

# Autonomous Vehicles: Levels, Technologies, Impacts and Concerns

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## Abstract

Autonomous vehicles also commonly known as driverless or self-driving vehicles, are automobiles that require no human involvement for operating or controlling them. In recent years, advancement in automated vehicle[1] concepts has progressed but still some human input is required, depending upon the level of automation. Experts anticipate that automobiles will be capable of driving themselves within 3-7 years. This paper describes current status, recent trends and research of self-driving vehicles in the automobile industry. A detailed analysis of the technologies used by automated vehicles to sense their environment and the level of automation in such vehicles is also included. The expected short-term and long-term, positive and negative, beneficial and harmful impacts of driverless technology such as greenhouse gas emission, energy consumption etc. are assessed. As widespread adoption of self-driving vehicles is considered to be inevitable, therefore requirement of certain technical and legal guidelines will be essential for safe and tension-free travel. The potential concerns regarding autonomous vehicles must be discarded with safe policies and technologies as discussed in the paper.

**Keywords:** Autonomous cars, sensor technologies, carbon emission, LIDAR, impacts, applications.

## INTRODUCTION

Automated vehicles have been generating significant attention and discussion, recently with almost every automobile company trying to develop their respective autonomous vehicle concept and are successful in achieving some levels of autonomy and are planning to start production of driverless vehicles in few years. Even though people have mixed feelings of excitement and insecurity regarding the driverless concept but will either accept or reject it on the basis of the impacts of autonomous vehicles. Researchers and analysts have already started considering the effects of autonomous vehicles on carbon emission, number of cars per person, etc. and are providing their views on vehicle automation. Self-driving[2] cars will need to outperform human driving capabilities for securing a larger consumer market. But surely, it will have a huge impact on the timeline of transportation and a landmark in human inventions.

## CURRENT STATUS AND RESEARCH

The automotive industry is rapidly evolving and now with the concept of self-driving cars, all the companies are focused on developing their own driverless cars[3]. Even the companies which are not into 'mainstream automobile' like google and uber are also investing and researching extensively in autonomous vehicles.

- Apple is also developing its self-driving car project "Titan".
- The concept of electric cars is already in practical use. Tesla and General Motors have successfully launched their respect electric cars in the market and are available to the consumers. But the autonomous vehicles[4] are still in research but cars with some levels of autonomy are available like Tesla autopilot and GM super cruise control.
- An MIT spin-off called iSee is developing and testing autonomous driving system using artificial intelligence. Also, an object detection system called YOLO (you only look once) developed by Joseph Redmon is being used in driverless vehicle concept.
- Component maker Faurecia has envisioned the cockpit for the autonomous car. When autonomous mode is selected, the steering wheel folds away and the screen behind it slides to the center of the dashboard.
- Waymo, the subsidiary of parent company of google is a self-driving technology company which is successfully testing its concept car.
- Waymo has also announced to launch self-driving trucks for delivering goods.
- Companies are launching concept cars like Aston Martin launched its concept car Lagonda Vision Concept, which is a luxurious electric, level 4 autonomy car.
- Renault has launched its autonomous concept car called SYMBIOZ which drives in manual or level 4 autonomous mode.

Many more advances are being done in this field rapidly but the aforementioned points are mentioned to show the seriousness and enthusiasm regarding vehicle automation.

The attached graph represents the future timeline regarding the adoption of autonomous vehicles by the public.

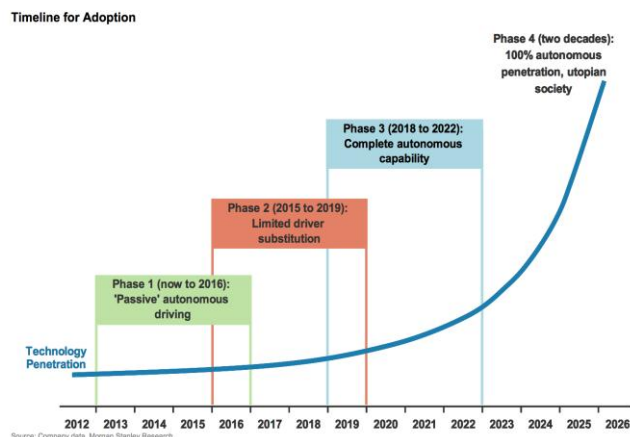
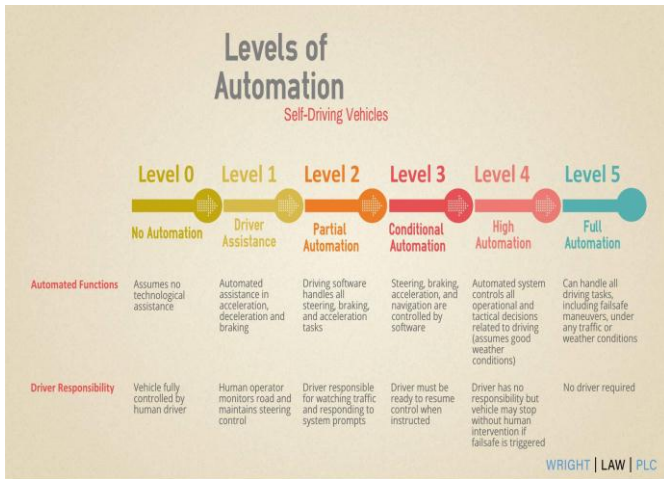


Figure 1: LIDAR SENSING OBJECTS [5]

## LEVELS OF AUTOMATION

The classification of automated vehicles is done with dividing them on the basis of extent of automation. The first classification was given by National Highway Traffic Safety Administration (NHTSA), USA[6] in 2013. But in 2016, SAE presented its classification of six levels of automation which was set as the international standard for all automated vehicles.



**Figure 2: SAE INTERNATIONAL LEVELS OF AUTOMATION[7]**

### LEVEL 0: NO AUTOMATION

Vehicles in which all the controlling operations are in driver's hands. The piloting, braking, acceleration, deceleration and emergency braking is done solely by the driver. Vehicles with basic warning systems like coolant temperature, oil pressure etc. also fall in this category.

### LEVEL 1: DRIVER ASSISTANCE

Some specific control functions that assist the driver in operating are included in level 1 cars. The driver is responsible for all operations but vehicle provides assistance if he utilizes it. Lane Keeping Assistance (LKA) steers the vehicle into a particular lane and Adaptive Cruise Control (ACC) is also an automated system which regulates speed and the driver steers. All the automated[8] systems work independently and still require some input from the driver. Nowadays, this level of automation is seen in most cars like Honda civic, jeep, BMW.

### LEVEL 2: PARTIAL AUTOMATION

In partial automation, the vehicle has control of the vehicle in terms of steering, acceleration/deceleration and braking but the driver must monitor the driving and should be ready to take control at any time in case the automated systems are unable to perform[9]. Level 2 automated cars are available in market and include two or more combined automated functions.

### LEVEL 3: CONDITIONAL AUTOMATION

In limiting self-driving, the vehicle is in full control and alerts the driver to retake control in situations which require driver assistance. The driver can take his 'eyes off' the road and should take control when the system needs it[10]. Vehicles with level 3 automation usually use RADAR technology for sensing their surroundings. Tesla autopilot system, General Motors super cruise technology and Audi A8 have level 3 automation.

### LEVEL 4: HIGH AUTOMATION

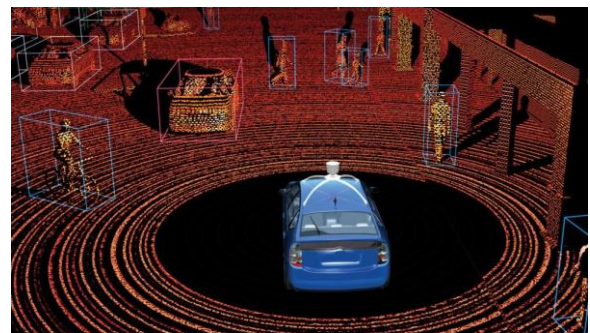
Vehicles in this level are capable of handling immediate response like emergency braking. Driver attention is not required and need not be in the driver seat. But driver can take control in unusual environment conditions. Google car prototypes fall under this category.

### LEVEL 5: FULL AUTOMATION

No human involvement is required. The vehicle will not allow the passenger to take control of the operations. Robotic taxi will fall under this category.

## SENSOR TECHNOLOGIES

Autonomous vehicles are being developed using complex algorithms and neural networks and advance technologies[11]. In this section, technologies used by vehicles to sense their environment have been assessed.



**Figure 3: LIDAR TECHNOLOGY USES LIGHT PULSES TO DETECT OBJECTS[12]**

### ULTRASONIC SENSORS

Ultrasonic sound waves are sound waves having frequency greater than 20,000 hertz. Sensors use these sound waves to locate nearby obstacles, the waves hit any object and reflect back thus mapping the surrounding and accordingly give the output back to the system[13].

- SONAR used in submarines and boats use same concept.
- Bats are able to navigate using a similar technique called echolocation.
- Ultrasonic sensors are useful in automated parking but can be used only at low speeds.

### IMAGE SENSORS

In image sensing, a number of cameras are placed in the vehicle to generate images of the surrounding[14]. Traffic lights and signs are easily interpreted. Image sensors are hard to use in fog, rain or night.

### RADAR SENSORS

Radio Detection and Ranging (RADAR) sensors emit high frequency radio waves which echo after hitting an obstacle and a tuned antenna picks up the signal and informs the system about the object position and speed.

- Radars are widely used in ships and aircrafts.
- Currently, radars are being used in some semi-autonomous vehicles[15] like Tesla.
- The reflected signals are hard to trace back in an open field or very packed space.

### LIDAR SENSORS

To overcome the difficulties with radars, Light Detection and Ranging (LIDAR)[16] was developed. Lidar sensors use low intensity and harmless laser beam to scan the environment. The data from the sensors and cameras are processed together in the master software which creates a real time virtual 3D environment. But lidar sensors are much more expensive than radar sensors. Google car and Uber self-driving taxis use lidar sensors.

## **4. IMPACTS AND APPLICATIONS**

In this section the expected impacts of autonomous vehicles on economy, carbon emissions and people's behavior are discussed.

Autonomous cars[17,18] would cause a decrease in number of accidents as it does not get distracted nor gets tired and also is packed with safety features like ABS and airbags. The driving will be free from human errors and will save huge losses of life and money. Also, cases of road rage will reduce effectively.

Drivers will have time for anything else other than driving which could be used for relaxing, working or for entertainment, thus adding up to the revenue of telecom industry for example, if internet is used while raveling therefore improving economy.

Platooning[19] refers to when multiple vehicles move closely to each other, reducing aerodynamic[20] drag on the cars in the middle, thus increasing efficiency and decreasing fuel rate consumption. Platooning will be possible by automated vehicles as there is no delay in perceiving and reacting to speed changes whereas in manually operated cars platooning can be dangerous. It will also reduce road congestion as cars would move in tight formations.

The speed limit can be increased as there is no chance for the computer systems to get distracted. This will reduce the time taken in a journey thus reducing traffic and the journey will be smooth and jerk free due to automated driving[21].

The efficiency of engines will increase as automated cars would drive the car in most efficient parameters, unlike humans who sometimes lug the engine or revving the engine unnecessarily. The computer system in automated cars would cause maximum fuel efficiency as it does not drive aggressively and there will be no wear and tear of clutch or gears due to less unessential gear-shifts[22].

Autonomous vehicles will have a huge impact on driver related jobs as it would no longer require drivers. It can cause loss in economy therefore, tackling this issue will be very important. Therefore, adoption of autonomous vehicles must be gradual so that it does not create a lacuna of unemployment.

Parking space will be reduced as the cars can be parked very close together and the freed spaces can be used for public parks and community centres.

The crimes[23] related to violation of traffic rules would decrease drastically. Also managing traffic flow would be very easy.

Emissions released by automated vehicles will be increased or decreased depending upon the human behavior. Either the driverless concept would cause increase in energy consumption or would dramatically decrease it. People may tend to go on long drives or trips to far-away places as they would not have to drive and commuting in cars would become easy and tension-free. Also, if people rather pick the self-driving taxis, it would reduce pollution and energy consumption.

## **5. MAJOR APPLICATIONS:**

- Driverless cars can be used as regular cars for driving from home to work.
- Autonomous vehicles can be used as self-driving taxis, where the passengers just have to input the destination. Uber[24,25] has already started trials for driverless vehicles offering lifts to customers.
- The delivery trucks deliver goods across countries travelling via long and dangerous routes, in harsh road and weather conditions. Self-driving trucks would be very essential for delivering through such conditions.
- It can be used by older people, people with disabilities and people who do not know how to drive.

## **6. POTENTIAL CONCERNS**

The concept of self-driving cars is creating excitement in people but at the same time some concerns are also being brought up regarding the technical, safety and law aspects[27] of driverless cars. The potential challenges are listed below:-

- Busy city streets with bustling traffic and incoming pedestrians will be a challenge for the autonomous cars[27].

- Difficult village roads or rough mountain roads which are uneven and bumpy and filled with potholes, the speed of the car must be controlled and ability of steering away from bumps or holes will be tested.
- The software and computer system of the car can be reprogrammed to disable the safety features with the intention of causing an accident.
- The sensing of objects or people become difficult in different weather conditions like snow, rain, etc.
- Also sensing around corners is very difficult and inability to track incoming traffic around the corner can be catastrophic.
- Autonomous cars[28] may require very high-quality specialised maps to operate properly. Where these maps may be out of date, they would need to be able to fall back to reasonable behaviors.
- The confusion in transmitting and receiving signals in case of radar and lidar.
- The car must be able to recognize animals and avoid it by steering away from it or stopping, depending on the conditions[29].
- The cost of maintenance and repair of the car will be very high.
- The car would have to be tested and the internal systems including the software would have to be checked from time to time to avoid any failure on the road.
- The car could be used for criminal activities like smuggling and also for terrorist activities, for example- car bombings or transportation of weapons and ammunition.
- The law and the traffic rules will have to be updated regarding the ownership and use of autonomous vehicles.
- The effect on economy due to loss of driving related jobs is also a concern.
- The decision taking ability of human is dependent on many factors. Ethically a person would consider crashing the vehicle to save a pedestrian. This type of moral reasoning and suitable decision making is vital for autonomous vehicles.
- If the vehicles would use GPS or a tracker then the privacy can be compromised as the time and position of the vehicle will be known at all times.
- Studies reveal that when the car is in autonomous mode, driver tends to pay less attention on the road and thus would not be able to respond in case of an emergency and the car needs driver's assistance[30].

## CONCLUSION

The automobile industry is ever-evolving with new technologies to increase the handling and efficiency of the car being invented and employed every year. The most anticipated and talked about topic – ‘autonomous vehicles’ will revolutionize the way people travel. With the advent of autonomous vehicles just around the corner, experts are evaluating the advantages/disadvantages and the impacts have been discussed thoroughly but surely the positive impacts of driverless concept are significant and cannot be disregarded. Also, the impacts turning positive or negative hugely depends upon the mindset of humans using it, thus regulations and rules are to be set for better results[31]. The obstacles are a cause of concern but can be improved with time and experience. Therefore, due to some challenges it would not be wise to discard the whole concept. The applications of autonomous vehicles are numerous which would certainly be very helpful for transportation industry as self-driving taxis and delivery trucks would reduce the manual labor a lot.

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