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To my parents José Luis and Patricia, my wife Noelia, and my daughter.
Technology Adoption in Automotive Product Development

By

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Abstract

The automotive industry is characterized by the early adoption of technology into their products. In recent years, the automotive industry has developed infotainment systems that encompass navigation, digital media, phone calls, safety and other elements. These infotainment systems are based on componentry similar to smartphones or tablet computers.

In contrast to tablet computers, the automotive infotainment systems have followed the typical automotive product development pace, leaving the automotive infotainment systems with outdated hardware and software when compared to the consumer electronic industry. The automotive industry follow a model year cycle while consumer electronics quickly adapt to consumer demand with many releases over a single calendar year.

The objective of this thesis is to present a new architecture specific to In-vehicle infotainment systems; providing a faster componentry adoption and faster software updates.

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Chapter 1 Introduction

One of the main goals for this thesis is to provide a broader understanding of why the automotive industry, as one of the major engineering development driven industries, is failing to implement similar systems at an equivalent pace as consumer technology industries like the smartphone industry.

Infotainment systems are considered important for the automotive industry because of the effect they have in the customer’s purchasing decision. According to a Ford internal research report, data shows that customers have certain preferences for one particular vehicle over a similar product based on the infotainment systems offered by the manufacturer (Ford Motor Co., 2013).

SYNC, one of the first automotive developed Infotainment systems developed by a joint venture between Microsoft and Ford, has been facing several reliability complaints leading to vehicle recalls. However, according to Ken Czubay, Ford vice president of U.S. Marketing, Sales and Service, “Customers buying Ford vehicles are treating SYNC as a must-have technology, purchasing the system when available.”

Infotainment systems are a key system in the automotive industry; recent research by Visiongain, an automotive industry analyst, shows that infotainment systems are driving customer satisfaction and represent an overall market growth estimated at $31 billion in 2013 (Visiongain, 03/07/2013).

Infotainment evolution is approached by the automotive industry as incremental additions to the current system, following the typical vehicle life cycle; launching a new model every year. This inherently slower pace in comparison to the consumer electronic industry, has caused the In-vehicle infotainment systems to follow the same pace as the overall vehicle; being upgraded with newer features and arguably improved reliability every year. This thesis presents a study of these two elements, dedicating specific chapters to reliability and product development pace.
As part of its core, the automotive product development process has the objective of improving the current vehicle by making use of newer technology; this thesis presents specific cases of infotainment systems developed by the automotive industry showing that the adoption of newer technology might not always turn into better performance.

The automotive industry is also characterized by adopting technology developed by Tier1 or Tier2 suppliers; in many instances the Original Equipment Manufacturers (OEMs) rely on their supplier base for upgrades in their technology; i.e., Hella, a Tier1 major supplier, is accountable for the biggest developments in automotive headlamp lighting.

In the case of infotainment systems, different OEMs have approached their development with analogous system architectures as Ford’s SYNC; making different joint ventures with different suppliers. For example, Ford’s SYNC was a development between Microsoft and Ford; Chrysler’s uConnect infotainment system was developed using Garmin’s GPS navigation system, and Honda adopted Aha app as the main interface in their HondaLink infotainment system.

In the automotive industry it is also common to find that many technologies are “pushed” by government regulations, forcing OEMs to adopt newer technology that in some cases do not lead to an increase in performance.

This technology push at times leads to incomplete systems and in some cases inefficient systems. The technology push chapter is dedicated to analyze the inefficiencies emerging from technology being pushed by legislations.
Chapter 2 In-car infotainment system popularity

The latest Ford internal research shows that nearly 80% of SYNC owners are likely to recommend Ford’s SYNC infotainment system and that almost 70% report using the infotainment system while driving.

According to Ken Czubay, Ford vice president of U.S. Marketing, Sales and Service, “Customers buying Ford vehicles are treating the infotainment system SYNC as a must-have technology, purchasing the system, when available nearly 80 percent of the time on current 2011 models” representing an increase of 4 percentage points compared to 2010 models, (Ford Motor Co., 2013). It is unclear the impact the touch screen “MyFord Touch” infotainment system has had on the overall customer satisfaction index; this is also analyzed in the reliability chapter.

A very similar system that offers similar functions offered by the In-vehicle infotainment systems is the smartphone. Voice recognition, music and video reproduction, communication device as well as entertainment are similar functions as those offered by infotainment systems installed in vehicles.

The new smartphone adoption rate is one of the highest we have experienced in the last years, but it can be compared to the automotive industry infotainment systems; customers are more frequently exposed to this technology and expect to have the same interaction in their vehicles. This makes things very difficult for the auto industry to keep the same pace; by analyzing the architectural differences and dissimilarities, the infotainment systems lack the advantage of being connected to the internet all the time, which makes smartphones portable computers with unlimited access to data.
Chapter 3 Technology Push/Pull

There are two major drivers of technology adoption. The first is the market pull or market demand. The second is market push, characterized by an effort from the technology producers to gain adoption of their technology.

The adoption pattern is affected by the relevance to the market of the product being offered. Market demand is when there is a real need from the market that can be satisfied by a particular product.

The automotive industry is often driven by a market push. Many times external players “push” the adoption of newer technology in lieu of better performance. In the automotive industry, federal legislation often times plays an important role in the adoption pattern since legislators often mandate the adoption of new technology. This thesis present several case studies exemplify the market “push” and the influence it has across the automotive industry.

For instance, the National Traffic and Motor Vehicle Act is a 1966 federal regulation that mandated the use of seatbelts in vehicles. The regulation that mandated automakers to install
seatbelts in the front seats on all new vehicles was “pushed” into the automotive industry.

The case of in-vehicle infotainment systems is no different. Recent European legislation going into effect in 2015 is “pushing” automakers to use 3G technology along with GPS in their vehicles. The e-call initiative requires all the automakers selling vehicles in the European Union to incorporate self-powered devices capable of calling 112 (911 equivalent) automatically and bring assistance to drivers involved in a collision.

3-1 Case Study: Electric Vehicles “Push”

Electric cars are also characterized by a technology push rather than by a market pull; automotive manufacturers are being forced to make investments in electric vehicles development in lieu of governmental incentives.

The latest Corporate Average Fuel Economy (CAFE) regulation, regulates how “efficient” the vehicles produced by a particular manufacturer should be, taking many considerations like the footprint of the vehicle, the efficiency expressed in MPG (miles per gallon) as well as technology used to generate power, which is the most important element in the CAFE regulations.

The new CAFE regulation can be understood as having penalties or incentives from the government to the automotive manufacturers depending on how efficient, in terms of MPG’s, their vehicles are (United States Environmental Protection Agency, 2012). The CAFE rules were written to encourage OEMs to improve the overall fuel economy of their brand by producing “improved” or more efficient vehicles. The CAFE standards for model year 2017-2025 were set at an average of 54.5 miles per gallon; meaning that OEMs are being urged to adopt new technologies to improve their overall efficiency.

The CAFE regulations encourage OEMs to adopt alternative fuels other than gasoline by using a “multiplying factor” for alternative technologies; regardless of the achieved MPG, a hybrid, electrical, electric cell, hydrogen or other means of propulsion will double the benefit
than the same vehicle with similar MPG but using standard gasoline as its source of energy which will count as one.

This is clearly an example of how “newer technology” is being pushed by the government rather than by the market demand.

The proposed infotainment system architecture will have to take into account the technology “push” driven by legislation.

Figure 3 explains the new regulations set in place showing that by 2016 a vehicle with a footprint of 40 sq. ft. will have to achieve a combined fuel consumption rating (MPG) of at least 42 MPG. To put it in perspective, the most efficient SUV vehicle in 2013 is the Lexus RX Hybrid with a wheelbase of 55 sq. ft.; it is only able to achieve 30 mpg combined (32 city, 28 hwy) (James Adcock, 2012).

The 2014 Toyota Highlander Hybrid, one of the more common SUV hybrids in the market, is able to achieve 28 MPG with its hybrid system. In contrast, the 2013 Mazda CX-5 with similar overall footprint is able to achieve 29 MPG combined (26 city, 32 hwy) with a
regular internal combustion engine, demonstrating that in many cases the hybrid technology being “pushed” by legislators doesn’t necessarily translates into improved performance (Hybridsuv.com, 2013).

Figure 4, Ashish Sood & Gerard J. Tellis. Technological Evolution and Radical Innovation

There are other examples how newer technology is being “pushed”; in this case, the hybrid, full electric or alternative fuel vehicles are being “pushed” by the government offering incentives to the end customer, penalties to the manufacturers and marketing campaigns to the general public. Many electric cars are being offered with a federal tax credit of up to $7,500 (Fueleconomy.gov, 2010).
The above chart represents the fuel efficiency of the Ford Escape across many years, and compares the fuel efficiency that the Hybrid technology introduced in 2005 in terms of MPG. In comparison the same Ford Escape Hybrid by 2005 was able to achieve 36 MPG on the highway, while the similar vehicle 2WD equipped with a 4 cylinder internal combustion engine was able to achieve only 28, representing an overall increase in fuel efficiency performance of nearly 28%. The hybrid technology made sense at that time, but by 2013 with the introduction of newer technology, a 4-cylinder internal combustion engine was able to achieve nearly the same fuel efficiency performance of 33 MPG but without compromising the engine’s power.

As exemplified in the electric vehicle case; newer technology might not necessarily translate into better performance. The adoption of newer technology only makes sense at the right time and at the right price.
3-2 Case Study: E-call Mandate “Push”

According to the European Union, in 2012 there were more than 1.2 million people involved in car accidents. The European Union study reveals that 28,000 people were killed and more than 1.5 million were injured due to these accidents, resulting in a cost of around 130 billion EUR (European Commission, 2013).

The number of people involved and injured during a vehicle accident set the precedent for the 112 eCall mandate. In July 2012, the European Parliament required all the automotive manufacturers to equip their vehicles with 112-based eCall systems by 2015. The 112 emergency number is the equivalent of the North American 911 emergency number. These self-powered communication modules require the car to be able to transmit location, process communication and be self-powered after a severe vehicle collision.

The idea behind the eCall system is to provide the European Union with a system able to reduce the number of people killed during a vehicle accident by providing a faster response to people that have been involved in an accident. The EU commission estimates that eCall could speed up emergency response times by 40% in urban areas and 50% in the countryside, and save up to 2,500 lives a year (Baker, 2013).

The eCall systems are based on independent modules that automatically self-activate when airbags have been deployed. These systems are GPS based and equipped with Global System for Mobile Communications (GSM) modules able to make calls and transmit data to the 112 public safety answering point. The mandate requires these systems to send vehicle identity, current location, time information and voice.
The 2012 EU mandate requires e-Call systems to be self-sustained; meaning that they cannot be incorporated as part of the automotive vehicle infotainment systems. The argument is that current infotainment systems are not reliable enough to handle emergency calls during an accident.

This case, clearly illustrates how many times the regulations are driving the automotive industry technology adoption pattern, forcing the industry into some inherent inefficiencies. For example, Ford’s SYNC infotainment system has been able to fulfill the same system function as the separate eCall module; being able to call the 911 emergency number in the case of airbag deployments. The redundant system is driving additional costs and componentry complexity to the automotive industry by technology being “pushed” by government regulations.
The adoption pattern of any new technology follows the normal distribution. Most of the users adopting the new technology will be concentrated in two standard deviations from the normal distribution mean. Geoffrey Moore described “the chasm” as the gap between early technology adopters and any technology adopted by the mass market. When technology is mandated and “pushed” by a third party, it facilitates the technology adoption by the mass market. A common example of this is the mandate to use airbags in all cars.

In the case of eCall legislation, it will facilitate the deployment of the infrastructure required to support such services; the eCall mandate is relying on enhancements of the cellular network deployed across the European Union; these enhancements will benefit the infotainment systems overall.

Chapter 4 Infotainment Early Technology Adoption

Advantage

In the fifteenth century, the introduction of mass printing technology demonstrated that a single technological breakthrough can impact the world and modify the way we behave, interact, think, consume and even develop new technology (“Inside the Tornado”, Geoffrey A. Moore, pp. 13-26).
A good example of early adoption advantage is Ford’s SYNC infotainment system. Ford was amongst the firsts OEMs to introduce infotainment systems into their vehicles. After Ford proved the technology and its implementation, many other competitors followed the same strategy. In this case Ford had a questionable advantage for being one of the first OEMs working on an infotainment system; by 2007, their SYNC infotainment system was considered one of the best infotainments in the automotive industry (Popular Mechanics, 2007).

In the auto industry, there is typically only one OEM that takes certain risks by incorporating a new technology. The common scheme is that after the first OEM adopts a certain technology, the rest of the industry will follow the same adoption using similar architectures.

After the introduction of Ford’s SYNC infotainment system, many OEMs followed the same architectural concept similar to the ones developed by BMW, Ford and Chrysler; by following the same architecture they were also reproducing the same mistakes and disadvantages that the in-vehicle modular architecture has.

The “MyFord Touch system” is an infotainment system that enables drivers of Ford vehicles to “seamlessly” integrate their own mobile phones or digital media players into their vehicles. The system allows the driver to use many of its functions by means of voice
commands along with the integration of an LCD display located in the instrument panel. This infotainment system architecture is based on single software and hardware releases without any feedback loop, forcing the system to work with one set of preloaded commands, maps, routes, etc.

The “MyFord Touch” infotainment system is the evolution of the SYNC infotainment system developed by a joint venture between Ford and Microsoft. The SYNC infotainment system had fewer features and no touch screen LCD but was at that time more reliable than the new Touch screen integrated system.

The new “MyFord Touch” system also adds more functionality within the vehicle like being able to control cabin temperature, airflow, navigation system, radio controls and many other media features.

After its launch in the 2011 Ford Edge, the “MyFord Touch” demonstrated a lack of robustness and was not able to deliver the “seamless” promise that customers were expecting. Ford lost the advantage they had with the simpler but more reliable SYNC system; the development of “MyFord Touch” followed the typical automotive development process, where the system was based on upgrades to SYNC architecture rather than considering a new architecture.

While there are some similarities between in-car infotainment systems and smartphones, there are also some architectural differences between them. Smartphones have a big architectural advantage over car-fixed systems since they are always connected to the Internet; therefore, the actual voice recognition is conducted “over the cloud,” meaning that the complex computations of translating the recorded voice into computational data and then linking these commands to relevant information across the Internet (like maps, routes, news information, etc.) is done in Google’s or Apple’s servers. This “over the cloud” approach has an architectural advantage over the car fixed in-vehicle infotainment systems, taking off the devices, complex data analysis and displaying more relevant information gathered through the Internet.
Smartphones depend on packaging voice recorded data and then sending this data for further analysis and retrieval from the cloud. The “over the cloud” model will always be more accurate and efficient due to the fact that the device acts just as the interface between larger amounts of information available over the Internet and superior computational resources available to the end user. On the other hand, it also has some downfalls; in order for the “over the cloud” system to be accurate and sometimes even able to operate, the device has to be able to reach an Internet connection at all times.

History has proven that voice recognition was better implemented on smartphones than on vehicles mainly because Google’s and Apple’s voice recognition and overall architecture is based on feedback loops, making this single element the most valuable architectural advantage over fixed In-vehicle systems.

The advantage that the smartphone has over the in-vehicle fixed infotainment systems is the ability to send updates over the air (OTA) seamlessly to their respective devices. In comparison, the automotive industry still requires either the customer or the dealer to perform these updates manually. For this reason most of the updates only get installed in new vehicles coming out of the plants where the OEMs still have control over what level of software gets flashed into the vehicle’s modules.

The latest automotive industry reports show that the new interactive and more sophisticated infotainment systems are not able to satisfy drivers’ expectations.

According to a 2013 Consumer’s Report study based on data from 1.1 million 2004-13 model year vehicles leased or owned by Consumer Reports subscribers “Ford’s MyFord Touch system was a big reason why Ford slumped in last year’s reliability survey and it again was a culprit behind Ford’s dismal performance on the 2013 survey” (Consumer Reports Magazine, 2013).

It is believed that Chrysler’s close relationship with the aftermarket might be the reason for a low number of complaints, since its Uconnect system is based on the Garmin navigation system.
As pointed out by many automotive industry analysts, problems related to vehicle infotainment systems are now the number one complaint category surpassing any other category. The category that includes in-car electronics has generated “significantly” more issues than any of the 17 categories in the 2013 survey.

Common problems are: failing to assertively recognize voice commands, screen freezes, phone connecting problems, screen lags as well as compatibility with MP3 players (Consumer Reports, 2012).

According to The New York Times, almost two-thirds of the 34 Ford and Lincoln models in the survey scored much worse than “Average,” which is the lowest rating. “In-car electronics is one reason those models occupy the bottom of the list (26th for Ford and 27th for Lincoln). The brands have fallen the last few years because of problems with the MyFord and MyLincoln touch infotainment systems” (The New York Times, November 3, 2013, page AU4).

Customer’s responsiveness expectations were compared to the smartphone industry and the customers were expecting the vehicle to behave the same way their phones do, with the same logic and the same interfaces (Schweinsberg, 2013).

In the overall driving experience, infotainment systems have become the top customer satisfaction offenders for the industry, driving customer complaints and dissatisfactions when executed poorly.

In-vehicle infotainment systems have now become a top priority system for the OEMs; vehicle manufacturers have acknowledged that these systems can drive sales but at the same time could represent loss in revenue and brand ranking when faced with repairs, expensive recalls and customer dissatisfaction.

Figure 9 exemplifies the process flow of in-vehicle infotainment system software updates compared with the Over The Air (OTA) software updates performed by the two architectures. It is clear that the cloud base OTA update is simpler and more effective when dealing with software updates.
The latest iterations of the Android smartphone platform, the voice recognition system is now able to download automatically data information of the latest voice recognition commands; meaning that now the user, and in this case the smartphone, doesn’t have to have an active connection to the Internet in order to have accurate voice recognition commands. This new iteration does not translate into a system being able to operate without an available Internet connection, it only means that a reduced and limited number of commands can be stored and executed locally by the device itself. This approach is now closing the gap for the advantages that In-vehicle or fixed systems have to operate without the need of having an available connection to the Internet all the time.
Chapter 5 Reliability (Consumer Reports Magazine, 2013)

After its debut in the 2011 model year, the “MyFord Touch” was criticized as being unreliable, difficult to operate, lacking responsiveness and system freezes. The incorporation of a touch screen panel located in the instrument panel was considered by Ford as the “natural evolution” of their long time awarded SYNC system (Consumer Reports Magazine, 2013).

A 2013 Consumer Reports survey showed that “younger car buyers are better utilizing infotainment systems, trying every feature available and coming away unimpressed.” This proves that, in order to compete in the smartphone league by offering a similar product, the auto industry now has to keep pace with the phone industry’s, standards in responsiveness, interconnectivity and features offered by smartphones.

In essence the introduction of a touch screen just as a way to interact with the infotainment system is not good enough. The SYNC system was well designed under the premises that voice recognition elevates the driving experience, making it safer and more comfortable by eliminating distractions and avoiding the need to remove the driver’s hands from the steering wheel to interact with the vehicle. These fundamental principles were not deeply considered during the “MyFord Touch” development; the new touch system required the customer to touch a “moving” screen while driving; some other elements were introduced to the system like controls for the air conditioning system, navigation system, volume of the radio, changing channels, and many other functions. One of the biggest disadvantages of the
new “MyFord Touch” system was the removal of knobs and buttons that the customer was accustomed having; there was not enough consideration to the “touch memory” that people have.

Voice commands centric  Touch screen centric with voice commands
  2007  2011

Figure 11, SYNC & MyFord Touch solution centric

By removing physical buttons and knobs, the driver was now forced to interact with the touch screen to perform simpler tasks like changing the temperature or changing radio stations. By removing the physical buttons and knobs, the whole infotainment architecture was diminished.

In an effort to make the new system more “appealing” and “cleaner” to the drivers, some of the basic controls were moved to the LCD touch screen. However, this change overlooked the human “motion memory”, meaning that for many actions we perform every day we really don’t need to look at our hands to understand our surroundings. For many common tasks like typing on a keyboard, opening a door, turning the ignition key in a vehicle or even turning on the lights in the darkness, we really don’t need to be carefully looking at our own hand. In most of these cases the “motion memory” inherent in our nature is actually better fitted to perform these tasks; eliminating the physical knobs means that the driver will have to use two of his senses to perform the same task; at some point the driver must take his eyes off the road to see and read the touch screen, making things even more dangerous than without the system. There have been many studies conducted by the industry indicating that the risk of having a car accident follows an exponential time-risk ratio; the longer the driver takes his or her eyes of the road, the more likely he/she is to be involved in a car accident. “We
think MyFord Touch and MyLincoln Touch require far too many glances away from traffic to operate even common functions” (Consumer Reports, 2012).

A basic layout of what the customer is required to do in order to operate the system:

a) Take the eyes off the road.
b) Watch the screen.
c) Identify where the command is located in the screen.
d) Take at least one hand from the steering wheel.
e) Countermeasure any inertia of the arm movement.
f) Touch that particular coordinate in the screen (left hand top corner).
g) Expect any audible feedback from the system. Note the lack of touch feedback.

All these challenges are very similar to the ones that the smartphone industry faces, but there is a fundamental difference. The customer is not supposed to operate the phone while driving; in fact, in many US states it is illegal to do so.

It has been observed that many users are able to operate their devices with only one hand, but in these cases often times the user does it without walking, running or performing any other task that would interfere with the natural movement of the hand.
The operation of a smartphone follows a pattern similar to the infotainment systems in vehicles, but in the case of the smartphones there are many advantages. For instance, most of the users will be standing still when operating their devices, holding them with their hand or in some cases both hands, the “moving” screen is often moving in the same dimension as their hand is moving, and in many cases there is some haptic, visual, as well as audio feedback when any input is made through the touch screen. The physical or haptic feedback hasn’t been implemented in the In-vehicles infotainment systems.
Figure 12 and figure 13 illustrate the architectural differences between SYNC and MyFord touch infotainment systems; adding more complexity to an architecture that was designed with a different objective in mind.

The biggest architectural difference between SYNC and “MyFord Touch” systems is the way the customer interacts with it; in the previous generation, the voice commands were the center of the system, converging all the inputs through a single channel (Consumer Reports, 2012).

According to research conducted by Consumer Reports in 2012, a high percentage of Ford and Lincoln owners were reporting having problems with the audio, pairing their device and whole system freezes. In this research it was found that approximately thirty percent of surveyed users reported that the “MyFord Touch” system was highly influential in their purchase decision. This is a well-documented case of technology being used as a selling factor rather than the incorporation of technology as a way of achieving efficiency.
Consumer Reports’ numbers showed that more than 50 percent of the users were experiencing some issue with the system, reporting lack of responsiveness and in many cases reporting that the system had a black screen or that the voice commands were not working properly. The customers were expecting more than what the system was able to deliver, and more than 70 percent reported that their system required repair.

It has become very difficult for the auto industry to keep the same pace as the consumer electronic industry, since their product cycles are completely different.

As shown in the above chart, the automotive industry is in essence a slower paced industry when compared to the smartphone or computer industry. The overall product cycle of a product or vehicle is between 4 and 6 years depending on its success. Many minor upgrades are launched every year as model year changes, meaning that the major components of a vehicle remain unaffected. Vehicles are, in the worst-case scenario, running on 5-year-old computer modules with several years old components, and in the best-case scenario, running on one-year-old computer hardware with some months old software by the time they are available to the public.
Since the SYNC infotainment system was developed by Ford and Microsoft it tends to follow the same pace as any other auto industry model year release, meaning that a slower pace will always be running on older software than the Internet loop and cloud based model adopted by Android or the smartphone industry.

In essence any infotainment system is running on some piece of hardware and software, the same way that smartphones do. However, the major difference is that even though the software side of the system can be upgraded, in the case of in-vehicle infotainment systems, the process involves a dealership re-flashing the module with the latest software, and even in this case, the “new” software to be flashed will be some months old.

Chapter 6 Infotainment Systems Cost

There are always several costs associated with the implementation or adoption of newer technology; these costs have a direct impact on the technology adoption speed.

Ford’s SYNC system was first introduced in 2007 as an option on the 2008 Model Year Ford Focus, for $395; Ford has maintained the same price since its introduction. According to Ford, as of 2013 there were more than 3 million Ford vehicles equipped with the SYNC infotainment system; in comparison there were 798 million Android users by February 2013 (Koetsier, 2013).

Recent infotainment systems have become more and more expensive, making it difficult to justify when compared to tablet or smartphones.

The consumer electronics industry has been more cost efficient on the value they deliver to the customer and the cost of their product. A clear contrast can be seen in Ford’s base SYNC system, which is being offered for $395 without any touch screen, any Internet connection and very limited computational capabilities. In contrast, the most reliable Android based tablet in the 2013 market available to customers, including a high resolution 7-inch screen, LTE connectivity, voice recognition, quad core processor, GPS, 32GB of internal storage,
dual camera and Wi-Fi module, sells for only $349.

The price of the most advanced MyFord Touch system including a touch screen tends to vary depending on the vehicle and is not available as a stand-alone feature but only sold as part of a package of $1,100 or in many cases even more. These higher costs are frequently difficult for the customer to justify when compared to more reliable, stable, accurate and powerful Android based devices (PC Magazine, 2013).

In the case of infotainment systems, it is essential to identify the cost of development and implementation; sometimes these costs are associated directly with the cost of the technology itself, but for the great majority, the higher costs are associated with the infrastructure that makes infotainment systems feasible. A cloud based infotainment system will require a reliable connection to the internet. The proposed infotainment system architecture in this thesis will require data and voice connection through a wireless network provider, which is already available to the smartphone industry.

If the automotive industry were to adopt an Android based infotainment system, the infrastructure costs would be minimal, because the deployment of wireless networks has already been implemented, and the cost of internal componentry can be taken “off the shelf” from the consumer electronics industry.

By taking “off the shelf” componentry, the development costs would be minimized and the software development costs would also be reduced, since Android is available to anyone who wants to incorporate and use it.

The architectural change that this thesis proposes is eliminating most of the in-vehicle internal components and offering a high quality screen that could pair with the drivers’ phone. The main solution would be to “mirror” the driver’s ecosystem and screen, offering the driver the ability of do everything he does on his phone but on a larger screen integrated in the vehicle’s dashboard. The proposed system would take the latest componentry made available to the consumer electronics industry and create a simple responsive replication Android based screen, eliminating redundancy and lowering the internal development costs.
Chapter 7 Incorporating Outdated Technology

Most of the OEMs are making efforts to close the gap with the smartphone industry by taking different architectural approaches; for example Chrysler’s uConnect system is now capable of staying connected to the Internet all the time by making use of wireless technology. At first this new approach seems like a feasible and workable solution to the architectural differences, but the reality is that the new feature is several generations behind any new smartphone device.

One of the features offered in the latest uConnect in-vehicle infotainment system offered by Chrysler is the ability to turn the vehicle into a “moving wireless Internet connection” or hotspot. However, there are several downsides in this system, the most evident is the fact that many people who buy the infotainment system for their vehicles probably already have a smartphone, and most smartphones already have this hotspot feature available.

Probably anybody who uses a smartphone is paying already for a plan that includes access to the Internet as well as being able to make calls. In fact the four major US carriers, Verizon wireless, AT&T Sprint and T-Mobile, are offering the hotspot feature at no cost or as part of the Internet plan offered for all smartphone devices. The uConnect system requires joining a 3G network being provided by the wireless carrier. This wireless access is being charged per day, per week or per month meaning that the system would probably not be connected to the Internet all the time once the connection time expires.

Probably the most outdated feature in the uConnect system is the hotspot feature. The system is only capable of connecting to the Internet at 3G speeds, while the whole smartphone industry already went through 4G and the vast majority of new smartphones are now capable of connecting to the Internet at LTE speeds, which is 40X faster than 3G.

Any customer who already owns a smartphone and is looking to integrate their device to the vehicle would probably already have Internet access on their own device, making the 3G hotspot feature completely outdated. Why would somebody need Internet access on a mobile
device that already has Internet? Why would somebody be willing to pay a monthly subscription that is more expensive than any of the US cellular carriers? This is an excellent example that shows why the current automotive product development process is failing to integrate technology at the same pace and meet customer expectations. The automotive industry is failing to deliver the same level of robustness, failing to incorporate up to date technology and failing to meet customers’ expectations.

Figure 15, Chrysler's UConnect data costs (Chrysler LLC, 2013).

Figure 16, AT&T Data plans (AT&T Wireless, 2013)

Chapter 8 Decoupling Infotainment Systems

We have to keep in mind that the auto industry is driven by standards, government regulations, suppliers, and market economy; therefore the development of new componentry for the infotainment systems falls in the same category as any new Powertrain Control Module (PCM) development.

The PCM modules are, in most of the cases, developed by a third party or supplier, and then the companies’ R&D engineers will do the programming side, going from conception,
design and development, validation and testing, regulatory certification and final launch. This means that inside the product development process of any automotive company, at any given time, there is always an organization responsible for code programming adhering to the typical vehicle product cycle. Therefore, these organizations are “familiar” with these developments, but the problem is that OEMs are treating the infotainment systems like the most familiar organizations they know which are the module calibration organizations.

There are also some other reasons why OEMs are failing to deliver up-to-date technology in their vehicles.

All the infotainment systems require pieces of hardware that are typically difficult to package inside the vehicle and away from the driver’s sight, meaning that these modules represent a challenge by their own packaging constrains.

These modules are particularly difficult to package due to their peculiar requirements, like being able to reach a GPS signal (closer to the headliner) away from any vibration zones (to prevent malfunctions), and away from wet areas. Similarly, the screens also have their particular set of requirements like being in sight and being able to be reached by the driver, but away from direct sunlight and away from direct vision zones to avoid distractions, away from any impact zone in case of collision, away from any wet zone, etc. None of the smartphone producers have to worry about these kinds of requirements, in comparison to the auto industry which must meet these requirements (since some of them are even federal regulations mandated by the government), otherwise the vehicles cannot be sold.

To solve this issue, it is crucial to decouple the infotainment systems from the typical automotive product development process and also to decouple the infotainment system from the whole vehicle, keeping the internal components packaged like “black boxes”, allowing the incorporation of the latest hardware available from companies whose core mission is developing microprocessors and then adopting a well-known platform.

While conducting this research it became evident that in order to become successful, the auto industry must focus on their core business, which is creating vehicles to transport
people, and let other industries develop the complex task of developing portable devices.

This thesis proposes the following system approach for the auto industry:

1) Adopt components available to the smartphone industry.
2) Package the internal components into the vehicle as a separate “black box”.
3) Decouple the “black box” from any other system to mitigate risk and reduce homologation requirements.
4) Don’t develop any interface other than replicating only the main physical buttons available on smartphones by making them redundant with the vehicle.
5) Eliminate any internal development to minimize resources needed.
6) Incorporate the open source and dominant platform available to handle the software interaction such as Android.
7) Let the smartphone industry work on the updates for the platform.
8) Allow third-party developers to program apps on the open source platform.
9) Offer “bare bones” hardware updates to the vehicles by just upgrading the necessary components into the “black box”.

![Android based infotainment system](image)

Figure 17, Black box infotainment design smartphone based, A. Pinto 2013
Chapter 9 Smartphone-based Infotainment and Crowd App Development

There is currently a big gap between the infotainment systems being developed in-house by the OEMs and those developed by the computer industry; Google, Apple and Microsoft are now dominating the voice recognition scene and exposing users to newer ways to interact with their devices. The smartphone industry was able to successfully integrate the portable devices into people’s lives more than the in-vehicle infotainment systems were.

Honda is taking a different architectural approach, outsourcing the design and development of its HondaLink infotainment system by partnering with Aha app. According to industry analysts, the Aha app is way behind the development implemented by other OEMs like Ford, GM and Toyota. “Its current crop of embedded navigation and voice control systems are incredibly long in the tooth, and despite all the features provided by Aha, there’s still a lot missing from HondaLink to make it competitive with Ford’s Sync system and new infotainment setups from top tier automakers like General Motors and Toyota” (Lavrinc, 2012).

Honda’s approach might not be architecturally incorrect, and they recognize that the previous iteration of their HondaLink infotainment system lacked many features that the customers were expecting and was behind the OEM industry standard. Honda decided to outsource their development, an architectural change in the right direction, recognizing that Honda’s core business is not software development. This is an important step, but the architectural change that is missing is the complete embrace of a dominant platform like iOS or Android.

After the evolution of many infotainment systems, Ford and GM are finally adopting the crowd development; in January 2013 both GM and Ford announced that they are opening their infotainment system platforms for third-party developers to create new apps that will integrate with the vehicle (Purewal, 2013).
By adopting crowd development, Ford and GM are now expecting their app database to grow exponentially, avoiding some of the related costs of developing applications for their respective platform. This system architecture approach is not new and is probably based on other open source platforms like Facebook, Apple’s iOS or Google’s Android platform.

In my opinion, this architectural change is half the solution required for bringing infotainment systems in the auto industry up to the smartphone standards. The model was well utilized by Google with their open source Android platform and has demonstrated to be a successful crowd development resource, but the problem now is that in order for developers to actually devote time and effort into integrating the respective GM’s or Ford’s infotainment system they will have to decide which platform they would like to create their app for; this incomplete and fragmented approach will leave the automotive industry once again behind the smartphone industry. Instead of competing with another industry that is years ahead in terms of developers, devoted resources, and user interfaces it would be better to adopt what the smartphone industry has already developed, avoiding the fragmentation that multiple platforms always creates.

General Motors is already experimenting with the integration model, abandoning the in-house infotainment development by adopting technology developed by the smartphone industry; the latest iteration of the MyLink infotainment system developed by General Motors known as MyLink 2nd Generation, is now capable of seamlessly integrating the driver’s iOS phone into the system, allowing a smartphone-based navigation experience, delivering a better and more familiar ecosystem to the driver. GM’s smartphone based MyLink 2nd generation is now able to update maps “on the fly” taking advantage of the full potential of the smartphone. By using the phone’s Internet connection, the system now eliminates the need to pay separate internet access, making the available maps always up to date, incorporating Internet radio, and in the case of iOS devices, letting the “intelligent personal assistant” Siri take over the voice commands, improving voice recognition, enabling voice commands for calling people, playing music, hearing and composing text messages, updating navigation directions, notifications and many other features already included into the iOS, eliminating frustrations from the customer
and eliminating the need for internally developing those features into the in-house OEM
development.

With this architectural change, GM is closing the gap between the automotive
infotainment systems and the smartphone industry; now the customer’s expectations are
exactly what their phone is capable of; in other words, the customer will expect the
infotainment to behave as their smartphone does, and since the 2nd generation of MyLink is
smartphone-based, the customer won’t be expecting something different than what the
smartphone is capable of delivering.

In this particular case, although SYNC was one of the first ones in the industry with an
infotainment system, it does not mean that it will always have the best competitive advantage.
All the advantages that a system has are always based on its’ system architecture.

The latest 2014 Honda Link infotainment system (Mysinchew.com, 2013) is finally
approaching the proposed infotainment system architecture by fully integrating iOS devices
with the vehicle, mirroring the smartphone screen into the vehicle’s cabin, integrating the
phone’s apps, contacts, navigation, music, inbox and many other features that the customer is
accustomed to have in their devices.

This architectural approach might be the solution to how to incorporate technology into
vehicles, recognizing that the infotainment system competition has already ended with the
smartphone industry as the winner, demonstrating that the first stage for successfully
integrating technology into vehicles is recognizing that other industries have done a better job
on incorporating portable wireless Internet technology into people’s lives.
Chapter 10 Adopting the Bring Your Own Device (BYOD) Model

With the architectural change proposed by the newest 2014 Honda system, the customer is not only being offered the latest ecosystem of the industry, but also allowing all the developers currently developing apps for the iOS platform to fully integrate the new capabilities of in-vehicle infotainment systems within their apps.

Many studies conducted by Von Hippel suggest that most of the innovations actually come from the users. He found that often times user “hacks” improve the overall experience by modifying the stock system that their devices came with. Joining a platform and opening the development for others to contribute to it will highly increase the possibilities of adoption by the end user.

In the proposed cloud-based infotainment systems, embracing user innovations will lower the software development costs and increase customer acceptance; the creation of customer forums and development tools will promote users to innovate into the proposed platform. Many of these “hacks” will be developed by the open source Android based community, making the system more appealing and customizable to the driver.

Honda is betting for their new infotainment system to gain rapid adoption by using an already adopted platform rather than developing their own.

By adopting any of the dominant platforms, more services will be offered and it is just a matter of time to find cloud services like Dropbox making their way into the vehicles; not just integrating files and pictures but, with the Dropbox model being adopted through the Android or iOS platform, the user will no longer be required to manually download music into their vehicle. This operation will be made automatically the other way around, so that the vehicle will download the multimedia content that the user owns into their vehicle using the phone’s data plan or by using the Wi-Fi connection available at the driver’s house.
Chapter 11 Risk management.

One of the key elements in the automotive industry is the risk associated with new developments and the potential recalls in the event of failure.

Most of the vehicle recalls are safety related or government mandated. When the drivers are being exposed to “unreasonable” risk of injury, the OEMs are ordered to schedule a recall for the vehicles involved in the failing component.

The best strategy to mitigate the potential risk in the proposed system design would be to incorporate such componentry in a “black box” decoupled system, meaning that the infotainment system will always be physically separated from any other vehicle component.

Another way for addressing risk is introducing flexibility into the design. By adopting “off the shelf” components used by the smartphone industry, most of these components have already been tested and validated, reducing the risk associated to the testing phase.

Every product development process is characterized by facing the same constraints, building better, faster, and cheaper; these constraints are inherent to any development and should be addressed by dividing them into three categories – Technical Risk, Schedule Risk and Cost Risk.

This thesis proposes an architectural change to address technology incorporation in the way of “black box” design, by adopting the already available set of components from a different industry and eliminating or minimizing the interfaces with the internal components of the whole vehicle, most of these risks will be reduced.

Cost Risk – will be minimized if adopting “off the shelf” components developed for a different industry where the technology originated; taking advantage of the main industry who developed the technology and supported the development by allocating financial resources.

Schedule Risk – will be minimized by itself if carry over components are used. In the case
where the technology is available and already proven in a different industry, the required development timing will be reduced since most of the component development is already available. A key factor in this architectural proposition is the use of open source software due to its inherent ease of incorporation. The main software platform in the open source scheme is available for the auto industry to modify and adapt to its unique needs.

Technical Risk – will not be greatly minimized but would be reduced since a similar implementation has already been achieved by the grandfathering industry.

Figure 18, Risk Categories ESD.36 System & Project Management, Olivier L. de Weck
Chapter 12 Conclusions

To fix the in-vehicle infotainment systems, the automotive industry will have to change the architecture of their systems. They will have to introduce systems more similar to Google’s voice recognition by adopting the newest wireless cellular technology but more importantly, incorporate the “cloud” model, where the calculations are done in one server and not within the actual in-vehicle module.

Some of the OEMs have already abandoned the previous in-vehicle model and started adopting the cloud model. Some of these OEMs include Honda’s Link system and GM’s new myLink, which is the evolution of the in-vehicle closed model. Mary Chan, vice president of GM, recently announced during Barclay’s global automotive conference that they will start offering LTE connectivity in their vehicles by 2015; the new upgrade to the 2015 myLink system will also be able to stream music as well as video content by making use of its’ Internet connection.

With these new systems based on real architectural changes, the potential of an OEM dominating the market grow significantly if they are executed correctly. On the other hand, it also seems that the GM is making the same mistakes they did in the past and trying to compete with the smartphone industry instead of adopting the new technology and listening to the customer’s needs and expectations. During the same conference it was also announced that the Internet service will be offered for a $20 monthly fee. This could possibly destroy the potential of having a system capable of being connected to the Internet all the time, and it also could replicate the same mistakes of other systems like Chrysler’s Uconnect.

During the development of this work, I found it interesting that being the first mover or first innovator will not always provide the best competitive advantage, but a comprehensive and holistic system engineering approach will dramatically increase the potential of being the leader. In the case of smartphones, Blackberry (arguably the pioneer in the industry) has now become almost unnoticeable in terms of smartphone industry numbers.
### Worldwide Smartphone Sales to End Users by Operating System in 3Q13 (Thousands of Units)

<table>
<thead>
<tr>
<th>Operating System</th>
<th>3Q13 Units</th>
<th>3Q13 Market Share (%)</th>
<th>3Q12 Units</th>
<th>3Q12 Market Share (%)</th>
</tr>
</thead>
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<tr>
<td>Android</td>
<td>205,022.7</td>
<td>81.9</td>
<td>124,552.3</td>
<td>72.6</td>
</tr>
<tr>
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<td>30,330.0</td>
<td>12.1</td>
<td>24,620.3</td>
<td>14.3</td>
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<tr>
<td>Microsoft</td>
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<td>3.6</td>
<td>3,993.6</td>
<td>2.3</td>
</tr>
<tr>
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<td>1.8</td>
<td>8,546.8</td>
<td>5.2</td>
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<tr>
<td>Bada</td>
<td>633.3</td>
<td>0.3</td>
<td>4,494.7</td>
<td>2.6</td>
</tr>
<tr>
<td>Symbian</td>
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<td>0.2</td>
<td>4,401.3</td>
<td>2.6</td>
</tr>
<tr>
<td>Others</td>
<td>475.2</td>
<td>0.2</td>
<td>683.7</td>
<td>0.4</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>250,231.7</strong></td>
<td><strong>100.0</strong></td>
<td><strong>171,652.7</strong></td>
<td><strong>100.0</strong></td>
</tr>
</tbody>
</table>

Source: Gartner (November 2013)

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**Figure 19, Smartphone market share 2013**

Being the first innovator will certainly provide a lead, but it is better to have an architectural advantage that will overcome any lead over time. As Ford was one of the pioneers in the infotainment development with their SYNC system, they had a lead over the competition; but as previously demonstrated, an architectural advantage like a continual connection to the Internet will give the edge over other platforms.

It is also more important to recognize when the system is not meeting customer expectations and to recognize when it is time to abandon certain developments and just incorporate available technology. It would be easier and more efficient to adopt the open source Android platform rather than each OEM developing their own system based on their own platform. History has proven that whenever there is segmentation, only 1-3 systems will survive; in the case of infotainment systems, there is no clear leader since the lead is already in the smartphone industry.
Investigation done by Fernando F. Suarez indicates the five phases of dominant designs, in this case, the evolution of infotainment platforms follows Fernando's research. In the evolution of in-vehicle systems, there is still not a clear dominant design, but there are dominant designs in the portable infotainment devices, indicating that most likely the vehicle infotainment evolution will be the adoption of an open source platform. Instead of spending resources and trying to compete with the smartphone industry, it will be in the OEMs best interest to integrate and adopt the already dominant design and abandon internal development.

**Figure 21, Fernando Suarez technological dominance**
12-1 Recommendations

The auto industry will definitely have to incorporate newer technology, but not in the same way this industry has been doing it for the past 10 years. The OEMs will have to adhere to their core business. For example, Ford no longer harvests rubber from the forest; instead they decided to leave the job of tire development outside of their scope and just adopt the latest development from their off the shelf suppliers. Reducing the scope of the vehicle system development and concentrating their resources on their core development function to “transport people” will provide the OEM with more resources to compete and have a stronger position, eliminating the effort trying to develop infotainment systems internally.

The adoption of an in-vehicle infotainment system has to be done by seamlessly integrating the customer’s smartphone and expanding the capabilities of the smartphone with the ones available in the vehicle.

Customers don’t want to pay additional fees for something they already pay for to use their devices. The same considerations must be made for similar behavior, since there is no real need for the customer to adapt to a different platform other than their own. In other words, adopting or developing an Android based device in the same vehicle could be the solution that manufacturers are looking for; allowing for third-party app development that will be fed seamlessly to the vehicle through Android’s store, eliminating the need of another app store deployment that will never be able to have enough development without the help of an open source platform.

The core business of Google or Apple is different than any auto manufacturer. These technology companies have more resources to develop reliable systems than the automotive industry, which should not try to compete but rather try to adopt.
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