A Systems Perspective on the Future of the Automotive Industry

by

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Abstract

This thesis provides a systems perspective on the trends anticipated in the global automotive industry and their impact on the industry value chain.

The global trends which are the emergent properties of the automotive industry, their effects, and the corresponding challenges that they bring to the automotive companies are analyzed in the thesis. These changes have also been used as a base to identify the constraints and the opportunities that are foreseen ahead for the automotive companies.

The 3 global trends that have been analyzed in detail are – technology advancement which is leading to disruptive innovation, changing consumer behavior from ‘owning to sharing cars’ which is leading to business disruptions, and finally the emergence of the East which marks the entry of Chinese companies as global car makers.

The analysis of each global trend has been supplemented with a case study to better understand their effects.

For analyzing technology disruptions, autonomous vehicle technology has been studied. From improving traffic safety and increasing driving speed, to reducing travel times, traffic congestion, energy consumption- self-driving cars can be beneficial in many ways. However, the operating environment for autonomous vehicles is a large complex sociotechnical system that must integrate existing legacy and future transportation systems. Successful implementation will need to consider social aspects- both from an individual’s personal preferences, and also from the
perspective of various global laws and regulations. To better understand this part, a systems analysis on implementing autonomous vehicles is presented in case study 1.

The business disruptions in the industry have been studied through the lens of Uber’s business development and strategy which is highlighted in case study 2.

To study the emergence of Chinese car makers in the global automotive market, Qoros Automotive Co. Ltd is analyzed through case study 3. This case describes the significant role of the East in the future.

These mega trends present the big auto companies with constraints and opportunities in terms of redeveloping competencies, innovating, and redeveloping internal capabilities. Strategic analysis as to how the big auto OEMs will need to design their value chain in the future is supplemented at the end of the thesis.

*Thesis Supervisor:* Charles H. Fine

*Title:* Chrysler LGO Professor of Management and Engineering Systems
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Chapter 1: Thesis Scope & Framework

3 important trends in the global automotive industry have been identified as shown in Figure 1, based on discussions with Prof. Charles Fine, and Dr. V Sumantran, ex Vice Chairman, Hinduja Automotive Ltd. The 3 trends, namely: ‘technological advancement’, ‘changing consumer behavior’, and ‘emergence of the East’ have been studied for their effects on the automotive industry- the challenges and opportunities that they bring to the major automotive players. Each global trend has been explained using a case study. The thesis also covers how auto OEMs will need to shape their product development, operations management and brand management initiatives in the future to achieve the right balance of global integration and local responsiveness in the value chain.
Chapter 2: The Global Auto industry

INTRODUCTION & HISTORY

The automotive industry comprises of all companies and activities that involve the design and manufacturing of all types of motor vehicles. The primary products include passenger cars, pick-up trucks, utility vehicles, as well as all types of commercial vehicles.

The history of the automobile industry, though brief compared with that of many other industries, has exceptional interest because of its effects on 20th-century history. Although the automobile originated in Europe in the late 19th century, the United States completely dominated the world industry for the first half of the 20th century through the invention of mass production techniques. In the second half of the century the situation altered sharply as western European countries and Japan became major producers and exporters.

One of the most important contribution of the automotive industry to the industrial world was the full-scale mass production – a process combining precision, standardization, and continuity. The first car to be truly mass produced was Ford’s Model T. Being mass produced it was cheaper. It was also easy to maintain and repair. The production of Model T revolutionized the automotive industry and drastically changed the industry dynamics. It was first sold in 1908, and more than 15 million were sold till 1927 when its production was stopped and it was discontinued. Since Model T introduced the concept of mass production, the automotive industry has not looked back and in the year 2014 alone almost 90 million vehicles were produced world-wide.[2]

Today along with the 2 big American companies Ford and GM, European companies like Volks Wagen, and Japanese companies like Toyota and Honda dominate the global automotive scene. Cross continental alliances like Renault-Nissan and Fiat-Chrysler have also worked well and have survived strongly in the highly competitive automotive industry.
Today the automotive industry has been highly consolidated and majority of the vehicles that are produced are done so by a few large firms. The small independent producers are not visible any more. The fundamental reason for this is - automotive companies need economies of scale to survive which can only be obtained from mass production of vehicles. [3]

Mass production requires substantial amount of investment in equipment as well as tooling. The small independent players cannot afford these investments needed to stay in business. Increasingly stringent and costly regulations aimed at correcting environmental damage due to the rising number of vehicles on the road also have been a factor in the move toward consolidation.

The past few years have seen a lot of changes happen in the automotive industry. Mergers, acquisitions, sales, bankruptcies- making it difficult to keep up with which car companies own which brands. The prominent was the Fiat-Chrysler partnership (Fiat is the corporate parent in the partnership), the Renault-Nissan joint venture, and the acquisition of the Jaguar and Land-Rover brands by the India conglomerate- TATA Group. As a result of all these and many more consolidations happening in the recent past, the automotive eco-systems is dominated by a few power houses which offer many brands to the consumer. Currently the consolidation can be represented by the details given in Figure 2.

Referring to Figure 2, the prominent companies which control the industry are Volkswagen, Toyota, Fiat, BMW, Renault-Nissan, Ford, GM. and Honda These companies each own multiple brands and operate in markets world-wide.

The Volkswagen group is a German automotive conglomerate which was started in the 1930’s with an aim to manufacture affordable cars. But today VW’s portfolio of brands ranges from luxury cars to sports cars to cheaper affordable vehicles. It owns high end brands like Porsche, Bentley, Audi, Bugatti, and Lamborghini but also offers relatively cheaper offerings in form of Skoda and its own Passat, Jetta, and Golf. VW brands like Audi and Porsche are consistently featured in top 100 most valuable brands.
Another important player in the auto industry is Toyota Motor Corp. known for its quality products and highly efficient manufacturing. It is one of the biggest car manufacturers in the world, if not the biggest one. It owns brands like Lexus, Daihatsu, and Scion. Toyota is often featured in the top 20 most valuable brands published by Forbes. Toyota’s plug-in hybrid- the Prius, is one of its best-selling cars in the US and other developed economies.
Fiat is an Italian car maker that recently got the Chrysler brand under its portfolio. Chrysler was one of ‘The Big 3’ American brands along Ford and GM. Fiat owns a fleet of luxury and high brands like Ferrari, Maserati, and Alfa Romeo. It also now has the iconic Chrysler brands of Jeep, Dodge, and Ram under its wings. Fiat is known for its stylish designs and high performance cars. The Fiat-Chrysler business is currently driven by the group’s influential and charismatic CEO- Mr. Sergio Marchionne, who is widely credited for turning around Fiat and recently managing Chrysler from bankruptcy.

Ford is also one of the top automotive companies and it features regularly in the top 50 of Forbes’ list of most valuable brands. Part of ‘The Big 3’ American group, Ford is the one who pioneered the use of the assembly line concept for cars in manufacturing its now famous Model T. Ford owns the Lincoln brand. Ford is also known for its pick-ups and other light commercial vehicles.

The Renault-Nissan collaboration is (Nissan is owned by Renault) a French-Japanese collaboration. Other big names in the auto world are BMW which owns the Mini and Rolls-Royce brands, Daimler- which owns the Mercedes Benz and Maybach brands, and last but not the least – Honda which owns the Acura brand of cars. [4]

**BUSINESS MODEL**

The underlying principle of the automotive industry on which the OEMs thrive is the economies of scale. The business model is based on mass production of vehicles. Volume production leads to consumption in large quantities all around the world. This mass consumptions needs a well-defined distribution channels to sell the cars to the final customer.

Hence the big automotive OEMs no longer compete as stand-alone entities, but rather as integrated supply chains, whose success or failure is ultimately determined in the marketplace by the end consumers. For better customer satisfaction and market understanding, companies are striving to achieve the best performance from their supply chains by three key components: responsiveness of supply chains, accurate demand forecasting and inventory management. The
role of suppliers and dealers has increasingly been of ‘equal’ partners in the value chain. The OEMs can no longer afford to dominate the value chain as aggressively as they did in early part of 20th century when many of the big auto companies orchestrated a very vertically integrated supply chain.

The automotive value chain can be broadly broken down into 2 categories- the back end and the front end. The back end can be said to consist of all activities before and during the vehicles are made. This includes designing the vehicles, procuring materials from suppliers, and converting the raw materials into finished products. The thesis talks about this back end in detail at a later stage under ‘Strategic analysis of the OEM value chain’.

The front end of the business consists of agencies that sell the actual product to the customers. In most cases these agencies are the automotive dealerships. These car dealerships sell new vehicles, used vehicles, finance and insurance products, and spare parts. They also offer car servicing facility. The OEMs sell the cars to the dealership at an invoice price. The dealers then offer optional packages and services, each with a separate add-on fee.

**ECONOMIC CONTRIBUTION**

The design, manufacture, and sales of automobiles drive economic growth around the world. The auto industry is one of the major sources of economic activity.

In the US alone, over $ 7 million private sector jobs were supported by auto OEMs, suppliers, and dealers as of 2014, and close to $500 billion was paid in annual compensation to these employees. Every vehicle manufacturer job creates about 6 other jobs in industries across the economy. The US automotive industry currently has foreign direct investment (FDI) valued at $74 billion – approximately 3% of all FDI in the US. Beyond the number of jobs created, the industry contributes substantially to federal, state and local tax revenues, providing more than $200 billion to the federal and state governments. Thus, the US automotive industry has an important contribution to the national GDP.[5]
Most of the major automotive companies support fully integrated operations in the country in which they operate - including research, development, design, engineering, headquarters, and manufacturing operations which boosts local employment and skill development to a large extent. But jobs related to the auto industry go far beyond designing, building and selling vehicles. The major automotive OEMs are also among the largest purchasers of aluminum, copper, iron, lead, plastics, rubber, textiles, vinyl, steel and computer chips, which drives these industries to a great extent.

MARKETS

Number of cars sold worldwide from 1990 to 2014 (in million units)

* Annual Average  **2015 figure is a projection

Figure 3: Worldwide car sales from 1990 to 2014
As seen in Figure 3, the worldwide annual cars sales have almost doubled from the end of the 20th century to 2014. This growth however is not balanced across the different regions of the world.

Following 5 regions have been considered in calculating the cars sales worldwide- North America (USA is the dominant market), Western Europe, Eastern Europe, Asia (China and India are the dominant markets), and South America (Brazil is the dominant market).

Referring to pie charts shown in Figure 4 and Figure 5, it can be observed that while car sales in North America and Western Europe have close to halved from late 90’s to 2014, Asian sales have doubled. Asian sales have been boosted by the emergence of China (world’s biggest automobile market) and India. The rise in sale volumes in the South American region are due to the burst of automotive sales in Brazil.

Annual Average of 1990 to 1999: Cars Sold (in million units)

![Pie chart showing annual average of cars sold from 1990 to 1999 by region]

Figure 4: Worldwide car sales from 1990 to 1999- Region wise distribution
2014: Cars Sold (in million units)

- North America
- Western Europe
- Eastern Europe
- Asia
- South America

Figure 5: Worldwide car sales 2014- Region wise distribution
Chapter 3: Automotive Industry as a System

Definition of a System

An integrated set of elements or assemblies that accomplish a defined objective. These elements include products, processes, people, information, techniques, facilities, services, and other support elements. *(INCOSE SE Handbook, V3.2.1)*

Systems Engineering Approach

Systems Engineering is an inter-disciplinary means to enable the realization of successful systems. *(INCOSE SE Handbook V3.2.1)*

This inter-disciplinary approach broadly includes the following steps:

1. Identifying system stakeholders
2. Defining customer needs and required functionality early in development cycle
3. Design synthesis for functionality
4. Designing the system structure / architecture
5. System validation and iteration

The systems approach considers both the technical and business needs of the stakeholders while using the cost, scope, and time triangle as the base for product / system development.

System of Systems (Meta-System)

These are large scale inter-disciplinary problems involving multiple systems as its components. These component systems (or sub systems) maybe completely different from each other physically, operate independently and have ‘different owners’. Each sub system acts like a mini system - i.e. it has its own stakeholders, hierarchical architecture, system boundaries and interdependencies. The functions of such sub systems merge together to perform the desired
function of the main system. In such large scale systems, complexity can be a major issue due to interdependencies within and between sub systems.

Systems Engineering gives a holistic view of the architecture, form, functionality and interdependencies of a system of systems.

A systems approach has been effectively used to analyze system of systems in a wide area of engineering fields like aerospace, marine and military applications, healthcare, power plants, by using a socio-technical approach.

A systems approach has been used hereafter to analyze the automotive industry as digital (man-made) eco-system. The analysis addresses the trends in the automotive industry as systemic changes that have a cause-effect relationship with the interdependencies within the automotive ecosystem.

The Automotive meta-system – an operational perspective

The Automotive industry has been one of the most important economic sectors of the industrialized world. From the pre-World War I ‘Brass Era’ to the current electric cars - the automotive industry has evolved a great extent leveraging the development in information and technology.

Along with the rapid growth in the IT sector, the automotive industry has also evolved in its approach towards manufacturing and operations management. The industry started with Craft Manufacturing in late 1800s where cars were built by craftsmen with pride. Components were typically hand crafted and hand fitted. Cars produced were expensive and only a few cars were produced.

When Henry Ford introduced the assembly line to produce Model T, manufacturing shifted towards concepts of mass manufacturing. Lower skilled labor could do the job as work became simplistic and parts became interchangeable. This phase indicated a change in the way the automotive business was perceived – from few and expensive cars to affordable cars. This probably was the first ever big ‘trend’ to hit the automotive ecosystem. A trend that was induced by the manufacturer himself – to help him serve more customers.
The second big ‘trend’ to hit the industry was the introduction of lean principles in operations management which were introduced by the Toyota Production System in the 1950s and 60s. When Eiji Toyoda visited Ford’s River Rouge Plant in the early 1950s, he was highly impressed by the scale of production (the Ford plant manufactured close to 8,000 vehicles/day). Toyoda saw a great potential in adopting the mass manufacturing system- with of course his qualitative twist. Toyoda, along with Taiichi Ohno developed the focus on constant incremental improvements in the mass manufacturing system they adopted from the Americans. Their efforts led to reduced production and labor costs while boosting overall quality. Due to the reduced costs and production flexibility, Toyota was in a better position to face the competition in the global markets.

Automotive Meta-System Stakeholders

The automotive industry has a variety of stakeholders who can affect or be affected by the actions of the business as a whole. Following entities play an important role in its operations.

Automobile manufacturing value chains, Technology drivers, Automobile customers (present and prospective), Research Institutions, Public parties and Governments, Employees, Banks / Insurance providers, Society and the community in general.

System Function

Each system has a form which is the instrument for the system function. The automotive industry is considered a system of systems (meta-system) for ease of analysis. Each system within this system of systems has a form which performs the required function for that system.

The entities within the automotive industry are linked through relationships that have formal and functional character. Some of entities are linked through relationships with entities outside of the system, which are in the context of the system.
Function and other characteristics of the system emerge as the functions of the entities interact, guided by the form of the relationships among the entities. It is the emergence that gives systems their power: that they possess functionally greater than sum of the parts.

The emergent properties of a system (meta-system in our case) can be identified using the following 4 steps: [Ref: SDM Lecture 1- systems thinking and system architecture-]

a. Identify the meta-system, its form and function
b. Identify entities of the meta-system (systems within the meta-system), their form and function, and the meta-system boundary and context
c. Identify the relationships among the entities within the meta-system and at the boundary
d. Based on the function of the entities and their functional interaction, identify the emergent properties of the system (meta-system in our case)

The function and the emergent properties of the automotive meta-system can be defined using the systems approach described above:

a. **Identifying the system form and function:**

**Form:** The automotive industry is a physical and informational embodiment of automobile manufacturing value chains, research institutions, regulatory authorities, financial institutions, service providing businesses, and customers.

**Function:** The automotive industry designs, manufactures, and provides products and services to cater to transportation needs of customers.

b. **Identify entities of the meta-system (systems within the meta-system), their form and function, and the meta-system boundary and context.** The form and function of each system within the meta-system is given in Table no. 1
<table>
<thead>
<tr>
<th>Entities</th>
<th>Form</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automobile manufacturing Value Chains</td>
<td>Product design and manufacturing centers</td>
<td>Design, manufacturing and sale of automobiles</td>
</tr>
<tr>
<td>Technology Drivers</td>
<td>Technology companies</td>
<td>Drive development of innovation in the technology world</td>
</tr>
<tr>
<td>Customers</td>
<td>Individuals or corporations</td>
<td>Buy and/or use transportation services</td>
</tr>
<tr>
<td>Research Institutions</td>
<td>Research centers</td>
<td>Academic and industrial research</td>
</tr>
<tr>
<td>Governments</td>
<td>Regulatory institutions</td>
<td>Design and implement trade, statutory compliance, and other related policies for the industry</td>
</tr>
<tr>
<td>Banks</td>
<td>Financial institutions</td>
<td>Provide monitory support to the automotive value chain</td>
</tr>
<tr>
<td>Society/Community in general</td>
<td>Environmental and societal entities</td>
<td>They don’t have a function, but they are affected by the activities, products, and by-products of the automotive value chain.</td>
</tr>
</tbody>
</table>

Table. 1: Major entities of the Automotive Meta-System

c. Identify the relationships among the entities within the meta-system and at the boundary

The detailed stakeholder network and their interactions are indicated in the figure 6. The stakeholder value network identifies the relationships among the entities within the automotive meta-system.

The relationship between these stakeholders is portrayed using arrows of different colors. Each color describes a specific type of relationship between the entities. The significance of each color is specified beside Figure 6.

A total of 20 stakeholders have been identified to be part of the automotive industry meta-system after a detailed analysis done as part of the ESD.413 final project on designing autonomous vehicular eco-systems.
The stakeholder value network doesn’t define the system boundary for the automotive meta-
system. The system boundary will depend upon through whose perspective the system is being 
viewed. The ‘system boundary’ per say for the insurance companies, will be different than the 
‘s’ystem boundary’ for the academic or research institutions.
d. Based on the function of the entities and their functional interaction, identify the emergent properties of the system (meta-system in our case)

Following significant emergent properties of the system can be identified based on the current internal functional interactions identified from Figure 6:

**Technology Development:**

The major entities driving the technological development within the automotive ecosystem are the auto OEMs (traditionally they have led the technology development process).

Recently the industry is seeing a shift in technology management. Tier 1 suppliers like Delphi and Bosch are coming up with technology to drive product development at the OEMs. Delphi recently put its self-driving car technology to test in Audi SQ5, and completed the ride from San Francisco to New York. The car was self-driven for 99% of the trip.

Technological companies like Google have leapt into the automotive industry with disruptive technology— that of a completely self-driving car. Google is jumping the technology S-curve with this approach.

Thus technology development has emerged to be associated with tech companies and tech suppliers rather than the traditional automotive OEMs, whose pace of technology development has been slow as compared to the disruptors.

Figure 7: Technological entities of the system
The regulatory aspect about the automotive industry is an emergent property which depends upon to a great extent on the emergence of technology. The exchange of information and regulations between the technology developers and the regulators, forms a dynamic part of the automotive eco-system (refer Figure 8).

Regulation is needed for implementing new technology, upgrading existing technology and infrastructure, and ensuring that the entire socio-technical automotive system is capable of handling any systemic change that affects the stakeholders. The role of the regulatory body evolves as the technology in the system evolves.

As an example, let’s consider the implementation of self-driving cars on American roads. Different states have taken different stance on implementing self-driving cars. There are a number of reasons for this, some of them are mentioned below-

a. Insufficient ‘proof-of-concept’ of the technology (Technology is still evolving)
b. No clear definition of infrastructure requirements
c. Different approaches being explored (by different companies) for implementing self-driving cars
d. Difficulty in incorporating self-driving cars in legacy transportation systems
One of the most important aspects about the automotive industry as a system is its emergent property of consumer behavior. Figure 9 shows 3 different ‘vehicle users’. A few years or a decade back the owner of the car was primarily the user. But today, this emergent property has changed.

The ‘car sharing’ concept has emerged as an important property of the automotive industry. This change in the consumer behavior can be attributed to the new technological platforms like Uber, Lyft, Zipcar, etc.

Uber and Lyft are technology platforms that connect drivers/car owners with people needing transportation services. Such business models enable the car owners to earn income as well as convenience for the consumers who need a ride. This also reduces the reliance on the taxi services.

Through the Zipcar model, people can rent cars as per requirement from multiple pick up locations across the US. This is very convenient not only for driving around the city, but also for longer trips, as cars can be rented for multiple days.

The business described above are booming due to the changing usage trend among the consumers- that of the shift from “owning to using” cars. This change in the emergent property of the automotive industry is the biggest trend that one can see.
Chapter 4: Emergent Properties of the system: BIG TRENDS

4.1 Technological advancement: Disruptive innovation

Speaking at an automotive conference in Bochum, Germany, Mark Fields, CEO of Ford Motor Co., said something that made everyone connected to the automotive industry stand up and take notice.

“There are others who we never thought five years ago would be competitors for us,” Fields said, stopping short of naming which companies were emerging as sector rivals.

Software major Google had recently unveiled an autonomous vehicle.

Fields further stated, “Guess what, they are looking at our industry, not taking anything for granted, they are questioning tradition and they are knocking down walls. I want to make sure Ford doesn't end up like the handset business” He went on to add that most mobile phone makers had become reliant on the business model of telecom providers. He did not elaborate on this point, but the message was loud and clear. [9]

As cars evolve technologically and connectivity platforms are revolutionized, opportunities for new business models – such as car sharing are emerging with rapid pace. The concept of ‘brand loyal car customer’ might soon become a thing of the past. Businesses like Zipcar will evolve and eventually decide the business model for the automotive industry in the future.

Fields also emphasized on innovative product development. He added, “There is always that pull to take things for granted. And to say that is the tradition. Our opportunity is to take those blinders off”.

Thus, Mark Fields clearly spoke about two things prominently – rapid technological advancement happening in the automotive domain (indirectly referring to Google’s entry into the autonomous vehicles race), and the change in consumer behavior from ‘owning to sharing’ (indirectly referring to car sharing platforms like Zipcar)
The big auto companies have to re-strategize their approach towards development and implementation of technology for autonomous vehicles. Google’s entry has drastically increased the ‘industry clock speed’.

The auto companies will now need to ensure that their rate of development of autonomous technology matches with what Google will offer in coming years. Along with playing the role of technology developers, the big auto OEMs will now also need to ensure that they have an end-to-end ‘implementation plan’ for the technology that they are developing by ensuring that they are on the same plane as other important stakeholders like the regulators and potential users. The big auto players now have relatively less time to get their technology to market as Google tries to take the autonomous vehicle eco system by storm.

4.2 Changing Consumer Behavior: From owning to sharing

Going by the current trends in the automotive industry and the emergence of Zipcar and Uber like business models, the auto companies may eventually become the “dumb pipes” of the industry; the auto companies being like the Verizons and the AT&Ts, while the Zipcar like business models will become the Apples and the Googles (trend setters), who will decide the way forward for the auto industry.

‘Sharing’ concept in the newer generation is a growing trend which cannot be ignored. (The focus here being on co-existing households). Although the yearning for a BMW and Porsche cannot be completely ignored, its impact as a “trend-setter” will be/may be limited in the coming future.

As the ride sharing concept gains momentum, two things will play a vital role in the future for sustenance of this trend- the rise of the internet and the ever increasing use of mobile devices.

Two types of business models are prominently driving the shift from “owning to using” cars.

The first business model allows people to conveniently rent cars for their own use or offer their own cars for rental services. The most successful business which does that currently is Zipcar.
Zipcar provides automobile reservations to its members, billable by the hour or day. Zipcar members pay a monthly or annual membership fee in addition to car rental charges. Zipcar was founded in 2000, in Cambridge, Massachusetts by Robin Chase and Antje Danielson. Members can reserve Zipcars online or by phone at any time, immediately or up to an year in advance.

Similar rental models to Zipcar have also emerged. Whereas Zipcar is B2C solution, offering their own cars, Getaround is a C2C marketplace, allowing not only people to rent cars near them, but to also offer their own cars. Both companies solve a similar problem and a need, but are distinctively different in their B2C versus C2C approach.

B2C competitors of Zipcar include Car2Go and WeCar. C2C competitors of Getaround include Relayrides and WhipCar.

The Zipcar model is similar to renting a taxi- but simpler and cheaper. Besides the cost saving that can be achieved compared with owning or renting a car, unlike the traditional rental companies, Zipcar takes care of car maintenance, insurance, parking and gas. People can pick up cars from designated parking areas, unlock the car with a Zipcard, use key and gas card in the car, and finally return the car to the designated location by locking it with the Zipcard. Customers don’t have to deal with people like in renting a car and filling out papers.

Another important factor that makes ride sharing easy are the ride sharing platforms like Uber and Lyft that seamlessly connect drivers of private vehicles with passengers looking for point-to-point transportation within a relatively confined geographic area. The reduction in the cost of mobile internet services is aiding the rapid growth of ride sharing platforms.

The other advantage of the ride sharing platforms is that they completely eliminate any intermediate agents or brokers, making the transaction efficient and easy. Businesses like Uber and Lyft match the supply of private drivers with customers with a mobile app service that brokers the deal.
4.3 Emergence of the East: China as a global car maker

<table>
<thead>
<tr>
<th>Region</th>
<th>Annual Average Sales: 1990 to 1999</th>
<th>Sales 2014</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(in million units)</td>
<td>% of total</td>
</tr>
<tr>
<td>North America</td>
<td>16.36</td>
<td>42</td>
</tr>
<tr>
<td>Western Europe</td>
<td>13.11</td>
<td>33</td>
</tr>
<tr>
<td>Eastern Europe</td>
<td>1.18</td>
<td>3</td>
</tr>
<tr>
<td>Asia</td>
<td>6.91</td>
<td>18</td>
</tr>
<tr>
<td>South America</td>
<td>1.64</td>
<td>4</td>
</tr>
<tr>
<td>TOTAL</td>
<td>39.2</td>
<td>100</td>
</tr>
</tbody>
</table>

Table 2: Distribution of global automobile sales[^7]

![](image)

Figure 10: Percentage comparison of region wise automobile sales
Referring to comparative graphs in figure 10, it can be observed that while car sales in North America and Western Europe have close to halved from late 90’s to 2014, Asian sales have doubled. Asian sales have been boosted by the emergence of China (world’s biggest automobile market) and India. The rise in sale volumes in the South American region are due to the burst of automotive sales in Brazil. Although the Chinese markets are booming with car sales, majority of the cars sold in China belong to non-Chinese car makers.

Established European, Japanese, and American auto makes have a strong presence in the dynamic Chinese market. The lack of quality carmakers in China (who can compete in quality with the top players) enables these foreign players to compete in the Chinese market with relative ease. But in the near future the competing grounds in China may get tougher for the big auto companies. Considering what Chinese car maker Qoros is planning to establish, the big auto makers might a face tough fight even outside China.

Speaking at the Global Automotive Forum (GAF) in Wuhan, China, in October 2014, Mr. Wang Xia, chairman of the China council for the Promotion of International Trade’s Automotive Committee said – “Going global is very important for Chinese automakers” [11]

Unlike the consumer electronics industry, the Chinese automotive industry has not been able to tap into global markets. Many eminent speakers at the GAF believed that local players will need to match world class automotive standards by improving technology and quality through better R&D, and further development of local supply chain, if China is to make its presence known in the global automotive industry. One of the reasons for motivating this push beyond China’s borders is the slowly moving local automotive market. After many years of witnessing a double digit growth, the Chinese automotive industry is expected to rise at a relatively modest 7% this year.

There is a wide-spread general consensus that unless Chinese players don’t compete globally, they will continue to lose ground in their home market to the global brands that are currently technologically more advanced, offer better quality products, and are ramping up their local production capacity in China at a rapid pace.
The focus of the discussion in Wuhan was:

- Need for an international mindset

- Strategy to go abroad and go up market to create more valuable brands

- Focus on developing own brands and promoting self-innovation

- Clear vision and a strategy, and not just a bold step

- Have a clear brand identity and a coherent product portfolio

- Knowledge gain from strategic M&A

The message in the Chinese automotive world is clear. Be prepared to operate and compete globally.

China, traditionally has never been seen as a serious player in the global automotive market. Chinese cars are many a times seen as cheaper versions of their European counterparts, with the design being “inspired” from the big European brands. The quality however doesn’t ever match that of the global brands that are so easily ‘copied’ by the local auto manufacturers.

But this trend is slowly changing thanks to companies like Qoros Auto who have taken the quality revolution quite seriously. Qoros Automotive Co., Ltd is a Chinese-Israeli car manufacturer making a big splash in the automotive industry. It is the result of a 1.5 billion-euro joint venture between Cheryl Automotive - a Chinese car manufacturer - and Israel Corporation in 2007.

With a factory in China and product design based in Austria, Qoros is the definition of an international company. It has been making waves in the automotive industry by being the first Chinese-made car to receive a 5 Star Safety rating in the Euro NCAP and several other awards for product innovation and design.

The Qoros case study is discussed in detail in the later section of the thesis.
Chapter 5: Effects of system emergence:

5.1 Technological Disruption

(Co-related to content in 4.1)

5.1.1 Plug-in electric vehicles & Autonomous/ self-driving vehicles

As technology grows rapidly, the automotive world has seen the emergence of two major technological trends that will change the way cars are perceived in the future.

Plug-in electric vehicles:

Issues like global warming, rapid urbanization, and depreciating levels of fossil fuels are challenging engineers and scientists to address sustainability related concerns. Government agencies around the world are increasingly beginning to introduce limits on carbon dioxide emission levels. Growth in technology and sustainability pressures have resulted in many top auto companies investing substantial amounts of money in developing hybrid cars (which run on gasoline as well as electric batteries) as well as cars which run only on batteries- the plug-in electric cars.

Plug-in cars are the face of ‘electric mobility’. Electric mobility includes everything from electric cars, truck, boats, and even airplanes which run on nothing but electricity. Subsidy from governments is a strong driving force for electric mobility. France is awarding close to 1 billion euros in grants over the funding period from 2006 to 2020. By 2020, China aims to have 12 million electric cars. In that year, the global number of hybrid and electric vehicles is forecasted at 88 million units.[12]

The prominent plug-in cars in the US today are Nissan’s Leaf, Toyota’s Prius, BMW i3, and Tesla’s Model S.
Graph shown in Figure 11 shows the best-selling all-electric cars (plug-in) in the US in 2014.

**Best-selling all-electric cars in the United States in 2014, based on sales (in units)**[12]

![Figure 11: Best-selling all-electric cars in the US in 2014](image)

Tesla’s Model S, with a range of 265 miles, tops the electric vehicle mileage for plug-in vehicles.

The plug-in electric vehicles differ from conventional hybrid electric vehicles due to the fact that they come with a rechargeable battery pack that can be charged from an external electric grid. In the conventional hybrid cars, the battery is recharged with power from the internal combustion engine and regenerative braking. These cars cannot be charged by an off-vehicle electric energy source.

Most of the plug-in all electric vehicles have lithium-ion rechargeable battery pack. Sony Corporation introduced the first commercially viable lithium-ion technology in 1991. Since then the technology has vastly improved. Prof. John Goodenough at the University of Texas at
Austin, is widely credited for the development of the Li-ion rechargeable battery. The Li-ion battery has a wide range of industrial application in today’s digital world.

As technology advances more rapidly today, one factor that may eventually decide the sales of plug-in vehicles is the availability of Li-ion battery packs. Large scale production of Li-ion cells might be needed in the near future to operate with economies of scale and satisfy the growing demand for electric cars.

Tesla Motors is the first company to see this need and plans to build the world’s largest Li-ion battery factory – called Gigafactory before 2020. The proposed factory would be approximately 10 million square feet and would produce Li-ion cells to build around 500,000 battery packs a year. With these economies of scale, Tesla expects to achieve a minimum of 30% reduction in production cost for their car batteries. Japanese electronics giant Panasonic has also invested in the factory. Based on partnership agreements between the two companies, Tesla will provide the land, building and utilities, and Panasonic will manufacture and supply cylindrical lithium-ion cells and invest in associated equipment, machinery and other manufacturing tools.

Such collaborations will help accelerate the expansion of electric vehicles into commercial markets. The total revenues from worldwide sales of electric vehicles were close to $200 billion USD in 2010. By 2020 the revenues are expected to reach $320 billion USD, and by 2030, reach close to $500 billion USD. [12]

**Autonomous/ Self-driving cars:**

Technology that is disrupting the very foundation of how people perceive transportation is the development of self-driving features in cars. Completely autonomous vehicles (level 5 autonomy according to SAE) are something that almost all auto companies are competing to implement. Starting with features like automated steering, acceleration, and braking, current level of technology suggests that fully autonomous cars are no more a part of fiction. Potential benefits of implementing self-driving features in cars could include increased road safety, decreased energy costs, increased roadway capacity for vehicles, greater mobility for those who cannot currently drive, opportunities to improve land use, and new uses of commuting time.
SAE has defined different levels of automation to categorize the emerging and deployed technologies. These levels of automation are as seen in table 3.

<table>
<thead>
<tr>
<th>SAE level</th>
<th>Name</th>
<th>Narrative Definition</th>
<th>Execution of Steering and Acceleration/Deceleration</th>
<th>Monitoring of Driving Environment</th>
<th>Fallback Performance of Dynamic Driving Task</th>
<th>System Capability (Driving Modes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>no Automation</td>
<td>the full-time performance by the human driver of all aspects of the dynamic driving task, even when enhanced by warning or intervention systems</td>
<td>Human driver</td>
<td>Human driver</td>
<td>Human driver</td>
<td>n/a</td>
</tr>
<tr>
<td>1</td>
<td>Driver Assistance</td>
<td>the driving mode-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the human driver perform all remaining aspects of the dynamic driving task</td>
<td>Human driver and system</td>
<td>Human driver</td>
<td>Human driver</td>
<td>Some driving modes</td>
</tr>
<tr>
<td>2</td>
<td>Partial Automation</td>
<td>the driving mode-specific execution by one or more driver assistance systems of both steering and acceleration/deceleration using information about the driving environment and with the expectation that the human driver perform all remaining aspects of the dynamic driving task</td>
<td>System</td>
<td>Human driver</td>
<td>Human driver</td>
<td>Some driving modes</td>
</tr>
<tr>
<td>3</td>
<td>conditional Automation</td>
<td>the driving mode-specific performance by an automated driving system of all aspects of the dynamic driving task with the expectation that the human driver will respond appropriately to a request to intervene</td>
<td>System</td>
<td>System</td>
<td>Human driver</td>
<td>Some driving modes</td>
</tr>
<tr>
<td>4</td>
<td>high Automation</td>
<td>the driving mode-specific performance by an automated driving system of all aspects of the dynamic driving task, even if a human driver does not respond appropriately to a request to intervene</td>
<td>System</td>
<td>System</td>
<td>System</td>
<td>Some driving modes</td>
</tr>
<tr>
<td>5</td>
<td>full Automation</td>
<td>the full-time performance by an automated driving system of all aspects of the dynamic driving task under all roadway and environmental conditions that can be managed by a human driver</td>
<td>System</td>
<td>System</td>
<td>System</td>
<td>All driving modes</td>
</tr>
</tbody>
</table>

Table 3: SAE Levels of autonomy for vehicles[^13^]
Technology Development

Technologies like adaptive cruise control, automated parking assistance, adaptive headlights, and lane-keeping assist have already made their way into many vehicles. The implementation of these features has been made possible due to development of technology in sensing and controlling domains. Affordable sensors like GPS receivers, radar and lidar systems, and advanced camera systems are helping to rapidly automate the sensing needs of autonomy. Technologies like Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) are also emerging independently.

Technology Implementation Challenges

In 2013, TRB (Transportation Research Board) and Stanford University cosponsored a workshop on the challenges and opportunities related to the increasing automation of motor vehicles and the environments in which they operate. Government, industry, and academic experts convened from around the world to identify research needs and to advance research in a range of disciplines.

Following major topics and research needs were identified at the workshop[^14]

Human Factors and Human-Machine Interaction

Different drivers have different capabilities, limitations, and expectations. Hence human factors consideration is necessary in designing vehicle automation level. Some of the important questions related to **driver characteristics and acceptance** are- How should driver needs for vehicle automation need to be identified? To what extent should drivers be allowed to personalize automated systems to accommodate tolerances for action and motion and to feel safe and comfortable? Regarding **function allocation and management**, following questions might need answers- How easily can the driver switch between ‘manual mode’ and ‘automated driving mode’? How will unexpected severe failure of the automation affect the driver’s ability to regain the control?
Infrastructure and Operations

Important factors that will drive infrastructural requirements and operational planning are-

**Effect on traffic management:** Will automation shift demand patterns? What elements of mapping and positioning will be needed? Should traffic managed separately for autonomous and non-autonomous vehicles?

**Infrastructure related:** What infrastructure will be needed to support vehicle automation? Will different traffic lanes be needed for autonomous vehicles? How can automation of vehicles be quantified in long-range infrastructural planning? How planning modules should be adjusted to accommodate disruptive technologies like self-driving cars?

**Testing:** What test-track and simulation models will be needed before automated vehicles can be tested on public roads?

**Licensing:** Will drivers need special training or license to operate autonomous cars?

Energy & Environmental Impact

Implementing self-driving cars will most likely have an impact on traffic flows, vehicle operations, vehicle ownership, choices of locations for activities, and patterns of land use. All these factors may have substantial impacts on energy and environment. Some of the important questions that will need to be addressed here are- What policies will encourage development and deployment of autonomous vehicles specifically to gain the energy and environmental benefits? Could the innovations accelerate improvements in vehicle efficiency or the adoption of alternative fuels and drive-trains? What effects will latent and induced demand have on travel distances, energy consumption, and environmental impacts?

V2X Communication & System Architecture

Although autonomous vehicles may operate without any real time communication with other vehicles, information systems, or infrastructure (as Google has shown that with its concept of autonomous vehicle), the need for V2V and V2X communication cannot be completely ignored. Different usage patterns and scenarios may need the use of such communications in the future.
Some of the questions that will arise while designing the system architecture are- What V2X functions would be likely in self-driving cars? How will need for V2X communication affect the development and cost of sensors in the future? How can V2X data be used to improve system’s efficiency and stability of traffic? In case of V2X communication, what will be the overall system architecture that will required and which stakeholders will operate the information network?

Shared Mobility & Transit

Automation of road vehicles may create new models for public transportation. Information technology has already begun to blur the distinctions between public and private transportation thanks to private vehicle sharing (Uber model), community pooled cars, and distributed rentals. How will completely automating cars affect the usage pattern in the future? Some important questions which complement this basic question are- Should automated vehicles have exclusive guide ways for shared usage? What are trade-offs for such exclusive infrastructure? What are the public transit needs that automation may address? How will automation affect public transit use, walking, and biking? What are the opportunities and challenges for automation in assisting those with impaired mobility?

Liability, Risk & Insurance

The current regulations of motor vehicle transportation and provision of automotive insurance assume that a vehicle has a human driver. When the role of a human driver reduces drastically or even becomes zero, the legislators and regulators will need a different perspective in laying out rules and regulations which promote safety and ensure compensation to those who are injured. Some typical questions that will arise are- Will automation take travelling to a higher safety standard? How might crash data be used in designing algorithms for future risk assessment? If exposure shifts from drivers to vehicle manufacturers and other companies, how might the insurance agency change? How will insurers quantify safety risk and financial risk? Other important concerns that arise are – Data ownership, access, and cyber security.
Thus, from all the concerns, uncertainties and questions mentioned above, it is clear that implementing autonomous vehicle is a complex socio-technical system that will need an elaborate systems thinking approach for effective implementation, use, and sustenance. A case study which follows this analysis, takes into consideration most of the uncertainties described above and how these concerns can be transferred to define system requirements for implementing autonomous vehicles in the future.

Case Study 1: Implementing autonomous vehicles: A Systems Engineering Approach

Technology for autonomous vehicles is being rapid developed today. Traditional automotive players as well as technology disruptors like Google are in the rat race to bring autonomous vehicles on road. While there is progress on the technological front, integration of autonomous vehicles with infrastructure, user needs and perceptions, regulations, and existing vehicle users will be a major challenge. A systems thinking approach is needed to integrate self-driving cars into legacy transport systems.

In this case study, a top down approach will be used to analyze and investigate the interactions and decisions made by key stakeholders, understand their needs, and model the dynamic environment in which they operate. By identifying the most critical systemic properties and generating a list of system-level requirements, an ideal system architecture can be developed that addresses these needs.

This case will study how internal functions interact to form the value path-way for successful implementation of self-driving cars or driverless cars. Internal functions including regulatory decisions, technological embodiment in vehicles, infrastructural development, and changing human preferences will be studied and analyzed during system design.
Proposing a systems engineering based design approach for autonomous vehicle systems

Following approach proposes a systems engineering based design methodology for self-driving car systems. The proposed approach is essentially useful for addressing safety related design decisions of the system; but can also be applied to generate design decisions for other system requirements like efficiency, convenience, cost, etc.

The systems engineering based approach used in the case study includes the following steps:

a. Identification of key stakeholders (role and requirements)

b. Concept exploration (Technology assessment)

c. Defining important architectural decision parameters for the system

d. Defining interdependencies in these architectural decisions

e. Propose a methodology to generate design decisions for system evaluation criteria

{Sample proposal: STPA analysis to generate safety related design decisions}

Identifying the key stakeholders of the Autonomous Vehicle Eco-System

With reference to Figure 6, which shows the ‘Detailed Stake holder Value Network of Automotive meta-system’- a Design Structure Matrix (DSM) has been represented in Figure 12 to show the connections related to policy, money, workforce, technology, knowledge, and goods and services between each type of stakeholder.
Based on the stakeholders value network DSM the following beneficiaries were identified:

- The direct beneficiary:
  - Vehicle user

- Primary benefit that flows to them:
  - Safer transportation

- Other non-primary benefits:
- Efficiency, speed, convenience, free time, availability.

- Indirect beneficiaries:
  - Technology companies, automotive OEMs, suppliers, construction companies, car dealers, service providers, insurance companies receive a benefit of revenue
  - Road users receive a benefit of safety

Stakeholders and beneficiaries classification according to value network flow:

<table>
<thead>
<tr>
<th>Stakeholder</th>
<th>Problem stakeholders</th>
<th>Beneficial stakeholders</th>
<th>Charitable beneficiaries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicle user</td>
<td>Operator / Driver</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Car Owner</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Passenger</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Government</td>
<td>Federal Government</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td></td>
<td>State Government</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Local Government (Roads, Infra)</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Govt Agency</td>
<td>Federal Regulators</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td></td>
<td>State DOT (Infrastructure)</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td></td>
<td>State DMV (Licensing, Registration)</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Technology creators</td>
<td>Automotive OEMs</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Technology Corporations</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Suppliers</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Construction Companies (Roads, Highways, Sensors)</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Technology providers</td>
<td>Car Dealers</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Service Providers</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Control decision maker</td>
<td>Insurance Companies</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Society and public</td>
<td>Road User</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>transportation</td>
<td>Public Transportation Providers</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Outside influencers and</td>
<td>Academia</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>technology researchers</td>
<td>NGO</td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>

Table 4: Stake holder and Beneficiary Classification

The needs and benefits for each of these stakeholders have been identified following the Kano Model as “want”, “should” or “must” depending on the relevance.
The needs are shown in the Table 5.

<table>
<thead>
<tr>
<th>Stakeholder</th>
<th>Needs</th>
<th>Parameter</th>
<th>Metric</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Vehicle user</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operator / Driver</td>
<td>Transportation</td>
<td>must</td>
<td>Distance/Time</td>
</tr>
<tr>
<td></td>
<td>Safety</td>
<td>should</td>
<td>Safety index</td>
</tr>
<tr>
<td></td>
<td>Convenience</td>
<td>want</td>
<td>JD Power</td>
</tr>
<tr>
<td>Car Owner</td>
<td>Efficiency</td>
<td>should</td>
<td>MPG, emissions</td>
</tr>
<tr>
<td>Passenger</td>
<td>Transportation</td>
<td>must</td>
<td>Distance/Time</td>
</tr>
<tr>
<td></td>
<td>Safety</td>
<td>should</td>
<td>Safety index</td>
</tr>
<tr>
<td><strong>Government</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Federal Government</td>
<td>Public support</td>
<td>should</td>
<td>Grade</td>
</tr>
<tr>
<td>State Government</td>
<td>Public support</td>
<td>should</td>
<td>Grade</td>
</tr>
<tr>
<td>Local Government</td>
<td>Public support</td>
<td>should</td>
<td>Grade</td>
</tr>
<tr>
<td>(Roads, Infra)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Govt Agency</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Federal Regulators</td>
<td>Public support</td>
<td>should</td>
<td>Grade</td>
</tr>
<tr>
<td>(Compliance)</td>
<td></td>
<td>must</td>
<td>Safety index</td>
</tr>
<tr>
<td>State DOT (Infrastructure)</td>
<td>Funding</td>
<td>must</td>
<td>Money</td>
</tr>
<tr>
<td></td>
<td>Technology (usage)</td>
<td></td>
<td>TRL</td>
</tr>
<tr>
<td>State DMV (Licensing,</td>
<td>Laws</td>
<td>must</td>
<td>Compliance</td>
</tr>
<tr>
<td>Registration)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Technology creators</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Automotive OEMs</td>
<td>Revenue</td>
<td>should</td>
<td>Money</td>
</tr>
<tr>
<td></td>
<td>Technology (infrastructure)</td>
<td>must</td>
<td>Patents/usage</td>
</tr>
<tr>
<td></td>
<td></td>
<td>want</td>
<td>Compliance</td>
</tr>
<tr>
<td>Technology Corporations</td>
<td>Revenue</td>
<td>should</td>
<td>Money</td>
</tr>
<tr>
<td>Suppliers</td>
<td>Revenue</td>
<td>should</td>
<td>Money</td>
</tr>
<tr>
<td></td>
<td>Technology</td>
<td>must</td>
<td>Patents/usage</td>
</tr>
<tr>
<td>Construction</td>
<td>Revenue</td>
<td>should</td>
<td>Money</td>
</tr>
<tr>
<td>Companies (Roads, Highways,</td>
<td>Technology</td>
<td>must</td>
<td>Patents/usage</td>
</tr>
<tr>
<td>Sensors)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Technology providers</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Car Dealers</td>
<td>Revenue</td>
<td>should</td>
<td>Money</td>
</tr>
<tr>
<td></td>
<td>Cars &amp; services</td>
<td>must</td>
<td>Availability</td>
</tr>
<tr>
<td>Service Providers</td>
<td>Revenue</td>
<td>should</td>
<td>Money</td>
</tr>
<tr>
<td></td>
<td>Services</td>
<td>must</td>
<td>Availability</td>
</tr>
</tbody>
</table>
Analyzing the technology for self-driving cars

Concept exploration

The self-driving process itself is too large and therefore further decomposition is needed into sensing, controlling, and navigating.

Navigating is an essential process but it is not part of the scope for this analysis so therefore it is assumed that the current GPS technology will be utilized for navigation. It could be expanded upon as well in the future to consider possible alternatives to the navigating process of the architecture. The other two processes, sensing and controlling, form the starting point for a multi-concept selection analysis.

Sensing

The sensing process is required so that the self-driving car can gather the information needed to make decisions. One possible alternative process would be infrastructure sensing where the infrastructure sensor operand could be specialized to using Vehicle-to Infrastructure (V2I) communication. This is where the sensors are primarily based in the infrastructure and the data is shared between the cars. Another alternative process would be vehicle sensing where the vehicle sensor operand could be specialized into two different possibilities: Vehicle to Vehicle (V2V)
communication, the vehicles use their onboard sensors and share the information to nearby cars, or onboard sensors, where the vehicle only utilizes its own sensor data and does not receive information from other sources.

**Controlling**

The controlling process is how the self-driving car can be controlled to operate with other traffic and avoid obstacles. One alternative process is the separating where the road infrastructure operand can specialize to exclusive roads. This is basically separating the self-driving vehicle from all other traffic, for example, a self-driving only lane.

The alternative process for controlling can be achieved by the responding process where the autonomous level operand specializes to Human (Level 0-2), Human in the Loop (Level 3-4) or No Human (Level 5). This describes the possible levels of automation the system could support which each could be used to control the car’s dynamic driving functions (steering, accelerating, and braking). Each level is based on the SAE J3016 standard definition and basically can be summed up as how much responsibility to the human driver (if needed at all) has in controlling the vehicle. Level 5 is no human is needed where level 0 is only a human is driving.

All these alternatives that have been described above can be represented using OPM diagram as shown in Figure 13, which portrays a solution-neutral problem statement.
All the possible alternatives described above (the possible specialized operands) have been combined into a morphological matrix shown in Figure 14.

We could also have varying degrees of some of the alternatives in a mixed type system.

For example, it wouldn’t be hard to conceive a possible solution that requires a sensor and communication infrastructure for one area but not the other.

Therefore the choices in the matrix below have been slightly expanded to capture the choices involving a mix of the possible alternatives for a single process.
Possible solutions for some simplified proposals from Google and NHTSA can be mapped out using the matrix shown in Figure 14.

**Figure 14: Morphological Matrix for self-driving cars**

<table>
<thead>
<tr>
<th>Sensing Process</th>
<th>V2X everywhere</th>
<th>Only onboard sensors</th>
<th>V2X/On board mixed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Separating Process</td>
<td>Separated</td>
<td></td>
<td>Mixed</td>
</tr>
<tr>
<td>Responding Process</td>
<td>Human (Level 0-2)</td>
<td>Human in the Loop (Level 3-4)</td>
<td>No Human (Level 5)</td>
</tr>
</tbody>
</table>

**Figure 15: Combination of form elements for self-driving cars**
Using the morphological matrix shown in Figure 15, the possible combinations of the form elements that will meet the function of the concept can be investigated. We can also evaluate these baseline proposals to compare to any other solutions proposed.

**Important architectural decisions for designing self-driving cars**

*The most important architectural decisions for the system are listed below:*

1. Level of autonomy allowed/required (levels from SAE J3016 standard):
   - Level 0 – No automation
   - Level 1 – Driver assistance
   - Level 2 – Partial automation
   - Level 3 – Conditional automation
   - Level 4 – High automation
   - Level 5 – Full automation

2. How much mix operation of different of autonomy levels is allowed?
   - Mixed – various levels
   - Not mixed (i.e. not allowed to operate on the same roads at the same time)

3. What infrastructure is required?
   - V2V only (vehicles only communicate between themselves)
   - V2I only (vehicle only communicate with infrastructure, not including GPS)
   - Both V2V and V2I
   - None (all information sourced through onboard sensors)

4. What level of human supervision should be required for legal/liability?
   - Human must always be present
   - Human only required under certain conditions
• Human is never required

5. Car ownership:

• Personal
• Shared

6. Transportation mode sharing:

• Mixed mode (private/public)
• Private only
• Public only

7. Requirements for operator

• Highly trained (above current typical licensing requirements)
• Same as current norm for licensing
• None (no license required)

Identifying the interdependencies between architectural decisions

For identifying the relationships between these architectural decisions, a Design Structure Matrix (DSM) approach has been used. All the DSMs shown below read from row to column.

![Figure 16: Initial DSM - architectural decision choice](image-url)
The DSM shown above in Figure 16 shows the coupling between each architectural choice.

The DSM can be interpreted as given below-

The Level of Autonomy defines what level of control is required by the driver/operator of the vehicle and therefore the technology needed in the car as well. This choice can impact the type of human supervision that is required. SAE level 0-4 requires a human present to drive the vehicle or take over for the automation and level 5 requires no human. Also the car ownership and transportation mode sharing, for the shared options of these applications only a level 5 fully autonomous vehicle makes this a beneficial choice over personal operation.

The amount of mix operation of different levels of autonomy choice impacts the level of autonomy, specifically through defining what level is allowable to be used and in what ways. Also the infrastructure and human supervision is impacted if it would be required to have special roads/lanes for different autonomous vehicle types and/or different levels of human supervision.

The infrastructure choice would impact the level of autonomy and the type of mixed operation due to requirements for specific use of data. This impacts the required functionality and therefore what level of autonomy can be used and also in what ways the vehicles can be used. Human supervision impacts the level of autonomy be defining what level is feasible.

If a human is always required than it may not be worth the effort or cost to have a level 5 vehicle that could be used in ways that do not require a human present. In a similar manner this choice could impact the ownership of the vehicle where personal use is favored and/or sharing may not be as attractive an option without level 5 capabilities. Supervision requirements can also impact the requirements for the operator. If a human is required what skill level is needed and if they are not required can someone without even a license be allowed in the vehicle.

Car ownership and Transportation mode sharing are tightly coupled in the way that if ownership of some vehicles is not shared it may not be possible to have mode sharing. The same can be true for mode sharing. If a possibility would be to take the train into the city and then use an autonomous vehicle to get you to your exact location than you would need shared vehicles. Other similar scenarios can be found as well. Requirements for the operator impact the level of autonomy and the choice of human supervision in the same ways as previously discussed.
The original order to make the choices in is shown by the order in the original DSM above. This was based on the number of interactions the level of autonomy has with the other items and on its relative importance. It decides the basic technologies used in the system and the baseline of the performance. The other items were then ranked in their perceived order of importance and impact as well. To check to see if there may be a better order partitioning algorithm has been applied on the DSM which resulted in the DSM below shown in Figure 17.

| Car Ownership | 5 | 6 | 7 | 1 | 4 | 2 | 3 |
| Transport mode sharing | 6 | 1 | 6 |    |    |    |    |
| Requirements for operator | 7 |    | 7 | 1 | 1 |    |    |
| Level of autonomy | 1 | 1 | 1 | 1 |    |    |    |
| Human supervision | 4 | 1 | 1 | 1 | 4 |    |    |
| Mix operation | 2 |    | 1 | 1 | 2 | 1 |    |
| Infrastructure | 3 |    | 1 | 1 | 3 |    |    |

**Figure 17: Partitioned DSM**

This partitioning moved the car ownership and transportation mode sharing to the top. Although these two can be decided relative to each other their overall importance in the system is still low—mainly impacting each other.

The other groupings seem to be somewhat of improvement and having requirements for the operator being a higher position architectural choice was unexpected based on its relatively assumed low level of importance. Based on the factors above and on some of the relationships of these decisions, the DSM was manually rearranged in the order below shown in Figure 18.
Using this order we can also group some of the decisions that were found and these can show some of the impact to different areas.

The green represents technology, regulations and laws, the red represents mainly infrastructure considerations, and the blue represents usage cases.

By studying the couplings, a more optimal order to make the architectural choices has been derived which can now be used to arrive at possible architectural solutions faster.

Considering Figure 18, following 3 system architectural choices might be the shortlisted in the coming future for implementing autonomous vehicles.

A. Level 5 vehicle autonomy with only on board sensors
B. Level 5 vehicle autonomy with on board sensors and V2X communication capability
C. Level 3 or 4 vehicle autonomy with on board sensors and V2X communication capability

The focus of choosing these 3 choices was to address the importance of technology, regulations, and infrastructural considerations. (The green and the red loop in Figure 18)
Propose a methodology to generate design decisions for system evaluation criteria

To analyze all the system requirements and generate design decisions for all system parameters is beyond the scope of this thesis.

The underlying purpose of this case study is to propose a systems engineering based approach to identify significant design parameters for implementing autonomous vehicles. Defining the correct design decisions for the system evaluation criteria will be critical. Different criteria might need (will need) different methodologies for arriving at design related decisions.

Irrespective of which system architecture is finalized in the future for implementing self-driving cars, following criteria (at the least) will be used to evaluate the system-

<table>
<thead>
<tr>
<th>CRITERIA</th>
<th>MEASUREMENT METRICS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety</td>
<td>-Crash safety</td>
</tr>
<tr>
<td></td>
<td>-Pedestrian safety</td>
</tr>
<tr>
<td></td>
<td>-Number of safety features</td>
</tr>
<tr>
<td>Environmental Efficiency</td>
<td>-Fuel economy</td>
</tr>
<tr>
<td></td>
<td>-Travel time</td>
</tr>
<tr>
<td></td>
<td>-Land usage required</td>
</tr>
<tr>
<td>Convenience</td>
<td>-How accessible is the system?</td>
</tr>
<tr>
<td></td>
<td>-How much driver attention is needed?</td>
</tr>
<tr>
<td></td>
<td>-Travel time predictability</td>
</tr>
<tr>
<td></td>
<td>-Travel effort</td>
</tr>
<tr>
<td>Cost</td>
<td>-Development cost</td>
</tr>
<tr>
<td></td>
<td>-Running and maintenance cost</td>
</tr>
<tr>
<td></td>
<td>-Insurance related costs</td>
</tr>
<tr>
<td>Usage</td>
<td>-High/medium/low usage system</td>
</tr>
<tr>
<td>Acceptance level</td>
<td>-Age/older users</td>
</tr>
<tr>
<td></td>
<td>-Motorcyclists/bicycles</td>
</tr>
</tbody>
</table>

55
Designing the system for safety: STPA analysis

*(Sample proposal: STPA analysis to generate safety related design decisions)*

While all the criteria mentioned in Table 6. are important, the most important feature of self-driving cars (as being promoted by the OEMs and technology companies) is improved safety. Almost 90% of motor vehicle crashes are caused at least in part by human error.

The most thorough analysis of crash causation, the Tri-Level Study of Causes of Traffic Accidents published in 1979, found that “human errors and deficiencies” were a definite or probable cause in 90-93% of the incidents examined. \(^{15.2}\)

Hence, as part of systems engineering approach, the use of STPA (System-Theoretic Process Analysis) methodology to identify the system safety requirements has been analyzed.
System-Theoretic Process Analysis (STPA):

- Involves investigation of an accident before it occurs
- The goal is to prevent or control the causal factors in order to prevent losses
- Incorporates the control system theory (studies relationship between the controller and the controlled process)
- Integrates driver-vehicle interaction in the overall modelling
- Produces traceable rationales that link unsafe interactions to vehicle and system level hazards and losses

- *Generates hazards and causal factors that are inputs to system safety requirements and constraints (design decisions)*

![Diagram of STPA approach]

Figure 19: STPA approach
The STPA methodology can be used to generate system level safety constraints which then get converted in design decisions.

To illustrate how STPA can be used to derive system level safety constraints in designing autonomous vehicles, a sample analysis has been done. Similar analysis can be done in detail to identify all the safety related design decisions needed for the system.

For identifying the unsafe control actions in the system, a control structure which describes the relationship between a controller and a controlled process is created.

In analyzing the implementation of autonomous vehicles, following control structures can be used to study interactions at different levels of the system:

- **High level control structure**

- **Control structure for the system**

- **Control structure for each level of automation**

The high level safety control structure shows the flow and processing of information between all significant stakeholders of the system. It includes direct as well as the indirect (outside the actual system) stakeholders.

Figure 20 shows a high level control structure for autonomous vehicles.
Figure 20: High level control structure for autonomous vehicles eco-system
Figure 21 shows control structure for the system of autonomous vehicles. It highlights the control loops (in red) and the feedback loops (in blue) which connect the controller and the controlled process.
Figure 22: Control structure for different level of automation in cars

Figure 22 shows the control loop and feedback loops for different automation levels in cars.

Based on the control structures shown in Figures 20, 21, and 22, STPA can be carried out in 2 steps.

**Step 1:**

This includes selecting a control loop connecting a controller and a controlled process. Referring to figure... following control loop is selected for sample analysis:

Controller: Traffic Controllers

Controlled process: Traffic Safety

Control loop actions: Routing and speed limit inputs from the Controller to the Controlled Process
Feedback loop actions: Speed, position, and destination status from the Controlled Process back to the Controller

After selecting the control loop, the possible unsafe control actions (UCA) for the loop are listed down. The table for possible scenarios related to unsafe control actions is shown below in the Table 7.

<table>
<thead>
<tr>
<th>TMSC</th>
<th>Not provided</th>
<th>Provided</th>
<th>too late/too early/too early</th>
<th>too long/too short</th>
</tr>
</thead>
<tbody>
<tr>
<td>Routing</td>
<td>TMS does not provide routing when there is heavy traffic, or road construction, or emergency situation (accident) or extreme weather/natural disaster, or special event/games concerts</td>
<td>TMS does provide routing when the routing information is incorrect</td>
<td>TMS provides routing too late to avoid the current road conditions</td>
<td></td>
</tr>
<tr>
<td>Speed Limit</td>
<td>TMS does not provide speed limit when traveling wrong speed for the driving road conditions</td>
<td>TMS provides the wrong speed limit for the driving conditions</td>
<td>TMS provides a new speed limit too early for the driving conditions</td>
<td>TMS provides changing speed limit too often</td>
</tr>
<tr>
<td>Signal command</td>
<td>TMS does not provide signal command when required</td>
<td>TMS does provide signal command when not required</td>
<td>TMS provides signal command too late when crossing the signal area</td>
<td></td>
</tr>
</tbody>
</table>

Table 7: Unsafe control actions for the loop 1

Similarly the unsafe control actions can be listed for the following loop as well:

Controller: Vehicle Controllers

Controlled process: Traffic Safety

Control loop actions: Throttle, brake and steering inputs from the Controller to the Controlled Process
Feedback loop actions: Speed, and direction status from the Controlled Process back to the Controller

The unsafe control actions for this loop are listed in Table 8.

<table>
<thead>
<tr>
<th>A/C</th>
<th>Not provided</th>
<th>Provided</th>
<th>too late/too early/too early</th>
<th>too long/too short</th>
</tr>
</thead>
<tbody>
<tr>
<td>Throttle</td>
<td>A/C does not provide the accelerate command when overtaking on the highway with an approaching vehicle</td>
<td>A/C provides acceleration command when following a slower vehicle</td>
<td>A/C provides accelerate command too late when overtaking on the highway with an approaching vehicle</td>
<td>A/C provides accelerate command too long when there is a vehicle in front</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>A/C does not provide deceleration command when following a slower vehicle</td>
<td>A/C provides deceleration command when the car following is travelling at a higher speed</td>
<td>A/C provides accelerate command too early when following a slower vehicle</td>
<td>A/C stops accelerate command too soon when overtaking on the highway with an approaching vehicle</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brakes</td>
<td>A/C does not provide braking command when the vehicle in front is stopped or braking</td>
<td>A/C provides braking command when the vehicle following is travelling faster</td>
<td>A/C provides braking command too late when the vehicle in front is stopped or braking</td>
<td>A/C does stops braking command too soon when the vehicle in front is travelling faster</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Steering</td>
<td>A/C does not provide steering command when needed to follow the correct route, to avoid an obstacle or to stay on the road</td>
<td>A/C provides steering command when travelling straight is required</td>
<td>A/C provides steering command too late when a turn is required</td>
<td>A/C provides steering command too long when turning</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 8: Unsafe control actions for loop 2

**Step 2:**

Based on the unsafe control actions identified in step 1, the control structure is now zoomed-in for scenario based analysis. The unsafe control actions are linked to specific scenarios to generate the safety constraints and the subsequent design decisions.

The zoomed-in control structure for step 2 is shown in Figure 23.

The level of autonomy considered for analysis here is level 3 - level 4
Figure 23: Zoomed-in control structure for step 2 considering level 3/4 autonomy in cars
Following 2 accident scenarios have been used to analyze the unsafe control actions and generate the safety constraints and design decisions.

*These are just sample scenarios; for arriving at all the safety related design decisions numerous accidental scenarios will be needed for analysis*

<table>
<thead>
<tr>
<th>Accident</th>
<th>Scenario</th>
<th>Unsafe Control Action</th>
<th>Proposed Design Decisions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Car B crashes into Car A</td>
<td>Car A send braking data too late to car B</td>
<td>State TMS provides a new speed limit too late for the driving conditions</td>
<td>Determine object obstructing the way and take action</td>
</tr>
<tr>
<td></td>
<td>Car A and Car B receive speed limit increase. At the same time Car A sends braking command to Car B.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wall of rain/fog</td>
<td></td>
<td>State TMS does not provide the speed limit when travelling wrong speed for the driving road conditions</td>
<td>Maintain a minimum separation from each vehicle based on speed, etc.</td>
</tr>
<tr>
<td></td>
<td>Car B is told to speed up by TMS 2 and Car A is told to slow down by TMS1 because the traffic status from TMS2 is delayed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Car collides with terrain or a fixed object</td>
<td>Car A maintains an unsafe speed through road construction because the TMS does not provide the slower speed</td>
<td>State TMS does not provide the speed limit when travelling wrong speed for the driving road conditions</td>
<td>Provide temporary roads before construction begins</td>
</tr>
</tbody>
</table>

Table 9: STPA Step 2- Scenario based analysis for unsafe control actions
Based on the scenarios portrayed, following safety constraints can be derived:

<table>
<thead>
<tr>
<th>Safety Constraint</th>
<th>Level of Autonomy</th>
</tr>
</thead>
<tbody>
<tr>
<td>TMS must provide signal command when required</td>
<td>Human Driver</td>
</tr>
<tr>
<td>TMS must not provide the correct routing for the current driving conditions</td>
<td>Human Driver</td>
</tr>
<tr>
<td>TMS must not provide steering command too late when crossing the signal area</td>
<td>Human Driver</td>
</tr>
<tr>
<td>TMS must not provide changing speed limit too often</td>
<td>Human Driver</td>
</tr>
<tr>
<td>TMS must provide signal command when required</td>
<td>Human Driver</td>
</tr>
<tr>
<td>TMS must not provide signal command too late when crossing the signal area</td>
<td>Human Driver</td>
</tr>
<tr>
<td>TMS must not provide signal command too early when crossing the signal area</td>
<td>Human Driver</td>
</tr>
<tr>
<td>TMS must provide the correct acceleration command when overtaking on the highway with an approaching vehicle</td>
<td>Human Driver</td>
</tr>
<tr>
<td>TMS must not provide deceleration command too late when following a slower vehicle</td>
<td>Human Driver</td>
</tr>
<tr>
<td>TMS must not provide deceleration command too early when following a slower vehicle</td>
<td>Human Driver</td>
</tr>
<tr>
<td>TMS must not provide deceleration command too long when the vehicle in front is stopped or braking</td>
<td>Human Driver</td>
</tr>
<tr>
<td>TMS must not provide acceleration command too soon when following a slower vehicle</td>
<td>Human Driver</td>
</tr>
<tr>
<td>TMS must not provide acceleration command too late when following a slower vehicle</td>
<td>Human Driver</td>
</tr>
<tr>
<td>TMS must not provide acceleration command too early when the car following is travelling faster</td>
<td>Human Driver</td>
</tr>
<tr>
<td>TMS must provide the correct deceleration command when overtaking on the highway with an approaching vehicle</td>
<td>Human Driver</td>
</tr>
<tr>
<td>TMS must not provide deceleration command too early when the car following is travelling at a higher speed</td>
<td>Human Driver</td>
</tr>
<tr>
<td>TMS must not provide deceleration command too late when following a slower vehicle</td>
<td>Human Driver</td>
</tr>
<tr>
<td>TMS must not provide deceleration command too long when the car following is faster</td>
<td>Human Driver</td>
</tr>
<tr>
<td>TMS must not provide acceleration command too soon when following a slower vehicle</td>
<td>Human Driver</td>
</tr>
<tr>
<td>TMS must not provide acceleration command too late when following a slower vehicle</td>
<td>Human Driver</td>
</tr>
<tr>
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<td>Human Driver</td>
</tr>
<tr>
<td>TMS must provide the accelerate command when overtaking on the highway with an approaching vehicle</td>
<td>Human Driver</td>
</tr>
<tr>
<td>TMS must not provide braking command too late when the vehicle in front is stopped or braking</td>
<td>Human Driver</td>
</tr>
<tr>
<td>TMS must not provide braking command too early when the vehicle following is travelling faster</td>
<td>Human Driver</td>
</tr>
<tr>
<td>TMS must not provide braking command too long when the vehicle following is travelling faster</td>
<td>Human Driver</td>
</tr>
<tr>
<td>TMS must not provide steering command too soon when the vehicle in front is stopped or braking</td>
<td>Human Driver</td>
</tr>
<tr>
<td>TMS must not provide steering command too early when the vehicle following is travelling faster</td>
<td>Human Driver</td>
</tr>
<tr>
<td>TMS must not provide steering command too long when the vehicle following is travelling faster</td>
<td>Human Driver</td>
</tr>
<tr>
<td>TMS must not provide steering command too soon when the vehicle following is travelling faster</td>
<td>Human Driver</td>
</tr>
<tr>
<td>TMS must not provide steering command too long when the vehicle following is travelling faster</td>
<td>Human Driver</td>
</tr>
<tr>
<td>TMS must not provide steering command too soon when the vehicle following is travelling faster</td>
<td>Human Driver</td>
</tr>
</tbody>
</table>

Table 10: Safety constraints mapped to stakeholders based on level of autonomy

Table 10 shows the safety constraints which they go as inputs to the design decisions. The safety constraints have been mapped to the responsible stakeholders based on the level of autonomy in cars.

Similar STPA approach can be used to finalize safety related decisions for the entire system.
Thus, STPA can be one way to arrive at safety related design decisions.

Theoretically speaking, the STPA approach can also be used to arrive at other design decisions, but it will need supporting methodologies to address criteria like cost, efficiency, convenience, etc.

{For example- to arrive at cost related design decisions, the NPV, IRR, or payback period for investments will be calculated along with the STPA approach}

A systems engineering approach described in the case-study above will be essential to identify the important stakeholders, the value flow network, and the interdependencies within the system to come up with the correct system constraints and design decisions.

*Following system engineering tools can be useful in designing the system:*

- **Object Process Methodology (OPM)** – For studying the system architecture
- **Axiomatic Design & Design Structure Matrices** - To study the static coupling within the system during design and implementation phases
- **System Dynamics**- To study the dynamic interdependencies between various stakeholders
- **TRIZ** – Innovative problem solving for complex system problems

While implementing a complex socio-technical system like autonomous vehicles, arriving at the correct system constraints and design decisions will not be easy and will need a number of iterations before the design designs for the system can be optimized.
5.1.2 Personalization and connectivity

Personalization and connectivity are two of the most important results of disruptions in information and technology. Connectivity has increased the demand for personalization in day-to-day activities that we do—including driving. The exponential growth in cloud-based services and mobile-based internet usage have led to increased personalization through connectivity in phone, PC, and even the car. As mobile-based internet services become more affordable over time, the demand for personalization (through connectivity) will increase substantially. To fully capture the opportunities presented by evolving consumer demand and technological advancements, automakers and mobile operators will need to re-evaluate the business models for connected car services.\[^{16}\]

One of the best examples of connectivity in cars is the MultiMediaHub (MMH) feature provided by the Chinese automaker Qoros Auto. In order to appeal to the younger demographic, Qoros has harnessed the popularity of social media. The Qoros MMH is delivered to the driver through an 8-inch touch screen. Using Qoros MMH, a driver can access media and social media, receive navigation information, connect to appointment calendars, and even share pictures through the QorosQloud. For drivers who feel the need to be connected on social media, Qoros MMH allows them to do so even when stuck in traffic. The MMH helps distinguish Qoros from both existing European and Chinese manufacturers as well as increase the value associated with their products.

Another example of how information and technology is being used to improve connectivity and personalization in the auto industry is the way businesses like Zipcar and Getaround are disrupting the shared vehicle market space. Getaround is a C2C marketplace which not only allows people to rent a car near them, but to offer their own as well. Getaround allows the users to remotely open, lock, and even track their cars using their phone. This keeps the users always connected to their cars. The car booking service is entirely automated. The renters can also open the cars with their phones. The renter doesn’t even need to meet the owner and get the keys.\[^{17}\]
5.2 Business disruptions

(Co-related to content in 4.2)

Case Study 2: Uber - Disruptor of a Global Industry

Background

Uber is a San-Francisco based venture funded private company founded in 2009 by Travis Kalanick and Garrett Camp who aimed to solve the city’s traffic problems. But the business that they developed has solved traffic problems in more than one city. The Uber model is currently operative in more than 50 countries and 200 cities world-wide. How did this happen? How did Uber become such a phenomenon and manage to disrupt the global transportation industry? This case study tries to answer this question and many more.

Business Model

Uber is a transportation management technology platform that connects private drivers with people who need transportation services using mobile app services. Thanks to the reducing costs of mobile internet services, ride sharing platforms like Uber are booming. These platforms enable point to point transportation within a relatively confined area. The Uber platform not only
provides transportation service to the people who need it, but also enables the drivers to use their private cars to earn income.

**The key features of the Uber business model are as follows:**

- The supply and demand are matched using a **dynamic pricing model**. When the demand for rides is greater than the supply of the drivers in a particular area, the price for a ride increases. This is called as surge pricing. Surge pricing is included to attract more drivers onto the Uber platform. It is also used to attract drivers using other ride-sharing platforms to use Uber. Attracting more drivers improves the likelihood of more cars being located near the journey’s point of origin. This leads to better service levels for the customers in the future.

- All transactions are handled via the Uber Mobile App without any human intervention. Payment is automatically done through the customer’s credit card connected to the Uber App.

- The location of the booked or reserved car can be tracked using the mobile app, whereby the customers know exactly when their car will come to pick them up.

- The users of the Uber App can rate the driver depending on how good or bad their experience has been. The drivers can also rate the customer. In this way the quality of the service is ensured all the time.

- By architecting a mobile platform that directly connects the passengers with drivers that are willing to use their own cars as ‘taxis’, Uber has eliminated the following aspects form their business—

  a. The cost and need for owning their own fleet of cars

  b. Cost of insurance of vehicles and their maintenance and repair

  c. Payments to the drivers (Uber doesn’t need to pay the drivers; customers pay them directly)

  d. The administrative cost of obtaining various license and regulatory permissions that traditional taxi services need.
Due to all these features bundled into their platform strategy, Uber has managed to disrupt the global transportation in less than 6 years since its inception.

The Uber App is perfect for someone who doesn’t want the hassles of owning and maintaining a car, but quickly get one when needed, anywhere, anytime. For someone wanting to extra money from their car, the Uber platform is perfect as well.

Products

Uber at the beginning offered luxury car service (limousine like service) in 2009. In 2012, Uber introduced its UberX service where any driver whose car met certain eligibility criteria set by Uber could offer his services by joining the Uber platform. Since 2012, Uber has introduced a number of products. These products (services) are listed below in Table 11.

<table>
<thead>
<tr>
<th>Product</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>UberX</td>
<td>Cars owned and driven by private drivers typically meant for smaller groups of people.</td>
</tr>
<tr>
<td>UberPop</td>
<td>Launched in some European cities that offers smaller and lower priced cars</td>
</tr>
<tr>
<td>UberPool</td>
<td>Ride sharing option with another person requesting an Uber on the same route Currently offered in New York</td>
</tr>
<tr>
<td>Uber SUV</td>
<td>Car service meant for larger group of people—typically more than 5</td>
</tr>
<tr>
<td>Uber Chopper</td>
<td>Service currently offered in New York for the wealthy who can afford it.</td>
</tr>
<tr>
<td>UberBlack</td>
<td>Limo or luxury car drivers who have a high rating (more than 4.5 out of 5)</td>
</tr>
</tbody>
</table>

Table 11: Uber Products
Uber - Going Global

Global Presence-

Uber is the first transportation management platform that is going global.

Uber began its first international operations in Paris in 2012, and in the same year expanded to London and Toronto. By end of 2012, it was operational in Australia as well.

Now after 3 years, Uber operates in over 50 countries in over 250 cities. Uber is operational in over 150 cities in the US. It is also operational in the Middle-East, Europe, Asia, Central and South America, and some countries in Africa. The current global footprint of Uber is shown below in Figure 24.

Uber has shown an incredible growth pattern, never seen before in the transportation management industry. This rapid international expansion has given them the first mover advantage in most of the countries that it operates in. Its global operation also contributes positively to the business on many other fronts. [18]

Figure 24: Uber’s global footprint [19]
a. Capturing potential in emerging markets-

Uber’s ability to continue to expand its services in emerging markets like India, Brazil, Russia, and China to increase its geographic coverage will continue to drive exponential growth over the next three to five years. The huge market potential in the emerging markets will drive the exponential growth that Uber is currently seeing. Growing penetration of smart phones and faster internet access also offer Uber significant growth opportunities in many emerging markets, such as Africa and Latin America.

In India alone, current taxi industry is estimated at $6-$9 billion and growing at 17-20 percent per annum. At this rate, the Indian market is projected to soar to a whopping $25 billion by 2025. Such is the potential in the emerging markets. [20]

b. Leveraging local market dynamics and knowledge for operational efficiency-

Different countries that Uber enters into and even different cities within the countries have different operations & logistics structure. The knowledge and speed with which Uber can integrate these local learnings and leverages them into profitable business practices, will give Uber competitive lead in those markets.

Uber’s international exposure has enabled it to measure as many inputs and outputs that they can capture. Obtaining all this information is a major reason why Uber has beat even its own revenue forecasts. According to Uber’s CEO, its profit is doubling every 6 months and the company is now creating 50,000 new jobs globally each month. Uber management uses sophisticated technology to measure service metrics related to all levels of customer service, such as speed and product quality.
c. Ensure a robust and scalable technology platform-

The large base of users that Uber captures helps Uber to test its software in different environment. This improves its robustness, security and scalability. Developing countries don’t have well-defined infrastructure and roads. For e.g. one-way status of roads change almost on a weekly basis in India.

Exposure to such varying conditions enables Uber’s software and platform to handle diverse environments. When a technology platform is secure and can handle diverse conditions, it can be extended to provide specialized services local to a particular region (Example of providing the chopper service in New York). Such scalability will be helpful in the future for fleet management, managing specialized vehicles, and even managing emergency situation vehicles like ambulances and fire brigades; especially in the developing markets.

d. Normalize risks-

Internationalization helps Uber to get rid of dependence on the competitive US market. The US market is most susceptible to disruptive innovations which can challenge Uber’s service. The Uber model is not difficult to replicate and Uber has already been challenged by new players in the US market like Lyft.

*Managing global operations*

*How does Uber balance the Global Integration – Local Responsiveness challenge? (GI-LR)*

Uber today is operating in more than 50 countries in over 200 cities. In this sense, it can be called a ‘global’ company. Uber’s value proposition in all its markets is the same- convenient, safe, and cheap mode of travel for its customers.
**Backend- Globally Integrated**

The backend technology for Uber is very much US based and highly integrated. The app, the software platform management, data analytics, research and development, and all such core activities of the business are globally integrated and carried out from Uber’s San Francisco office. Having a strong globally integrated backend ensures that Uber is able to implement a standardized process to be operational in the new market fairly quickly. The strong data analytics at the backend helps Uber to implement features like competitive pricing, app security, and effective customer data management. Hence from the back-end technology perspective Uber is still very globally integrated- i.e. very much American.

**Front End- Locally Responsive**

Although the backend of the business (the technology base) is globally integrated, other aspects about the business like market study and marketing, operations planning and management, leadership development, and laws and policy management are more designed to suit the local requirements of the countries and cities that Uber operates in.

The front end of the business is tightly connected with the local markets that Uber operates in. Operational factors like customers, competitors, local laws and policies, drivers and cars are different for different countries and even different for cities in the same country. Uber needs to have local insights and local connections to manage the local operating environment which can be highly volatile. Uber will also need to more flexible in adapting to local competition. Even the organizational structure currently in place is conducive for local responsiveness with the each region having its separate leadership.

The local challenges that Uber typically faces when entering a new country/city is to build driver networks, build knowledge base on local needs, and hire local leadership to handle the localization process. The biggest challenge is to understand the local needs and perceptions to decide the pricing, the preferred payment methods, and the required security measures needed to ensure the safety of the customers.

Uber’s globalization is based on resource from home-base advantage (technology and business analytics), and adapting to different local markets. In this business process, different local
knowledge is gathered allowing them to enhance their local responsiveness and shorten the implementation time when entering new markets.

*The GI-LR strategy for Uber can be summarized as shown in Figure 25.*

![Figure 25: GI-LR strategic framework for Uber](image)

**Competitors**

Uber’s competitors are traditional taxi drivers, limousine services as well as the new entrants like Lyft, Sidecar, Curb, and the likes which are replicating the Uber platform in disrupting the industry. The major difference between cabs and the Uber model is that cab fares are regulated, while Uber pricing is based on a dynamic model which is driven by the demand and available...
supply in given region. So the cost of an Uber ride maybe be lower or higher compared to a taxi ride at any given time- depending on the demand-supply conditions.

Table 12 shows a descriptive comparison between Uber and its competitors. [21]

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Uber</th>
<th>Lyft</th>
<th>Taxis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Service request medium</td>
<td>Mobile app and SMS</td>
<td>Mobile app and SMS</td>
<td>Phone calls and recent development of mobile apps</td>
</tr>
<tr>
<td>Fare</td>
<td>Variable fare depending on demand-supply condition</td>
<td>Average fare is less than the taxi ride</td>
<td>Regulated fares</td>
</tr>
<tr>
<td>Payment method</td>
<td>Through registered credit card through the app</td>
<td>Through registered credit card through the app</td>
<td>Credit card or cash. Some cabs take only cash. The payment is done by the customer after the ride</td>
</tr>
<tr>
<td>Safety</td>
<td>Drivers are vetted, but not as thoroughly as Lyft</td>
<td>Drivers are thoroughly vetted, even stricter than the taxi companies</td>
<td>Drivers are vetted. Appropriate levels of insurance present. Regulated practice</td>
</tr>
<tr>
<td>Convenience</td>
<td>Highly convenient due to ease of use and accessibility. Just one click on the mobile app is needed</td>
<td>Same level of convenience as Uber</td>
<td>Less convenient due to hassles of calling up every time a ride is needed</td>
</tr>
</tbody>
</table>

Table 12: Uber-competitor comparison

While it’s true that Uber has enjoyed first mover advantage similar services like Lyft are slowly catching market share. Lyft was launched in 2012 and is currently operating in over 50 cities in the US and growing fast. But Uber is still aggressively spending on marketing and has used the social media to its advantage to preserve its place as a market leader. Uber has significantly more
fans on Facebook and more followers on Twitter. Uber currently has geographical as well as social media advantage with a stronger brand image than Lyft. Uber also enjoys a strong investment backing and is currently valued at close to $41 billion after round E founding as of December 2014.\[22\]

**Challenges for Uber**

Although it has lot of first mover advantages, Uber is facing challenges in certain areas which will strong need strategic initiatives to overcome. Some of the major challenges that Uber are facing are-

*Infrastructural and cultural issues in emerging countries*

In countries like India where Uber sees a lot of market potential there are some basic hurdles that it will need to overcome. Many people in the developing countries don’t have access to credit cards as most of the daily transactions are carried out using cash.

Mobile phone penetration is still limited in these countries and access to mobile internet underdeveloped. Uber which relies heavily on its mobile app for getting customers on board will find it difficult to tap the big potential in these markets. They might need to rely more heavily on SMS services than the mobile app. Tie-up with service providers might be one option that they might need to explore to have a robust SMS service.

Local competitors like Ola in India use cash as the medium of transaction and more than 90% of Ola’s passengers pay in cash, with a vast majority of the cab bookings being done through their call centers.

*Regulatory challenges outside the US*

Uber has faced a number of regulatory hurdles especially as it tries to rapidly expand outside the US. Uber is facing a number of challenges in India, China, and Europe. Uber was recently banned in Bangalore, India stating safety concerns (There was an incident in India where a woman using Uber’s service was raped by the driver).
Uber was banned in Germany in late 2014, and the court gave the following judgment,

"The Uber App violates German unfair competition law. In Germany, commercial passenger is only allowed with a permission by the local authorities which the Uber drivers don’t have. The injunction was brought by a taxi operators’ union which also operates a taxi app. A hearing will only take place if Uber applies for it. The injunction is immediately enforceable; Uber can apply for suspension of immediate enforceability." [23]

Similar hearings followed in South Korea where drivers need a license to provide taxi services.

Such regulatory hurdles not only slow down Uber’s growth trajectory, but also hurt its reputation. The latter could have a longer term effects even if Uber agrees to comply with regulations in the markets in which it enters later.

Increasing competition:

The Uber business model is easy to replicate and there is nothing proprietary about the technology platform. Business like Lyft and Sidecar have already emerged strongly and Uber’s first mover advantage will eventually start to fade. The low barriers of entry means that Uber will need to keep differentiating itself and keep updating the technological platform to sustain its first mover advantage.

Lyft has adopted a unique pricing strategy where it offers lower prices during ‘happy hours’. Uber on the other hand has quite an opposite pricing strategy of using ‘price surging’ to match increased demand to limited supply. This pricing war means Uber is already on the back foot when it comes to competing based on price.

In developing countries like India much options like the ‘auto- rickshaws’ are available to the public, which are both cheap and as convenient and easy to get (if not more convenient!) than Uber rides. No smart phone needed, no internet needed to get an auto-rickshaw. Just walk down from your apartment and 9 out of 10 times, one finds an auto-rickshaw waiting at the corner of the road.
Safety Issues

There have been cases reported of Uber drivers raping in India and even in the US. Such incidents can have a long term negative effect on Uber’s credibility and damage its brand image. The background check on the drivers might need a more robust approach than the one Uber is currently using.

The way forward for Uber

Google has invested substantially in Uber through Google Ventures. It needs to be seen what value Google will see in Uber’s business model as is it rapidly evolves. Google itself is working on developing autonomous vehicles and it would be interesting to see if Google might want to integrate its autonomous vehicle technology into the Uber business model to start an autonomous ‘public transport system’. This is on the technology front.

On the operational side, Uber still wants to rapidly expand in new markets outside the US to get the first mover advantage in many markets. This strategy will dive Uber’s growth which it has managed to retain strongly so far.

Having said this, the challenges mentioned above are some serious issues that may hamper Uber’s growth trajectory and it will interesting to see how Uber addresses these issues on its way to being a truly global company.
As mentioned before, Qoros Automotive Co., Ltd is a Chinese-Israeli car manufacturer making a big splash in the automotive industry. It is the result of a 1.5 billion-euro joint venture between Chery Automotive - a Chinese car manufacturer - and Israel Corporation. With a factory in China and product design based in Austria, Qoros is the definition of an international company. It has been making waves in the automotive industry by being the first Chinese-made car to receive a 5 Star Safety rating in the Euro NCAP and several other awards for product innovation and design.

Brand and Strategic Positioning for Qoros

Qoros is adopting a unique strategy in the author’s opinion. It’s adopting a strategy of “GOING OUT TO GO IN”

Qoros’ main target market is its domestic market, China, but it is building a presence in the European car market to further appeal to its target market: metropolitan and technologically savvy Chinese.
Using the ‘ADDING’ strategic framework to evaluate Qoros’ strategy reveals the unique advantages and challenges the company faces as it expands into the European market and penetrates deeper into China.

**China Market: The ADDING Value Scorecard**

**A - Adding Volume**

**D - Decreasing Costs**

**D - Differentiating**

**I – Improving Industry Attractiveness**

**N – Normalizing Risks**

**G – Generating Knowledge**

(1) **Adding Volume or Growth**

Of China's 1.357 billion people, only 240 million \(^{[25]}\) own or have access to vehicles. The penetration rate of car owners (58 people in a thousand) remains a small percentage compared to the United States (804 people in a thousand). \(^{[25]}\) In addition to this, the car market is exploding, with an annual growth rate of 18.6% \(^{[27]}\), which makes China a desirable opportunity for the car industry.

To be a top ten seller of cars in China, Qoros would need to sell approximately 200,000 to 300,000 cars per year. The current manufacturing facility in Changshu has the capacity to produce 150,000 cars in a year. The facility, however, is made to expand to a capacity of 250,000 and eventually be extended to 450,000. This means that Qoros’ capacity is substantial enough to support its goal of being a top ten car seller in China. There is still a long way to go, however. In the first 4 months of 2014, Qoros sold 1,490 cars (industry data predicts 100 were sold in January, 350 in February, 440 in March, and 600 in April). Selling through distinguished dealers
has given 70 touch points in China to consumers. Qoros intends for this number to grow and already has 120 additional dealers signing a letter of intent.

With an eye on the Chinese market, Qoros is only aiming for 10% of sales to come from European markets. Even with this relatively low figure, Qoros faces an up-hill battle in entering European markets as automotive sales in Europe have been steadily declining. That is partially why Qoros has begun its entry into Europe by attempting to penetrate the smaller market of Slovakia. In the European Union, Slovakia has the fourth lowest density of cars.

Despite its smaller size, Slovakia was strategically chosen due to its smaller market size and lack of domestic brand to compete with Qoros. By selling as little as 100 cars, Qoros can become a leading car manufacturer in Slovakia. Furthermore, Slovakia positions Qoros to easily transition to other countries within the European Union. The current strategic move is to pursue Eastern European countries, Nordic, and then the rest of the EU. By becoming the premiere car in even a country as small as Slovakia, Qoros significantly increases its brand image in China.

(2) Decreasing Costs

Qoros’ entry into the European market brings only a few decreases in costs. Slovakia, the only European market Qoros is currently selling in, is over 6,000 miles from its manufacturing plant in Changshu, China. The cars must transverse 6 international borders to reach their destination. Qoros is still considering the possibility of building a second manufacturing plant in Eastern Europe. With no current manufacturing site in Europe, Qoros faces additional logistics and transportation costs in transporting cars to the Eastern European market.

Modular designs and strategic partnerships

Qoros has found innovative ways to cut costs as it expands internationally. At the core of Qoros’ product offerings is its innovative “infotainment” technology – Qoros MMH or Multi-Media Hub. This system, integrated into every Qoros model, is a navigation system and social media hub. Qoros MMH was awarded the prestigious Red Dot Awards recognizing the high quality that went into its design. To keep costs low and its software continuously upgraded, Qoros invested with Microsoft Azure to host the Qoros MMH’s software. This allowed Qoros to cut
costs associated with upgrading software. All cars connected to the Qoros system could now be instantaneously upgraded at once. This appealed to customers as it ensured those with older models that they were benefiting from the newest technology. It also greatly benefitted Qoros as it allowed the company to utilize Microsoft’s data warehouses instead of having to rebuild infrastructure when entering a new market. Three to six months of infrastructure set up was no longer necessary; Qoros could be fully active within days. [31]

**Platform strategy**

Another cost-cutting feature of the Qoros design lies in its modular foundation. Both the Qoros 3 Sedan and the Qoros 3 Hatchback can, and are, built on the same production line. [32] They both share a 1.6 liter naturally aspirated and turbo-charged engine. This allows for Qoros to harness economies of scale as well as utilize postponement to reduce costs in the manufacturing stage. For the time being, Qoros has curbed the production of right-sided driving and diesel cars in order to harness the strengths associated with a modular platform. The production of such cars would require significant re-engineering and costs that Qoros plans to tackle once its market share grows in China.

(3) Differentiating or increasing willingness to pay

Qoros faces the problem of proving it is not just a luxury car knock-off. To distinguish itself from competitors like BMW, Audi, and Volkswagen, Qoros has dedicated itself to distinctive design, reliability, safety, and brand image. Historically, the reputation of Chinese cars has been of low quality and unsafe. [33] By expanding into the European market, Qoros is looking to distance itself from such a reputation. It is in this manner that Qoros has gained the most value by expanding internationally. Beyond defining itself as a quality car manufacturer, Qoros understands that its target consumers prefer international or established brands. In order to achieve this distinction, Qoros recognized the need to move onto the international stage to prove it could build to international standards.
Robust Design

Qoros achieved its goal in 2013. Its first car, the Qoros 3 Sedan, was the first car manufactured in China to receive a 5 Star Safety rating from Euro NCAP and was named the safest small family car in 2013. The Euro NCAP rating measures safety in four different areas: safety assist, pedestrian protection, adult protection, and child protection. A combined score is a culmination of the score from each section. In 2013, the Qoros 3 Sedan was the highest ranked car, with an over-all score of 88%. This was a strategic victory for Qoros as it allowed it to differentiate itself from other cars manufactured in China (none of which had been able to hit such high industry standards).

Personalization and Connectivity

Beyond establishing itself as an international car, Qoros also needs to appeal to its desired demographic: Metropolitan and technologically savvy Chinese. The Chinese market is composed of a different demographic than the rest of the world. Sixty percent of mid-segment cars are sold to those under 40, while this number is closer to 20% in Europe. In order to appeal to this demographic, Qoros has harnessed the popularity of social media. The Qoros MMH is delivered to the driver through an 8-inch touch screen. Using Qoros MMH, a driver can access media and social media, receive navigation information, connect to appointment calendars, and even share pictures through the QorosQloud. For drivers who feel the need to be connected on social media, Qoros MMH allows them to do so even when stuck in traffic. The MMH helps distinguish Qoros from both existing European and Chinese manufacturers as well as increase the value associated with their products.

(4) Improving industry attractiveness or bargaining power

Customer centric approach

The automotive industry is thoroughly saturated with international car companies. In Europe, the market has stalled, making penetration into Europe even more difficult. Qoros is not allowing that to hold them back and is determined to disassociate Chinese cars with poor quality. In addition to building cars to the highest safety standards, they have been offering strategic
promises to clients such as offering to solve any technical problems within 24 hours. With its distinguished customer service, accolades, and certifications, Qoros is aiming to give Chinese car manufacturers a better name.

At the core of its ability to improve the reputation of Chinese manufacturers in the automotive market is how new the company is. As the head of sales and product strategy stated: “We have the big advantage that we’re starting from scratch, from zero. We have no legacy, no baggage. We have the luxury of looking at the car world with a fresh eye.” This allows Qoros to try new technologies and take risks that established car companies are unable to pursue.

As a relatively small player, however, Qoros has yet to realize significant economies of scale or bargaining power. The unattractiveness of Chinese cars and their smaller position in the market serve as a large hurdle to Qoros’ success both internationally in Europe and domestically in China.

(5) Normalizing (or optimizing) risk

Changing the brand image of Chinese cars

The majority of the risk associated with Qoros lies in the reputation of Chinese cars as being subpar on quality and safety. By harnessing the reputation of the European car market, as well as distinguishing itself through a variety of awards and certifications, Qoros is helping to mitigate the risk associated with being a Chinese car manufacturer. The more it serves to distinguish itself, the more it will be able to rise above the reputation of its industry.

From a diversification platform, Qoros’ venture into Europe for sales purposes does little to mitigate its risk. The current Qoros strategy allows for approximately 10% of sales to come from European markets. Therefore, the company remains heavily dependent on the economic and political situation of China. Qoros must be careful or else it could make itself “too international” to gain the Chinese government’s approval (the Chinese government wants to see a Chinese car company do well in China, not an international venture). This potentially could hurt their position in China. The current initiative to keep from diesel or right-hand-side driver
markets (which includes all of the British Empire) further limits the markets that Qoros can enter to help mitigate risk.

(6) **Generating knowledge (and other resources and capabilities)**

**Innovation through strategic partnerships**

One of the strengths of Qoros’ strategy has been its reliance on strategic partnerships that has allowed it to focus on product innovation. Qoros has outsourced its aftermarket logistics to Unipart [40], its technology infrastructure to Microsoft [41], and has also contracted various business units to companies like Harman, Neusoft-Alpine, and Magna Steyr. [42] This has been possible due to shared key performance metrics and the move from weekly meetings to joint problem-solving sessions with suppliers. These meetings became collaborations between Qoros and partner employees that has allowed Qoros to focus on its product innovations. All executive decisions were made outside these meetings to limit the impact of negotiation. [43]

**Talent acquisition and management**

Qoros defines itself not as a Chinese company but more as an international company that happens to be Chinese. At the core of its strengths lies an experienced and diverse team of European designers and engineers. The brainchild behind the Qoros 3 Sedan is Ged Volker Hildebrand. Hildebrand is the former head of the North American brand of Volkswagen and currently holds the position of Vice President at Qoros. Included in top management are industry experts from BMW, GM, SAAB, Nissan, and McKinsey Consulting. Qoros has used the intellect of its senior managers to do the unheard of -- create a European car using a Chinese manufacturer. By using international industry powerhouses, Qoros is positioning itself to replicate the best practices that have defined the automotive industry.

**Generating knowledge**

Qoros has begun its entry into Europe by attempting to penetrate the smaller market of Slovakia. By choosing a smaller market, Qoros is generating knowledge on how to import cars into Europe. All the necessary procedures and capabilities can be found in a stable EU member nation
that utilizes the same currency. \[^{[44]}\] This gives Qoros an advantage against its competitors who try to penetrate all European markets at once too quickly and end up spreading themselves too thin. It is the knowledge gathered from its suppliers, key senior managers, and entry into Slovakia that have given Qoros its edge.

**In Conclusion**

Qoros has created a unique and strategy international strategy by focusing on developing brand and reputation abroad. In China, international brands are the preferred cars and sell best. Qoros strategy of gaining international accolades, producing distinctive design, and maintaining strong client interactions have helped separate it from the stigma of poor quality and safety that surrounds Chinese car manufacturers. Slowly but surely, the global automotive industry is going to take notice of Qoros Auto and similar Chinese players who will be successful in changing the perception about Chinese made cars.
Chapter 6: Challenges to the OEMs

For most part of the last century American and European automotive companies have dominated the global market with well-designed and innovative products. The fulcrum for their growth has been optimization and enhancement of the core technology related to automobiles. Be it powertrain optimization, safety enhancement, or efficiency management, the big OEMs have induced innovation led solutions to capture customer attention and fulfill their needs.

As development of core automotive functions continues to ride on innovation and technology, the real challenge to the OEM will be- to innovate to capture evolving consumer demand and technological advancement. As autonomy and connectivity in cars continue to raise rapidly, the automotive market will become more complex, requiring business model innovations that iteratively configure supply, delivery channels, and bundling of different services. The emergence of the East as an important part of the automotive value chain will definitely have its implications on the strategy of the big auto OEMs. To compete in the East and sustain the technological edge in the West, the big automotive will have to overcome many challenges. Three of these most important challenges are described in the section that follows.

6.1 Uncertainty in designing support systems for autonomous and electric vehicles

There is no doubt that hybrid electric, plug in electric, and autonomous cars will form a major part of atleast the Western market in the coming future.

As described in the case-study for implementing autonomous vehicles, most of the major OEMs are focused on rapidly developing self-driving technology. However, as seen in the analysis, implementing autonomous cars is a complex socio-technical system that will need a holistic, top-down approach. There is still a lot of uncertainty of the impact by public policy and consumer perception to the technologies being adopted. Then there are differences in global perception, regional regulations, and preferences.
A scenario based SWOT analysis for autonomous vehicles is shown in Table 13.

<table>
<thead>
<tr>
<th>STRENGTHS</th>
<th>WEAKNESSES</th>
<th>OPPORTUNITIES</th>
<th>THREATS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increased safety (in future)</td>
<td>Unproven technology</td>
<td>New market</td>
<td>XYZ company designs artificial intelligence algorithms- creating a monopoly</td>
</tr>
<tr>
<td>Convenience</td>
<td>No common implementation architecture developed so far</td>
<td>Development of new technologies</td>
<td>Restrictive legislation passed</td>
</tr>
<tr>
<td>Positive environmental impact</td>
<td>Perceived safety risks (currently)</td>
<td></td>
<td>Public transit lobbies for use only outside of cities</td>
</tr>
</tbody>
</table>

Table 13: Scenario based SWOT analysis for autonomous vehicles

Anyone of the scenarios mentioned under ‘threats’ could impact how widespread autonomous vehicle technology will be implemented or embraced by potential users.

Based on legislations, customer preferences, and evolution of particular technologies, OEMs will need to adopt constantly while autonomous vehicles are being tried and tested.

Currently, OEMs like Ford, Audi, Daimler AG are the leading suppliers of technology that is driving the deployment of autonomous features in cars. These companies and their tier 1 suppliers are working on individual technologies that may ultimately lead to completely self-driving cars in the future. This road map of developing fully autonomous vehicles is a gradual path and all the stakeholders in the value network are slowly developing their internal capabilities to ensure effective implementation of autonomous vehicles.
Working on technology is one part, but planning and designing for actual implementation will need the OEMs to work closely with government authorities, infrastructural companies, and local regulatory bodies. While technologies like V2V and V2X are being developed by the OEMs, the infrastructural requirements for these technologies should also be taken into consideration. What role will the OEMs play in designing and planning for the complementary needs of implementing V2X systems? How will the local regulatory bodies support the implementation of infrastructure? Will the government take responsibility to develop and maintain the infrastructure that will be needed in the future?

Currently everyone is working on different technologies and which technology will emerge out as the best and the safest is still a question which is unanswered. As technologies advance in the future, will the system and infrastructural requirements change? From defining the system requirements (other than the actual technology), assessing which stake-holders in the system should take ownership for the supporting sub-systems (mainly the infrastructure), and the timeline for actual planning, development, and installation of needed infrastructure – all these factors are part of the bigger picture and will play a big role in the successful implementation of self-driving cars on public roads. The OEMs will need to consider all these questions and other uncertainties while developing the actual technology. Developing the technology in isolation might hamper or delay the implementation of autonomy in vehicles.

Thus, the real challenge for the automotive OEMs in implementing autonomous technology can be summarized in the following problem statement-

*To enhance the safety, convenience, and efficiency of personal transportation by integrating autonomous vehicles into the current transportation system architecture using autonomous vehicles, infrastructure enhancements, and standards and regulations*

The balancing act therefore looks difficult and challenging.

For plug-in electric vehicles similar issues related to availability of charging stations, elimination of ‘range anxiety’ from users’ mind, and large scale production of Li-ion battery packs to sustain
the implementation of plug-in hybrids are some of the important issues that need immediate attention.

According to CBSnews.com, many Silicon Valley company employees had started finding it hard to access car-charging stations at work last year. Installation of vehicle charging ports at some companies it seems has not kept pace with soaring demand. German software company SAP had said that its charging stations were not enough for the people who came to work in electric vehicles. ChargePoint which, which operates a large EV-charging network indicated that the growing demand for EV will compel the Silicon Valley companies to provide one charging port for every two of their employees’ electric vehicles. Companies everywhere will begin facing similar problems. Pacific Gas & Electric Co. expects 800,000 electric vehicles to be on Californian roads by 2020 - creating a high demand for charging stations. Currently, there are about 5,000 public and workplace charging stations in California and 20,000 nationwide.

Another important consideration for the EV market is the availability of affordable Li-ion battery packs. As mentioned in the report earlier, Tesla Motors has plans to build the world’s largest Li-ion battery factory – called Gigafactory before 2020. The proposed factory would be approximately 10 million square feet and would produce Li-ion cells to build around 500,000 battery packs a year. With these economies of scale, Tesla expects to achieve a minimum of 30% reduction in production cost for their car batteries.[45]

6.2. Increased product complexity due to demand for connectivity and personalization

High end car makers like Ferrari, Lamborghini, and Rolls-Royce have been traditionally known to offer personalization experience on many of its features like variety of interior colors and materials. Even the bodywork color can be personalized. Custom work can be done on front and rear spoilers, instrument cluster cover, and even infotainment controls and screen trim. But the personalization trend is going to change significantly as information and technology establishes connectivity in vehicles. ‘Digitized personalization’ will drive the product development process in the future.
Technological developments in mobile internet, cloud computing, and embedded systems have triggered a wide-spread demand for personalization and connectivity in cars. Automotive OEMs will need to integrate these factors in their product planning and development process. Developments in adjacent industries – including demand for services in the consumer electronics sector – are likely to greatly inspire the types of in-car services requested by vehicle owners in the future. The growth in the deployment of high bandwidth cellular services will enable proliferation of multi-media based infotainment. While integrating connectivity features in the core product development process, auto OEMs will need to look into-

a) Strategic partnerships (for reducing time-to-market) – develop internally or outsource technology development?

b) Trends in technology and adoption costs- can better technology prediction help to optimize development costs?

c) Consumer service needs and willingness to pay- how to create right value for money?

The digital personalization will not be restricted to the Ferraris and the Lamborghinis. As the ‘internet of things’ platform develops with rapid pace, accessibility and deployment costs for technology will drop. Almost all global auto makers will be in able to adopt the digital personalization process- assuming they address the above 3 questions correctly and on-time.

6.3. Accelerating product obsolescence: Technology Revolution & Increasing Industry Clock Speed

The automotive industry no longer serves as a stand-alone industry. Technnoly based companies have become an important part of the automotive value chain. Big auto companies like Audi and Ford are collaborating with technology companies to offer enhanced products and services. Technology companies ( or the technology industry in general) have a greater ‘industry clock speed’ where the innovation S-curves jump more frequently as compared to the innovation curves for automotive industry. Technology companies, as they enter the automotive space- will
invariably drive the auto companies to innovate more frequently, set innovation benchmarks, and invariably force the auto companies to adopt a platform based product strategy. The technology companies will provide ‘add-ons’ to personalize the product platform and cater to changing consumer needs.

As consumers today expect more technology enabled features in cars, the auto OEMs will face rapid product obsolescence. Some current features, platforms, and even products may not be viable in coming years. Products that don’t suffice the hardware-software integration requirements will become obsolete. As technology expands rapidly, consumer demand for new products that support personalization, connectivity, and digitized experience will rise exponentially. Some of the challenges that the OEMs will have to face in the coming future are-

- Decreased product life cycle times
- Quicker time-to-market needs for new products
- Unpredictable demand for products based on changing consumer behavior
- Decreasing customer loyalty
- Unclear role of autonomy in vehicles and transportation
- Growing role of technology companies in introducing innovative mobility solutions

All these challenges will pose a number of questions in front of the OEMs. The bigger challenge however, for the OEMs will be to ensure that they don’t simply become the “dumb pipes” of the industry; the auto companies being like the Verizons and the AT&Ts, while the Zipcar and Uber like business models will become the Apples and the Googles (trend setters), who will decide the way forward for the auto industry. Technology driven consumer behavior will be hard to predict given the rapid rate development happening in information and technology.
Chapter 7: The OEM Perspective

As the automotive industry experiences change from the traditional ways of business, the big OEMs will need to do their SWOT analysis all over again. The foreseen trends in technology, changing consumer behavior, and the emergence of the East- will make the auto OEMs reassess their long-term corporate strategies. As they do the reassessment, following constraints, opportunities, and implications will need consideration.

7.1 Constraints, Opportunities & Imperatives

Constraints

Skill level
It wouldn’t be realistic to say that technology (especially software based) development is the core-competency of the automotive OEMs. As technological balance shifts from mechanical innovation to software based innovation, the automotive companies may find themselves short of the required skillset. They may have to increasingly depend upon their suppliers for technology. Integrating technology into the product is equally important and the integration domain might need special skills as well. Integration, testing, and validation will be crucial. The only feasible solution might be to use the platform strategy to ensure that the integration is easier and the time-to-market with new technologies is relatively faster.

Speed of development
As technology influences consumer behavior, the frequency of demand for new products will rise. New products might be needed for different business models. As the shared vehicle market grows and autonomy in vehicles increases, different business models might emerge that may need specific products. Due to the ‘internet of things’, the probability of new business models coming up and (disrupting the automotive industry) can be judged to be quite high. This unpredictability in future business models will mean that the OEMs will need to have a fast time-to-market product strategy. Thus, the speed of developing new products will be important in the
future. Aligning the product development process to trends in technology development and consumer behavior will be critical

**Opportunities**

Along with challenges and constraints, the mega trends in the automotive market also bring in opportunities for OEMs to realign their value chain through a strategic lens. Looking at the bigger picture, the OEMs can consider following business aspects as opportunities to redefine and realign their value chain activities:

- Map and redevelop competencies
- Drive innovation based product development
- Develop internal capabilities

**Map and redevelop competencies**

This may be the best time for the OEMs to map their strengths and weakness. SWOT analysis considering different business scenarios (shared vehicle market, autonomous vehicles, plug-in electric car market, etc.) will help the OEMs to identify and map their strengths with respective to these technology based business disruptions. Mapping the firm’s competencies in terms of ‘readiness levels’ could be a good indicator of where the firm has strengths and where it needs to improve. Technology based value stream mapping will be useful to analyze how competencies are distributed in the value chain.

The mapping process can be represented as shown in Figure 26.
Product innovation is going to form the base of value creation for the OEMs in the future. As technology companies increasingly become a part of the automotive value chain, consumer expectation for innovative products will rise. To be able to match the new industry ‘clock speed’, the OEMs will have to have innovative offerings. Even the platforms that these OEMs design in the future, will require compatibility with disruptive technologies that the technology companies offer.

The product development process will need to align following factors to create value in future business scenarios-

- Understand ‘innovation’ in the business context
- Co-relate technology trends to changes in consumer behavior
- Anticipate future technologies and their applications
- Organize R&D to support innovative cross-functional collaborations
- Involve technology suppliers early for new product development

- Adopt global platform strategies to reduce time-to-market

**Develop internal capabilities**

Planning for capability development will be crucial to sustain innovation in products and processes. Based on competency mapping, capability requirements will need to be defined. Capabilities in technology mapping and development, agile product development, and leaner (yet responsive) supply chains will be critical. As technology based companies disrupt the automotive industry (Tesla with its electric cars and Google with its autonomous vehicle), the demand for innovative products will rise rapidly. The OEMs will need internal drivers that give the desired capabilities in the future. Some of the capabilities and the corresponding drivers are shown in Table 14.

<table>
<thead>
<tr>
<th>Capability</th>
<th>Internal Drivers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Innovative product pipeline</td>
<td>- User centered innovation</td>
</tr>
<tr>
<td></td>
<td>- Ability to identify ‘lead users’</td>
</tr>
<tr>
<td></td>
<td>- Cross functional development process</td>
</tr>
<tr>
<td></td>
<td>- Innovation ‘culture’</td>
</tr>
<tr>
<td>Technology compliant product</td>
<td>- Technology mapping capability</td>
</tr>
<tr>
<td>platforms</td>
<td>- In-house technology expertise</td>
</tr>
<tr>
<td></td>
<td>- Technology Readiness Level (TRL) assessment capability</td>
</tr>
<tr>
<td>Reduced time-to-market for new</td>
<td>- Global platforms for products</td>
</tr>
<tr>
<td>products</td>
<td>- Enhanced integration and testing capability</td>
</tr>
</tbody>
</table>

Table 14: Developing internal capability- an OEM perspective
**Imperatives**

*Boundary-less design, development, and manufacturing*

Emergence of auto companies like Qoros has created a platform for truly global value chains—the product being designed using European standards and manufactured in China, in case of Qoros Auto. Creating a ‘global’ product not only adds ‘business value’, but it will also help to optimize costs, reduce development times, and help create common product ‘platforms’ which could be used in multiple markets in the future.

Boundary-less collaborations also include cross-industry partnerships which many leading auto OEMs are now adopting to drive innovation in their product offerings. Big auto companies like Audi and Ford, and even relatively newer companies like Qoros, are tying up with technology companies to offer digital services to the tech-savvy customer. Described in Table 15, are some of the important cross-industry partnerships shaping product development in the auto industry.

<table>
<thead>
<tr>
<th>OEM</th>
<th>Technology partner</th>
<th>Feature/Service developed</th>
<th>Synchronization level in system</th>
</tr>
</thead>
<tbody>
<tr>
<td>Audi</td>
<td>Nvidia + third party developers</td>
<td><em>Audi virtual cockpit—Complete digitization of console</em></td>
<td>Lower level synchronization</td>
</tr>
<tr>
<td>Ford</td>
<td>Microsoft + third party developers</td>
<td><em>Ford Sync—Hands free, voice commands and limited integration</em></td>
<td>Medium level synchronization</td>
</tr>
<tr>
<td>Qoros</td>
<td>Microsoft + WirelessCar</td>
<td><em>QorosMMH—Cloud enabled consumer centric digital ecosystem</em></td>
<td>High level synchronization</td>
</tr>
</tbody>
</table>

Table 15: Cross-industry collaborations
Designing the value chain for Global Integration and Local Responsiveness (GI-LR)

The 3 mega trends discussed in the earlier sections are a global phenomenon and not restricted to a particular market or region. Some regions might experience the effects of the trends early, others later. The OEMs will need to develop strategies that will help them to address these global challenges in most efficient way. Going forward, all strategic decisions will have global implications, and therefore, balancing the decision making process (in terms of optimizing the use of GI-LR framework) will be critical.

Global Integration [46] refers to – operating at ideal scale, in the right places, standardizing key elements, integrating learning and innovation across locations. Globally integrated strategy results in benefits from economies of scale, common product platforms, and global innovation management process. Globally integrated strategy is (can be) generally applied to the ‘back-end’ of the business. Back-end refers to technology management, IT and supporting systems, ‘platforms’ for products, and global sourcing of materials.

Local Responsiveness [46] refers to tailoring strategies to suit local market demands. Business ‘front-end’ activities like marketing and product positioning, and executing legal requirements might typically need locally responsive strategy.

The correct application of the GI-LR framework will help the auto OEMs to seamlessly integrate the front-end and the back-end activities and compete on the global scale while addressing the 3 mega trends.

For applying the GI-LR framework to an OEMs value chain, 3 stages have been considered-

a) Design and Product Development
b) Manufacturing Management
c) Brand, Marketing & Sales Management
a) Design and Product Development

In context of applying the GI-LR framework, it is essential to differentiate between product design and product architecture development. Product architecture is defined in context of product platforms. Architecture is essentially driven by the use of ‘platforms’ and product design refers more to the physical rendering, styling, and ‘add-ons’ of the product. Differentiating design from platforms will help to clearly distinguish between the strategic approaches needed for both of them.

Architectures can be globally integrated by using common platforms for products. Going by the global trends and the unpredictability in consumer behavior, platform based architectures can be useful in responding quickly to changing customer needs. The platforms though, might need updates to make them ‘compatible’ with IT disruptions which will shape the consumer demand and introduce new business models in the industry. The primary benefits of having globally integrated product platforms are-

-Improved speed to market

-R&D expenditure reduction

Figure 27: GI-LR strategy for products and platforms
The GI-LR strategy for product development can be represented by the plot shown in Figure 27. Product platforms can add great value if integrated on a global level leading to use of common systems, components, and modules. Such platforms will support global procurement and manufacturing. Platforms can contain multiple architectures (similar in technology and application) to cater to different but similar markets. Finally, car design, rendering, branding, and feature management might need a more locally responsive (market specific) strategy.

b) Manufacturing Management

Operations management (sourcing and manufacturing) will be influenced to a large extent on creation of global product platforms.

![GI-LR strategy for manufacturing management](image)

Figure 28: GI-LR strategy for manufacturing management
As shown in Figure 28, global product platforms will enable global procurement and manufacturing. Global sourcing can help drive standardization across products, help reduce complexity infused by shorter product life-cycles, and help maintain product quality per global standards. Manufacturing strategy can also be aligned to the use of common platforms. Platforms can enable centralized manufacturing with factories having high capacity and high productivity. Manufacturing of product platforms can be done on a global scale with parts sourced globally. These platforms can then be used to accommodate multiple architectures, which can be used to address product needs in different but similar markets.

Manufacturing activities at local level should include integrating and assembling the required ‘add-ons’ to the architecture. Local manufacturing should enable demand postponement (extremely important for changing consumer behavior) and flexibility. Local level manufacturing should focus only on ‘integration’ aspects. Some of the components needed to address specific local needs can be sourced locally if required. This type of local sourcing can be carried through short-term or temporary contracts depending on the estimated product life-cycle for the local brand/product. Global level procurement for platform components should be through long-term contracts (preferably with lesser number of suppliers).

Common product platforms, global sourcing, and global platform manufacturing will enable the OEMs to drive economies of scale. Local level product integration, branding, and design should be done to address local markets and changing consumer demand.

Tie-up with technology suppliers, in the beginning, may be done to address specific markets (markets which are technology savvy). But as technology spreads across the globe through ‘internet of things’, the tie-up with technology suppliers will be needed to address global needs. Technology procurement will eventually be a part of the global procurement process and will be needed to be incorporated in the product designing platforms. As innovation shifts from the mechanical world to electronic and software domain, technology companies will become strategic partners for OEMs and drive the definition of product platforms.
c) Branding, marketing, and sales management

Brand management will need a more strategic approach in the coming future as the automotive business revolves around technology disruptions. Auto companies will need to evolve as ‘international brands’ as globalization, technology, and changing customer usage patterns dominate the scene.

Strategic aspects that the auto companies will need to focus on as part of ‘global brand management’ are-

*Global positioning of the company*

The auto companies may need to completely change their global brand image from a ‘car maker’ to a ‘technology based transportation solutions company’.
Global brand management is going to revolve around technology centered business models. Car-making will become just one part of the transportation solutions domain. The auto makers may need to horizontally expand their value chains to ‘offer more’ to the customers. That might be the only way to survive in the global transportation business. Positioning themselves as a technology driven global automotive solutions company might be necessary in the future.

Partnerships

The global brand repositioning might need strategic partnerships (with technology companies) to drive the value delivered to the customer. To ensure that the brand evolves with same pace as technology, strategic partnerships with technology companies might be necessary. Such partnerships may be needed for specific products, specific regions, or for even a specific amount of time.

Initiatives

It’s not easy to change a company’s global brand perception. Initiatives like investing in alternative technology, alternative business models, and alternative markets might be needed in the future to change a company’s brand image globally. “Aligning trends in the consumer demand and technology based core-competency to deliver value to the customer” will form the base-line to select the correct initiatives in the future.

Sales strategy on the other hand will need more localization and less of global integration to cater to the demand in different markets. Critical factors that will govern the implementation of sales strategy are-

Image management

Although global brand positioning is important, most of the times, local sales are driven by ‘image’ or perception of the brand in the local region. This is mainly due to local advertisement strategies, economic conditions in the region, demographic description of the region, and technology and business trends in that part of the world.
Value proposition & Local needs

The local demand is driven by the value that the local customers seek. Aligning core competencies and marketing strategies to define the correct ‘value’ for local markets will be critical. Marketing campaigns will be needed to be more locally responsive with a less of global dimension. Local marketing initiative will be driven by local sales strategy identified based on ‘value’ desired by the local market.
Chapter 8: Conclusion

The automotive industry is on the cusp of changing from an industry dominated by ‘car-makers’ to an industry driven by technology disruptions. Technology companies will play a significant role in the automotive value chain in the coming future. Development in IT, penetration of mobile internet, and changes in consumer behavior are paving ways for new, different, and innovative business models. Chinese car-makers like Qoros Auto are also changing the perception of Chinese auto-makers for good.

Vehicle autonomy and rise in car sharing market are the 2 cornerstones (as seen today) which will shape the future of the automotive industry. Technology will propel new business model currently unknown. The big auto makers will no longer be in a position to ‘orchestrate’ the value chain unless they can provide platforms which enable value creation in the future.

Google’s basic direction is that technology can be made that does not require any V2X capabilities and a sophisticated enough vehicle (Level 5 autonomy) can be immediately integrated into the current system. In this case the machine directly replaces human driver. In some ways if this is possible than one could argue that there is not much needed in changes to the current system and only some laws about licensing and liability need to be established. With the issue of advanced notice of vehicle-to-vehicle communication rule by NHTSA, this suggests that V2V will be part of the architecture even if others do not think it is necessary.

Finally, automotive OEMs have been working on the foundational technologies needed for self-driving vehicles for some time and features, such as, adaptive cruise control, lane keeping assist and self-parking have been available in the market. With demonstrations of the integration of these features, like the Audi Highway Pilot (that is an almost production ready), it seems the OEMs plan to slowly introduce self-driving technologies into the market as customers become more comfortable with them (unlike Google).

As more and more people accept the car-sharing concept and shift from ‘owning to using’ cars, the differentiating factors between successful business models (like Uber and Zipcar) and their fast growing competitors will be safety, clean cars, reliable pick-up locations/time, and payment convenience. If competitors offer these services at a better pricing strategy, Uber might need to
recalculate its dynamic pricing model and shift to a model which uses permanent pricing to retain its customers. To attract more drivers (to match the demand), Uber might need to pay the drivers more (form its own share). If Zipcar like businesses continue to flourish over time, OEMs will eventually need to create product platforms that can accommodate technology and features that drive the car sharing experience. Such product platforms might be needed to be mass-produced in the future (requiring changes in existing manufacturing systems) to cater to the demand in the car sharing space.

Thus, the 3 trends described earlier will bring challenges as well as opportunities for the auto OEMs to realign strategies, recalibrate competencies, and reorganize their role in the global value chain. As technology advances rapidly, the auto OEMs might need to reposition themselves in the same league as the global technology companies like Google, Tesla, and Apple.

Product development, operations management and sales, marketing and brand management will require correct balance of global integration and local responsiveness. Strategic re-alignments through partnerships, long-term contracts, and development of internal (technological) competencies will be critical in the coming future for the auto OEMs.
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