Autonomous Vehicles

ABSTRACT

There are many paradigm shifts taking place due to information explosion and the concept of autonomous vehicle is one shift. The car, which is embedded, can simulate the human driver completely and direct the vehicle on the road. Autonomous vehicle is the drastic change in technical brilliance and developments in different fields with EMBEDDED SYSTEM as pioneer.

An autonomous car is a vehicle that can guide itself without human conduction. This kind of vehicle has become a concrete reality and may pave the way for future systems where computers take over the art of driving. An autonomous car is also known as a driverless car, robot car, self-driving car or autonomous vehicle.Autonomous vehicles are electronically integrated vehicles which can find their way and function without the need for human input.

Autonomous cars are the future smart cars anticipated to be driverless, efficient and crash avoiding ideal urban car of the future. To reach this goal automakers have started working in this area to realized the potential and solve the challenges currently in this area to reach the expected outcome. In this regard the first challenge would be to customize and imbibe existing technology in conventional vehicle to translate them to a near expected autonomous car. This transition of conventional vehicles into an autonomous vehicle by adopting and implementing different upcoming technologies must be streamlined. This includes achieving the objectives of autonomous vehicles and their implementation difficulties.

Extensive network guided systems in conjunction with vision guided features is the future of autonomous vehicles. It is predicted that most companies will launch fully autonomous vehicles by the advent of next decade. The future of autonomous vehicles is an ambitious era of safe and comfortable transportation.

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(Autonomous Vehicles Overview)

1.1 What are Autonomous Vehicles

An autonomous car is a vehicle that can guide itself without human conduction. This kind of vehicle has become a concrete reality and may pave the way for future systems where computers take over the art of driving.

Fig.1 A Abstract working of Autonomous Vehicles

Autonomous vehicles are electronically integrated vehicles which can find their way and function without the need for human input. The equipments and technologies used are costly the main equipments used in this technology are radar ,lidar, position sensor, gps module,Multicore, heterogeneous processor, JAUS interoperable communication systems, high resolution cameras are very costly now.

1.2 History & Aspects

Experiments have been conducted on self-driving cars since at least the 1920s; promising trials took place in the 1950s and work has proceeded since then. The first self-sufficient and truly autonomous cars appeared in the 1980s, with Carnegie Mellon University's Navlab and ALV projects in 1984 and Mercedes-Benz and Bundeswehr University Munich Eureka Prometheus Project in 1987. Since then, numerous major companies and research organizations have developed working prototype autonomous vehicles including Mercedes-Benz, General Motors, Continental Automotive Systems, Autoliv Inc., Bosch,Nissan, Toyota, Audi, Volvo, Vislab from University of Parma, Oxford University.

The idea of self-driving vehicles dates back much further than Google's research in the present day. In fact, the concept of an autonomous car dates back to Futurama, an exhibit at the 1939 New York World's Fair. General Motors created the exhibit to display its vision of what the world would look like in 20 years, and this vision included an automated highway system that would guide self-driving cars. While a world filled with robotic vehicles isn't yet a reality, cars today do contain many autonomous features, such as assisted parking and braking systems. Meanwhile, work on full-fledged autonomous vehicles continues, with the goal of making driving a car safer and simpler in the coming The impacts of autonomous vehicles, coupled with greater inter-vehicle and system connectivity, may be far-reaching on several levels. They entail changes to (1) the demand and behavior side, (2) the supply of mobility services, and (3) network and facility operational performance.

We focus here on their impact on traffic flow and operations, especially in mixed traffic situations in which autonomous vehicles share the road with regular, human-driven vehicles, along with connected vehicles that may also have some automated functions. These mixed traffic situations correspond to likely deployment scenarios of the technologies, especially in the long transition towards 100% deployment. We explain using elementary traffic science concepts how autonomous vehicles and connected vehicles are expected to increase the throughput of highway facilities, as well as improve the stability of the traffic stream. A microsimulation framework featuring varying behavioral mechanisms for the three classes of vehicles is introduced. The framework is used to examine the throughput and stability questions through a series of experiments under varying market penetration rates of autonomous and/or connected vehicles;

at low market shares, the impacts are relatively minor on either throughput or stability.

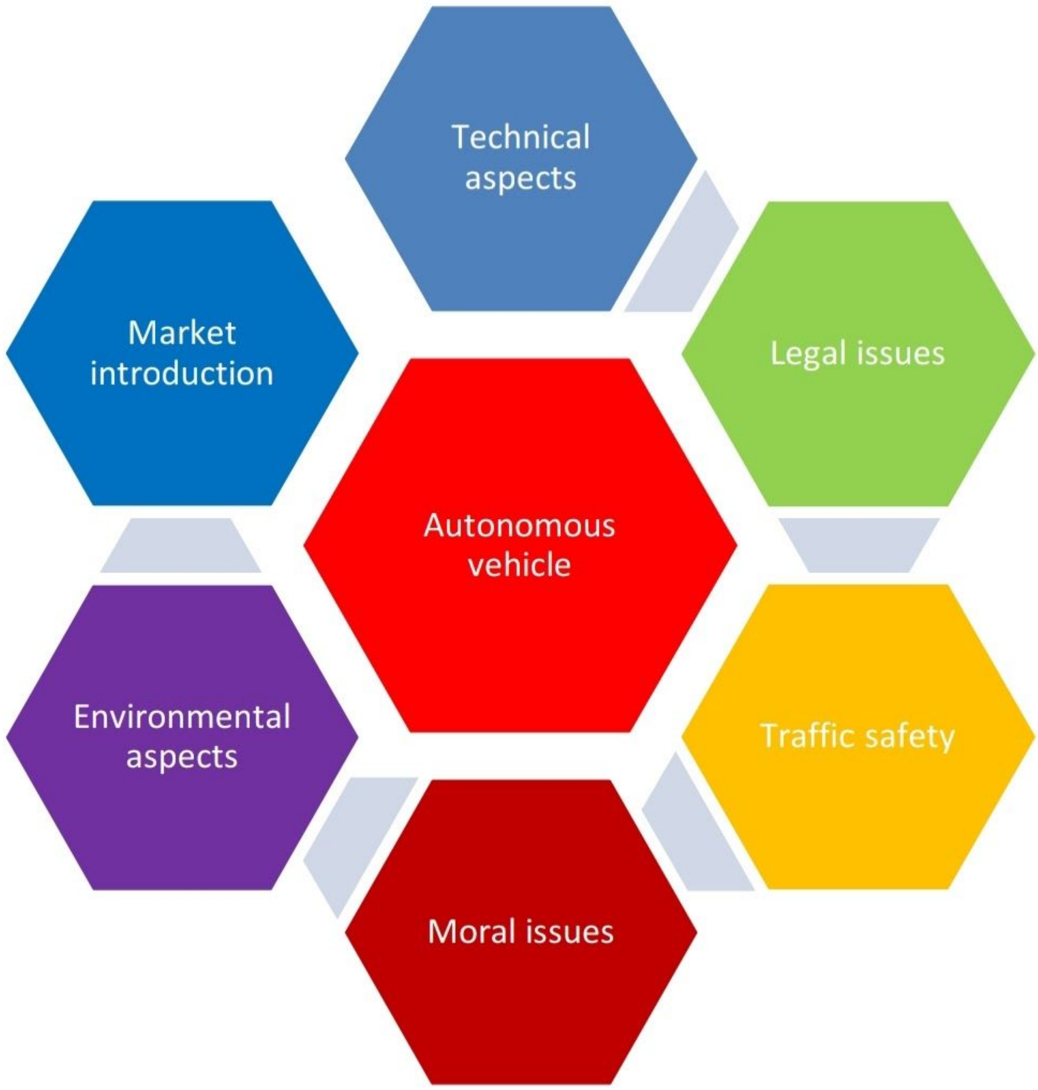

Fig 2 Aspects in Autonomous Vehicles

Aspects in AV :

Environmental and traffic safety Aspects:

New technologies can significantly reduce vehicle emissions by reducing fuel consumption : according to the opinion of several experts, by optimizing the acceleration and braking actions of the driverless vehicle the fuel consumption can be drastically reduced, by up to 60%.; as autonomous vehicles are able to communicate with each other and with their environment, they can be organized into platoons with controlled speed; this may result in a reduction of fuel consumption by 5-20%; because of the advanced navigation system which uses car to car communication, further reductions in fuel consumption can be obtained by avoiding congestion zones, particularly in crowded urban traffic.

Human errors cause a significant part of traffic accidents. By excluding the driver as the weakest link, it is expected that the automated vehicles will travel more safely, reducing the number of accidents. However, it is also likely that new technologies will cause new types of accidents, especially in cases when the responsibility of driving is transferred from the human driver to the vehicle or vice versa. Further risks may appear because of the presence of conventional vehicles and driverless cars on the roads or because of the incompatibilities between the different autonomous technologies.

Legal Aspects of Autonomous Driving

In the pursuit to accomplish the fully automated driving, several technical issues have be solved and the automotive industry seems to be up to this task . As all revolutionary innovations, the technical developments in driverless vehicles are more advanced than the regulatory processes. Worldwide, the regulations regarding all aspects of the road traffic have as the main objective to provide the best road safety, so the autonomous cars must prove that they are safer or at least as safe as their predecessors. Consequently, the legal challenges are among the most critical issues, including the public policies, traffic code, technical standards, and tort law. For example, steer-by-wire technologies have been available for a long time, but could not be integrated into the vehicles because the Convention on Road Traffic signed in Vienna in 1968 stated that, in order to determine the path of the vehicle the steering system should contain a mechanical constraint between the steering wheel and the wheels.

Moral and ethical aspects

The self-driven vehicles must make good decisions even in extreme emergency situations. Is this always possible? Imagine that a vehicle is approaching a pedestrian crossing, the traffic light is green for the car, but suddenly a pedestrian passes to the road. Although it is the rule that the designated pedestrian crossing place should be approached with extreme caution and the speed of the vehicle must be sufficiently low to be able to stop before the pedestrian crossing, if necessary, but the pedestrians can only cross the road if they are convinced that there is no risk. What is the right decision in this case?. Does the car swerve into the traffic from the opposite lane or in the roadside electric pylon, exposing the car owner to unforeseeable consequences? Is it a duty of the car to protect its owner at any cost? Would the dilemma change if not one but two people stepped on the road? Who is responsible for the consequences: the owner, the user or the computer programmer, who stays in his ergonomic chair some thousands of miles away and has no idea what happened? There is, however, a strong need to develop moral algorithms that can solve such situations according to acceptable moral norms.

Market

There is no doubt that the interest for driverless cars is increasing. According to a survey conducted by the Boston Consulting Group in 2015, 55% of potential car buyers said they would consider buying a semi-autonomous vehicle, while 44% said that they would consider buying a fully autonomous car . Almost all the major automotive manufacturers are working on meeting this demand. According to the HIS, an international market research company, in 2020 the market share of the 4th and 5th level autonomous vehicles will be 0.004% (4,200 cars), which will increase in 2025 up to 0.5% (578,000 cars) and in 2030 it will reach 3.8% (4,503,000 cars) . Autonomous vehicles are marketed following three scenarios: 1) traditional carmakers are integrating more and more automatic components into their products until the vehicle becomes fully autonomous, 2) new market players brake into the market with new concepts, 3) co-operation of traditional car manufacturers with new market players delivering a technology that allows the production of 3rd or 4th cars [3]. The optimistic scenario takes account of less restrictive safety regulation, more pork-barrels, appearance of new market players, the conservative one considers that the present condition will not change.

Autonomous technologies are becoming increasingly sophisticated and technically accessible, and in some cases, these can already be installed in commercial vehicles. As several carmakers have announced that they will start the production of highly automated cars in 2017, it seems realistic that autonomous cars will make their appearance in developed countries in the near future.

We can estimate that in 2030 a significant number of driverless vehicles will travel on the roads. According to today's research and development, it is unclear how these technologies will be able to handle extreme and unexpected events. There is a concern over the development of several different technologies that will result very different products, which in some situations will not be able to work together and communicate with each other. There are trends that rely solely on the signs of sensors in the car, others need infrastructure improvements that help decision making. As the cause of most traffic accidents is human error or omission, it is anticipated that the emergence of autonomous technologies will reduce the number of car accidents. There is not enough statistical data to sustain this statement yet. The increasing trend of automatization level of cars will radically change the composition of car industry players, as with the rise in automation levels, mechatronics will be not only an additional part of the automobile industry but also an indispensable and integral part of it. There is a reasonable expectation that automated cars will perform the same or better in all aspects than their conventional counterparts. However, it seems that the current regulations do not keep up with the development of technologies and sometimes hinder the development and testing of autonomous technologies.

History

1920

In 1925, Houdina Radio Control demonstrated the radio-controlled "American Wonder" on New York City streets, traveling up Broadway and down Fifth Avenue through the thick of the traffic jam. The American Wonder was a 1926 Chandler that was equipped with a transmitting antenna on the tonneau and was operated by a second car that followed it and sent out radio impulses which were caught by the transmitting antenna. The antennae introduced the signals to circuit-breakers which operated small electric motors that directed every movement of the car.

1930

An early representation of an automated guided car was Norman Bel Geddes's Futurama exhibit sponsored by General Motorsat the 1939 World's Fair, which depicted radio-controlled electric cars that were propelled via electromagnetic fields provided by circuits embedded in the roadway.

Bel Geddes later outlined his vision in his book, Magic Motorways (1940), promoting advances in highway design and transportation, foreshadowing the Interstate Highway System, and arguing that humans should be removed from the process of driving. Bel Geddes forecasted these advances to be a reality in 1960.

1950

In 1953, RCA Labs successfully built a miniature car that was guided and controlled by wires that were laid in a pattern on a laboratory floor. The system sparked the imagination of Leland M. Hancock, traffic engineer in the Nebraska Department of Roads, and of his director, L. N. Ress, state engineer. The decision was made to experiment with the system in actual highway installations.

In 1957, a full size system was successfully demonstrated by RCA Labs and the State of Nebraska on a 400-foot strip of public highway at the intersection of U.S. Route 77 and Nebraska Highway 2, then just outside Lincoln, Nebraska. A series of experimental detector circuits buried in the pavement were a series of lights along the edge of the road. The detector circuits were able to send impulses to guide the car and determine the presence and velocity of any metallic vehicle on its surface. A previous test installation of the system in September 1954 along U.S. Route 73 and U.S. Route 75 in Cass County, Nebraskawas utilized as an experimental traffic counter. It was developed in collaboration with General Motors, who paired two standard models with equipment consisting of special radio receivers and audible and visual warning devices that were able to simulate automatic steering, accelerating and brake control. It was further demonstrated on 5 June 1960, at RCA Lab's headquarter in Princeton, New Jersey, where reporters were allowed to "drive" on the cars. Commercialization of the system was expected to happen by 1975.

Also during the 1950s throughout the 1960s, General Motors showcased the Firebirds, a series of experimental cars that were described to have an "electronic guide system [that] can rush it over an automatic highway while the driver relaxes".

1960

In 1960, Ohio State University's Communication and Control Systems Laboratory launched a project to develop driverless cars which were activated by electronic devices imbedded in the roadway. Head of the project, Dr. Robert L. Cosgriff, claimed in 1966 that the system could be ready for installation on a public road in 15 years.

In the early 1960s, the Bureau of Public Roads considered the construction of an experimental electronically controlled highway. Four states – Ohio, Massachusetts, New York and California – were bidding for the construction. In August 1961, *Popular Science* reported on the Aeromobile 35B, an air-cushion vehicle (ACV) that was invented by William Bertelsen and was envisioned to revolutionize the transportation system, with personal self-driving hovering cars that could speed up to 1,500 MPH.

During the 1960s, the United Kingdom's Transport and Road Research Laboratory tested a driverless Citroen DS that interacted with magnetic cables that were embedded in the road. It went through a test track at 80 miles per hour (130 km/h) without deviation of speed or direction in any weather conditions, and in a far more effective way than by human control. Research continued in the '70s with cruise control devices activated by signals in the cabling beneath the tracks. According to cost benefit analyses that were made, adoption of system on the British motorways would be repaid by end of the century, increase the road capacity by at least 50% and prevent around 40% of the accidents. Funding for these experiments was withdrawn by the mid-1970s.

Also during the 1960s and the 1970s, Bendix Corporation developed and tested driverless cars that were powered and controlled by buried cables, with wayside communicators relaying computer messages. Stanford demonstrated its Artificial Intelligence Laboratory Cart, a small wheeled robot that once accidentally navigated onto a nearby road.

Preliminary research into the intelligent automated logic needed for autonomous cars was conducted at the Coordinated Science Laboratory of the University of Illinoisin the early to mid 1970s.

1980

In the 1980s, a vision-guided Mercedes-Benz robotic van, designed by Ernst Dickmanns and his team at the Bundeswehr University Munich in Munich, Germany, achieved a speed of 39 miles per hour (63 km/h) on streets without traffic. Subsequently, EUREKA conducted the €749,000,000 Prometheus Project on autonomous vehicles from 1987 to 1995.

In the same decade, the DARPA-funded Autonomous Land driven Vehicle (ALV) project in the United States made use of new technologies developed by the University of Maryland, Carnegie Mellon University, the Environmental Research Institute of Michigan, Martin Marietta and SRI International. The ALV project achieved the first road-following demonstration that used lidar, computer vision and autonomous robotic control to direct a robotic vehicle at speeds of up to 19 miles per hour (31 km/h). In 1987, HRL Laboratories (formerly Hughes Research Labs) demonstrated the first off-road map and sensor-based autonomous navigation on the ALV. The vehicle traveled over 2,000 feet (610 m) at 1.9 miles per hour (3.1 km/h) on complex terrain with steep slopes, ravines, large rocks, and vegetation. By 1989, Carnegie Mellon University had pioneered the use of neural networks to steer and otherwise control autonomous vehicles, forming the basis of contemporary control strategies.

2000

The US Government funded three military efforts known as Demo I (US Army), Demo II (DARPA), and Demo III (US Army). Demo III (2001) demonstrated the ability of unmanned ground vehicles to navigate miles of difficult off-road terrain, avoiding obstacles such as rocks and trees. James Albus at the National Institute of Standards and Technology provided the Real-Time Control System which is a hierarchical control system. Not only were individual vehicles controlled (e.g. throttle, steering, and brake), but groups of vehicles had their movements automatically coordinated in response to high level goals.

In the first Grand Challenge held in March 2004, DARPA (the Defense Advanced Research Projects Agency) offered a $1 million prize to any team of robotic engineers which could create an autonomous car capable of finishing a 150-mile course in the Mojave Desert. No team was successful in completing the course. In October 2005, the second DARPA Grand Challenge was again held in a desert environment. GPS points were placed and obstacle types were located in advance. This year, five vehicles completed the course.

In November 2007, DARPA again sponsored Grand Challenge III, but this time the Challenge was held in an urban environment. In this race, a 2007 Chevy Tahoe autonomous car from Carnegie Mellon University earned the 1st place. Prize competitions as DARPA Grand Challenges gave students and researchers an opportunity to research a project on autonomous cars to reduce the burden of transportation problems such as traffic congestion and traffic accidents that increasingly exist on many urban residents.

In January 2006, the United Kingdom's 'Foresight' think-tank revealed a report which predicts RFID-tagged driverless cars on UK's roads by 2056 and the Royal Academy of Engineering claimed that driverless trucks could be on Britain's motorways by 2019.

In 1998, Willie Jones states that many automakers consider autonomous technology as part of their research yearly. He notes "In May 1998, Toyota became the first to introduce an Adaptive Cruise Control (ACC) system on a production vehicle when it unveiled a laser-based system for its Progres compact luxury sedan, which it sold in Japan".

Autonomous vehicles have also been used in mining. In December 2008, Rio Tinto Alcan began testing the Komatsu Autonomous Haulage System – the world's first commercial autonomous mining haulage system – in the Pilbara iron ore mine in Western Australia.

Rio Tinto has reported benefits in health, safety, and productivity. In November 2011, Rio Tinto signed a deal to greatly expand its fleet of driverless trucks. Google began developing its self-driving cars in 2009, but did so privately, avoiding public announcement of the program until a later time.

2010

Many major automotive manufacturers, including General Motors, Ford, Mercedes Benz, Volkswagen, Audi, Nissan, Toyota, BMW, and Volvo, are testing driverless car systems as of 2013. BMW has been testing driverless systems since around 2005, while in 2010, Audi sent a driverless Audi TTS to the top of Pike’ s Peak at close to race speeds. In 2011, GM created the EN-V (short for Electric Networked Vehicle), an autonomous electric urban vehicle.In 2012, Volkswagen began testing a "Temporary Auto Pilot" (TAP) system that will allow a car to drive itself at speeds of up to 80 miles per hour (130 km/h) on the highway.Ford has conducted extensive research into driverless systems and vehicular communication systems. In January 2013, Toyota demonstrated a partially self-driving car with numerous sensors and communication systems. Other programs in the field include the 2GetThere passenger vehicles from the Netherlands and the DARPA Grand Challenge in the USA; some plans for bimodal public transport systems include autonomous cars as a component.

On May 27, 2014, Google announced plans to unveil 100 autonomous car prototypes built from scratch inside Google's secret X lab, as manifestations of years of work that began by modifying existing vehicles, along with, "in the next couple of years" according to Google in the above blog post, a pilot program similar to that which was used for the Cr-48 Chromebook back in 2010.

In October 2014 Tesla Motors announced its first version of AutoPilot. Model S cars equipped with this system are capable of lane control with autonomous steering, braking and speed limit adjustment based on signals image recognition. The system also provide autonomous parking and is able to receive software updates to improve skills over time.As of March 2015, Tesla has been testing the autopilot system on the highway between San Francisco and Seattle with a driver but letting the car to drive the car almost unassisted.

In July 2015, Google announced that the test vehicles in its driverless car project had been involved in 14 minor accidents since the project's inception in 2009. Chris Urmson, the project leader, said that all of the accidents were caused by humans driving other cars, and that 11 of the mishaps were rear-end collisions. "Our self-driving cars are being hit surprisingly often by other drivers who are distracted and not paying attention to the road.

That's a big motivator for us." Over the six years of the project's existence the test vehicles had logged nearly 2 million miles on the road.

1.3 Autonomous Vehicles Goals

- Saving Lives, Cutting Emissions
- Transformative Power Of Deep Learning
- Waymo and Tesla both have the same goal toward fully L5 driverless self driving cars, but they differ in approach from a design and engineering philosophy. Elon Musk relies on computer vision systems that use a combination of ultrasonic, radar and camera devices. Waymo on the other hand use a very fundamental device among driverless car makers and that is LiDAR. Elon believes Tesla can rely on it's sophisticated hardware with AI software while Waymo implements LiDAR at the heart of it's systems.

1.4 Autonomous Vehicles Benefits

- The biggest safety benefit from driverless vehicles is the potential to markedly reduce the number of accidents, with general agreement amongst Australian and international experts that 90% of all accidents could be eliminated through advanced driverless vehicle technology.

- This technology could also reduce the impact of human error in road crashes, which cost Australia $27 billion annually, on top of the cost of human lives.

- Better vehicle experience

- Without the need for a driver, cars could become mini-leisure rooms. There would be more space and no need for everyone to face forwards. Entertainment technology, such as video screens, could be used to lighten long journeys without the concern of distracting the driver.

- Over 80% of car crashes in the USA are caused by driver error. There would be no bad drivers and less mistakes on the roads, if all vehicles became driverless. Drunk and drugged drivers would also be a thing of the past.
- Travelers would be able to journey overnight and sleep for the duration.
- Traffic could be coordinated more easily in urban areas to prevent long tailbacks at busy times. Commute times could be reduced drastically.
- Reduced or non-existent fatigue from driving, plus arguments over directions and navigation would be a thing of the past.
- Sensory technology could potentially perceive the environment better than human senses, seeing farther ahead, better in poor visibility, detecting smaller and more subtle obstacles, more reasons for less traffic accidents.
- Speed limits could be increased to reflect the safer driving, shortening journey times.
- Parking the vehicle and difficult maneuvering would be less stressful and require no special skills. The car could even just drop you off and then go and park itself.
- People who historically have difficulties with driving, such as disabled people and older citizens, as well as the very young, would be able to experience the freedom of car travel. There would be no need for drivers' licenses or driving tests.
- Autonomous vehicles could bring about a massive reduction in insurance premiums for car owners.
- Efficient travel also means fuel savings, cutting costs.
- Reduced need for safety gaps means that road capacities for vehicles would be significantly increased.
- Passengers should experience a smoother riding experience

1.5 Level of Automation

Level Zero: No Automation

At Level 0 Autonomy, the driver performs all operating tasks like steering, braking, accelerating or slowing down, and so forth.People who are a bit more experienced know that automobiles didn't always come with all those computerized controls. There was a time when cars had no computers at all, and in the early days they didn't even have power steering or power brakes. At level zero, all aspects of the driving task are in the hands of the driver.

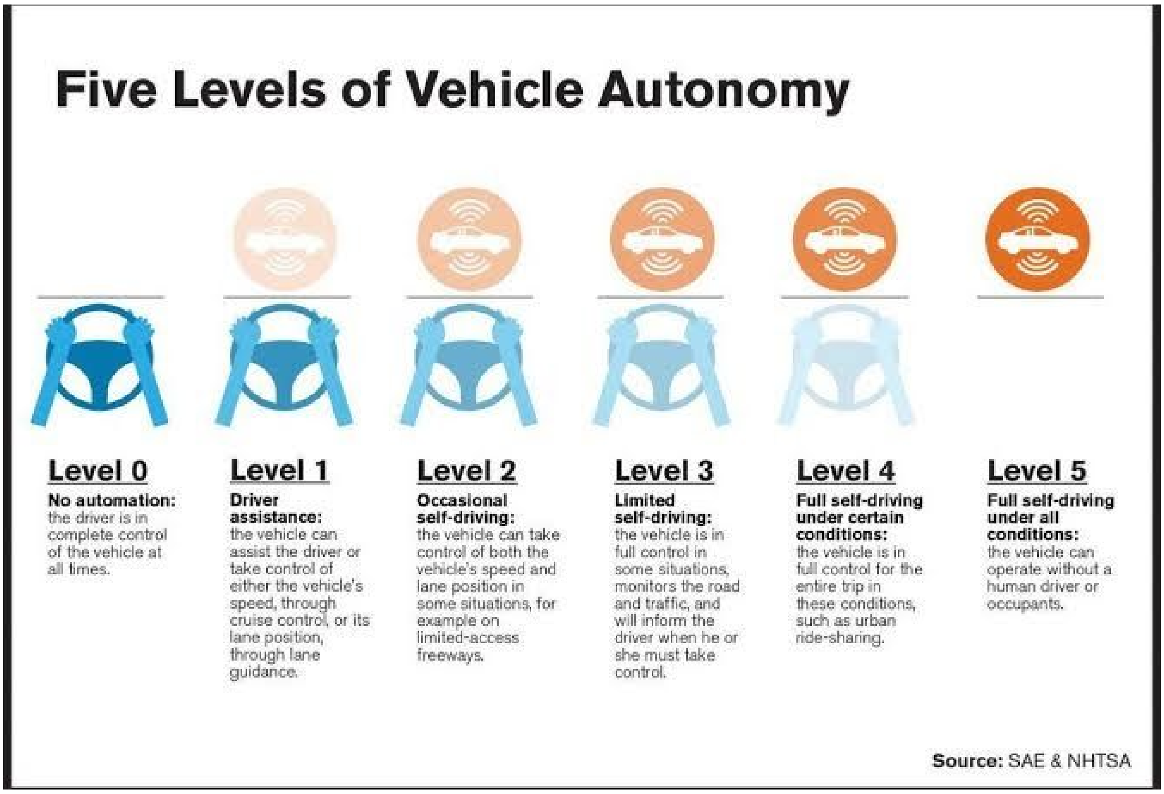

Fig 3. Levels of Autonomous Vehicles

Level One: Driver Assistance

At this level, the vehicle can assist with some functions, but the driver still handles all accelerating, braking, and monitoring of the surrounding environment. Think of a car that brakes a little extra for you when you get too close to another car on the highway.At this level, the automobile includes some built-in capabilities to operate the vehicle.Most modern cars fit into this level. If your vehicle has adaptive cruise control or lane-keeping technology, it's probably at level one.

Level Two: Partial Automation

Most automakers are currently developing vehicles at this level, where the vehicle can assist with steering or acceleration functions and allow the driver to disengage from some of their tasks. The driver must always be ready to take control of the vehicle and it still responsible for most safety-critical functions and all monitoring of the environment.At this level of automation, two or more automated functions work together to relieve the driver of control. An example is a system with both adaptive cruise control and automatic emergency braking. The driver must remain fully engaged with the driving task, but you will notice the gradual transfer of control from man to machine

Level Three: Conditional Automation

The biggest leap from Level 2 to Levels 3 and above is that starting at Level 3, the vehicle itself controls all monitoring of the environment (using sensors like LiDAR). The driver’s attention is still critical at this level, but can disengage from “safety critical” functions like braking and leave it to the technology when conditions are safe. Many current Level 3 vehicles require no human attention to the road at speeds under 37 miles per hour. Audi and others have announced Level 3 autonomous cars to launch in 2018. An autonomous vehicle expert at Ford noted that they plan to take the company straight to Level 4, saying “We’re not going to ask the driver to instantaneously intervene — that’s not a fair proposition.”
This level is marked by both the execution of steering and acceleration/deceleration and the monitoring of the driving environment. In levels zero through two, the driver does all the monitoring. At level three, the driver is still required, but the automobile can perform all aspects of the driving task under some circumstances. Levels three and higher qualify as automated driving systems (ADS).

Level Four: High Automation

At Levels 4 and 5, the vehicle is capable of steering, braking, accelerating, monitoring the vehicle and roadway as well as responding to events, determining when to change lanes, turn, and use signals.

At Level 4, the autonomous driving system would first notify the driver when conditions are safe, and only then does the driver switch the vehicle into this mode. It cannot determine between more dynamic driving situations like traffic jams or a merge onto the highway.

Level four vehicles don't need a human driver. The vehicle can essentially do all the driving, but the driver can intervene and take control as needed. This level of automation means that the car can perform all driving functions "under certain conditions." The test vehicles currently on the road would fall under this category.

Level Five: Full Automation

Last and least (in terms of human involvement), is Level 5 autonomy. This level of autonomous driving requires absolutely no human attention. There is no need for pedals, brakes, or a steering wheel, as the autonomous vehicle system controls all critical tasks, monitoring of the environment and identification of unique driving conditions like traffic jams. NVIDIA recently announced an AI computer to help achieve level 5 autonomy, where drivers simply plug in their destination and leave the rest up to the vehicle itself.
A completely automated vehicle can perform all driving functions under all conditions. In this situation, humans are just passengers. "It's hard to imagine a world where Level 5 autonomous vehicles become the norm, available to all.

For Level 5 autonomous cars to work we need to understand that no sensor is perfect. These cars will require a variety of sensors to properly see the world around them. For instance, radar can't make out complex shapes, but it's great at looking through fog and rain. Lidar is better at capturing an object's shape, but it is short-ranged and affected by weather. Autonomous vehicles use multiple sensors to act as backups to each other. "The information provided by the sensors overlaps and that's good. The AI system will need to be trained to recognize objects on a road. Training an AI to recognize stationary objects that look similar, like stop signs, is relatively straight forward. Training an AI to recognize a person running across a highway is a little more complicated.The challenge is that the surroundings that influence the autonomous vehicle's decisions are governed by thousands of parameters, such as:

- Traffic conditions.
- Pedestrian conditions.
- Weather conditions.

When vehicle-to-everything (V2X) communication is established, a car will also need to consider information being communicated by other autonomous vehicles and smart infrastructure in the area.Ensuring the decisions made by the self-driving car are safe is the hardest part of reaching level five autonomy. To ensure safety, it is essential to test, redesign and validate decision making software algorithms over billions of driving scenarios — even the unlikely ones.

2. BUILDING BLOCKS OF AUTONOMOUS VEHICLES

2.1 Modules Of Fully Autonomous Vehicles

2.1.1 Sensing

Depending on the level of autonomy, the type and number of sensors a vehicle supports can fluctuate. For example, for Level 1 autonomy where automatic cruise control and lane departure assist features are supported, only a few sensors (Radar, camera and ultrasonic) are needed. However for Level 3 and higher autonomy levels, higher resolution sensors that enable 3D perception are needed. In addition to Radar, cameras and ultrasonic sensors used in lower autonomy levels, a high resolution 3D sensor is required to compensate for the low resolution of Radar. This high resolution 3D sensor uses laser beams called LiDAR (Light Detection And Ranging). LiDAR works much like radar, but instead of sending radio waves it emits infrared light waves. Wavelengths used in LiDARs are 1000 times shorter than the millimeter radio waves used in Radar. LiDAR also provides much higher bandwidth, and all of this enables higher resolution which translates into increased safety.

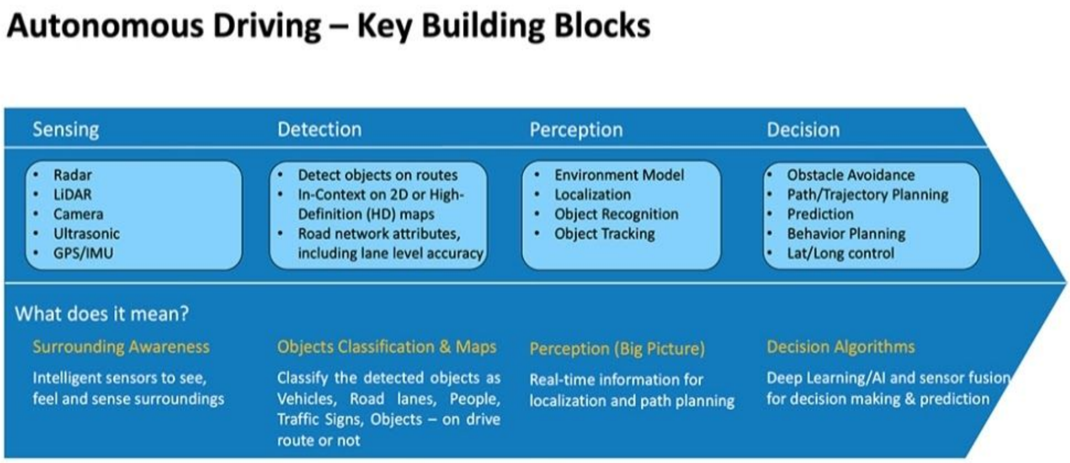

Fig 3. Building Blocks in Autonomous Vehicles

2.1.2 Object Detection

Optical vision is an essential component for autonomous cars. Accurate detection of vehicles, street buildings, pedestrians and road signs could assist self-driving cars the drive as safely as humans. However, object detection has been a challenging task for decades since images of objects in the real-world environment are affected by illumination, rotation, scale, and occlusion. In recent years, many Convolutional Neural Network (CNN) based classification-after-localization methods have improved detection results in various conditions. However, the slow recognition speed of these two-stage methods limits their usage in real-time situations. Recently, a unified object detection model, You Only Look Once (YOLO)

However, when applied to auto-driving object detection tasks, this model still has limitations. It processes images individually despite the fact that an object's position changes continuously in the driving scene. Thus, the model ignores a lot of important information between continuous frames. In this research, we applied YOLO to three different datasets to test its general applicability. We fully analyzed its performance from various aspects on KITTI dataset which is specialized for autonomous driving. We proposed a novel technique called memory map, which considers inter-frame information, to strengthen YOLO's detection ability in driving scene. We broadened the model's applicability scope by applying it to a new orientation estimation task. KITTI is our main dataset. Additionally, ImageNet dataset is used for pre-training, and three other datasets. And Pascal VOC 2007/2012 , Road Sign , and Face Detection Dataset and Benchmark (FDDB) were used for other class domains.

2.1.3 Perception

Perception is the term used to describe the visual cognition process for autonomous cars. Perception software modules are responsible for acquiring raw sensor data from on vehicle sensors such as cameras, LIDAR, and RADAR, and converting this raw data into scene understanding for the autonomous vehicle.

The human visual cognition system is remarkable. Human drivers are able to instantly tell what is around them, such as the important elements in a busy traffic scenario, the locations of relevant traffic signs and traffic lights, the likely response of other road users, alongside a plethora of other pertinent information. The human brain is able to derive all of this insight using only the visual information being acquired by our eyes in split second time. This visual cognition ability extends in a generalised way across numerous types of traffic scenarios in different cities, and even countries. As human drivers, we can easily apply our knowledge from one place to another.

However, visual cognition is incredibly challenging for machines, and the idea of building a generalisable visual cognition is currently the biggest open challenge within the fields of autonomous driving, machine learning, robotics, and computer vision.

2.1.4 Decision

There is a great deal of buzz generated over autonomous vehicles or self-driving cars across the automotive industry globally. However, in the Indian context, there are reservations over adoption of autonomous vehicles or self-driving cars. The general line of thought is that autonomous vehicles or self-driving cars would end up eliminating jobs of drivers in a large way and India will not be ready with required infrastructure in years to come. Sharing his perspective on adoption of autonomous vehicles.

With more and more control of driving being relinquished to the in-vehicle computers, it is imperative that those computers emulate the functions of a human brain. Human drivers learn the *"art of driving"* from experiences over a period of time. While driving, they communicate with one another through hand movements, subtle eye contacts, revving up of the engine or slight honking. This non-verbal communication is deeply imbibed in our driving habits and comes handy during our daily commute.

There is a top misconception that autonomous driving systems are pre-programmed with millions of elaborated and classical *"if-else-then"* rules for every situation a vehicle may come across. For example, IF a frail old man and a kid come in front of the vehicle together, THEN hit the one with lower chances of injuries. The autonomous driving systems, however, aren't based on *"ethics of driving"*. As a matter of fact, these systems rely heavily on artificial intelligence and deep learning capabilities to make informed decisions and discern its surroundings just like a human driver.

2.2 Integrating Various Components in Autonomous Vehicles

One of the major factors relating to the commercial success of autonomous vehicles will be ease of component integration. Autonomous vehicles often require multiple components that span languages, interfaces, and hardware. The difficult task of combining these systems requires an effective architecture that allows for integration of autonomous vehicle components independent of technology, hardware, and vehicle platform. Standards such as JAUS (Joint Architecture for Unmanned Systems) provide a template that allows for technology insertion, reuse, and standardization of autonomous vehicle components. This paper focuses on the necessary framework for component integration of multiple heterogeneous autonomous vehicles. Autonomous Solutions Incorporated (ASI) utilizes the JAUS architecture to facilitate the commercialization of autonomous durability test vehicles for facilities such as the Goodyear proving grounds. This implementation is profiled to illustrate the benefits of system architecture for autonomous vehicle components.

Integration is the process of integrating, which is to form, coordinate, or blend into a functioning or unified whole. System integration of autonomous vehicle components is a difficult and expensive task. The number of autonomous vehicles and their application domains increase every day. The technologies that enable these vehicles will continue to evolve to meet industry needs. Autonomous vehicles include components such as positioning systems, sensors, actuators, controllers, cameras, and data repositories that all have different interfaces. Many vehicles are built ground up with the needed components in mind. These systems typically hard-code the component interfaces. This produces a problem when a component changes or new components are needed. It becomes necessary to understand and modify every part of the system affected by the component change. This process is time-consuming and costly. The commercialization of autonomous vehicles requires a common architecture to allow components to be added, removed, and modified without affecting the rest of the system.

The absence of a common architecture for autonomous vehicles has resulted in many one-off systems that are difficult to maintain and cannot be reused for other platforms. JAUS is a framework for autonomous vehicles that defines components and the message passing protocol. JAUS is independent of platform, mission, or hardware. JAUS overcomes the difficult part of object-oriented design by specifying those components that are common to autonomous vehicles. The interface definitions of JAUS emphasize the information hiding principle that allows component implementations to change without imposing side effects on the rest of the system. System designers are free to use functional and real-time design strategies when implementing components and subsystems as long as the messages sent between components is formatted in a JAUS message. Commercialization of autonomous vehicles is greatly benefited by the JAUS architecture. Companies such as Autonomous Solutions Inc. have benefited from the

JAUS architecture by developing reusable components that are being utilized on many different vehicles.

3. IMPLEMENTATION

3.1 Hardware Components

There is no consensus on the “correct” functional architecture for the autonomous car among academics and industry experts. Nonetheless, we can broadly categorize the main components of the autonomous vehicle, like any other machine, into hardware and software. We can further divide these two categories into additional subsets. Hardware splits broadly into sensors, Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) technology, and actuators. Software splits broadly into processes for perception, planning, and control. Lets talk more about each of these sub-categories in future posts later, but for now, let us look at the basics.

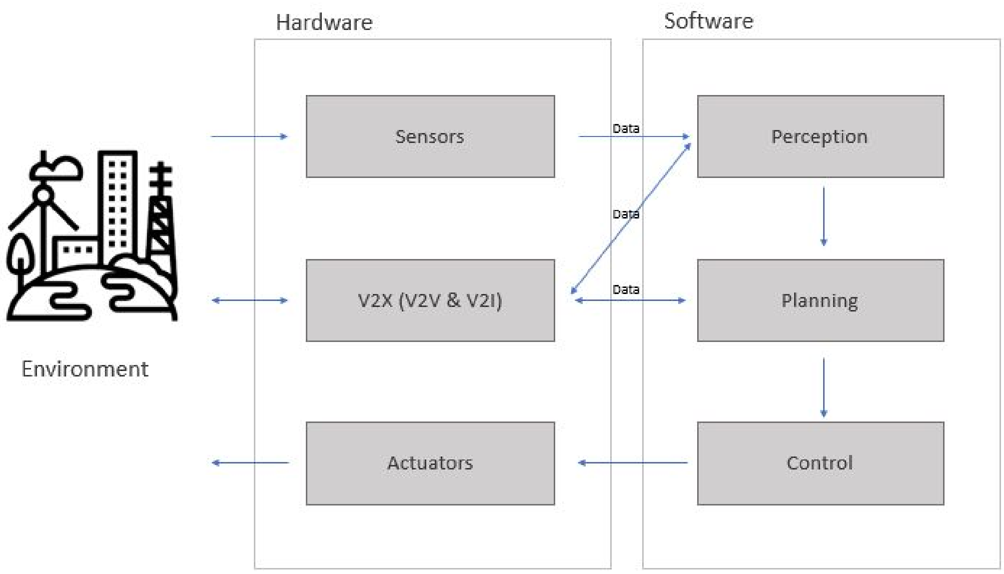

Fig 4 Functional Architecture of Autonomous Vehicles

The hardware components of the autonomous car are analogous to the physical parts of the human body, which allow us to interact with the stimuli of the outside world. The hardware components enable the car to complete such tasks as seeing (through sensors), communicating (through V2V technology), and moving (through actuators).

3.1.1 Sensors

Sensors are the components that allow the autonomous to take in raw information about the environment. Sensors are like your eyes, which enable you to understand what's going on in your surroundings. The main sensors in autonomous cars include GPS/Inertial Measurement Unit (IMUs), camera, LiDar, and radar. Each of these sensors have their respective advantages and disadvantages. LiDar, for example, is great at capturing information in various types of ambient light (whether night or day), whereas cameras may have difficulty in handling certain occlusions caused by shadows or other poor lighting conditions. Accordingly, most autonomous vehicles combine the readings of multiple sensor types to add extra redundancy and compensate for the weaknesses of the various sensors in a process called *sensor fusion*.

3.1.2 V2X technology (V2V and V2I technology)

V2V and V2I components enable the autonomous vehicle to talk and receive information from other machine agents in the environment, such as transmitted information from a city light that it has turned green or warnings from an oncoming car. You can think of V2X technology as akin to your mouth and ears. Your mouth allows you to communicate to other humans, and your ears allow you to understand what other humans are communicating to you.

3.1.3 Actuators

Actuators are the components of a machine responsible for controlling and moving the system. Actuators are like muscles of your body, responding to electrochemical signals from your brain so that you move such parts as your arm or leg.

3.2 Autonomous Vehicle Software

Whereas the hardware components of the autonomous car enable the car to perform such functions as see, communicate, and move, the software is like the brain, which processes information about the environment so that the car understands what action to take — whether to move, stop, slow down, etc. Autonomous vehicle software can be categorized into three systems: perception, planning, and control.

3.2.1 Perception

The perception system refers to the ability of the autonomous vehicle to understand what the raw information coming in through the sensors or V2V components mean. It enables the car to understand from a given picture frame whether a certain object is another car, a pedestrian, or something else entirely. This process is analogous to how our brains process the information we obtain through sight into meaning. The photoreceptors of our eyes (the sensors) absorb light waves emanating from the environment and converts those light waves into electrochemical signals. Networks of neurons pass these electrochemical signals all the way back to the visual cortex of the brain, where our brain processes what these electrochemical signals mean. In this way, our brain can understand whether a certain light pattern hitting our retina represents a chair, a plant, or another person.

3.2.2 Planning

The planning system refers to the ability of the autonomous vehicle to make certain decisions to achieve some higher order goals. This is how the autonomous vehicle knows what to do in a situation — whether to stop, go, slow down, etc. The planning system works by combining the processed information about the environment (i.e. from the sensors and V2X components) with established policies and knowledge about how to navigate in the environment (e.g. do not run over pedestrians, slow down when approaching a stop sign, etc.) so that the car can determine what action to take (e.g. overtake another car, how to reach the destination, etc.).

Analogously, just like the planning system in the autonomous car, the processes in the frontal lobe of the human brain enable us to reason and make decisions, such as what to wear in the morning or what we should do for fun on the weekend.

3.2.3 Control

The control system pertains to the process of converting the intentions and goals derived from the planning system into actions. Here the control system tells the hardware (the actuators) the necessary inputs that will lead to the desired motions. For example, an autonomous vehicle, knowing that it should slow down when approaching a red light, translates this knowledge into the action of applying the brakes. In humans, the processes that occur in the cerebellum play the analogous role. The cerebellum is responsible for the important function of motor control. It enables us, for example, to chew when the desired intention is to eat.

3.3 Operations

Now that we have a good understanding of the main components of an autonomous vehicle, let's review a scenario of how they all work together.

3.3.1 Scenario: The car has stopped at an intersection in front of the red light.

3.3.2 Mission: The car should move forward when the traffic light turns green without violating any traffic laws or hurting other beings.

- **Sensors:** The car's sensors take in raw information about the environment. It does not know what this information means yet — at least not until it gets to the perception stage.
- **V2X technology:** The traffic light communicates to the car that it has just turned green. Other surrounding cars communicate their position in the environment.
- **Perception Stage:** The vehicle turns the raw information coming in from the perception stage into actual meaning. The camera information reveals that the light has just turned green and that there is a pedestrian crossing in front of the vehicle into the street.
- **Planning Stage:** The vehicle combines the sensing information processed during the perception stage with the incoming V2X information to determine how to behave. The car's policy is to generally move when the light turns green; however, it has an overriding policy that it should not run over pedestrians. What should the car do in this scenario? The car decides that, based on the combination of environmental information and the general policies of how it should operate, it should not move.
- **Control Stage:** The car must translate its decision to not move into an action. In this case, this action (or rather, inaction in this case) is to stay still and keep the brakes applied.

- **Actuators:** The car keeps the brake applied, which is the result of its decision-making process stated above.

As you can see, the technology behind the autonomous vehicle is not extremely difficult to understand when boiled down into major concepts.

3.4 Sensor Fusion

Today, no single sensor can satisfy all autonomous driving requirements for all weather conditions and distances. For example, even though cameras provide high resolution 2D images, their performance is significantly degraded at low and high intensity light conditions as well as in poor weather conditions.
Similarly even though Radar works well in poor weather conditions, resolution of radar data is not sufficient for object classification.

Performance aspect	Human	AV			CV	CAV
		Radar	*Lidar*	*Camera*	*DSRC*	*CV+AV*
Object detection	Good	Good	Good	Fair	n/a	Good
Object classification	Good	Poor	Fair	Good	n/a	Good
Distance estimation	Fair	Good	Good	Fair	Good	Good
Edge detection	Good	Poor	Good	Good	n/a	Good
Lane tracking	Good	Poor	Poor	Good	n/a	Good
Visibility range	Good	Good	Fair	Fair	Good	Good
Poor weather performance	Fair	Good	Fair	Poor	Good	Good
Dark or low illumination performance	Poor	Good	Good	Fair	n/a	Good
Ability to communicate with other traffic and infrastructure	Poor	n/a	n/a	n/a	Good	Good

Fig 5 Comparison of sensing capabilities of human drivers and sensors in highly automated vehicles

Thus to overcome limitations of individual sensors, artificial intelligence (AI) algorithms use data from multiple sensors to create 3D perception for autonomous driving. For example, LiDAR and Radar data enable 3D object detection for all weather conditions and distances, whereas camera data is primarily used for short-mid range 2D object detection. Both 3D and 2D data as well as location, and vehicle status information are combined/intelligently fused (thus the sensor fusion) to predict object's trajectories and plan the vehicle's next action.

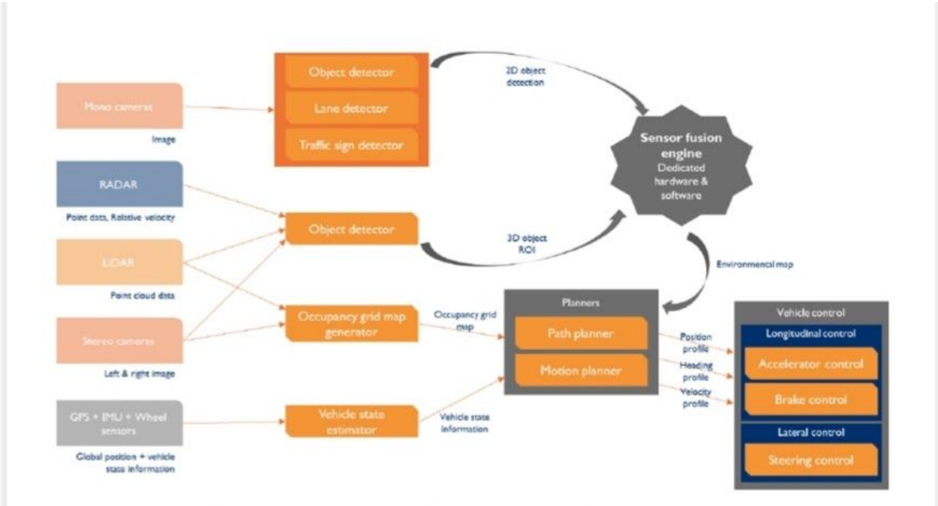

Fig 6 Sensor Fusion

Both camera and radar sensor technologies have been around for some time and are considered to be in high volume and a mature phase. Mass deployment of automotive cameras started with the back-up camera and they are now being used on the front and sides of the car to provide surround view. Stereo cameras developed by Intel and others are an extension of the existing technology combined with more chip-scale integration and processing power.

Automotive radar was first introduced commercially in early 1990s (technology developed in late 1960s) and now is available as a single chip device from multiple suppliers. The initial design of Radar was based on discrete high speed electronic components using high power radio wave pulses (Amplitude Modulation). Most recent Radars use Frequency Modulation Continuous Wave (FMCW) frequency modulation technology to enable low power, single chip devices. FMCW radars operate at 24GHz or 77-80GHz frequency range. The higher operating frequency provides higher accuracy for distance and speed measurements as well as more precise angular resolution. LiDAR technology, when compared to radar and camera, is at the early stages of technology development. Today, the end users of this technology (Waymo, Cruise, Baidu, Uber, Toyota, etc) are still experimenting with different technologies and are in search of new technologies that can enable small, low cost LiDAR that can be manufactured in millions of units per year.

3.5 Working

Various self-driving technologies have been developed by Google, Uber, Tesla, Nissan, and other major automakers, researchers, and technology companies.

While design details vary, most self-driving systems create and maintain an internal map of their surroundings, based on a wide array of sensors, like radar. Uber's self-driving prototypes use sixty-four laser beams, along with other sensors, to construct their internal map; Google's prototypes have, at various stages, used lasers, radar, high-powered cameras, and sonar.

Software then processes those inputs, plots a path, and sends instructions to the vehicle's "actuators," which control acceleration, braking, and steering.

Hard-coded rules, obstacle avoidance algorithms, predictive modeling, and "smart" object discrimination (ie, knowing the difference between a bicycle and a motorcycle) help the software follow traffic rules and navigate obstacles.

Self-driving cars can be further distinguished as being "connected" or not, indicating whether they can communicate with other vehicles and/or infrastructure, such as next generation traffic lights.

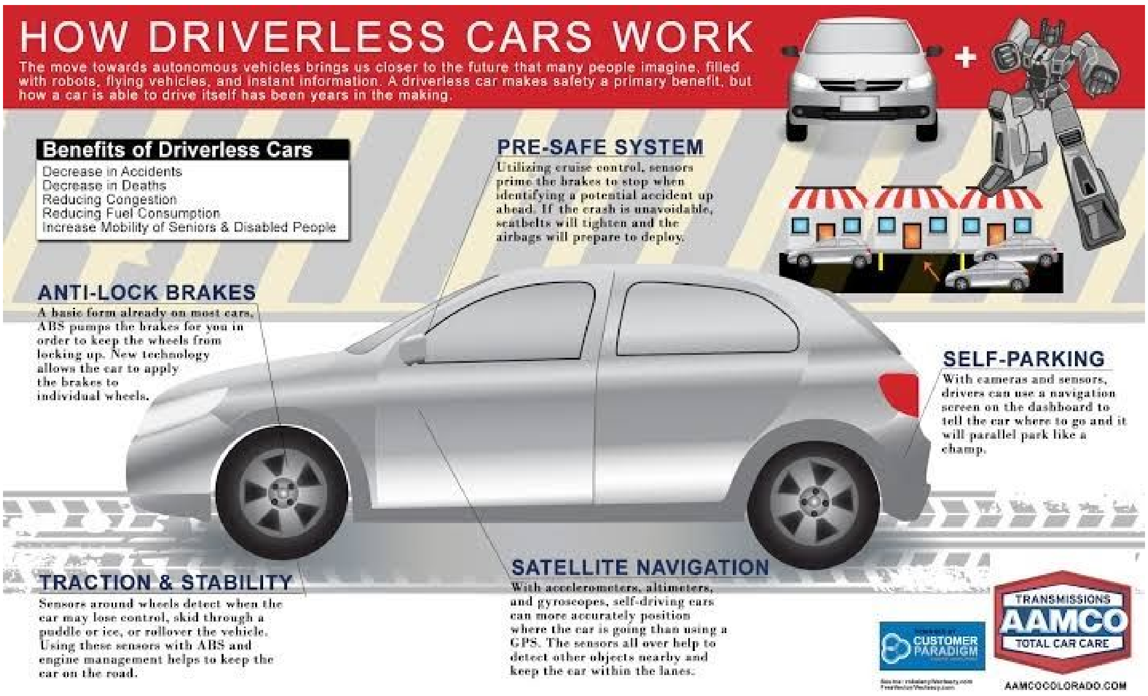

Fig 7 Working Of Autonomous Vehicles

3.6 Case Study : Google 's Waymo

Waymo began as the Google Self-Driving Car Project in 2009. Waymo's mission is to make it safe and easy for people and things to move around. We aim to bring fully self-driving technology to the world that can improve mobility by giving people the freedom to get around, and save thousands of lives now lost to traffic crashes.

- 1.35 million deaths worldwide due to vehicle crashes in 2016
- 2.4 million injuries worldwide due to vehicle crashes in 2015
- 2 out of 3 people die in vehicle crashes
- The theme to this vast majority of incidents : Human error and Inattention

They put technology through the world's longest and toughest ongoing driving test. We've now driven over 10 million miles on public roads and 7 billion miles in simulation. That's hundreds of years of human driving experience that benefits every vehicle in our fleet. With every mile we drive, we never stop learning.

Before our cars drive in any location, our team builds our own detailed three-dimensional maps that highlight information such as road profiles, curbs and sidewalks, lane markers, crosswalks, traffic lights, stop signs, and other road features.

Our sensors and software scan constantly for objects around the vehicle—pedestrians, cyclists, vehicles, road work, obstructions—and continuously read traffic controls, from traffic light color and railroad crossing gates to temporary stop signs. Our vehicles can see up to three football fields away in every direction.

Our software predicts the movements of everything around us based on their speed and trajectory. It understands that a vehicle will move differently than a cyclist or pedestrian. The software then uses that information to predict the many possible paths that other road users may take.

With Waymo in the driver's seat, we can begin to reimagine many different types of transportation, from ride-hailing and logistics, to public transport and personal vehicles.Today, our software is learning to drive big rigs in much the same way a human driver would after years of driving passenger cars. The principles are the same, but things like braking, turning, and blind spots are different with a fully-loaded truck and trailer.

The gulf between the most advanced self-driving car companies and their rivals that have struggled to make their technology safe for the roads widened last year, according to new figures released on Wednesday. The data, covering testing of autonomous vehicles in California, underlined the big lead that Waymo, the Alphabet subsidiary which began life as Google's self-driving car project, has built up over its main rivals. By contrast, Uber, which suspended its tests after a fatal accident involving one of its cars in Arizona last March, saw a deterioration in its reported test results last year.

The company views a shift to autonomous cars as one of the biggest long-term factors affecting its prospects in ride hailing, though in the past it has considered spinning off its project. The figures are affected by many factors, including the level of difficulty the companies set for their vehicles and different ways of measuring the results, weakening the value of direct comparisons between companies from one year to the next.

However, the publication of test figures in California — the only US state to require the disclosures — still provides the strongest public evidence of the state of autonomous vehicle technology. At Waymo, which began work on driverless cars more than a decade ago, the company's back-up drivers in California only had to intervene and take control of the vehicles once every 11,018 miles last year.

That was nearly twice the average distance its robot cars drove without human intervention in 2017 trials. "A lower rate of disengagements shows that our cars are getting better at recognising and handing a wide variety of situations," Waymo said, including "edge cases", or rarely seen situations that are difficult for a car to handle. But the company added that the disengagement rates shown in the California data were only one measure of performance.

Cruise Automation, the General Motors-owned company that is Waymo's closest rival, registered an even bigger improvement from its tests, though it still lags by a wide margin. Its drivers were required to take back control once every 5,205 miles, compared with once every 1,236 miles the previous year. At the other end of the spectrum, Uber reported a disengagement rate — the number of times its drivers take control for every mile driven — of 2.86 in 2018.

That reflected a higher level of human intervention than 2017, when its drivers were required to take control 2.5 times for each mile driven. Uber said it measured performance "by looking at a variety of measures including computer-generated simulation of real-world events and test track results". It added that its drivers "are trained to err on the side of caution and to take manual control of our system any time they think it is necessary".

4. INDUSTRY DISRUPTION

The driverless technology industry is expected to be worth £900 billion globally by 2025 and is currently growing by 16 per cent a year.It took 50 years for electricity to be adopted by 60% of households in the United States and only 10 years for cell phones. The adoption of self-driving cars could be even faster. Forecasts suggest that there will be as many as 21 million driverless cars in the United States and 27 million in Europe by 2030. In fact, ridesharing leaders like Uber and Lyft are banking on it.

- INSURANCE
- FOOD DELIVERY
- AUTO REPAIRS
- RIDE-HAILING
- PUBLIC TRANSPORTATION
- ENERGY AND PETROLEUM
- INTERNET SERVICE PROVISION
- CYBERSECURITY
- TRAFFIC ENFORCEMENT
- MILITARY OPERATIONS
- DATA CENTERS & INTERNET INFRASTRUCTURE

4.1 Key Industry Disruptions

4.1.1 Insurance

The shift to autonomous vehicles will cause dramatic changes in how insurance premiums are generated. With most autonomous vehicles likely to be owned by original equipment manufacturers (OEMs), OTT players, and other service providers such as ride-sharing companies, the number of individual policies will decline, along with revenues from premiums generated by these policies. And, since autonomous vehicles will be considerably safer than vehicles driven by humans, there will be fewer road accidents, leading to reduced pricing for insurance policies. Estimates are that claim frequency could drop significantly when compared to claims for vehicles driven by humans. While insurers of autonomous vehicles will make fewer payouts for claims, this will not compensate them for lost policy revenues.

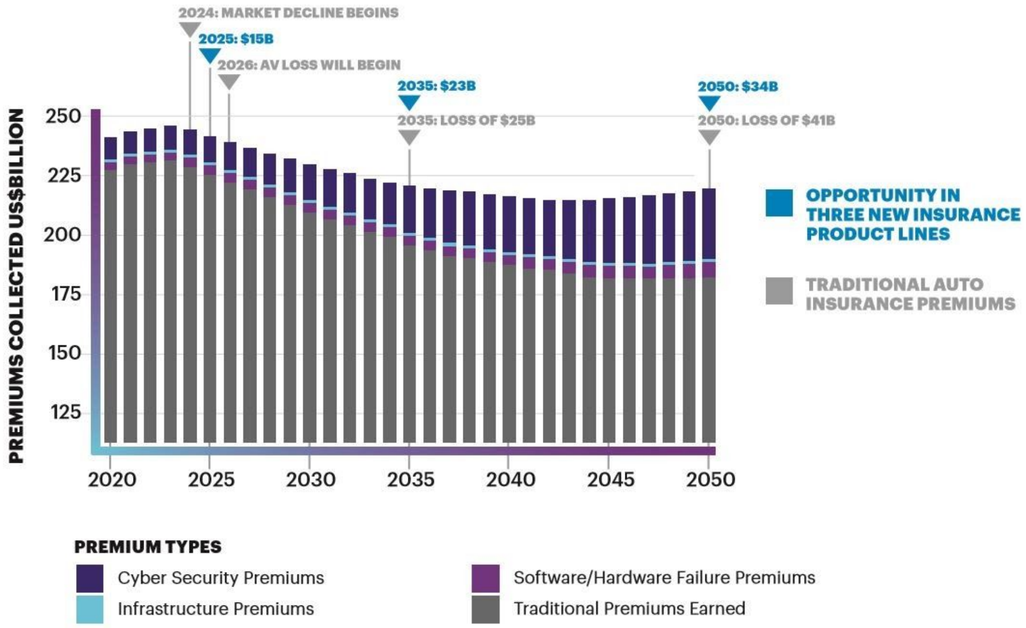

Fig 8. Insurance Disruption Variation

CYBER SECURITY The opportunities here include protecting against vehicle theft, unauthorized vehicle entry, and the use of "ransomware" to hold vehicles hostage until payments are made to unlock software controls. Insurers will also be writing policies to protect against criminal or terrorist hijacking of vehicle controls through hacking. And, with many cars serving as connected devices, insurers will offer protection against identity theft, privacy invasion, and the theft or misuse of personal information. The cyber security model was based on benchmarks of cyber security spending in the US information technology sector.

PRODUCT LIABILITY Insurers will write policies to cover manufacturers' liability for communication or Internet connection failure as well as for the potential failure of software – including software bugs, memory overflow, and algorithm defects – and hardware failures such as sensory circuit failure, camera vision loss, and radar and lidar (light detection and ranging) failures. Liability coverage will be needed not only by OEMs but by their tier 1 and tier 2 suppliers as well. The product liability model was based on historical automotive software and hardware failure rates, using National Highway and Traffic Safety Administration (NHTSA) data

INFRASTRUCTURE Autonomous vehicle manufacturers and/ or service providers will need to shoulder responsibility for the infrastructure put in place to control vehicle movements and traffic flow.

As autonomous vehicles shift the industry focus from personal ownership and liability to commercial and product liability, the biggest payers of new premiums will become OEMs, technology giants and governments. In addition, there may be other revenue opportunities related to managing risk connected with new products and services indirectly related to autonomous vehicles.

The threat posed to traditional automobile insurers by the rapid evolution of autonomous vehicles is real, but so is the $81 billion opportunity represented by new forms of cyber, product liability and infrastructure insurance. Early mover advantage will go to insurers getting a jump on actuarial modeling, the development of new product offerings, the creation of new distribution channels and the formation of partnerships with new premium payers – all critical elements of success.

Most people tend to think about vehicle connectivity in terms of using a phone in the car or getting a restaurant through an app on the dashboard. In fact, it runs much deeper than that, especially when autonomy and shared mobility are in the picture. The shared mobility revolution is dependent on both autonomy and connectivity, because the rider must hail the car, and the car must be there, and it must respond in an accurate and timely manner.

4.1.2 Energy

Autonomous vehicles will have tremendous impact on our cities and regions. This rapidly emerging technology will affect the transport system in its entirety including changes in energy consumption; increased safety, climate change impacts, efficiency of transport operations and the platooning of trucks carrying freight.

The energy impacts of autonomous vehicles may vary significantly along two pathways: (1) the extent to which the partial or full automation of the autonomous vehicle technology is implemented; and (2) whether there is a significant portion of shared autonomous vehicles vs. personal autonomous vehicles. Therefore, we analysed three different scenarios based on different assumptions about the two pathways, which are presented in Fig.1. We analysed each of the three scenarios separately based on literature that connects autonomous vehicle impacts with energy use change. A “partial automation with shared vehicles dominating” scenario was not developed due to lack of data but future research might examine this scenario more closely.

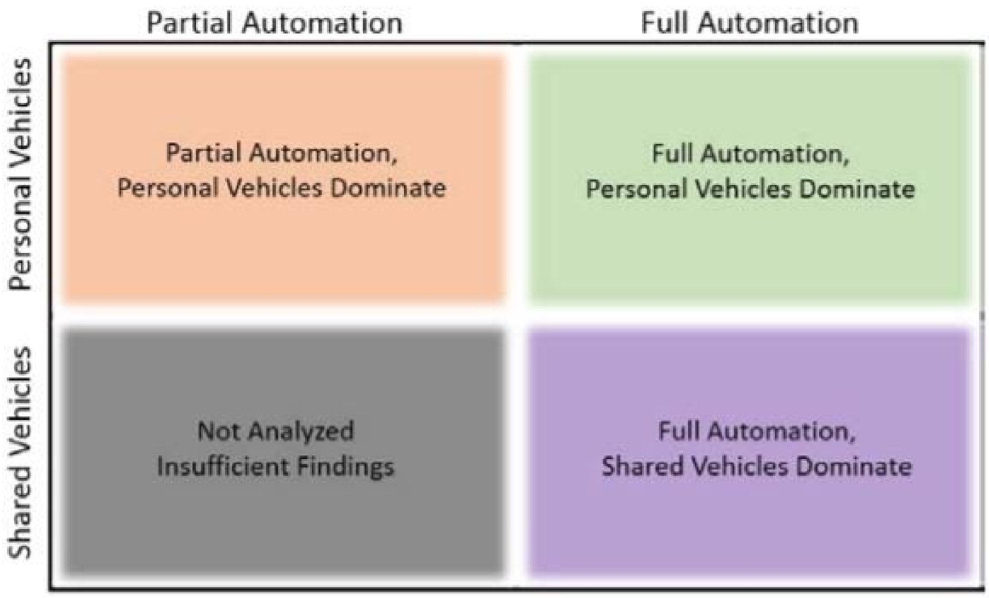

Fig 9 Automation Scenarios

In comparing full versus partial automation at the vehicle level, the 6-level standards introduced by SAE International (SAE, 2016) defines full versus partial automation levels. Partial automation is defined by levels 1, 2, and 3. Full automation levels are used to classify highly autonomous vehicles (HAVs) and have levels 4 and 5. Some of the literature also uses market penetration to characterize the level of automation at the system level. For the scenario analysis, we employ some of the early intermediate stages as partially automated. For example, when approximately ten percent of all cars are fully automated it would be considered partial automation versus 90 percent of all cars being fully automated which we consider as full automation for our estimation purposes.

Large uncertainties exist under the three scenarios presented above. However, given the wide variability, the estimates show that under a full automation scenario, considered largely inevitable in the long-term, the energy emissions impacts are substantially less under a shared vehicle future than one where personal vehicles dominate. Full automation of vehicles, suggested by the literature, is going to induce travel demand and attract new user groups, which will generate more trips and VMT that results in more energy consumption. Dynamic ridesharing and shared autonomous vehicles are the foreseeable pathway to reduce the potential negative impacts on traffic congestion and energy consumption while keeping the merits of autonomous driving and point-to-point mobility convenience.

Given the importance of addressing greenhouse gas emissions in the transportation sector, the path towards a low-energy future is best served by the pathway where shared vehicles are serving the movements of people, particularly in metropolitan regions where the vast majority of travel occurs and where a majority of the U.S. population resides. Funding and financing mechanisms and policies that encourage ridesharing are also very important considerations and are awaiting more research exploration

4.1.3 Cybersecurity

Advanced driver assistance technologies depend on an array of electronics, sensors, and computer systems. In advancing these features and exploring the safety benefits of these new vehicle technologies, NHTSA is focused on strong cybersecurity to ensure these systems work as intended and are built to mitigate safety risks. NHTSA promotes a multi-layered approach to cybersecurity by focusing on a vehicle's entry points, both wireless and wired, which could be potentially vulnerable to a cyberattack. A layered approach to vehicle cybersecurity reduces the possibility of a successful vehicle cyber-attack, and mitigates the potential consequences of a successful intrusion. A comprehensive and systematic approach to developing layered cybersecurity protections for vehicles includes the following:

- A risk-based prioritized identification and protection process for safety-critical vehicle control systems.
- Timely detection and rapid response to potential vehicle cybersecurity incidents on America's roads.
- Architectures, methods, and measures that design-in cyber resiliency and facilitate rapid recovery from incidents when they occur; and
- Methods for effective intelligence and information sharing across the industry to facilitate quick adoption of industry-wide lessons learned. NHTSA encouraged the formation of Auto-ISAC, an industry environment emphasizing cybersecurity awareness and collaboration across the automotive industry.

Current Research

- Anomaly-based intrusion detection systems research: Researching metrics and objective test methods to assess effectiveness of such solutions.
- Cybersecurity of firmware updates: Researching cybersecurity of automotive electronics update mechanisms through physical and over-the-air means.
- Cybersecurity considerations for heavy vehicles: Researching similarities and differences between passenger cars and larger vehicles from a cybersecurity considerations standpoint.
- Research on reference parser development for V2V communication interfaces: Developing a formally verified and mathematically proven message parser for V2V communication interfaces.
- In-house cybersecurity research at the Vehicle Research and Test Center (VRTC) in East Liberty, Ohio: This research explores the cybersecurity risks of today's

vehicle electronic architectures and aims to establish principles and guidance that could improve the cybersecurity posture of passenger vehicles through applied research

Attacks on Autonomous Vehicles

- Sensor jamming, spoofing and blinding: Current approaches to self-driving automation leverage a variety of cameras, lasers, GPS, radar and other sensors to give the vehicle the environmental and situational awareness it needs. Each of these types of sensors can be blinded or jammed, thereby hindering the vehicle's ability to retain full awareness of environmental conditions or potential obstructions.
- DoS/DDoS [(distributed) denial of service] attacks: Autonomous cars will be fitted with a number of communications systems that are designed to receive and share information necessary for safe navigation and driving. These communications systems could include vehicle-to-satellite, vehicle-to-vehicle, vehicle-to-internet and more. There is also communication within the vehicle itself via the 'controller area network'. Disruption of any of these methods of communication can degrade the ability of the car to operate appropriately.
- Forged vehicle communications: Another risk involving communications would be the forging of vehicle communications to spoof hazards that don't exist or attempts to cause a vehicle to behave in ways it wasn't designed or intended to. One potential problem revolves around protocols that lack cryptographically sound integrity checks. These protocols may be vulnerable to spoofing depending on their implementation and communication methods.
- Leaked data: Autonomous cars will, by nature, have a significant amount of data about the travels and potentially some of the communications of its passengers. Additionally, personalization features as well as other functionality may have to store sensitive information about passengers, such as payment details and other personally identifiable information (PII). If the vehicle is compromised, this information could be obtained by an attacker.
- Physical attacks: Certain attacks could be carried out by those with physical access to the vehicle. Vehicular systems that are exposed to passengers such as USB ports or OBD-2 ports might provide mechanisms to allow for malicious use or exploitation. As with other technological systems, physical access often bypasses controls that are specifically in place to prevent remote exploitation.

Potential mitigations

Designers should take all the above threats into account when developing autonomous driving systems and build in sufficient defense systems and redundancy to address these.

Some of these examples may include:

- Safety protocols that put vehicles in 'lock-down' mode: When enabled, the attack surface is reduced to the minimum necessary to safely carry passengers to their destination. These protocols could be activated at times when specific threats are present or likely.
- Access controls to prevent unauthorized communication: Systems that only allow accepted types of communications may provide adequate defense, but additional research into other vehicle-based solutions against DoS and DDoS attacks should be conducted.
- Sharing of threats and other security concerns via V2V communications.

It remains to be seen how effective the security measures engineered into autonomous vehicle systems will be when these are the default vehicles on the road. The auto industry has built processes around how it handles defects and vehicle recalls, but it has yet to prove itself capable of effectively responding to widespread cybersecurity issues.

While cyberattacks pose a risk to the vehicle owners themselves, a bigger potential impact is the longer-lasting effect on the reputation of vehicle manufacturers. Loss or tampering of customer data through a cyberattack could lead to reduced customer trust– affecting sales and share price.

Vehicle manufacturers have taken steps to improve cybersecurity, such as the establishment in 2015 of a threat intelligence sharing group called the Automotive Information Sharing and Analysis Center (Auto-ISAC). However, with more and more vehicles boasting automatic driving systems, manufacturers must take every precaution to defend against malicious threats that could lead to serious consequences and undermine the trust the public places in these innovations.

5. CONCLUSION & FUTURE SCOPE

5.1 Stakes and Challenges

- The risk of a third party taking control of the vehicle or the surrounding infrastructure.
- The risk of a third party accessing an individual's personal information.
- Risk of Fraudulent activity for making an insurance claim.
- Resulting Unemployment
- Very Sophisticated lifestyle

There are a few factors that will impact whether or not autonomous vehicles will become widespread in the future. For one, there is a serious adoption curve for many consumers who are not sold on this technology, whether that be because they don't feel safe in a driverless vehicle or because they aren't ready to give up the freedom and independence that comes with owning their and driving their own vehicle. Another hurdle to consider is related to the technology associated with self-driving cars, as many speculate there will be a need for vehicle-to-vehicle communications across auto makers to make sure these cars can share the road safely.

In terms of potential impacts to companies directly in the automotive industry such as taxi services, new car dealerships and repair shops there is going to be a period of adjustment and pressure to keep up with the latest technology. Ultimately, industry players will evolve and react as they have in the past. From the aftermarket perspective, an increased number of autonomous vehicles could lead to an increased interest in car customisation with additions like advanced video technology to entertain passengers.

I think the adoption of autonomous vehicles will be gradual as we as a society adjust to the changes. While some are predicting we'll see an influx of these vehicles in the next five to ten years, I believe a more realistic prediction is within the next 20 to 25 years.

There are many challenges in making autonomous and electric cars fit for our public roads. Electric, autonomous cars will need to become more integrated with national intelligent transport infrastructures and systems such as satellite navigation systems in cars; traffic signal control systems; parking information, weather reports, bridge de-icing, container management systems; variable message signs; automatic number plate recognition or speed cameras to monitor applications, such as security CCTV systems and similar.

As smart cars on the roads will increase, a key component of future intelligent transport infrastructures will be support for charging stations. Some early prototypes are beginning to communicate with the grid, the cloud and other vehicles. It will not be long until smart cars by default will likely keep an activity log for service and debugging. Privacy, of course, will be an issue, whether it is the insurance company, the car maker, a local dealer, or even police authorities all seeking another means to track our every coming and going. Crucial components of the future will be the mobile networks, ad hoc (car to car) networks, vehicles to and from road sensors, and satellite communications.

5.2 CONCLUSION

Driverless cars are a relatively new and exciting technology. Like any new advancement before them, there is an inherent risk involved, especially at the early stages. However, that risk has to be controlled in order to ensure driver safety.

While driverless cars excite the imagination, they still have a long way to go before they are adequately safe and regulated. This will not be an easy transition as it means people will have to embrace giving up control at 70 plus miles per hour. This also comes at a time when everything, including cars, is vulnerable to online attacks. Nevertheless, driverless vehicles appear to be an important next step in transportation technology. Even if they suffer several growing pains along the way, a car where everyone rides shotgun is likely the car of the future.

The concept of a car that does not need a driver may seem futuristic to most people, but that concept has become one of Google's most popular innovations aside from their universally-known search engine. The idea of a self-driving vehicle is very appealing to many people, but in reality "driverless is really driver-optional" . It is reasonable to predict that in the future, there will no longer be a need for driver's licenses. Hopefully, they will be able to fully perfect their driverless cars and lead humanity to the future.

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