

The Cambrian Explosion

An automobile is no longer created or used just to get you from point A to point B; the automobile can tell you how to get from point A to point B avoiding the most traffic, the weather you should expect in point B, provide your favorite music along the way, and increase your safety through built in features such as airbags as well as driver assistance features. The fields of shared, digital, and self-driving automobiles, have seen some of the most successful companies recently in the evolution of the automobile. While the automotive industry is experiencing tremendous changes, and may be compared to the Cambrian explosion, there are some barriers that are preventing this evolutionary explosion from representing the industry exactly.

The advancement and integration of technology is influencing and changing the way we approach many tasks in life, not excluding driving automobiles. The dynamics of the automobile industry are experiencing a paradigm shift as technological advancements convert the previous mechanical machine into a computer run machine, case p. 2. This is a fundamental change in the design, construction, and utilization of automobiles. The shift towards computer run machines is opening new pathways for individuals with technological skills and background to enter the industry; whereas previously individuals with mechanical expertise were leading the innovation of the automobile industry. New smaller companies are finding success entering this business, as formerly there were only a handful of massive corporations in control of all aspects. Since January 2012, entrepreneurs founded 164 companies with funding exceeding \$100,000, case p. 4. These new companies are creating original technologies that provide competition for the older companies. The older companies have never experienced this level of competition before and it has become destructive to these well-established companies in some situations, case p. 2. The

companies that are rooted in mechanical automobiles are having a hard time keeping up with the innovations of the technological based entrants to the industry.

The organizational structures of the companies that are designing components of automobiles is shifting. Traditional, gigantic car companies typically utilize a hierarchical structure. Now with smaller companies entering the scene, there is a higher span of control and more autonomy as the company's structure is flattening. This strategic flexibility provides new firms a competitive edge, case p. 2.

Not only are the technological changes introduced by the emerging companies affecting the automobile industry, they are causing an unequivocal impact on economic growth of the whole economy, case p. 2. Previous waves of technology innovation have characteristics of periods of great experimentation and entrepreneurial activity resulting in the acceptance of innovative products shortly after, case p. 2. An interesting aspect of these waves of technological innovation is that most fundamental innovation has occurred during the initial years of the industry's existence. During this time new companies can compete more effectively to impose standards before the arena becomes saturated with new entrants. The economy experiences great expansion of innovative companies and alterations of the accepted standards during this exponential growth period.

The automobile industry has experienced growth and a modification of the accepted standards recently, however this process is taking time to evolve and innovators are experiencing failures along the way. The Cambrian explosion occurred in a millisecond of time, case p. 1, but the progress of the automobile industry is taking time to develop. This is one of the ways in which the Cambrian explosion is not an ideal analogy for the changes occurring in the automobile industry. An important step in the evolution of the automobile was the introduction

of alternative fuels which has ultimately led to the introduction of electric vehicles. One of the first widely accepted alternative fuels was E85 which is composed of 85% ethanol and 15% unleaded gasoline. This fuel is typically derived from corn, which as a quickly reproducible substance is considered friendlier for the earth. The Energy Policy Act of 1992 declared E85 an alternative fuel and it spread across the country from 1997-2002 (Ethanol History, 2011). This alternative fuel has not only stopped increasing in its popularity, but it is a challenge to find a gas station today that supplies E85 gasoline, except in the Midwest. This is an example of an innovation in the automobile industry that after 26 years of effort has not had a major impact on the way we operate vehicles today. Since cars were not readily available to individuals until the implementation of the assembly line by Henry Ford in 1913, cars have been available for approximately a century. One quarter of that time E85 has been obtainable, but this alternative fuel has not impacted the automobile industry in a significant manner.

There have been companies, such as Better Place, that created an innovative new feature for the automobile, however the company was ultimately unable to find success. Better Place designed and sold a car without a battery and swapped out the battery when needed, case p. 3. This company grew and thrived from 2007-2013 however ultimately went bankrupt. Better Place is another example of how not finding success in the evolution of the automobile industry is unlike the Cambrian explosion. However, Better Place did threaten to change the economic foundations of a well-established industry as a startup, which provided a foundation for other new companies to continue to make progress in the technological innovations of the automobile.

The Cambrian explosion represented a major diversification of other organisms, case p. 1, and resulted in new species of animals. The evolution of automobiles is taking smaller steps at a time and existing, gigantic producers are funding most research and development. The

research and development is affordable only to previously existing, massive producers of automobile, for example Volkswagen has the largest budget for research and development in the world, case p. 3. Thus, the changes in the automobile industry are not resulting in new species of automobiles as much as alterations of previously existing vehicles.

Christiansen's Digital Disruption

Christiansen defines disruptive technology as that which results in worse performance for previously existing products. This is opposed to sustaining technology which enhances performance of established products, Introduction p. 7. A disruptive innovation results in a new firm overriding an existing company. The new firm only needs to overcome the expectations of the old firm in a new dimension, not necessarily the old firm's performance, case p. 2.

Shared cars are an example of a digital disruption in the automobile industry. Shared car companies are overcoming the expectations of previously established car companies in a new dimension of the utilization of the car, not the creation of the car. Sharing a car does not attempt to improve the performance of the car from a fundamental, mechanical standpoint. However, sharing cars may result in worse performance of the cars due to individuals driving the cars who are not owners and thus have less vested interest in the wear they put on the car as they are driving.

Digital automobiles are encompassing the arenas of navigation and communication systems, driver assistance programs, electrical vehicle systems, and data processing. Entrepreneurs are adding these technologies into existing automobiles and thus enhancing their performance. With the exception of electrical vehicle systems, the firms that are creating these new digital technologies are not attempting to take over the existing car companies, but are

adding value to the existing product. Therefore, these digital automobile technologies are considered sustaining technology.

Self-driving automobiles are not disruptive technology as they are seeking to improve the existing product through increasing safety. Christiansen explains that most established companies do not invest in disruptive technology due to its typical commercialization in emerging markets and lack of interest by the most profitable customers, introduction p. 9. This is not true in the case of self-driving automobiles where well established companies are investing a lot of money in research and development. Developed markets, such as the US automobile market, as well as wealthy customers are very interested in self-driving automobiles.

Disruptive technology is also described as typically cheaper, simpler, smaller, and more convenient, introduction p. 9. The convenience and low cost of shared cars is a driving factor of this innovation which contributes to its disruptive technology identification. Digital and self-driving automobiles maybe simpler and more convenient to operate ultimately, but they are certainly not cheaper and currently they are much more complex than the existing product. Digital and self-driving automobiles do not fall into the category of disruptive technology.

The Nexus of Forces

The Nexus of Forces is the compilation of social, mobile, cloud, and big data to create a user driven ecosystem of modern computing. Within a company the Nexus of Forces will result in the shifting of control, hyper flexibility, and extreme collaboration, lecture week 1. For users in the ecosystem, the Nexus of Forces increases choices as well as the scale and reach of providers. Ultimately there is a shorter time gap between an individual's desire and receipt of that desire.

Shared automobiles are a great example of all aspects of the Nexus of Forces working together. A company creates a social network that individuals access with their mobile devices to find the nearest available automobile. The vast scale and access of this network depends on the cloud. The companies have an opportunity for collection and analysis of big data to improve the accessibility and availability of their fleet of cars. The management, operations, and technology departments must work together in extreme collaboration and flexibility to be successful in all areas the Nexus of Forces encompasses.

Due to the variation inherent in the different types of digital technologies studied, it is not as obvious how the Nexus of Forces applies to digital technologies in the automobile industry. However, most advancements require the collection and utilization of big data to determine the desires of consumers as well as opportunities for improvement during the production process. Digital technologies such as navigation and communication systems and data processing are connected to the cloud and often run on a mobile device. Other digital technologies such as driver assistance programs may be self-contained within the vehicle. However, if digital automobile companies do not keep up with the advancements made due to the Nexus of Forces they will be left behind in this technology loving society.

Self-driving automobiles are a fully functioning mobile device themselves. There must be a navigation system of some sort in the vehicle, so that the automobile knows how to get where it is going. This navigation system will be connected to the cloud. Companies developing self-driving automobiles have an opportunity to collect and analyze big data to improve the functionality of their systems.

Digital Natives and Digital Immigrants

Startups are colonizing new architecture for the automotive industry in the niches of shared, digital and self-driven vehicles, case p. 1. As digital natives the startups are thinking and processing information fundamentally different than their predecessors, Prensky p. 1. These startups vary from the traditional automobile giants, in that they are beginning with the technology, not necessarily the automobile. Only 25% of the successful companies studied have at least one experienced manager coming from the automobile industry, case p. 6. Experience in the industry does not appear to be a decisive factor as to whether a company will find success. Outsiders with digital expertise are leading the changes in the automobile industry. Existing companies (digital immigrants) are purchasing stakes in new companies (digital natives) or purchasing the whole company, case p. 7.

The advantage of digital natives is that they are comfortable with the technology and are simply adapting their expertise to a new situation involving automobiles. The advantage of digital immigrants is that they appear to bring with them a background in the automotive industry and can help determine how the new advancements will affect existing situations. The disadvantages of each group, digital natives and digital immigrants, are the advantages of the other group. Although digital natives bring with them technology expertise, they are lacking industry expertise. Therefore, digital natives and digital immigrants need to work together through the changes occurring in the automotive industry to ensure the most effective use of technology while incorporating experts in the industry.

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1. Cambrian Period and the Automobile Industry

The Cambrian period started about 545 million years ago, and it is recognized as an evolutionary time where Earth exhibited the rapid appearance of a wide variety of animals.¹ The fast pace conferred to the Cambrian period is now discussed by scientists, who argue that this “explosion” of new creatures was a more gradual change.² Nevertheless, the Cambrian period still represents a critical point in time, where Earth not only experienced a diversification of life but also witnessed the results of it, such as new ecological interactions and the increased complexity of life.³

The evolution in the automobile industry, specifically the current blossoming of diverse transportation services and car technologies, resembles the Cambrian Period. With the invention of the first gas-powered car in 1885 by Karl Benz⁴ and the proliferation of cars in the early 1900s with Ford’s implementation of the assembly line, the automobile industry did not observe many changes until mid-1900s. Turn signals were only added in 1939, power steering in 1951, cruise control in 1957, and heated seats in 1966.⁵ Additionally, “in the late 80’s and early 90’s, keyless entry systems, electric doors and windows, sunroofs, and CD players began to gain popularity.”⁶

¹ Royal Ontario Museum and Parks Canada. "The Burgess Shale." The Cambrian Explosion - Origin of Animals and the Cambrian Explosion - Science. June 10, 2011. Accessed February 03, 2018. <http://www.burgess-shale.rom.on.ca/en/science/origin/04-cambrian-explosion.php>.

² "Timeline - The Cambrian explosion: Life on the rise." BBC Earth. Accessed February 03, 2018. http://www.bbc.co.uk/science/earth/earth_timeline/cambrian_explosion.

³ Royal Ontario Museum and Parks Canada. "The Burgess Shale." The Cambrian Explosion - Origin of Animals and the Cambrian Explosion - Science. June 10, 2011. Accessed February 03, 2018. <http://www.burgess-shale.rom.on.ca/en/science/origin/04-cambrian-explosion.php>.

⁴ "Evolution of the Automobile." I Drive Safely. August 16, 2010. Accessed February 03, 2018. <https://www.idrivesafely.com/blog/evolution-of-the-automobile/>.

⁵ Ibid.

⁶ Ibid.

However, the variations observed in the automobile industry throughout the 1900s were merely new features, while the structure of the car and the industry remained the same. Indeed, at the beginning of the 21st century, the automobile industry began to show a spur of diversification similar to the Cambrian Period. Together with the growing environmental concerns and the proliferation of urban areas, new concepts started to emerge. In 2000, Toyota released worldwide its first mass-produced hybrid electric vehicle.⁷ Tesla Motors released its first electric car in 2008,⁸ and in late 2010, the Chevy Volt (hybrid) and the Nissan LEAF (all-electric) were released in the U.S. market.⁹ On the other hand, car sharing started to gain traction in the U.S. in the early 2000s, with the appearance of Zipcar and Flexcar.¹⁰ Moreover, discussions about the autonomous vehicle spiked in the 2000s and 2010s, with the design of new self-driving cars and the creation of races to impulse the momentum,¹¹ such as the DARPA Grand Challenge.¹²

2. Automobile Industry and the Digital Disruption

Scientists believe that multiple causes acting simultaneously, rather than one single stand-alone process, explain the Cambrian explosion.¹³ The same seems to hold true in the evolution of the car industry. Some of the technological advancements encountered in the 2000s and 2010s that created the perfect environment for the automobile transformation were (1) the expansion of satellite communications, (2) the development of other communication technologies, (3) the enhancement of

⁷ "The History of the Electric Car." Energy.gov. September 14, 2014. Accessed February 03, 2018.

<https://www.energy.gov/articles/history-electric-car>.

⁸ Gregersen, Erik, and Barbara A. Schreiber. "Tesla Motors." Encyclopædia Britannica. October 16, 2017. Accessed February 03, 2018. <https://www.britannica.com/topic/Tesla-Motors>.

⁹ "The History of the Electric Car." Energy.gov. September 14, 2014. Accessed February 03, 2018.

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¹⁰ "A brief history of car sharing." News RSS. December 14, 2011. Accessed February 03, 2018.

<https://www.portlandoregon.gov/transportation/article/370287>.

¹¹ "Autonomous cars through the ages." Wired.com. February 6, 2012. Accessed February 03, 2018.

<https://www.wired.com/2012/02/autonomous-vehicle-history/>

¹² Nguyen, Tuan. "How a 1930's Exhibit Set the Stage For Driverless Cars." ThoughtCo. March 07, 2017. Accessed February 03, 2018. <https://www.thoughtco.com/history-of-self-driving-cars-4117191>.

¹³ "What Caused the Cambrian Explosion?" NCSE. November 08, 2017. Accessed February 03, 2018. <https://ncse.com/blog/2013/10/what-caused-cambrian-explosion-0015114>.

sensors, and (4) the evolution of Artificial Intelligence (including the improvement of algorithms, data collection practices, and machine learning).

The innovation propelled by this technological evolution made the competencies of old industry incumbents obsolete and created new market linkages.¹⁴ It also resulted in a new dominant design for the automobile: shared, digital, and self-driving. According to Christensen in “The innovator’s dilemma: When new technologies cause great firms to fail,” products based on disruptive technologies are cheaper, simpler, and frequently, more convenient to use. However, the product presents a worse performance, at least in the near-term.

The shared, digital, self-driving car seems to fall into these categories. For an urban dweller that might commute to work by foot, bike, or train, it is much cheaper to use a shared car when necessary than buying a car and spending on regular maintenances. Moreover, the digital aspect of the car and the car services also make the product – going places in a car – simpler. Instead of searching, bargaining, and deliberating on the decisions of buying a car, users now can order a car service or find a shared car with a few clicks on their phones. Finally, self-driving cars are more convenient, as the users can enjoy the commute time doing other activities. The cost savings and convenience from the new car design can also benefit society at large. Research shows that self-driving cars can increase road capacity and reduce accidents.¹⁵

Throughout the 2000s and 2010s, society observed new companies in the car industry overcoming market’s expectation in some new dimensions of performance.¹⁶ Zipcar, for example, used the flexibility of a small business and the interest of angel investments as a competitive advantage in its beginning.¹⁷

¹⁴ Ferràs-Hernández, Xavier & Tarrats-Pons, Elisenda & Arimany Serrat, Núria., "Disruption in the automotive industry: A Cambrian moment." *Business Horizons*. Vol 60, Issue 6. Nov-Dec 2017.

¹⁵ Nguyen, Tuan. "How a 1930's Exhibit Set the Stage For Driverless Cars." *ThoughtCo*. March 07, 2017. Accessed February 03, 2018. <https://www.thoughtco.com/history-of-self-driving-cars-4117191>.

¹⁶ Ferràs-Hernández, Xavier & Tarrats-Pons, Elisenda & Arimany Serrat, Núria., "Disruption in the automotive industry: A Cambrian moment." *Business Horizons*. Vol 60, Issue 6. Nov-Dec 2017.

¹⁷ Eha, Brian Patrick. "Zipcar Timeline: From Business Idea to IPO to \$500 Million Buyout." *Entrepreneur*. January 02, 2013. Accessed February 03, 2018. <https://www.entrepreneur.com/article/225399>.

Uber, on the other hand, disrupted the cab industry by launching its business with nothing to lose, while incumbents were too afraid to experiment and risk their current strategy.¹⁸ Those bold entrepreneurial moves also point to the era of disruption that the car industry is experiencing.

3. New Car Design and The Nexus of Forces

The new dominant car design (shared, digital, and self-driving) involves the nexus of forces (social, mobile, cloud, and data).

- Social: In the digital world, users are becoming more sophisticated and with higher expectations.

The social aspect in the new car design is very important. Users can now share their dissatisfaction and experiences in real time. Because users can read each other's comments, it becomes a collective experience. Furthermore, with the digital aspect of the new car design, users and companies can trace back with precision most of the incidents and/or comments. For example, if a user complains about a specific experience, a company can investigate the user profile and the service history and localize information such as the day, the area, and the car at service. As the user can now experience his/her time in different ways while riding a self-driving car, companies can also promote an online social experience to users during the ride.

- Mobile: Users want to request services from anywhere at any time. Consequently, mobility is key to the success of the new design. The development of GPS technologies can help users find with accuracy a shared car location, while car service providers can also identify the users' locality. Moreover, users and providers can easily communicate through mobile technology. The development of apps, the compatibility with various mobile devices, as well as the updates to achieve better customer satisfaction are also essential characteristics for users when experiencing the new car design.

¹⁸ Ferràs-Hernández, Xavier & Tarrats-Pons, Elisenda & Arimany Serrat, Núria., "Disruption in the automotive industry: A Cambrian moment." *Business Horizons*. Vol 60, Issue 6. Nov-Dec 2017.

- Data: The information shared on social media is relevant to users and providers to understand and evaluate the services. For provider specifically, the data shared on social platforms can assist in diagnosing issues and examining areas for improvement and investment. On the other hand, the new design collects a large amount of data, due to its digital features. Data gathered by the car sensors are used not only for R&D but also to navigate the car that is now self-driving. While information such as the amount of battery spent considering various speeds might help on the design of more efficient cars, other information such as the recognition of a stop sign can help the car navigates itself safely.
- Cloud: The cloud is the basis of all the Nexus Forces. “Without cloud computing, social interactions would have no place to happen at scale, mobile access would fail to be able to connect to a wide variety of data and functions, and information would be still stuck inside internal systems.”¹⁹ In the new car design, the cloud is important to store the data from social interactions, and as well the data collected by the cars. It will also be an instrumental tool for the self-driving cars to access information and make decisions along the way. For example, information such as traffic patterns and weather conditions can be easily accessed on the cloud, and it can assist a self-driving car making decisions to avoid roads and plan its speed.

4. Digital Natives & Digital Immigrants

Enterprises in the automotive industry can be divided between Digital Immigrants and Digital Natives. While incumbents such as General Motors and Fiat Chrysler might represent Digital Immigrants, new car manufacturers and car service providers such as Tesla and Uber might portray the role of Digital Natives.

The automobile Digital Immigrants were slow to become more social media oriented, and they are still behind in the pace of innovation. While Tesla was investing in electric cars in the early 2000s, GM

¹⁹ Thompson, Eric. “Lecture - The Nexus of Forces” University of Colorado Denver, Denver, CO. Accessed February 03, 2018.

became serious about a hybrid offering in mid-2010s²⁰ and released an all-electric vehicle only in 2017.²¹ Fiat Chrysler is finally entering the race of hybrids in late 2010s, even announcing that “most of the fleet will be hybrids by the 2020-to-2025 timeframe.”²²

Indeed, the purchase of 9% equity ownership of interest in Lyft²³ shows that GM is trying to keep up with the automobile disruption. Although GM did not launch a car service itself, it opted to release a program (“Express Drive”) in partnership with Lyft,²⁴ in which drivers may rent GM cars on a weekly basis. GM has partnered with Uber²⁵ on a similar initiative as well.

Additionally, the incumbents are also attempting to stay relevant in the industry by acquiring and initiating partnerships in the sphere of autonomous vehicles. In 2016, while GM acquired Cruise Automation Inc.²⁶ (an autonomous vehicle technology company), Fiat Chrysler announced a collaboration with Waymo²⁷ (formerly the Google Self-Driving Car Project) with inclinations for mass-production of self-driving cars.²⁸

While the Digital Natives have the advantage to move faster and experiment more, with the help of angel investors and venture capitalists, Digital Immigrants have the advantage to wait and validate if a new technology is just a fad or a new trend by observing the Digital Natives. Furthermore, Digital

²⁰ Rosevear, John. "General Motors Gets Serious With the 2016 Chevrolet Malibu Hybrid." The Motley Fool. March 23, 2016. Accessed February 03, 2018. <https://www.fool.com/investing/general/2016/03/23/general-motors-gets-serious-with-the-2016-chevrolet.aspx>.

²¹ "ELECTRIC AND HYBRID VEHICLES." Electric Vehicles: Hybrid Vehicles | Chevrolet. Accessed February 03, 2018. <http://www.chevrolet.com/electric-hybrid-vehicles>.

²² Edelstein, Stephen. "Most Of Fiat Chryslers U.S. Vehicles Will Be Hybrid By 2025, CEO Says." Green Car Reports. November 05, 2015. Accessed February 03, 2018. https://www.greencarreports.com/news/1100750_most-of-fiat-chryslers-u-s-vehicles-will-be-hybrid-by-2025-ceo-says.

²³ General Motors, 2016 10K, p. 6. <http://www.gm.com/content/dam/gm/mol/docs/10-K.pdf>, accessed February 03, 2018.

²⁴ Ibid.

²⁵ Ibid.

²⁶ General Motors, 2016 10K, p. 6. <http://www.gm.com/content/dam/gm/mol/docs/10-K.pdf>, accessed February 03, 2018.

²⁷ Fiat Chrysler Automobiles, 2016 Annual Report, p. 8. http://reports2016.fcagroup.com/downloads/financial/FCA_2016_Annual_Report.pdf, accessed February 03, 2018.

²⁸ "Fiat Chrysler to Supply Thousands of Pacifica Hybrid Minivans to Waymo for Driverless Ride-Hailing Service." Body Shop Business. January 31, 2018. Accessed February 03, 2018. <http://www.bodyshopbusiness.com/fiat-chrysler-supply-thousands-pacifica-hybrid-minivans-waymo-driverless-ride-hailing-service/>.

Immigrants have more capital to invest in R&D, and more cushion to make mistakes. Digital Natives, on the opposite side, do not usually enjoy the extensive capital presented by Digital Immigrants and can shut down the doors if the investment in innovative ideas does not provide enough return.

Finally, Digital Immigrants can benefit from its brand influence. These industry giants can easily attract partnerships in order to stay on track with market trends. Digital Immigrants also have a broader ecosystem developed throughout the years that might be of advantage when looking for ways to remain competitive. Digital Natives, on the other hand, have to build brand recognition and might not experience the easiness to establish partnerships at the beginning.

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Question #1

There are many parallels that can be made between the Cambrian Explosion and the current progress shown in the automotive industry. Multiple firms are beginning to compete, new technologies that have not historically been part of automotive deliverables are being researched and incorporated into designs, and outside expertise is flocking to develop new automotive innovations. These developments highlight that the automotive industry is ripe for an explosion of new technologies and products. These shifts in industry dynamics and the potential new offerings that are currently being developed to meet customer needs and expectations will facilitate the rapid development and evolution of automobile offerings. The removal of barriers to entry, new technology development, and contributions of outside experts that are new to the automobile industry, when combined, will accelerate the eruption of new offerings in a manner that is analogous to the Cambrian Explosion when new a variety of organisms came to be through the phenomenon of diversification.

Historically, automobile development has been a costly endeavor that only the major corporations were willing to undertake. In fact, the old automotive industry was a "fortress" industry and it was generally accepted that it was nearly impossible for a startup to compete or even threaten the steadfast mainstays [1]. The barriers to entry have been significantly reduced over the past few years and now startups and entrepreneurs are

able to target customer needs that have yet to be met by the historical automobile giants. The combination of both technology and novel business models, like in the cases of Uber and Tesla, has effectively removed barriers to entry. The new facets of the automobile industry, such as electric vehicles and autonomous driving, are being pursued by many companies, including the historical giants and new startups [2]. If the historical barriers to entry were still intact, then the major players would be the only ones undertaking some of this new technology and product development. With the emergence of “new technology-based firms (NTBFs),” focusing on some of the very specialized areas of driverless vehicles and battery pack efficiency, the barriers to entry no longer exist, or at the very least, they have been significantly reduced to the point where new organizations can participate in automobile technology development [2]. Insurmountable barriers to entry have been eliminated, or drastically reduced, because new organizations, firms, and entrepreneurs now can compete with the former industry giants. The entry of new firms to compete will breed competition and facilitate acceleration of new technologies in a race to be the first to market with the latest and greatest solutions for customers.

As previously discussed, the elimination or reduction of barriers to entry will allow new firms to compete with the established automotive players. These new entrants into the automobile industry are not focused on the historical, needed technologies, such as motors or mechanical component development, but they base their technical contributions around consumer technologies that can be enhanced and applied to cars. For example, autonomous cars will require a myriad of sensors and advanced computer processing power that can be found in modern cameras and high performing gaming PCs. As cars integrate multiple sensor platforms and packages, the automobile will essentially

become a hub for information as it is “transformed into a big data orchestrator [3].” These technologies are well established in other industries, but are considered relatively new for automobiles. As more and more consumer-based technology is integrated into cars and leveraged in the automobile industry, the number of new products with enhanced functionality that is enabled by advanced sensors and powerful data processing will cause a spike in development activity and subsequent product offerings.

Finally, the influx of human resources and capital that have not historically participated in the automobile industry serve as a bellwether signal for rapid expansion. The majority (55%) of companies that are new participants in automobile technology development have founders with advanced science or technology degrees and these founders may not have a specific focus on technologies that have been reserved for automobiles or even have experience in the car industry [4]. Having new opinions and intersections of ideas from other industries that are rooted in different technological disciplines indicates that barriers to entry have been removed since transitions into the automobile industry have been popular among those with different, yet advanced, backgrounds, experiences, and education. As advancements are made in high-tech disciplines outside of the traditional automobile research and development pipelines, opportunity will continue to present itself for engineers and scientists to transition their findings, rooted in other industries, to the automobile industry as interest in electric, connected, and autonomous cars continues to grow and becomes realistic.

Like the explosion of biodiversity in the Cambrian period, the automobile industry is well primed to undergo a similar expansion of products and producers. The erosion of barriers to entry, application of technological advances to cars, and the migration of

scientists and engineers with diverse backgrounds will allow for an entrepreneurial approach to automobile development that has been controlled, until now, by a powerful few. New firms, competing against the established industry, with new technologies and ideas from different disciplines will create a metaphorical explosion of new products.

Question #2:

When looking at the overall automobile industry, it is hard to align the overall change in functionality and performance of new cars under the definition of disruptive innovation. For a disruptive innovation to occur, all that is needed is for a product to “overcome the expectations of the old firms’ market in some new dimensions of performance [2].” For automobiles, individual consumers, for example, will always have performance expectations with respect to gas mileage, price, and maintenance costs. With the new car designs that include novel technologies, these types of performance characteristics remain the same and continue to simply improve in many cases. This is in direct contrast to Clayton Christensen’s definition where disruptive technologies are usually simpler, first commercialized in emerging or smaller markets, and do not appeal to the most profitable customers [5]. In other words, the development of new cars with advanced technologies and innovations should not be considered disruptive since they fail to meet the appropriate criteria. With that said, if the overall industry is decomposed into the “new dominant design components” of shared, digital, and self-driving automobiles, the emergence of disruptive innovations becomes clearer.

With shared vehicles, the characteristics of performance drastically change from typical consumers expecting to maximize gas mileage and minimize maintenance costs over the life of their purchase or lease. In light of the concept that disruptive innovations

often are simpler than the incumbent products, having shared cars, such as with car2go, greatly simplifies the overall car ownership process. Not having to worry about insurance, registration, upkeep, or parking can drastically simplify the car ownership and care requirements for someone that needs to use a car. With shared vehicles entering markets in big cities, it may seem like large, established markets are the targets, but in reality, a small subset of these large cities represents the intended customer. By narrowing the market to those that live in cities that need to only occasionally use a vehicle, the concept of shared automobiles meets the criteria of disruptive innovation in that the market is smaller and emerging as compared to the standard car buyer market. Finally, the disruptive innovation trait of a technology not appealing to the most profitable customer is satisfied by shared automobiles. Those that are the most profitable customers for the established car manufacturers would not find appeal in sharing a small car with strangers when they have the means to purchase and care for their own car, or even multiple cars. When the concept of vehicle sharing is examined with respect to the rest of the automobile industry, it meets all of the requirements of a disruptive innovation since the car use process is simplified, there is appeal to a small market, and there is little attraction to the traditionally high profit customers.

Digital communications and connectivity are invading nearly every facet of life all over the world. Presently, new automobiles have options for integration with cellular phones, Wi-Fi, and can even communicate diagnostics and download new firmware over wireless connections. Enabling the ability to talk on the phone or even dictate a text over voice commands without having to touch a physical phone greatly simplifies driving and performing multiple, complex tasks simultaneously. Newer cars, with these advanced

connectivity features, are available to the market that is interested in purchasing a new automobile. Since the pre-owned market can be considered large, the market size for those interested in a new vehicle with connectivity features may be considered relatively small. While hands-free devices and connection abilities add convenience, the appeal may not be great for the customers that contribute the most to profit. For these customers, as an example, having the dealer update component firmware over a standard connection or a wireless connection may make little difference because the ultimate results are equivalent. Having a digitally advanced car fulfills the required traits of disruptive innovation since the technology facilitates hassle-free and simple driving, is appealing to a smaller market when compared to the total population that might be interested in a vehicle purchase, and makes little appeal to high profit customers because there may be no noticeable positive impact on how they use the car.

Self-driving cars are mentioned at least daily in the mainstream press and they, like the concept of shared and digitally connected cars, meet the established criteria of disruptive innovation. The process of driving can be complicated and requires advanced perception, sensing, and the ability to react. Autonomous vehicles greatly simplify driving for anyone. Since driving becomes an uncomplicated task with a driverless car, one could consider the new wave of technologies that enable self-driving cars' functionality to be well aligned with the principals of disruptive innovation. To be interested in a self-driving car, one must be willing to take a safety related risk and have a desire to be part of the innovative, first-adopter market segment. This slice of the market has traditionally been small, and the size is further reduced if the anticipated high cost of self-driving cars is added as a variable, which aligns with the disruptive innovation criteria of having utility in

a small, emerging market. Finally, to meet the last requirement of disruptive innovation, self-driving cars do not appeal to the most profitable customers of car manufacturers. As of today, the most profitable customers are simply those that purchase the highest margin automobiles and this is not necessarily related to any specific technology or feature that may exist. For example, an added feature may add revenue, but the cost-of-goods to add that feature may end up diminishing profit if the margin is low or negative. In contrast to the overall introduction of new cars not meeting the definition of disruptive innovation, self-driving cars fit the definition well since they make driving simpler, appeal to smaller, newer markets, and are not necessarily appealing to the existing set of the most profitable customers.

Question #3:

When considering social, mobile, cloud, and big data technologies, or the “Nexus of Forces,” there is a direct link to the aforementioned disruptive innovations of shared, digital, and self-driving automobiles.

Sharing automobiles creates a type of a social network since all users share common goals and objectives in being able to use a car service at time and days that are convenient to them. These sharing networks also depend on mobile technologies, the cloud, and data management to ensure the right information is delivered to the user at the appropriate time to facilitate their car sharing experience. The digital functionality that is enabled in the latest generation of automobile also parallels the “Nexus of Forces.” Inherently, connected vehicles and those with advanced sensor technologies leverage mobile communications, cloud technologies, and big data methodologies to perform functions that range from being able to make hands-free calls to being able to predict when an engine component will fail for preventative maintenance purposes. On-line chat

rooms and message boards that allow owners of these new technologies and experiences also facilitate the social aspect of connected, digital automobiles. Similarly, to digitally connected cars, self-driving automobiles satisfy the four requirements of the “Nexus of Forces” principals. For self-driving automobiles to function safely, they must all be able to communicate with each other. This car-to-car communication, while not necessarily between people, creates a social network that allows cars to drive safely and effectively. Mobile connectivity also enables functionality needed to ensure that these autonomous vehicles drive according to their prescribed performance and obey sets of accepted traffic rules. Similarly, cloud technologies and approaches to managing big data from all of the on-board sensors and technologies are also required to facilitate the driverless experience. The latest generation of shared, digitally enabled, autonomously driving vehicles directly reflect the “Nexus of Forces” that will lead to new business opportunities and models while forcing the incumbent automobile manufacturers to adapt their strategies and architectures to remain competitive.

Question #4:

In the automobile industry, the older incumbent companies, such as General Motors, Ford, Toyota, and Daimler, can be considered “Digital Immigrants” because they have been forced to incorporate externally developed technologies into their product development activities. “Digital Natives” in the car industry, like Waymo and Uber’s special self-driving car project, have been the bellwethers for bringing novel technologies and innovations to what some may have considered a fairly stale industry. For the older companies that have been well established in the automobile industry, they have been able to satisfy the needs of the current generation of their customers for a long period of

time. The historical demographics that they have appealed to are now shifting towards a younger generation of “Digital Natives” that expect, if not demand, technology to be included in every aspect of their lives. While it may seem that there are significant challenges for “Digital Immigrants” to keep up with fast-paced technology development, they are actually well suited to incorporate the external, inorganic developments of companies that have been born from the “Digital Native” generation.

The historic “Digital Immigrants” will be required to incorporate the latest technologies into their products to remain competitive as user needs shift since younger generations will become the primary customers for cars in the immediate future. Undertaking research and development to pursue digital connectivity and advanced sensors to accomplish the ultimate goal of creating an autonomous vehicle is an expensive endeavor. To avoid the expense and potential risk that follows novel research and development programs, the incumbent vehicle companies have the luxury of learning from and investing in some of the “Digital Native” companies and their technologies. In other words, from both the cost and risk perspective, “Digital Immigrants” should leverage inorganic developments, which can eventually be incorporated into a product development pipeline through licensing or acquisition, to reduce the risk of having to undertake these types of programs without having the necessary expertise or resources. On the other hand, the current stalwart car manufacturers carry the risk of losing a first-to-market advantage if they do not own the technology themselves. Similarly, they run the risk of having to pay a premium on someone else’s technology that they will be required to incorporate in their products, but that was developed by someone else, to maintain a competitive edge. The main advantage of being a “Digital Immigrant” is that

development risk can be assumed by an external entity, but the eventual incorporation of new technology might come at a premium since it was not developed organically or in-house.

“Digital Natives” have the ability to be flexible in their business models and have the freedom to undertake product development efforts without the constraint of needing to support existing customers. Because these newer entities may not have an established customer base, as opposed to the large car manufacturers, they have little responsibility to ensure that past customers remain satisfied. This affords flexibility and resources needed to undertake new projects that would otherwise not be possible under a “Digital Immigrant” portfolio. With that said, this flexibility and agility may not allow the “Digital Natives” to be competitive in the car industry on their own. While they may develop novel and interesting technologies that meet the needs of the latest generation of car purchasers, their contribution is only a small piece of the overall functionality of a car. For example, a “Digital Native” startup may develop a best-in-class self-driving module with artificial intelligence, but they will not have the expertise or ability to develop an engine or battery module for an electric car. Because the “Digital Natives” lack expertise and experience with regard to creating a comprehensive solution, they may not be able to compete in the automobile industry despite their ability to have flexible and agile business models and technologies.

There are certainly positive and negative aspects to being classified as either a “Digital Native” or as a “Digital Immigrant.” Those companies that fall into the “Digital Native” category have the ability to quickly pivot as technology changes, but they lack the ability to create an all-inclusive solution for customers. Large car companies may lack

the internal expertise and the ability to develop technological innovations for vehicles, but they have, in most cases, decades worth of experience in meeting a full suite of customer needs. If existing car companies were to leverage the developments made by “Digital Natives,” they would be able to remedy the gap of having the latest technology in their products while still being able to offer a full, complete car solution to customers. Since there are shortcomings in being either a “Digital Immigrant” or a “Digital Native,” the best possible solution is to combine the positive aspects of both classifications. Existing car manufacturers would be wise to partner with “Digital Immigrants” to avoid the risk associated with new technology development and remain able to offer a fully functioning and complete vehicle to customers.

References:

- 1) Case Study – Page 857
- 2) Case Study – Page 856
- 3) Case Study – Page 858
- 4) Case Study – Page 860
- 5) Innovator’s Dilemma Expert – Page 9