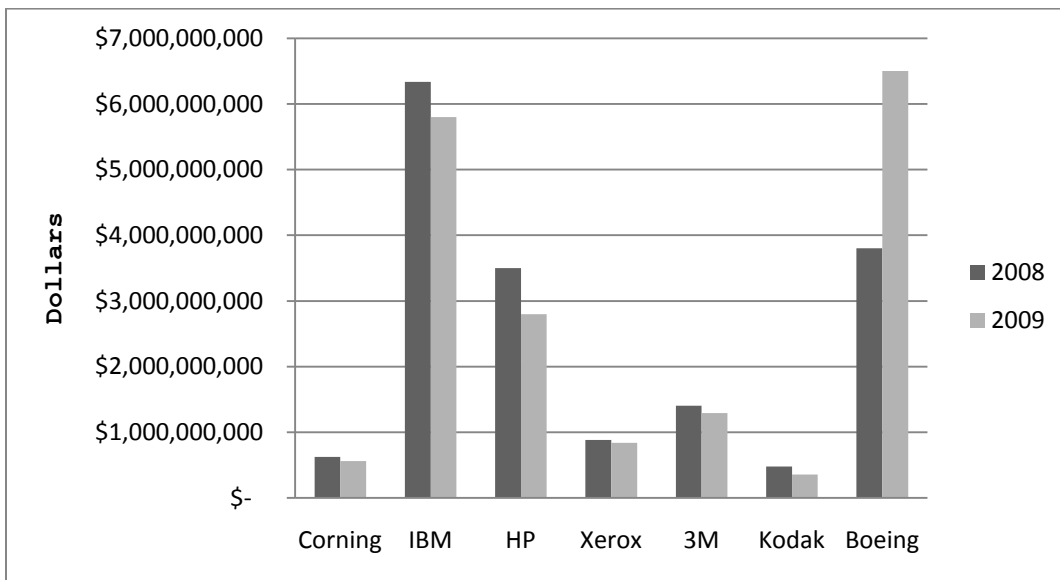


Figure 203 R&D Expenditures (source: created with data from individual companies' annual report, 2009)

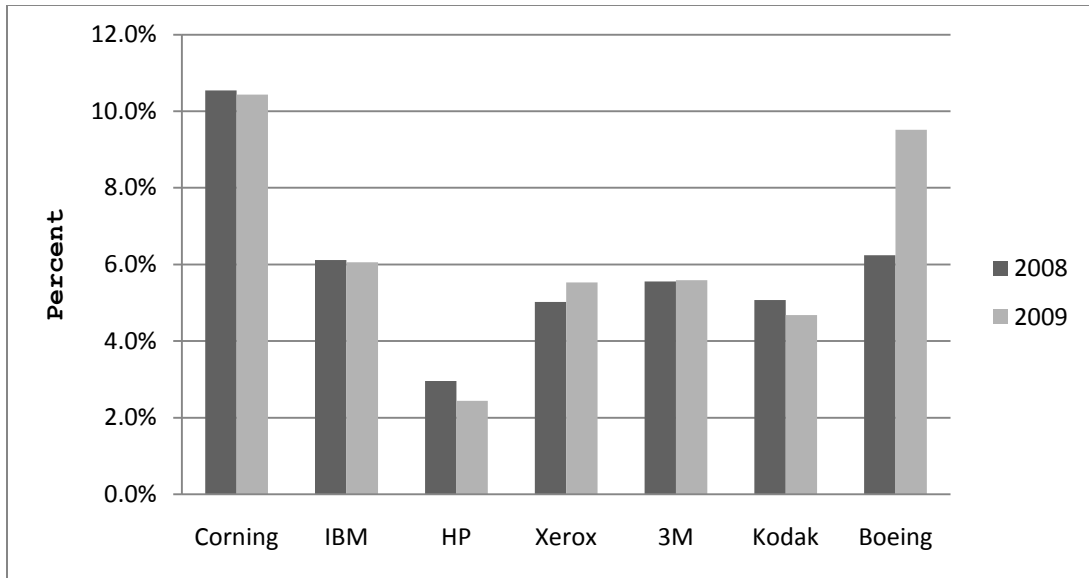


Figure 204 R&D vs Revenues (source: created with data from individual companies' annual report, 2009)

It is unfortunate, or perhaps a forecast of future revenues/earning problems to come, that some of these now invest less than five-percent into R&D as a percentage of revenues.

CHAPTER 20

FORD AND HONDA A SUMMARY COMPARISONS

20.1 Introduction

This chapter examines several characteristics as presented in earlier chapters of how Ford and Honda perform or align themselves, strategically. This chapter begins with research and design dollars and how these investments relate to quality and reliability. Then examines management practices/changes, compensation and diversification followed by labor comparisons. Finally, we look at different financial aspects; credit worthiness and yearend financial results, market share (plant openings/closings), stock price, and dealerships.

20.2 R&D, Quality and Reliability

When examining research and design investment as a percentage of gross sales, Ford and Honda seem to be very similar, roughly five to five-and-half percent of gross sales, see Figure 205. However, when examining the actual dollars spent, Ford out spent Honda by roughly 3.75 billion dollars in 1994, that eventually diminished to just 1.7 billion dollars in 2008 and Honda actually over took Ford (most likely because of Ford's

large financial losses accumulating and later reduction in R&D percentage), in 2009, see Figure 206.



Figure 205 Ford and Honda R&D vs Gross Sales (source: Honda annual reports, 1994-2009; Ford annual reports, 1994-2009)

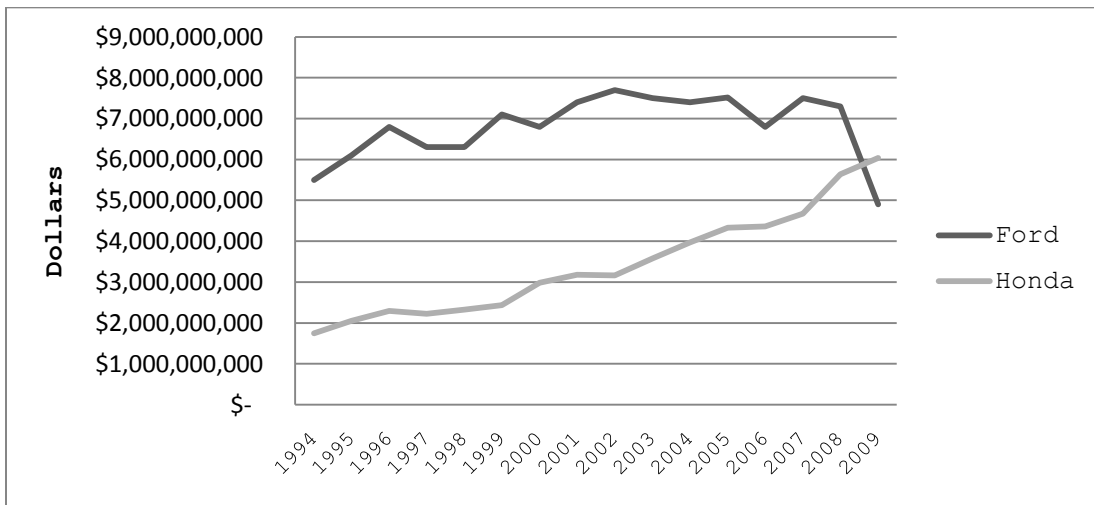


Figure 206 Ford and Honda, R&D Expenditures (source: Honda annual reports, 1994-2009; Ford annual reports, 1994-2009)

When examining the effectiveness of R&D dollars, perhaps, given the expectations from today's consumers for reliability and quality is to look at this performance as a percentage of R&D dollars spent. Figure 207 represents this comparison:

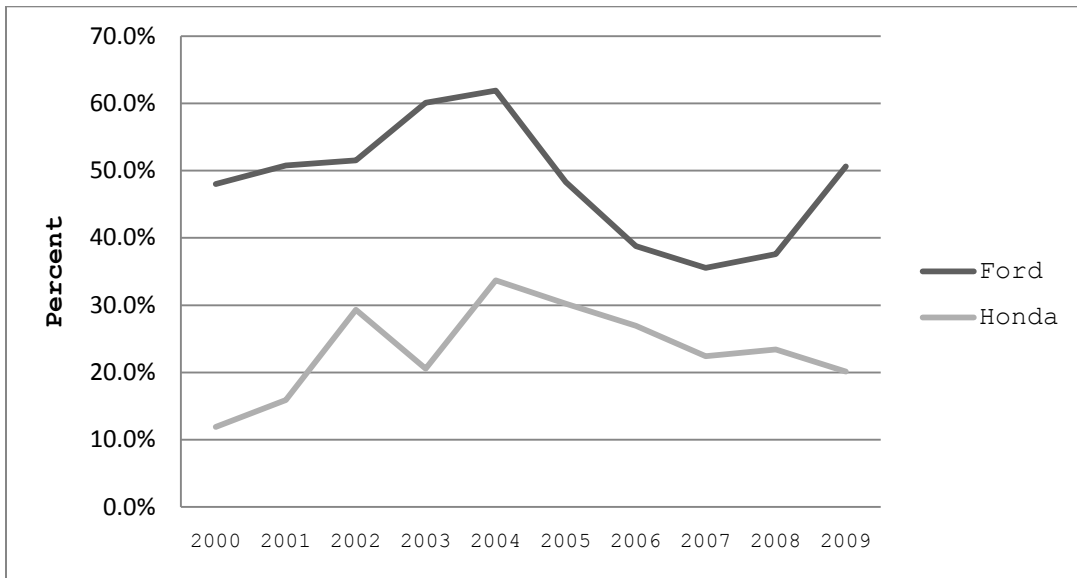


Figure 207 Ford and Honda Warranty Costs vs R&D Dollars (source: Honda annual reports, 1994-2009; Ford annual reports, 1994-2009)

Figure 207 represents the warranty costs from 2000 to 2009 as recorded in each of the companies' annual reports. As can be seen, Ford has been trending much higher than Honda, although, when looking at the latest JP Powers and Associates initial quality (previously presented), Ford has improved considerably and has recently one Motor Trend's car of the year award as well (also previously presented). Warranties are very similar to legacy costs though, past models can keep presenting themselves until all warranties have expired, so it may take several more years, for new vehicles' reliability

development discipline/experience results for/on new vehicles to catch up, given that Ford can actually develop a long-term improvement development plan that can eliminate on-going reliability issues and change consumer perception. What is not addressed in Figure 207 is the “other” quality and reliability issues related to recalls with attached suites; as presented earlier in Tables XVII and XVIII in Chapter 17, Ford has had a history of these large type recalls with severe financial consequences. Figure 208 now captures some of the basic recalls (claims and warranty cost) as well as the allowances for rebates to sell vehicles that are not moving.

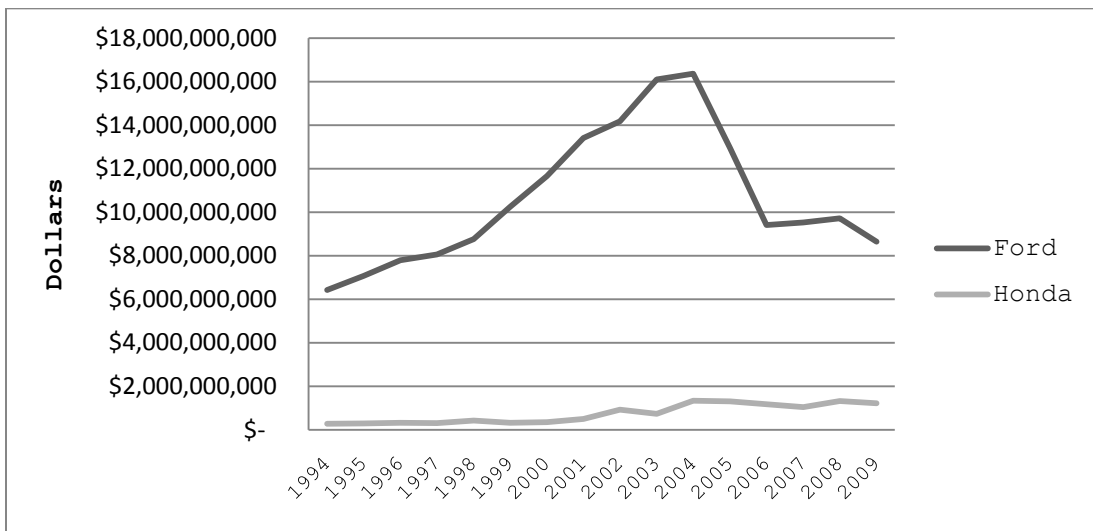


Figure 208 Ford and Honda Dealer Claims and Allowances (source: Honda annual reports, 1994-2009; Ford annual reports, 1994-2009)

Resale of Honda’s vehicles have been historically higher than Ford’s as well; while Honda has been maintaining 75 percent of its value after 3 years, Ford’s only been maintaining half. However, according to the research firm Automotive Lease Guide, Ford in making strides in this category (Naughton, 2010). Ford’s vehicles are

maintaining an additional \$2,420 more per vehicle after three years than in previous years. Again Ford has struggled with maintaining higher levels of quality consistently, and we know it takes many years of engineering and product development and field testing to overcome existing legacy costs and to actually change consumers' perception. Even a new Vice President of Global Marketing for Ford, Jim Farley (recruited from Toyota), stated that in his experience it takes reviving their entire product line up and do it consistently over five-years-plus to truly change perception; to actually really increase Ford's overall reliability resulting in changing customers perception of Ford (Naughton, 2010).

Also, Honda has spent monies on small engine refinement and electronically managed engine performance (mechatronics) to enhance their performances (power and fuel efficiency) going back forty years. Honda's strategy has remained constant (actually part of their culture) since they introduce their first Honda civic Engine (CVCC) back in the 1970s which was the only engine that could then meet the environmental emission standards of that time without the use of the expensive, performance inhibiting catalytic convertor. Figure 209 compares Honda's mileage performance against Fords mileage performance.

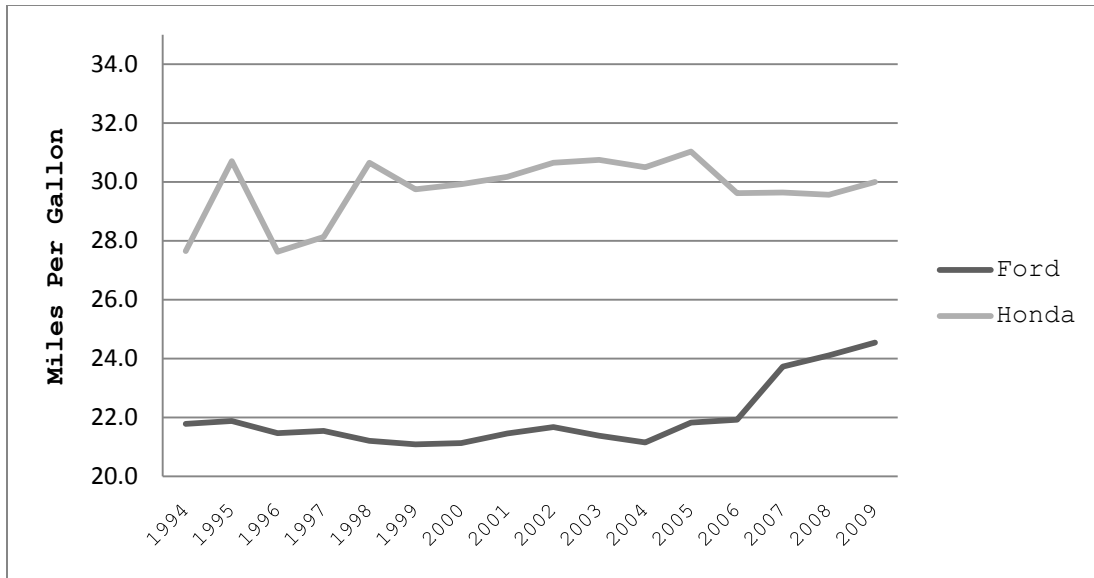


Figure 209 Ford and Honda Fleet Mileage Performance (source: Environmental Protection Agency, 2010)

While Ford was busy building SUVs on the body over frame design that had a lower CAFÉ requirement, Honda entered into the SUV market building their SUVs on their current car platform, which not only required their fuel efficiency meet car CAFÉ standards but it also help reduce the learning curve on reliability and quality for these SUVs/crossovers and still permitted plant flexibility. Following Honda’s lead, Ford has announced that its next generation Explorer SUV will be built on an automobile platform.

20.3 Management

Diversification and Direction

Over the past several decades, Ford’s managerial direction has been guided by the business MBA cost structure thinking; dealing with legacy costs and union threats of strikes that would disrupt cash flows. Ford’s direction has changed based on current

leadership's goals and objectives as previously discussed; diversification into credit business, consumer electronics and refrigeration; parts suppliers, car rental, aftermarket parts, and global purchases of less than stellar performers with no structured plan to improve and turn around. Ford has counted on larger vehicles (more expensive higher profit) or by again beefing up the options on their midsize and large cars to obtain higher prices (Ford Taurus is a good example: based at \$25,000 and tops out on the SHO for at approximately \$43,500).

In order to quickly increase financial reports, Ford has in the past aggressively sought out companies to expand their portfolio, while core automotive business strategic performance has faltered: product development over budget, late and hampered by quality and reliability issues (see examples in Chapter 17 of Explorer, Taurus, and Thunderbird), globalization poorly executed (global car designs must have several designs to satisfy several markets, basically different models with large number of parts that are not shared), plant flexibility (ability to produce several vehicles from same assembly line), and ability to focus on more fuel efficient, higher quality and reliable vehicles (a lesson that should have been learned in the 1970s).

Honda on the other hand, has remained focused since the 1970s on engine technology with electronic integration and control, global car production, high quality and reliability, flexible plants; core automotive business strategies. Their past and current leadership has all come from the research and design area, focusing on future long-term technologies, applying electronics to the car and understanding all aspects of mobility; and sticking to the knitting.

Just in the last decade, Ford has squandered roughly 22 billion dollars in regards to purchase of and investing in Jaguar, Land Rover, Volvo and Kwik-Fit; roughly equivalent to what they spend on three years of R&D; and even with these poor decisions and direction, poor financial performance, problematic quality/reliability/product development performance, their executives are rewarded quite generously versus what Honda awards their executives for solid performance.

In 2007 Ford's new CEO Alan Mulally was compensated 21.6 million dollars in total compensation and the total top five executives for Ford had a combined total compensation of 60.7 million dollars, while Honda's top 21 executives had a combined total compensation of 11.1 million dollars, but with similar perks that are received by their American counterparts. Ford has also been involved with large payouts as severances (retirements?) as an example, Nasser's \$23 million package after Ford had just lost \$5.5 billion or even Mulally's 2009 Proxy documented potential involuntary termination of roughly \$17.5 million.

Labor Work Force

One of the greatest challenges facing Ford (and GM/Chrysler) is the 60 plus years of union negotiations leading to higher pay, higher retirement benefits, premium high cost health care insurance, guarantee employment and less flexible workforce. Prior to the bailout of GM and Chrysler, which resulted in concessions on part of the UAW workers, Ford was averaging close to \$15,000 per every employee (active, retiree or retiree beneficiary) in health care and retirement benefits. On top of this, Ford's average salary (without benefits) for active workers stands at roughly \$28 per hour, plus,

maintaining unemployed workers for 1 year, and still guaranteeing employment at other locations.

With the renegotiations, these costs are expected to be reduced through the UAW managed pension plan, which Ford has to disperse an additional 13.2 billion dollars, and new employee's wages (if they do any hiring in the foreseeable future) set at \$14 per hour without entrance into the pension plan. The total cost per vehicle (assuming normal volumes of 12-14 million cars sold and current market share of 16% for Ford), Ford's health care cost and retirement obligation is estimated to be roughly \$1,200 per vehicle while Honda's estimated to be at approximately \$1,000 per vehicle. Ultimately though, Ford still has to deal with UAW while Honda strives to remain union free and aggressively locates away from union supported areas; Ford still needs to negotiate, and further reductions seem to be unexpected if not reversed if Ford begins to show sustainable progress.

20.4 Financial Aspects

Figures 210, 211 and 212 compare Ford's gross revenues, net income and operating income from automotive with Honda's gross revenues, net income and automotive operating income.

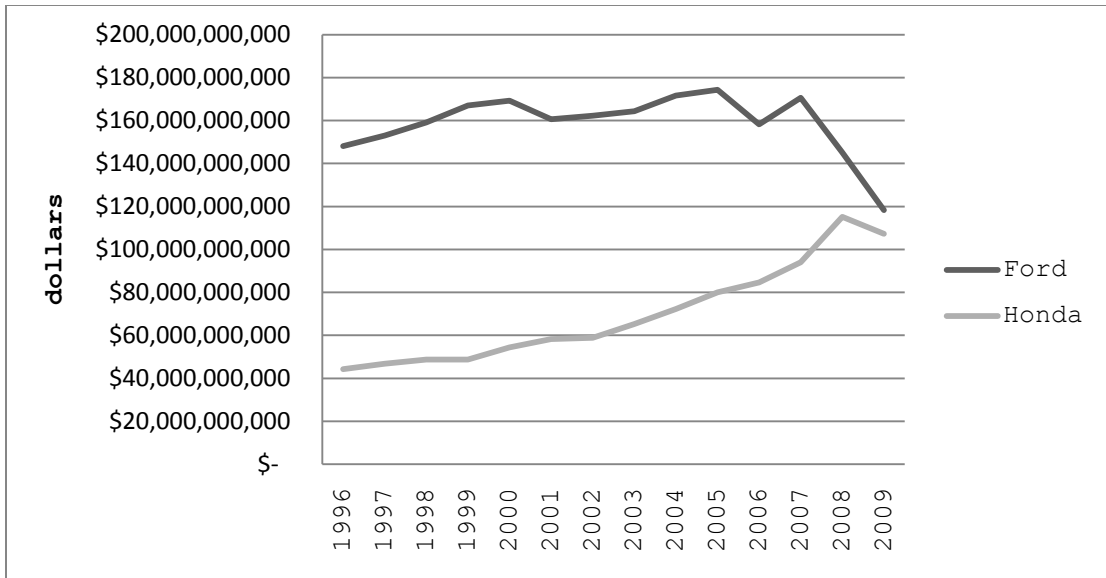


Figure 210 Ford and Honda Gross Revenue (source: Honda annual reports, 1994-2009; Ford annual reports, 1994-2009)

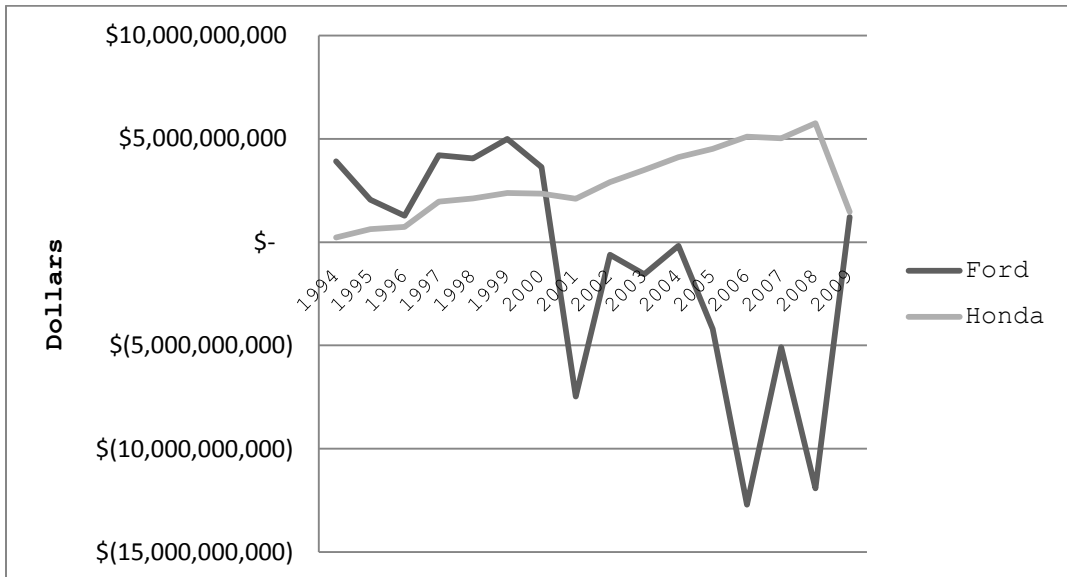


Figure 211 Ford and Honda Net Income (source: Honda annual reports, 1994-2009; Ford annual reports, 1994-2009)

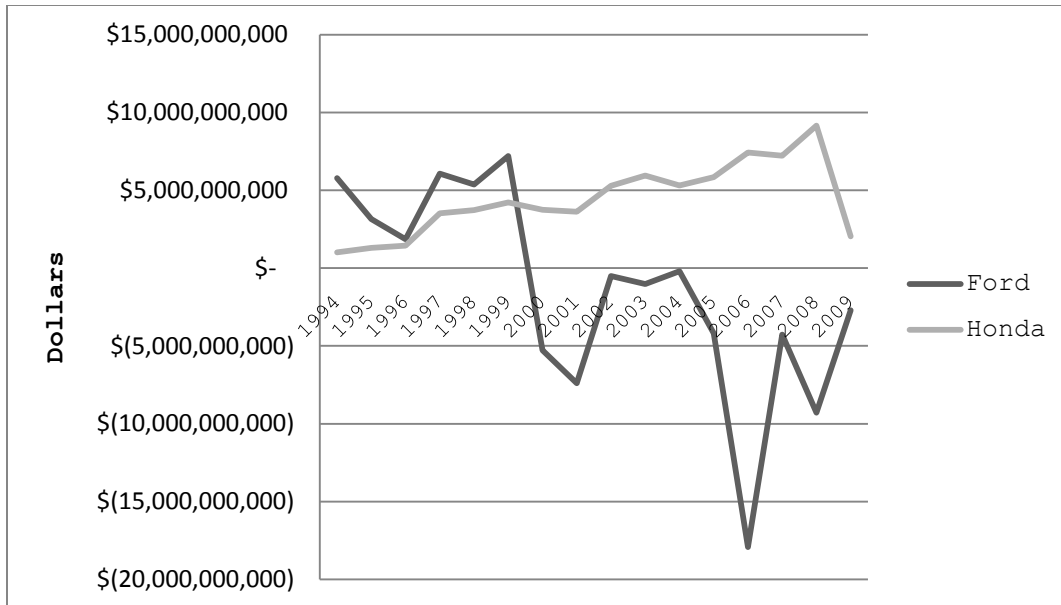


Figure 212 Ford and Honda Automotive Operating Income (source: Honda annual reports, 1994-2009; Ford annual reports, 1994-2009)

With all of the factors previously discussed, the outcome between Honda's approach and Ford's approach show that Honda has been much stronger in returns than Ford; and Honda, out of the larger North America suppliers, remained profitable in 2009 (though weaker) vs even Toyota losing money from an automotive operating income standpoint.

The performance from all the above characteristics also shows in the stock price on the New York Stock Exchange (Figure 213) and since earlier in the decade, Ford's credit rating has been very poor; Moody's Investor Group has had Ford's rating at the B level for the past 8 years, although recently, March 2010, Ford's rating was bumped up due to higher market shares, volume and profit to a level of B2 from B3 (still the fifth level below investment grade). Prior to this raise, Ford's \$1.8 billion of 7.45 percent notes due on 2031 were traded at 15.4 cents on the dollar in 2008. Mulally needs to retire \$10.5 billion in revolving debt out of profits that comes due in December 2011, so the

future credit rating and stock price is imperative for Ford's ability to raise less expensive cash for investment in future model releases, advertisement and R&D. Ford's secured credit is currently rated at Ba3 while its unsecured debt rating is at B3. While Honda credit rating has been very good, the only issue occurred from the down turn (car demand falling), not from Honda's performance, is the latest downgrade of Honda credit rating in 2009 from Aa3 to A1 by Moody's Investor Service. A1 rating is the fifth-highest rating, and had little effect on cost of borrowing for Honda. So Ford has an additional hurdle to overcome against Honda, price of money.

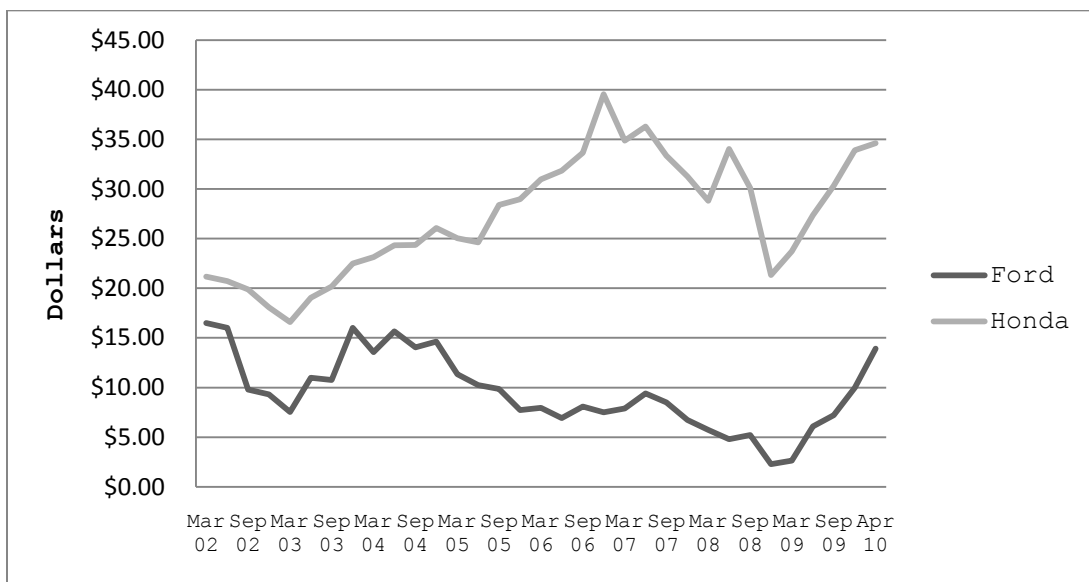


Figure 213 Ford and Honda Stock Price (source: Y-charts, 2010)

Given the cost of employees perhaps an important comparison is the automotive operating income per employee as Figure 214 depicts.

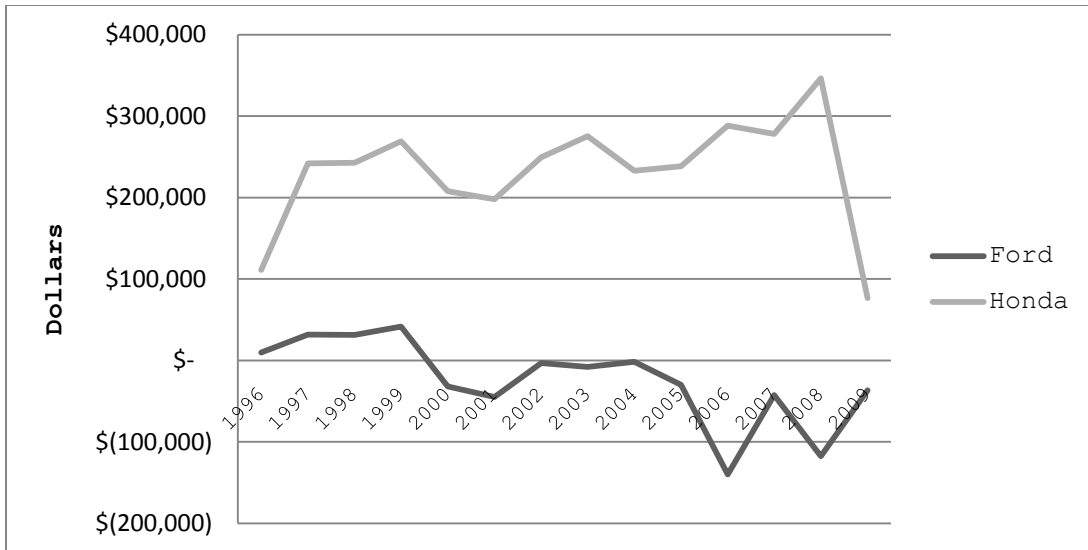


Figure 214 Ford and Honda Operating Income/Employee (source: Honda annual reports, 1994-2009; Ford annual reports, 1994-2009)

Figure 215 depicts Ford and Honda's market share performance over the past several years:

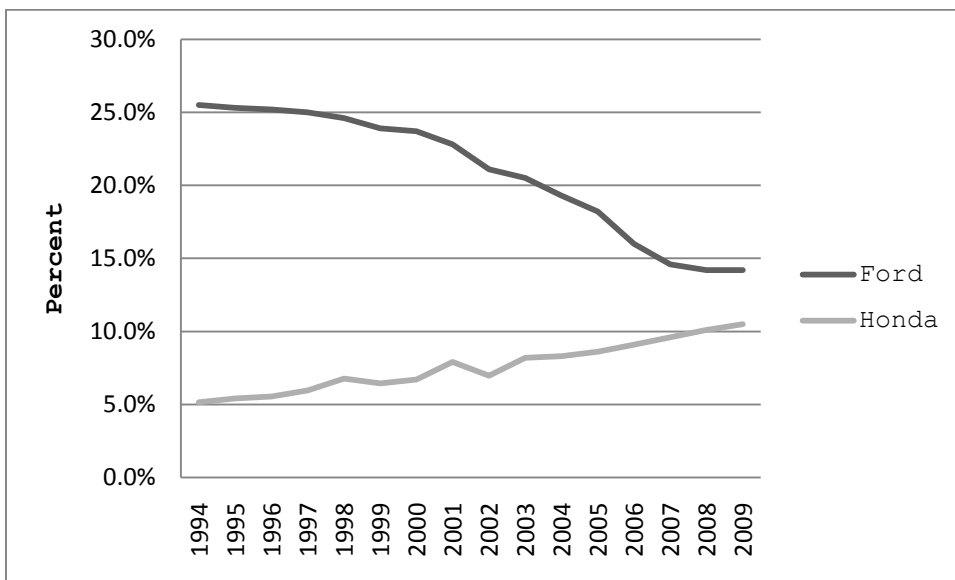


Figure 215 Ford and Honda NA Market Share (source: Honda annual reports, 1994-2009; Ford annual reports, 1994-2009)

As can be seen from the graph, Ford's market share has dropped fairly significantly over the past several years while Honda has been able to capture additional market share.

It even gets worse for Ford (as well as GM and Chrysler), for the market they dominated for years (light trucks and SUVs) have been aggressively pursued by the foreign companies. And they are locating these plants in North America to build these vehicles as well as luxury and small cars; most notably in the South (see chapter 16) where the population growth and infrastructure investment (and intellectual growth/investment) has been the greatest. So where these foreign transplants have spent approximately \$43 billion, with local governments spending an addition \$4 billion on tax breaks, training programs and land to attract these implants, Ford has spent roughly a billion per year over the last six years to close plants (planned 17 closures), reduce capacities and buyout workers (planned 30,000 job cuts) and it is only going to become more competitive when all of these plants come on line, come up to full production and expand. Figure 216 depicts the market share of the larger suppliers in 2009 and 2010 through April:

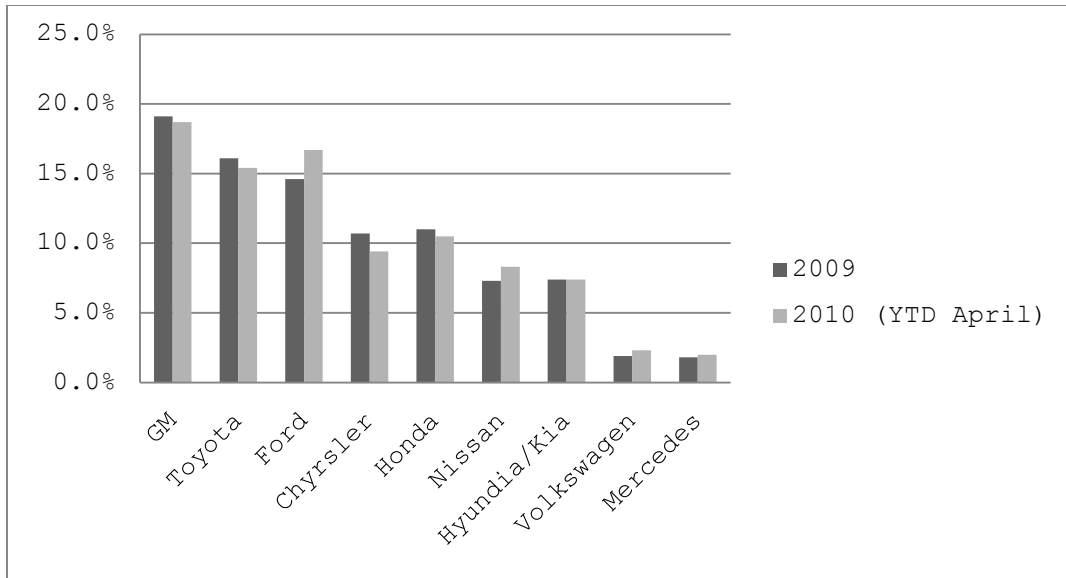


Figure 216 US Market Share, 2009 and 2010 YTD April (source: Ward's auto data, 2010)

Volkswagen is capturing close to two percent of the market through imports alone and now with its new \$1 billion plus Chattanooga, TN, plant coming on-line it opens up much more opportunity and better cost structure to acquire more North America market share. Other aggressive growth includes Hyundai's \$1.5 billion plus investment in 2005 in its Montgomery, Alabama plant followed by an additional \$1.2 billion plus investment in its new Kia plant in West Point Georgia; BMW's combine investment of build and expanding its Spartanburg, North Carolina plant for over \$4.1 billion and Mercedes' \$1 billion plus investment in Talladega, Alabama.

The Japanese manufacturers are as well building and expanding; Toyota has recently built plants in San Antonio, Texas and Blue Springs, Mississippi for roughly \$4 plus billion; Nissan's new plant in Canton, MS coupled with expansion in its 1982 plant in Smyrna, TN brings their investment to approximately \$4.2 billion and despite the economic downturn the CEO of Nissan, Carlos Ghosn, has no plans to reduce capacity

(Welch, 2009), with intentions to export to other countries because of the weak dollar; and Honda has built plants in Lincoln, AL and Greensburg, IN recently (2001 and 2008). Even lowly Subaru, with sales were up last year significantly to its loyal group of unique customers is planning on increasing the output 40-percent from its Indiana plant to about 300,000 vehicles this year.

So with all of these foreign automotive companies building and expanding their plants in North America, the competitive pressures will only continue to rise for the “Big 3”, or what remains of the “Big 3”. This may even be a larger problem given recent economic reduction and less vehicles being sold; when over the past several years, the number of vehicles sold in North America was usually around the 16 million mark, now experts are predicting 12-14 million. This new lower forecasted rate is what is being attacked by the above mentioned foreign implant projects. Recent Alabama announcements confirm this stating that production at Alabama’s three auto plants is up more than two-thirds in 2010 vs 2009 (Kent, 2010).

The reduced market share for Ford also creates another issue with its dealerships. When Ford controlled 25 percent of the market, a large Dealership base was not much of a problem, but now after losing close to 10 percentage points, with further reductions not unimaginable, this can become even a larger problem. Ford, because of state by state franchise laws, cannot just go out and reduce the amount of dealerships; when GM eliminated the Oldsmobile brand, the dealerships were awarded \$2 billion by the court system. Ford currently has 3,700 dealers while Honda is approximately 1,200.

Even though Ford has made some strides over the past couple of years with Mulally now at the helm, they still seem to be resorting to practices that they instituted

some many years ago (cannot escape the old paradigm); come in at a base price and add options to make money to cover their large legacy issues/costs; Taurus, which was the number car in sales volume for years was abandoned by Ford, only to be brought back by Mulally, bases as roughly \$25,000 and tops out at roughly \$43,500; while Honda keeps upgrading and refining their vehicles like the Civic and Accord improving every year on quality and reliability not just incorporating more features to demand a higher selling price.

The F150, Fords number one selling vehicle, is similar, starting out roughly \$20,000 and topping out at near \$50,000. And only recently had Ford began entering in the Hybrid market and higher performing smaller engines with their EcoBoost design, with turbo and direct injection. As a sign of the current economic pressures being brought on by the competitive incentives from increased rebates, discounts and low cost financing from Toyota (Tundra), Nissan (Pathfinder), Dodge/Fiat (Ram), GM (Silverado, GMC), Ford has just announced \$4,500 discount/rebate on all F150s. This has again hurt their bottom-line and budget dollars (including R&D) necessary to invest in the technology, organizational, new product development systems and processes, manufacturing reconfigurations investment, advertisement and customer support needs brought on by this new major disruptive new technologies S-curve beginning era.

20.5 Summary

It has been presented that during the recent sales slump period the North American market as well, as the global market, are in the beginnings of (a) major new technology (systems) disruptive, discontinuity, S-curve change region (A-B paradox) of

uncertainty. It is evolving/transitioning through to the next/new technology (systems) S-curve long term life cycle phase. This period of A-B transition will require major (new) technology skill base changes/additions, organizational changes, technologies management changes, manufacturing capabilities change requiring major research and design and facilities investments. The perspective, as presented in previous chapters, is that Ford no longer has the deep financial resource pockets to sustain funding this; and thus Ford's future (and that of GM who is in worse enterprise shape) is in jeopardy or doubt; like the US consumer electronics companies (and several others).

To successfully compete with the Japanese in the future (more hybrids, and electronic make up) Ford has many issues that they must overcome in order to survive. When you look at the challenges of changing your whole organization premise for the major S-curve shift to more electronics and integration (mechatronics) to mostly electronics, to all electronic vehicles, there has been past patterns/paradigms in most major historical product segments; it does not look good for Ford (GM or Chrysler). It is thought that the likely hood of them surviving in anything but a dramatically reduced future market volume, market share; and (or disappearing) completely are very high. Table XX summarizes the characteristics of the automotive industry explored:

Table XX Ford and Honda comparison

	FORD	HONDA
Employees		
Legacy Costs	1,500 per car, new contract puts Ford's payout to pension fund of \$13.2 billion	0
On-going benefit	\$1,150 per car	1,000 per car
Flexibility	Fixed Costs, must be negotiated	layoffs, OT, reduced wages and benefits
Union	Mandatory UAW representation	Plant by Plant efforts needed for unionization
Wage Per Hour	74	48
Severance Costs	High	Low
	VISION severance, retirement pension/healthcare portion; bankruptcy shared cost	
Dealer Ships		
Number	3700	1200
Profit per	325,000	800,000
Ability	Service accounts for large portion of profit	Car sales are more profitable
Direction	Heavy reduction needed at high cost	If current trend is maintained will need to expand base
EPA		
MPG	24.5	30
Engine Type	Larger V6 and V8, NOTE: Ford attempting to reverse this trend with the EcoBoost and turbo charge and direct injection; long-term reliability unproven	Small high revving 4 and 6 cylinders. More energy and dollars being spent now on hybrid technologies; continually improved
Quality/Reliability		
	Better than average, efforts to improve, however, unstable history of highs and lows. Legacy reputatoin is very poor; warranty cost high (50% of R&D)	Best in class, long history of very reliable cars
Exectutive		
Backgrounds	NBA/Accounts, however, Mulally is not status quo, engineer from Boeing	All R&D managers
CEO Compensation (2007)	21 million	900,000
Leadership		
	Large Truck and SUV experience	Electronic Incorporation (mechatronics)
		Engine Refinement
		Reliability Refinement
		Robotic Technology
		Plant Flexibility
		Globalization
		Hybrid Technology
		Employee relationships, quality circles, employee empowerment
		Alternative Fuels
Financial Performance		
Stock Performance	Perform low over last several years; will hurt their ability to raise cash when they do a stock sell; cash for R&D, new model development, pension fund payment	Stock performing well
Credit	Low credit rating; cost of money bozzed high	Investment grade rating; advantage of lower borrowing rate
Plant Locations		
	Northern US, losing population, aging infrastructure, loss of technologies, poor climates; several plant closings with more to come	Original factories same, but all new expenditures are in sun belt; expansions in current plants with a new plant in IN ready for production

(source: Author's depiction)

CHAPTER 21

SUMMARY AND CONCLUSION

21.1 Summary

In the previous 20 chapters we examined, in detail, a large number of metrics affecting the automotive industry and the challenges that have been faced throughout the last several decades. The results and comparison of the specific metrics between Honda and Ford followed. This chapter summarizes where the auto industry stands on the sigmoid curve (with some summary history of where it has been), outlines the current major discontinuity(ies) and adds a perspective of further S-curve(s)direction. Some discussion on who appears to be better positioned for the challenges of transitioning from the current S-curve to the future potential S-curve was also presented. Finally, this chapter concludes with a list of some suggestions for future areas of work.

Figure 217 depicts current S-curve movement with discontinuity:

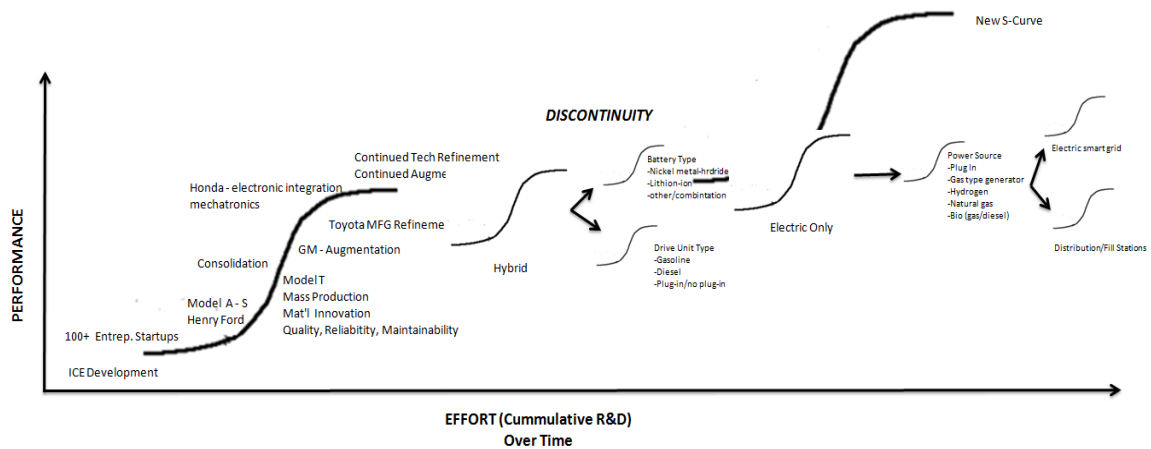


Figure 217 S-curve Transitioning (source: Author's depiction)

After over 100 years of evolution and expansion, the global personal transportation vehicle industry is entering a new challenging, disruptive technology system change period; similar to the consumer electronics product disruptive change from the vacuum tube to solid state electronics or a CRT to HDTV which required a whole new network. The personal vehicle transportation industry is in the early (or middle) “hybridization” region of a similar disruptive (discontinuity) technology period. Refinements in mechanical system technologies, augmented with electronics, mechatronics control systems, turbo-charge and direct injection smaller (reduced cubic engine and enhance performance) engines, expanded augmented hybrid battery/motor power device system are occurring. All of these systems are moving toward all electronic (fuel cell?) stand-alone power systems and tied into a smart power grid supported/augmented distribution network.

This era represents a major evolution change from mostly mechanical, ICE (gas and diesel) product system; through hybrid version product system requiring more computer science engineering, and software engineering controlled electronic hybrid; to

essentially a mechatronics consumer sophisticated appliance/product. In this sense it is increasingly becoming a modern “consumer product appliance” like a HDTV, VCR or a modern refrigerator, “cell” phones, and personal computers. Increasingly we will see more design for manufacturing product subsystems and system integration (parts simplification); and with broadband on board, high speed electronic configuration and control systems; and smaller higher efficiently electric motors.

We will also see increasing multiplexing (replacing wiring harnesses and cables), solid state electronic microprocessors system on a chip, and the economies of volume will increasingly bring faster new products to market. There will also be volume growth to drive value engineering cost reduction efforts. Similar to the Japanese introduction of solid state televisions, this effort will require whole new system architecture. This would be similar to the changes in the HDTV “broadcasting/receiving network support system change. This resulted in a requirement for a benefit from new smart power system grid networks.

What will, from a customer standpoint, lead and fuel this later growth and price reduction is the increasing growth of the “frugal” economy (frugal customers). In the North American market, it will be the potential reduced buying power of globalization of more customers. They are forecasted to have less buying power (working but at a lower inflation adjusted income). It is predicted that a large emerging market of large population of the relatively lower income BRIC countries (Brazil, Russia, India and China) will occur. This large population, low income group is currently being addressed by small, simple cars like the NANO vehicle, produced by Tata Automotive in India for roughly \$3,000 per vehicle.

There are, as happens during the discontinuity period, many large companies and small entrepreneur companies addressing/introducing first generation products in this early new electronic revolutionary technology system (mix) period; as Keys (1993, 1995, 1997) documented prior. This field has expanded in numbers, both small and large, with multi-million dollar investments, both private and governmental.

Two of the more known electric vehicles due out in late 2010 include the Chevrolet Volt (built on the Cruz platform) and the Nissan Leaf. The Volt is expected to sell for \$35,000-\$40,000, less any Government backed rebates (currently at \$7,500) and the four-door Leaf is expected to sell at \$32,500 less any rebates (Bloomberg Business Week, 2010). Telsa, an innovative startup, has had an all electric \$100,000+ sports car (roadster) on the road for several years, about 1,000 all together. Telsa is now teaming with Toyota and Daimler to build electric vehicles and has purchased the California NUMMI plant as well. Thus far, investments in Telsa include investments of \$50 million from Daimler to make electric smart cars; Toyota's acquiring \$50 million to develop electric cars; and \$645 million government loan to develop its Model S electric sedan (Ohnsman, 2010).

Other electric car start up examples (of many worldwide) include Fisker Automotive who vows to produce 130,000 electric cars (in a closed GM plant in Delaware that they purchased for \$18 million) by 2013 and who also received \$465 million loan from the US Government; BYD, a large battery and electronic equipment company in China, who is now starting to build electric cars (BYD E6), received \$230 million investment in 2008, from Warren Buffet (purchase ten-percent of the company, for which his investment stock is now worth \$2 billion). The later actually got its start in

developing/manufacturing Li-ion batteries and only entered into car production three years ago, and is saying that they plan on being bigger than Toyota by 2025; and an independent small Cleveland local company example in Tallmadge, Myers Motors, which has a one seat vehicle that the company hopes soon to have at least 1,000 preorders on the books soon to drive the price down to \$25,000 less government rebates. In all the Obama administration has passed \$2 billion in grants for advanced battery manufacturing and the Department of Energy is disbursing \$25 billion in low-interest loans to encourage companies to build “green” cars; perhaps more is needed (financially and regulatory) to close the gap between U.S. and Japan in battery technology.

There are several challenges facing the electric car for truly becoming the car of the future. First, in the transition from battery to fuel cell, the actual battery design itself is a challenge. The two front runners for car batteries are the nickel metal-hydride (NiMH) and the lithium-based ion (Li-ion). The NiMH is a mature reliability proven, lower power density, heavy material and relatively inexpensive battery; and proven in large volume but it recharges slowly and its relatively low power density mean it takes many to power the car (e.g. the Telsa sports takes 1000 linked together). The major benefit is that it is mature and proven; vehicles are subjected to a wide array of climate temperatures, vibrations, noise and potential impact (crash), the NiMH has a “consumer products” history known to be able handle this with known high reliability. It is hoped by many, that better refinement in manufacturing processes (where the Japanese are leaders) coupled with higher volumes will ultimately make the NiMH a viable long-term solution for electric vehicle (all electric or hybrid) power source.

The new generation competitive battery, Li-ion, is a relatively new chemistry with a number of “ion” candidates being used in some portable consumer electronics currently; which offers extended life between charges; faster charging, no charging memory (e.g. no affects if the batteries are charged when only half expended) and overall weight savings. The Li-ion’s potential of a low price, faster charging, higher power density and lighter materials (smaller package) is ideal. However, the Li-ion is untested in the duty cycles (unknown reliability) in the extreme market variation that it will have to contend with in the life of a vehicle; and once the system design architecture is set for this type of such battery (or any other) to be used by the automotive manufacturers electronics power system; it will be frozen around this design technology.

Another problem with the large use of electrical vehicles is the more distributed power grid system architecture needed to recharge these vehicles. Currently the power grid in the U.S. is a “dumb” grid; centralized around historical big cities, mostly located on the east costs (hence the brown out a few years ago from New York through Ohio); it sends power out to where along wires with little or no sense of consumption demand; the grid cannot easily adjust where, when and how much power is need where. The grid being used today has been the same grid for decades. There are three major hurdles to accomplish to transform from dumb to smart: 1.) the high voltage transmission grid also imposes important constraints on the desired flexible deployment of renewable energy because it simply does not go where many of these resources will be developed; (2) congestions and bottlenecks hurt the reliability of the grid overall, particularly where it is needed to move large volumes of new power from remote generation to major demand load regions; (3) the monitoring and control technology on both transmission and

distribution networks is also weak. The lack of smart technology to provide utilities and consumers with better information and allocation in real time hurts the security and efficiency of the entire electricity system. It will have to be required by the local demand distribution of future solar, wind, and wave (and others) power generation centers of mostly the southwest, west and northwest to (peak) demands all over the U.S.; from the increased solid state electrification of the smart network (home, business, etc).

Designing and manufacturing the required “smart” technologies and subsystem elements and components is a challenge; but deployment and actual implementation/deployment of the smart grid involves major networking difficulty as well. There are several policy changes needed to overcome this challenges according to Hendricks (2009):

- A new nationwide, with regional cooperation, planning process,
- Efficient certification, standards and processes
- Broadcasting cost sharing,
- Enhanced federal infrastructure building support,
- A new renewable energy workforce training, and
- Dealing with local, state and regional political systems.

So given all of these potential deliverables and challenges, the following can be summarized:

1. Drawing upon the most recent deep waters drilling worst ever oil spill disastrous (and still occurring) experiences the U.S. must aggressively pursue alternative energy (R&D) independence strategies and investment.

2. The U.S. must also quickly invest in creating a “smart energy grid” that is capable of distributing, on demand, the variety (alternative) energies from the supply location to where ever the peak customer demand is.
3. Developing Battery Technology – The US companies are far behind that of the Japanese companies and some European companies; those who lead in battery development can potentially take a lead, or large majority stake in the automotive industry. This is some concern that the U.S. is switching a dependency on foreign oil for foreign next generation(s) batteries.
4. Transition to all electronics/mechatronics – Japan (Honda) has been involved and has led to development and incorporation of electronics and mechatronics into the automotive since the early 1970s; and Japan in general has led the development of electronics/mechatronics and robotics for 30 + years
5. Developing All New System Architecture(s) for the Auto Industry – Japan, through consumer electronics (and other industries) has demonstrated the ability to effectively and efficiently invest monies into research and development; and time capital in order to bridge the discontinuity and move to the next S-curve of technologies; especially in “robotics” and mechatronics areas.
6. Modular Design Components – This process has been deployed for several decades in the consumer electronics arena; potentially, the construction of the all electronic car subsystems will/could be outsourced to collaborating companies with final assembly performed by what will then be the (new) automotive system integrative and assembly companies, or even by the customer themselves, as in

the case of computers (order the necessary parts over the internet and assemble); perhaps a Sony-Honda-Best Buy combination.

7. Leap Frog – Perhaps one company will leap frog the hybrid/electric powered/all electric powered vehicle to fuel cell technology and take an advantageous lead. Honda has roughly 200 hydrogen powered vehicles, the second generation FCX Clarity, in use or expected to be with customers by the end of the year. With this experience they are gaining knowledge which is accelerating their movement along the fuel cell learning curve perhaps enough to reduce price sufficiently to offer their fuel cell competitively priced to gain market share in the next (future) generation from the hybrid/electric vehicles.
 - i. However, the different fueling infrastructure needs may present a challenge that needs to be over come as well
 1. Filling stations to replace gasoline/diesel/ethanol/biofuels
 2. Distribution network
 3. Generation stations, home or business
8. Recruiting and Development the “new” technical expertise – the Japanese companies in the past have seem to perform better when it comes to redeveloping the entire architecture system when needed, and provide for better competency training/education.
9. The Educational system of the U.S. needs to expand their curriculum towards producing more skilled electrical/mechanical/mechatronics smart engineers/technical designers.

21.2 Conclusion

If the U.S. automotive (Big 3) industry vehicle producers want to renew themselves and assure long term viability in the future (surviving the discontinuity and transitioning to the new S-curve technology), they must lead in the efforts into making this transition; they must commit to increase their R&D budgets to the levels as previously described to survive in the high technology type industry;

- They must increase their R&D budgets to the 8-12 percent range. This increased budget must also be invested properly into the above mentioned technologies;
- They must recognize the new mechatronics and systems engineering and management skill base it will need for its future and staff aggressively;
- They must continuously define and redefine the new vehicles products systems architectures that a continually evolving change core technology system/subsystem base will require;
- They must define, setup and implement the system engineering, project and program management, product life cycle management, concurrent/collaborative engineering processes that will be required to deliver high quality, high reliability/dependability products consistently;
- They must partake in the formation of “partnerships” with highly skilled/experienced companies in electronic integration, battery development, module development, and electrification;

- They must continually invest in the engineering and testing equipment, flexible manufacturing processes, and customer service/field equipment and facilities to make and support this continuous new products stream;
- They must be able to sell their vehicles at a competitive price while making enough profits to generate the monies for these types of investments while keeping their investors/stock holders happy.

These actions may permit Ford to economically weather through the discontinuity period to reinvent themselves into this electrification/mechatronics architecture system. It should be noted though that while comparing Ford with Honda, it appears that Honda has a tremendous (attacker's advantage) lead in all over the above mentioned areas and Ford must move very quickly; and not only the lead but it appears that Ford (and GM) will need further negotiations (help) covering their legacy costs sufficiently enough to raise the additional capital for this needed sustained R&D investment and the above mentioned actions.

21.3 Future Work

There are many paths that can be taken for future work, for example:

1. To further improve the understanding of the challenges of major companies dealing with and managing technology and the disruptive transition to a new generation of technologies. Kodiak and Xerox are successful companies struggling to deal with this digital core technologies business base change; whose transition struggles could be studied as further examples;

2. To enhance our understanding of how this MOT knowledge can potentially bring economic growth to the region;
3. Because of the historical importance of the automotive industry to our state and region, to address studies of how to use this knowledge to strengthen the state's opportunity to gain, economically, from these new generation automotive changes. What new first, second tier kinds of suppliers might we want to cultivate;
4. For any high technology company application, to look at new product life cycle management templates that would help in new start ups and maturing companies to ultimately improve their product success;
5. To set-up a center for high technology business and engineering leadership development in the region to monitor and assist in:
 - a. New technology development
 - b. Identifying new technology needs
 - c. Audit to see where technologies have progressed and how to accelerate progress

Also to look at who left the region and why; identify who and how to attract more business; and what needs to be done to strengthen the regions position;

6. To do competitive technologies industry analysis to help the region and state become more successful in creating and developing its high technology path to new economic success;
7. To address a strategy to help academic institutions identify what needs to be done to better prepare students for the new technologies future;

8. In addition, as practically every new generation product (industrial, consumer appliance home product, medical product, vehicle and home smart integrated network systems) is becoming a biological emulating mechatronics system, we need to do more to significantly address (academically) a better understanding of what it takes to create and implement such new product systems.

These are just a few of the possible research and development efforts. The pursuit of which could significantly improve our regions and states high technology competitive future.

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