Chapter 23
Exploring Connected Cars

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Abstract Developments in technology have impacted the automobile industry on a large scale. Connected car is a major concept related to mobile technology and Internet of Things (IoT). This paper aims to elaborate this major concept emphasizing the factors of future mobility in human lives.

Keywords Automobiles · Internet of Things · Connected cars · Mobility · Technological convergence

23.1 Introduction

Information technology is responsible for a paradigm shift in economic and social objectives globally. This paper aims to elaborate the impact of technology on automobile sector and how the development is contributing toward a sustainable society.

Two things have happened in the computer and information technology field over the past three decades:

(a) The cost of computation has gone down as microchips became smaller, cheaper and more powerful (Byrne et al. 2017).
(b) Cost of information transfer over wireless channels has gone down as governments and companies have invested heavily in large communication networks and mobile technology (Byrne and Corrado 2015).

Innovative minds around the world have leveraged these advancements to develop solutions for problems in their respective industries. The automotive industry is no exception.

How to make cars better? One way is to improve the body and components of the car. Suppose a company wants to improve the fuel efficiency of the vehicle, the com-

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pany may invest heavily in research so as to improve the engine and the aerodynamics of the vehicle. This method will be expensive and might take years to bear fruits. An alternative way is to connect the car to the Internet and leverage GPS technology to find uncongested routes during driving which will reduce the travel time, thereby saving fuel. Some of the existing trends in connected cars, including some innovative solutions that already exist, are discussed below. Some of the developments that are expected in the future are also mentioned.

23.2 Technological Innovation in Connected Cars

When someone mentions connected cars, it conjures up a lot of images in our heads. Some people imagine self-driving cars. Others start thinking about a framework where all the cars that are in proximity to each other, exchanging information with each other in order to maintain a safe distance. Although these technologies may become commonplace in the future, they are far too advanced to be utilized by common people as of today. We will look at some of the technologies that are being used by consumers today, which are no less impressive and are creating tremendous value for drivers, car companies, and governments. Apart from these three stakeholders, there are several new start-ups that are developing solutions to connected cars technology.

The general idea of connected cars is to provide as many services to the car drivers as possible using the Internet and digital technology. These services can be provided through smartphone applications or through embedded digital devices inside the car. The benefit of leveraging digital technology is that a large number of services can be provided at a very low per capita cost. Many of these technologies are software based, which means it can be distributed to millions of customers very quickly, i.e., the services can be scaled rapidly and cheaply. Also, these services can be continuously improved and updated at a much higher pace than the mechanical or electronic improvements in the car itself. This is the reason why car companies and governments are focusing very keenly on connected cars technology.

23.2.1 Global Positioning System

Over the last two decades, transportation system has evolved a lot in terms of information sharing by relying heavily on global positioning system (GPS) services (Dey). Most people carry a smartphone with them. These phones come with inbuilt GPS chip and they are connected to the Internet through Wi-Fi or mobile service providers. Applications have been developed that can tell the phone user his/her exact location on the map as well as routes from their current location to any particular destination that they want to go to. This technology is used extensively by drivers.

There are many potential applications of this mobile-based GPS technology. The most common application is to find the shortest route to the desired destination. The word shortest may be used in the context of the time required to reach the destination. If there is traffic congestion, the application may reroute you through a less congested route.

Drivers can use this technology to find useful utilities like hospitals, restaurants, etc., in the vicinity of their current location (Mladenow et al. 2016). One popular application is to find nearby gasoline stations. There are companies that have built applications which allow a customer to find gasoline stations close to their location along with the respective price of gasoline at those stations and their distance. Customers can choose the best option among all the closest gasoline stations, based on the price or how much gasoline he has left in his tank. This can save the customers money during their gas refill.

A common problem with the technology is that the GPS may not always be very accurate. It is a satellite-based technology and the accuracy with which the car or mobile phone can be located depends on the geography of the location and strength of the signals. For example, the GPS signal may not be available in urban canyons. In simple words, urban canyons are streets which are flanked by the tall building, obstructing the GPS signals. The signal may be lost inside tunnels too. So while a car is driving on the road in a large city, the GPS signal may be lost suddenly. A lot of services require the GPS signal to be strong and may not work in its absence. This causes inconvenience and frustration to the end user (driver) who may not appreciate the technological challenges involved in the GPS system.

23.2.2 On-Board Diagnostics

On-board diagnostics (OBD) is a small hardware device one can plug into their car. Most cars come with a slot for this device. The device can collect information about the car while it is being driven. It can be connected to the smartphone through bluetooth. It can also be connected to the cloud through the Internet, where the data collected by the OBD device can be stored. Typically, the device records information such as the speed of the car. It is also used to record fuel consumption and other performance indicators from the internal electronics of the car. This device is being used to develop a lot of solutions.

Several companies have built software applications around the OBD technology. Car companies use these devices to monitor the performance of their cars and provide on-road assistance in case of a breakdown. Customer may pay a small amount for this device and a regular subscription fee. In return, they may get a constant feedback on the health of the car. He can also be informed about his fuel economy. This may save money for the customer in maintenance and fuel costs and generates extra revenue for the car company (Kim et al. 2010). This also gives car companies a real-time performance measure of their models. This information can later be used to improve their performance.

Start-ups have developed smartphone apps which use data from OBD device to provide insights to the driver. The data collected during the drive can be used to inform the driver about the quality of his driving. For example, the driver can be notified that he was speeding excessively during the drive. The driver may use this information as a feedback to improve his driving and become a safer driver. Or parents may use this information to monitor the driving of their teenage children.

23.2.3 Smartphone-Based Solutions

The modern smartphones come with inbuilt motion sensors and GPS. Some companies have developed applications for drivers using these sensors. When the driver is driving, the applications collect data from these sensors and process it using artificial intelligence (machine learning) algorithms. Once again, this data can be used to inform the driver about the nature of his driving. This will help make both the driver and the vehicle safer. For example, when a driver using a smartphone is driving a car, the GPS data extracted from his smartphone can be used to predict if the driver is a good driver by understanding his speed patterns. The motion sensors can be used to determine whether the person was talking on the phone while driving (Wang et al. 2013). It can also be used to detect other risky maneuvers like excessive braking, accelerating, aggressive lane-changing or risky turning.

The advantage of using the inbuilt sensors of smartphones is that it eliminates the need for extra hardware (like the OBD device). This makes it extremely convenient for the driver to use this technology since all he needs to do is to download and install the application on his smartphone. The services can be provided to millions of customers at very low cost. However, the accuracy of the analysis provided by these applications depends on the quality of the sensors on the phone and the skill of the developers who write the algorithms.

The inbuilt motion sensors are more reliable than the GPS since they do not rely on satellites and are not affected by the location of the phone or car. However, customers may be concerned about the fact that the private companies may gain access to their private information with these intrusive technologies. They may also not consent to be tracked by the GPS since monitoring their location may also be considered a breach of privacy. It is important for companies to maintain ethical standards and not take undue advantage of the driver's trust.

23.2.4 Insurance

Drivers are interested in reducing the cost of insurance (premiums) and insurance companies are interested in reducing payouts. As mentioned above, connected cars can be used to analyze the quality of driving of drivers. By analyzing a driver for a certain period of time, insurance companies can determine whether the driver is

safe or risky. The insurance premium can be designed accordingly. Customers may themselves use this information to get favorable insurance deals. This technology can also be used by fleets to identify its risky drivers. This is an emerging technology in saving money for both individuals and insurance companies.

Currently, most insurance companies use statistical models to determine what the insurance premium for a driver should be. These models mostly use demographic information of the driver as independent variables. So, for example, a 40-year-old person with a family may be assumed to be safe, whereas a 25-year-old unmarried man may be considered to be risky. These models are not very accurate since it doesn't take into account the individual driving skills and risky behavior of the driver into account. These models can be unfair to safe drivers in certain demographics and at the same time might lead to higher losses for the insurance companies. But with connected cars, it is now possible to evaluate each individual driver. Using the information from the above-mentioned technology, it is now possible to create new variables which can be included in the statistical models. The accuracy of the models is bound to improve, and this will lead to savings for both the drivers and insurance companies. Several insurance companies are experimenting such models, and in the near future, we shall these connected cars technologies will be used extensively for insurance purposes.

23.2.5 Collision Detection and Alerts

Safety is one of the biggest concerns for both the drivers and the car companies. Some cars come with inbuilt collision detector which notifies the car company through the Internet. Some companies have developed applications which can detect collisions using smartphone sensors too (Ali et al. 2015). This information is extremely crucial and can save lives by enabling the car company to send timely help to the site of the collision. The alert can be sent to the nearest hospital. In case the collision is not serious, the customer can be called up and asked whether he requires any assistance.

Apart from detecting actual collisions, it may also be of interest to find the propensity of a driver to have a collision. As mentioned earlier, there are technologies that can be used to determine risky driving maneuvers. It is reasonable to say that the more riskily a person drives, the more are the chances of him having a collision. Insurance companies may be keen to have this information. A few companies are working on building statistical models that can calculate the chances of a person having a collision. As more and more customers use this technology, the database of collisions recorded by these companies will grow larger. This information will be used to continuously improve these models and get deeper insights into collisions. It will also help companies to train drivers to drive safely.

23.3 Mobility Trends in Cities and the Role of Governments

Around the globe, cities are becoming larger, and in future, these growing city spaces will absorb the rural spaces too. The general trend is that of urbanization, wherein rural populations are rapidly migrating to the cities. Developed countries are already heavily urbanized, but developing countries are particularly dealing with the problem of rapidly growing urban population. Countries like India and China are struggling to provide infrastructure and facilities to their urban citizens as they are not able to grow these facilities at the same pace as the people pouring in from rural areas. Governments all over the world are trying to solve the problems of these growing spaces through technology and digitization, which will eventually result in the creation of smart and innovative spaces (smart cities). These hypothetical smart cities will be much more sustainable compared to present scenario of living, supported by three pillars of technology, i.e., intelligent communication system, connected transport and green society. The building blocks of these three key elements would be safe and accurate information sharing.

Transportation infrastructure is one of the most important services that governments must provide their urban citizens. Apart from building roads, the governments are also concerned with the safety of the motorists and smooth operation of their daily traffic.

In order to achieve this, they are focusing on smart transportation systems, i.e., "Smart," secured and cognitively intelligent way of transportation in which the wireless networks, Internet, and digital technologies are used in innovative ways (Blythe et al. 2010). Smart vehicles, i.e., connected cars, would be an integrated part of these solutions.

As mentioned earlier, the low cost of distribution digital technology to a large number of people makes it a very attractive proposition for governments. Therefore, connected cars technologies will be used extensively by governments in order to improve their transportation infrastructure. Some companies are already lobbying city governments and municipalities to implement some of the solutions mentioned above, or even make it mandatory for car drivers to use them.

A major issue most of the current cities are facing is traffic congestion. Smart transportation systems can help in solving this problem. For examples, if all the cars are connected, city transportation departments can monitor these cars and find out whether there is a traffic congestion in any particular area. If there is a collision, the medical emergency services can be quickly deployed and the transportation department can assist in clearing the road for the ambulances. At the same time, the traffic police can be optimally deployed in order to minimize the burden of cops while maximizing the benefits to motorists. For example, cops can be relieved of duty from roads where there is no congestion and more cops can be deployed on roads where there is congestion or collision.

Cities today are well connected logistically and are well versed in mobile networks, which could serve as the backbone to the concept of a connected transportation. The next step would be to integrate Internet and mobile services with the cars

on the road. Cab aggregator companies are already using them to provide innovative services like pool rides and personal rides based on the preference of car size. The governments must also learn how to utilize these new channels of intelligent transportation systems. However, setting up a connected transportation environment involves a lot of complexities. We will discuss the challenges.

The first challenge is the investment required in state-of-the-art mobile and digital infrastructure. The higher the speed and bandwidth of Internet available to citizens, the easier it will be to deploy the multiple services through smart transportation systems. The governments will have to learn to deal with the large amount of data generated by thousands or millions of connected cars. This task is not trivial and will involve a significant development effort. Deploying the networks, big data management systems and artificial intelligence algorithms in metropolitan cities would be a mammoth task. Also, this infrastructure will have to be rehauled and updated every few years in order to keep up with the rapid improvements in technology. The algorithms are also updated as they become smarter over time as they learn more and more from new data around the world, and the system must be updated with the latest algorithms. Raising money for this system may also be a challenge as state and central governments may not be very keep on granting money to individual cities. So city governments might be forced to convince their citizens them to pay for it through taxes. This would require the governments to create good awareness among their citizens about the connected cars technology.

The second complexity arises due to the reluctance of drivers to adopt new technology. Technological solutions are not equally appealing to all citizens. This is especially true of hardware devices. Very few drivers may be eager to purchase and attach new devices to their cars and many would not have the technological know-how to do so. They may also not find new smartphone applications very appealing or be willing to go through the trouble of downloading and installing them and pay monthly subscriptions. Governments and companies must work together to get as many car drivers as possible to use connected cars technology. Governments may plan to provide subsidies to some promising technologies that can be considered as social or public good, for example, the collision alert technology. They can also explore the option of making some of these technologies mandatory through legislation.

The third complexity arises from the limitations of the technology itself. For example, there is a large variation in the quality of smartphones that drivers use. So the same software application might have a very different performance for different drivers. Besides, software-based solutions undergo updates frequently, but not all customers may be willing to keep updating their software that frequently. So some drivers may not be happy with the services and that will make them reluctant to use the technology. In the long run, governments and companies will have to collaborate and invest in research and development, which will result in better quality hardware and software through continuous improvement, thereby making it affordable to all drivers.

23.4 Future of Automobiles

With the evolving technology of transportation, future of automobile industry will undergo many changes. Some of the advanced technologies that are being explored in the automobile sector are mentioned below, and their pros and cons are analyzed. The challenges faced by each of these technologies are also discussed.

23.4.1 Electric Cars

With the rising concerns of global warming and air pollution, governments all over the world are encouraging electric cars. Electric cars are the most popular green cars, and the number of people owning them is rising (Nykvist and Nilsson 2015). However, electric cars are more expensive than the cars that most people drive. So most electric cars are purchased by those people who are in the highest income brackets or by those who are environmentally conscious. Research is being conducted on making electric cars cheaper, and some affordable cars are expected to be on the market soon. Many electric cars use state-of-the-art technology and are equipped with modern electronic devices. Unlike internal combustion engines, these cars don't have ignition. So there are cars that can be started and turned off using the owner's cell phone. Features like these make electric cars very conducive to connected cars technology.

There are many challenges to scaling up the electric cars in order to replace conventional cars. The cars require batteries for storing electricity, and as the number of electric cars increases, there will be a strain on the natural resources that are required as raw materials in the batteries. There is already a shortage of lithium which is used in the lithium-ion batteries, and it caused prices to rise in 2015. The cars take several hours to charge, which puts a limit on the distance you can travel. Electric cars are suitable for use as city cars, i.e., to be used by people to travel to offices during the day and then charged overnight. It is not feasible to use electric cars for long distance travel. Also, electric charging stations are not as common as petrol stations. The infrastructure required to support a large fleet of electric cars cannot be scaled up easily. It is unclear whether the existing national electric grids can support the load of millions of cars charging simultaneously. Developing countries, which are already suffering electricity shortages, cannot afford to supply the surplus electricity that is required by electric cars. Currently, most of the electricity in the world is generated by coal, which is only available in finite supply. Besides, burning coal also leads to pollution and emission of greenhouse gases. Therefore, the scaling up of renewable energy sources is a prerequisite for electric cars to become a viable alternative to conventional cars.

23.4.2 Self-driven Cars

In the past decade, some very large companies have invested in the development of self-driven cars (autonomous cars). A few companies have also demonstrated self-driven cars on the road. As mentioned earlier, in recent years the cost of computation has reduced considerably and machine learning algorithms have become more powerful. These developments have made it possible to teach a computer how to drive a car at a low cost. These cars use computer vision and artificial intelligence to take decisions on the movement of the car.

However, the cars have only been tested successfully under controlled conditions. Some experts are skeptical about the feasibility of large-scale deployment of electric cars on the roads. There have been collisions in some of the experiments. Besides, many individuals may be reluctant to forfeit control of their car and give it to a computer (Howard and Dai 2013). Owners may be concerned about their cars getting hacked and stolen, including theft of personal data and breach of privacy. There is also a legal aspect. In case there is a collision, who should be held liable? In case both the cars were self-driving, how to determine whose fault it was? In case one car was self-driving and one was manually driven, can the self-driving car be determined to be at fault? Since the owner of the self-driving car is not driving himself, he can possibly deny liability. In this case, should the company which designed the car be held liable? Similar questions arise in the case of traffic rules violation.

These problems raise the question of legislation. The task for governments at all levels will have to work in order to create a new legal framework and regulations for self-driving cars. This would include the task of assigning liability in case of a collision. Designated areas might be created where autonomous vehicles can be tested before setting them on the road. Just like drivers are tested before giving driving licenses, autonomous cars will also have to be tested before allowing them on the road. Performance standards for the cars on the road should also be established. For example, in areas where Internet bandwidth is limited, it may be necessary to put a limit on how much bandwidth can each car use for services like GPS. There is also the question of what things are the people seated inside the car allowed to do, e.g., when are they allowed to manually take over the driving controls? The traffic rules that need to be followed by autonomous cars may also be different from those of manual cars.

Apart from regulations, the governments will have to consider the social and economic impact of the introduction of autonomous vehicles (Clements and Kockelman 2017). This technology is considered to be disruptive, as they can cause a lot of jobs to become obsolete. The section of workers which is most likely to be impacted is the taxi drivers since their livelihood would be at stake. This kind of disruption can lead to strikes from taxi drivers unions. Even in advanced countries, there has been opposition to cab aggregators and ride-hailing services. On certain occasions, there have been violent agitations by the cab drivers. Autonomous cars are much more disruptive to the cab drivers and there is bound to be a lot more opposition in the future. Governments might have to prepare themselves for these agitations. They will also

have to prepare a roadmap on how to rehabilitate the workers who lose their jobs due to automation. There could be an impact on other industries as well, for example, car insurance industry would require a complete restructuring. The insurance companies might have to lay off people and also design new insurance policies for autonomous cars.

Historically, an introduction of new technology has lead to the obsolescence of jobs that use inferior technology in the short run. But in the long run, technology has created new and better jobs. Economists, social scientists, and engineers will have to brainstorm in order to forecast what kind of new jobs will be created due to autonomous cars technology. They can provide suggestions to the governments on how to create a conducive environment for the creation of these new jobs. In short, the governments, academics, and companies will have to work together in order to ensure a smooth transition from the current transportation paradigm to the next.

23.5 Conclusion and Future Scope

The recent developments in the field of connected cars have opened new and interesting avenues of research. While analyzing the technology, one must be careful of both the positive and negative impacts of the technology. It is also important to bear in mind the complexity, challenges, and unintended consequences that governments and society will have to face due to the introduction of disruptive technologies.

The biggest driver of connected cars technology is the falling cost of digital technology and the rapid expansion of the Internet. As more and more electronic devices are connected to the Internet and billions of people use them, the amount of data available for analysis is exploding. Data is being gathered from sources which were not imaginable two decades ago. At the same time, artificial intelligence, data mining, and distributed computing technology have made it possible to use this data to teach computers to make decisions. Many industries all over the world are shifting toward computer-driven decision making. Connected cars are the concept of leveraging all of the above technologies in order to make cars safer and more efficient, and providing new services to drivers.

This paper has focussed on some of the innovative technological solutions that are being provided to drivers today. Since smartphones are available cheaply and used by almost all car drivers, they have become the primary channels for connected cars. Private companies have developed several innovative solutions for drivers that use the facilities available in the smartphone. Apart from this, there are OBD devices that the driver can plug into the car. The services include driver safety, collision detection, cab aggregation, and navigation assistance. These services are also being used by insurance companies in order to decide the riskiness of drivers and calculating their premiums. However, there are concerns regarding invasion of privacy and data theft.

Governments will play a major role in the acceptance and success of connected cars technology. Their primary responsibilities will be to establish the infrastructure necessary to support this technology as well as educate the public about its pros and

cons. Governments will also benefit from this technology as it will assist them in traffic management and public safety. However, the expenditure on this project of connected cars is going to be significant and the technical challenges are daunting. Collaborating with promising private companies would be the best way forward.

There are several innovations which are still in experimental stage much might become widely available in the near future. Autonomous cars are the best example of such technology. While they will bring significant benefits to drivers, they may also cause significant disruptions in the future. These disruptions may be both economic and social in nature. Governments would be required to prepare proper legal and regulatory framework for the adoption of these technologies in daily life. While there is no clear solution to the problem of job losses due to automation, history has shown that new technology eventually leads to the creation of new kinds of jobs. The task for the governments will be to assist their citizens in making a smooth transition.

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