UNIT 10 FUTURE OF SUSTAINABLE SMART TRANSPORTATION SYSTEMS-II

Structure

10.1 INTRODUCTION TO AUTONOMOUS VEHICLES

The advancement of automobile technology seeks to provide safety benefits and automated driving systems (ADS) that, one day, will be able to handle the entire work of driving for us when we don't want to or can't. Fully autonomous automobiles and trucks that drive us rather than the other way around will become a reality. Self-driving cars or transportation systems that move without the involvement of a human driver are referred to as autonomous driving.

Objectives

After studying this unit, you should be able to:

- Explain autonomous vehicle and challenges
- Differentiate between connected and autonomous vehicles
- Describe the impact of CAVs on transparent
- Discuss about the benefits of CAVs

10.2 WHAT IS AN AUTONOMOUS VEHICLE?

Definition of Autonomous Vehicle as defined by Gartner glossary is "*An autonomous vehicle is one that uses various in-vehicle technologies and sensors, such as adaptive cruise control, active steering (steer by wire), anti-lock braking systems (brake by wire), GPS navigation technology, lasers, and* *radar, to drive itself from a starting point to a predetermined destination in "autopilot" mode.*” (Glossary, n.d.)

Through its capacity to perceive its surroundings, an autonomous vehicle, also known as a driver-less car, is able to operate itself and execute required duties without the need for human involvement. A completely automated driving system is used in an autonomous vehicle to allow it to respond to external situations that a human driver would handle. (TWI, 2021)

Degrees of Autonomous Vehicles:

There are six different levels of automation is as shown in table 10.1, and as the levels progress, the driver-less car's autonomy in terms of operation control grows.

1st Degree: The automobile has no control over its functioning at level 0, and the human driver is in charge of all driving. At level 1, the ADAS (advanced driving assistance system) in the car can aid the driver with steering, acceleration, and braking.

2nd Degree: In some circumstances, the ADAS can handle steering, acceleration, and braking at level 2, but the human driver must maintain total attention to the driving environment throughout the voyage, while simultaneously completing the rest of the required tasks.

3rd Degree: The ADS (advanced driving system) can perform all parts of the driving task at level 3 in specific conditions, but the human driver must be able to restore control when the ADS requests it.

4th Degree: In the 4th Level cases, the human driver performs the required tasks. In some circumstances where human attention is not required, the vehicle's ADS can execute all driving duties autonomously.

Degree 5th: Level 5 entails complete automation, in which the vehicle's ADS can execute all functions under any situation, The human driver is not necessary to assist with driving. Full automation will be possible because to the deployment of 5th Generation network technology, which will allow automobiles to communicate not only with one another, but also with traffic lights, signs, and even the highways itself.

Table 10.1: Level of Automation in Automated Vehicles

	Name	Narrative definition	Execution of steering and acceleration/ deceleration	Monitor - driving environment	Fallback performance of dynamic driving task	System capability (driving modes)
Human driver monitors the driving environment						

0	No automation	The full-time operation by the human driver for all aspects of the driving task, even when assisted by warning or intervention technologies	Human driver	Human driver	Human driver	n/a
1	Driver assistance	The execution of either steering or acceleration/deceleration by a driver assistance system based on information about the driving environment, with the expectation that the human driver will handle the remaining components of the dynamic driving task.	Human driver and system	Human driver	Human driver	Some driving modes
2	Partial automation	The execution of both steering and acceleration/deceleration by one or more driver assistance systems based on information about the driving environment, with the expectation that the human driver will handle the remaining components of the dynamic driving task.	System	Human driver	Human driver	Some driving modes
Automated driving system ("system") monitors the driving environment						

3	Conditional automation	The automated driving system's performance of all components of the dynamic driving task in a given driving mode, with the expectation that the human driver will respond properly to a request to intervene.	System	System	Human driver	Some driving modes
4	High automation	Even if a human driver does not respond adequately to a call to intervene, an automated driving system's execution of all parts of the dynamic driving task in a certain driving mode.	System	System	System	Some driving modes
5	Full automation	The automated driving system's full-time performance of all components of the dynamic driving task under all roadway and environmental situations that a human driver can manage.	System	System	System	All driving modes

Source: SAE International

10.2.1 CAVs Implementation Timeline

When thinking about upgrades, another important item to consider is when different levels of CAVs will be implemented in the fleet. The prediction of the implementation timeline is influenced by a number of factors.

Many automotive manufacturers, notably Maserati MY 2018, Nissan Leaf 2018, and Audi A8 2019, have demonstrated that Automation level 2 is now widely available. However, it is unclear when vehicle manufacturers will begin to build higher degrees of AVs. Ford, for example, plans to skip Level 3 and start producing Level 4 vehicles in 2021. BMW also mentions 2021 as the year for developing level 4 vehicles, and expects that fully autonomous vehicles would be accessible between 2025 and 2030. Although the prediction concerning the proportion of AVs in the fleet is unclear. However, an S-curve theory, often known as Gal's Insight (Gal, 2018) , can be utilized to forecast innovation deployment. Automated vehicles time line forecast is shown in Figure 10.1.

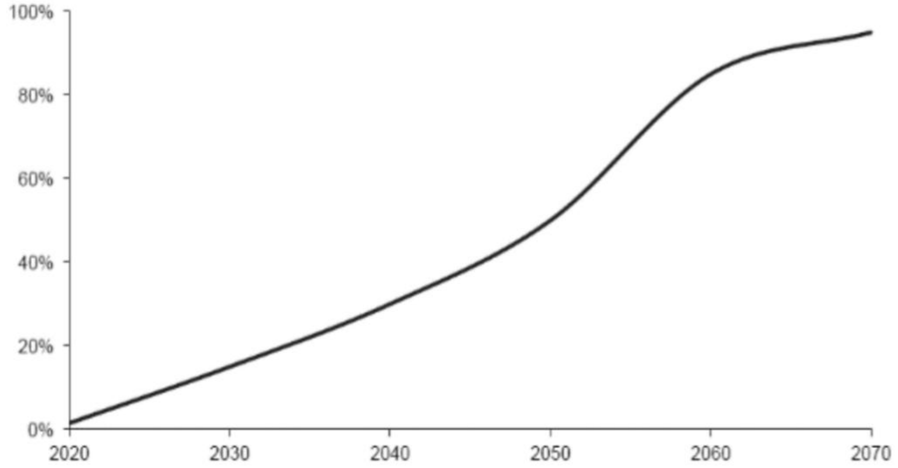
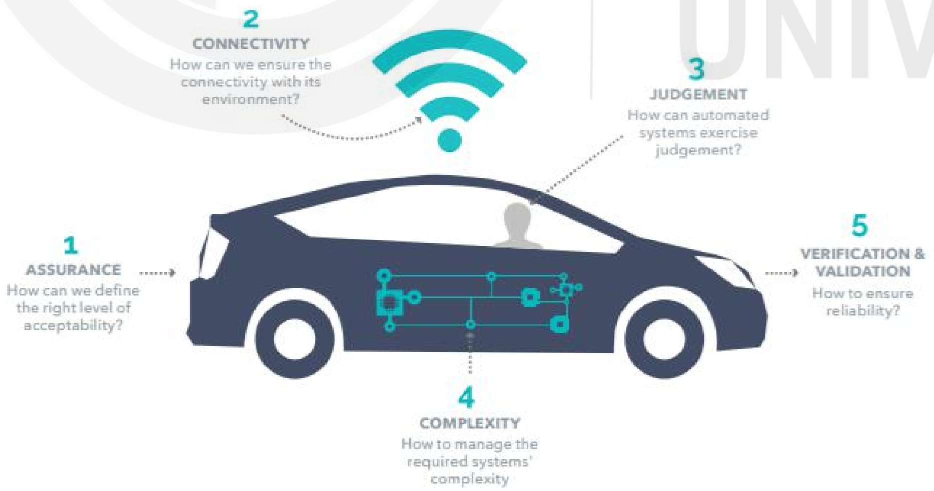


Figure 10.1: AVs Timeline Forecast

10.3 AUTONOMOUS VEHICLE CHALLENGES

Assurance of systems and software: There are numerous similarities between the process of delivering this confidence and that of current systems and vehicles. The challenge of defining accountability Safety refers to a road system rather than a single vehicle; it can only be determined by looking at dynamic interactions between components and consequences occurring outside the system boundary. Characterizing the surroundings is challenging. There are several aspects of everyday driving that will be difficult to define or reproduce for testing: Temporary violations of traffic regulations, snow on road markers, police officers' hand gestures during an accident, and other commonplace "black swan" scenarios. However, there are several problems that are unique to autonomous road vehicles: automotive transportation is far less regulated (and therefore less safe) than other modes of transportation like rail or aircraft, and the road system is already vulnerable to single-point failures (that is, misbehavior of a single vehicle or pedestrian).



Because autonomous vehicles sense the environment differently than humans, they will make mistakes that are different from those made by humans. This has implications for both the vehicle (as the design must not simply seek to replicate human behavior) and other road users (whose safety may be jeopardized by the presence of entities that do not respond as expected). Functions that can replace the driver in certain instances but must be replaced by the driver in others pose the question of why the (uninvolved) driver will continue to be effective if the automation fails. Driver attention to dangers will be reduced as a result of automation. Control cannot be immediately returned to the driver unless there is "look-ahead" prediction that identifies a problematic scenario and alerts the supervising human in a timely manner, without causing a panic (over)reaction.

Figure 10.2 : Automated Vehicle detection in CAVs

When opposed to manual driving, autonomous function alters several aspects of duty and liability - activities like picking an acceptable speed for the current conditions, which are the exclusive responsibility of a human driver in a manually driven car, become product behaviors. There is a manufacturer, a designer, a vendor, and an operator in this system. The legal and commercial implications of this shift are outside the purview of this study, but the expectations regarding decision-making functionality that have been raised cannot be overlooked. (2020, Jackson) It takes a lot of effort to create (and update) maps for self-driving automobiles.

10.4 DIFFERENCE BETWEEN CONNECTED AND AUTONOMOUS VEHICLES

Although connected and autonomous vehicles are sometimes confused, there is a significant difference between the two. The major distinction between connected and autonomous vehicles is the latter's capacity to act independently while being led by final safety recommendations.

One may be able to employ remote parking and route advice in linked automobiles, but the driver retains complete control. In a self-driving automobile, one can act as the passenger but the driver or the decision maker is vehicle itself. The different between connected vehicles and autonomous vehicles are given in table 10.2 and in Figure 10.3 and Figure 10.4.

Table 10.2: Different between connected vehicles and Autonomous vehicles.

Connected Vehicles	Autonomous Vehicles
• In the most basic terms, connected car technologies allow other vehicles to interact with them while also allowing them to connect to the rest of the world. • The goal of connected car	• Autonomous Cars, as contrast to linked vehicles, are completely self-contained. This indicates that the car's technological systems are becoming self-driving. Many automobiles, especially at Level 3,

technology is to provide valuable information to a driver or vehicle so that they may make safer and more informed decisions. As a result, a "connected vehicle" does not imply that the vehicle makes decisions for the driver, as an autonomous vehicle would.

are already equipped with self-driving capabilities. Self-driving, self-parking, and auto-collision avoidance are just a few of the features.

- Cars will be fully autonomous in the near future, which implies that no driver input is necessary and that every function on the vehicle is automated.
  - However, until a vehicle is capable of driving itself, it cannot be considered really autonomous (AV). Fully autonomous vehicles are computer-driven and do not require a human driver. Right now, manufacturers are gradually phasing in various levels of autonomy until complete autonomy is reached.

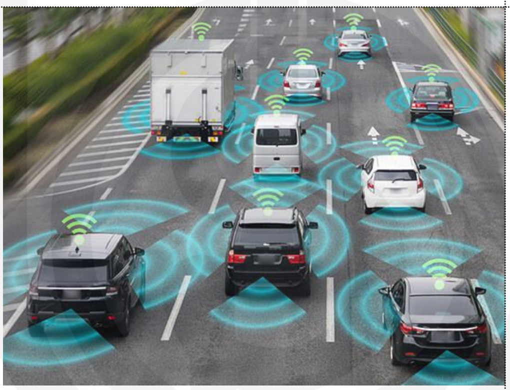


Figure 10.3: Connected Vehicle Technology

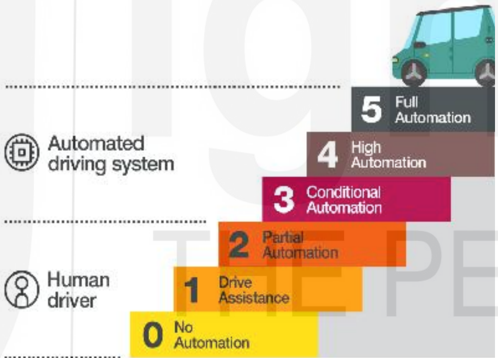


Figure 10.4: Automated Vehicle Technology

10.5 CONNECTED AND AUTONOMOUS VEHICLES WITHIN A SMART CITY

Smart cities aim to integrate technological development with various functions/components such as mobility, energy management, natural resource management, water management, and waste management, air quality, land use, service network, and construction, as well as the economy, social participation, increased employment, and citizen safety. Smart cities are being advanced for a variety of reasons, including major economic and environmental developments. Global warming and its environmental consequences, in particular, have been taken into account in the design and development of smart cities.

Due to the strong integration of technology in people' everyday lives, today's cities are undergoing significant changes. As a result, creating a framework to unite all elements of everyday life in a city, as well as digitizing services and incorporating intelligence into their functioning, is critical.

Smart city growth is influenced by a number of variables, including transportation supply (mobility services, infrastructural details, and ICT), demand (socio-demographic characteristics), and city size. CAVs provide substantial benefits in each of these variables.

10.5.1 Social Benefits due to CAVs in Smart Cities

CAVs can enhance traffic flow for individual vehicles as well as traffic throughout the city since they interact with many systems. Connected vehicles can not only reduce traffic congestion on the roads, but the additional services enabled by connection may also make commuters' life simpler in a number of ways. A connected automobile, for example, may utilize the cloud to locate available parking spots, propose the best routes, and allow passengers to surf the web or make conference calls while travelling. Ridesharing and robot-taxis, which bring economic and environmental advantages while also fostering social contact, are also supported by a linked infrastructure.

10.5.2 CAVs in Smart Cities: Economic and Environmental Benefits

CAVs pick the quickest and most fuel-efficient routes using AI and real-time cloud-based data. Human drivers, on the other hand, tend to misuse the accelerator or brakes, wasting fuel. CAVs, on the other hand, may be designed to follow rules for maximum efficiency all of the time. In reality, self-driving vehicles have the potential to reduce transportation energy usage by up to 90%. This is a win-win situation for both the economy and the environment, as lower fuel use means lower carbon emissions.

Many CAVs are also electric cars (EVs) or hybrids, reducing or eliminating dependency on fossil fuels entirely. CAV technology, on the other hand, takes use of the EV advantage by utilizing sensors and connection to optimize the vehicle's power consumption. Even surplus power generated by the car's powertrain may be returned to the city's smart grid via electronic CAVs.

Smart city development is resulting in an infrastructure that is highly connected and perfect for connected autonomous vehicles (CAVs). Self-driving cars, trucks, and buses can be intrinsically linked to crucial data, reducing traffic and improving road safety. Smart cities will be enabled by CAVs, which will provide substantial value to the city's economic, social, and environmental objectives.

Cities are moving beyond collecting data in Siloed systems to manage traffic flow. They are now using connected networks and cloud technologies to link these data sources to each other, to in-vehicle sensors such as GPSs, and to cloud-based data sources for weather data, street conditions and more. The next step is to combine these connected data sources with sophisticated data analysis and artificial intelligence (AI) capabilities for an interconnected system that can power smart decisions on a scale as big - or as targeted - as the city requires.

10.5.3 Safety Benefits of CAVs in Smart Cities

CAVs are safer than human-driven vehicles, according to research CAVs create considerably fewer collisions than automobiles driven by humans. One explanation for this is technological advancements other being automobile sensors communicate with their surroundings and can adjust to changing conditions to prevent collisions with other vehicles, people, and other objects. Another reason is that, unlike humans, CAVs do not become weary or distracted when making decisions, and they do not freeze in the middle of a decision. The car makes judgments based on an analysis of data from vehicle sensors and linked data from the cloud - data that a human driver may not have access to. CAVs Applications in smart cities is shown in Figure 10.5.

Figure 10.5 : CAVs Applications in Smart Cities

Connected transportation systems have the potential to substantially increase efficiency throughout the city. Smart technology help cities to better serve their residents despite sometimes quickly expanding populations, from better traffic management to the ability for public transportation users to follow bus or train whereabouts. to carry out a connected and automated vehicle operation forecasting procedure in a smart city, it’s critical to do micro-simulations to predict possible fuel usage and conflicts, especially in the early stages, when linked and autonomous cars will coexist with traditional automobiles.

Individuals with motor issues, such as the Old Age people, people with disabilities, and marginalized groups, would benefit from self-driving automobiles. Mobility as a service is expected to reduce the cost of a trip to less than the cost of a public transportation ticket, therefore assisting in the reduction of social barriers. Similarly, the emergence of CAVs has the potential to help the community in a number of ways. It may be quantified in both direct and indirect ways.

The advent of the linked and autonomous car will result in a shift in transportation modes as well as urban planning and management. Densities, urban structures, and land use must all be examined in this global perspective in order for new mobility models to emerge. Vehicle automation has resulted in new mobility models that give the required accessibility while also encouraging sustainable land use. The urban environment will alter as a result of self-driving automobile technology, and these changes will be permanent. Hence, it is critical to understand the implications of its use, avoid negative developments, and maximize the benefits of the connected and autonomous vehicle's introduction.

Modern society's smart city concept must work in tandem with energy efficiency aims (which include the energy efficiency of buildings and businesses).

10.6 THE DEVELOPMENT OF CAVS IN URBAN MOBILITY

CAVs (Connected and Autonomous Cars) are vehicles that are equipped with numerous sensors to collect data from the surrounding environment, which is then analyzed and processed by a computer built into the vehicle, allowing it to travel autonomously. One of the most significant inventions of the first two decades of the twenty-first century is autonomous driving, capable of revolutionizing the urban and extra- urban mobility system and transforming the lifestyle of people who move daily. In the last decade, the technology related to autonomous driving has accelerated thanks to Artificial Intelligence (AI) onboard vehicles. Thanks to the introduction of AI in driving systems, vehicles are becoming more and more "intelligent", able to park themselves, change the speed or direction of travel, and react and predict obstacles while driving. With the introduction of CAVs, more excellent road safety is expected for drivers and weak road users with greater accessibility and less environmental impact. However, many challenges still need to be overcome to reach this scenario, which is not without risks. Above all, the possibility of not decreasing road congestion instead of encouraging it. For self-driving cars to safely handle any traffic condition and any impulsive behavior of other road users, such as cars, pedestrians, and cyclists, and thus ward off human intervention, millions and millions of test kilometers are needed in extreme situations, such as heavy rain, snowfall, and other weather events. In a future in which CAVs will be widespread, there will always be a coexistence of private and shared use regarding the transport of people. The former will correspond to the private car without substantial differences from current vehicles, apart from the technological equipment present in the automation. On the other hand, will be vehicles intended for community use, in which users will find themselves on board, as is currently the case on collective transport vehicles, with the possibility of using the time in the way they prefer, not having to pay attention to driving and with the obvious advantage of not having to bear the costs of owning a vehicle for private use. In short, the difference between vehicles for personal use and shared use will be in the way of use compared to the usable technology present onboard the vehicles. This circumstance is an essential factor if the time onboard is used up for work activities. In this regard, it is estimated that with autonomous driving, the value of time (VOT) can be reduced by 30%, compared to manual driving, reaching the level of collective transport. However, it is necessary to take into account an ambiguity deriving from a lack of traffic reduction, since if people used the time in the car to work or carry out activities in the same way as they would do at home or in the workplace, the time spent would become irrelevant. Queuing from the vehicle and therefore the problem of road congestion would take a back seat. Nevertheless, this problem is currently secondary, as it will take many more years to see the large-scale spread of CAVs.

10.7 RELEVANCE OF CAV'S IN FUTURE YEARS

In 2050, the possibilities presented by CAVs appear to be endless. Next-generation technologies can be a valuable ally in attaining our sustainability goals in many ways.

Electrification is a critical step toward achieving a goal of zero emissions by 2050. Removing exhaust fumes from city streets will significantly improve air quality. Furthermore, smart cities might intelligently manage resources to become economically sustainable, energy self-sufficient, and responsive to the quality of life and demands of their residents, growing in tandem with innovation and the digital revolution while remaining a viable and appealing reality. Connectivity is essential for autonomous and long-term transportation. Mobility is viewed as a means of giving access to needed services rather than as a goal in and of itself.

Level 5 automated cars (the highest in the SAE rating) are expected to be available by 2030.i.e., vehicles capable of driving on any type of road, in any weather condition, and the passengers onboard can completely disregard driving during the journey. A self-driving vehicle continuously and automatically makes decisions about its behavior and, therefore, the machines must capture every detail: pedestrians, cyclists, trucks, animals and, in general, every smallest obstacle around them, whether stationary or in motion, is fundamental in determining whether to brake, turn, slow down, accelerate or continue. The evolution of these vehicles is closely correlated to the development of technology and sensors, and mechanisms outside the cockpit with which the vehicle communicates with the road infrastructure (so-called smart road), also becoming a useful tool for providing information on traffic and safety. The advantages of autonomous driving include:

i) Greater safety when moving around, and therefore a reduction in accidents, given that the driving system is not subject to fatigue or distraction and is less subject to risks linked to environmental conditions (low light, fog, rain)
ii) The possibility of getting around more easily for the elderly and disabled
iii) The reduction of traffic and pollution (thanks to smart roads, traffic should be smoother with a consequent reduction in polluting emissions)
iv) Reducing driver stress

The disadvantages of this technology are numerous and ethically significant:

i) The reduction of jobs
ii) The possibility that the software that governs the cars could be affected by errors
iii) Like any electronic device connected to a network, the self-driving car is also attackable by hackers
iv) The safety risk of personal data of drivers, passengers, and third parties

Even in heavily populated locations, adopting networked autonomous vehicles would boost road capacity and minimize congestion. Roads with self-driving automobiles, intelligent traffic lights to regulate traffic, object-to-object communication, but most importantly, big green spaces, fluid traffic, and sustainable mobility with bike-sharing and car-sharing of electric and/or hybrid vehicles.

10.8 IMPACT OF THE CONNECTED AND THE AUTONOMOUS VEHICLE ON TRANSPORTATION

Within Cities, all kinds of sustainable and innovative mobility are critical actors in the transportation sector. Shared mobility services such as car sharing, bike sharing, carpooling, and sharing electric micro-cars and electric vehicles are popular among people because they are efficient and ecologically beneficial, reducing traditional urban traffic and harmful emissions.

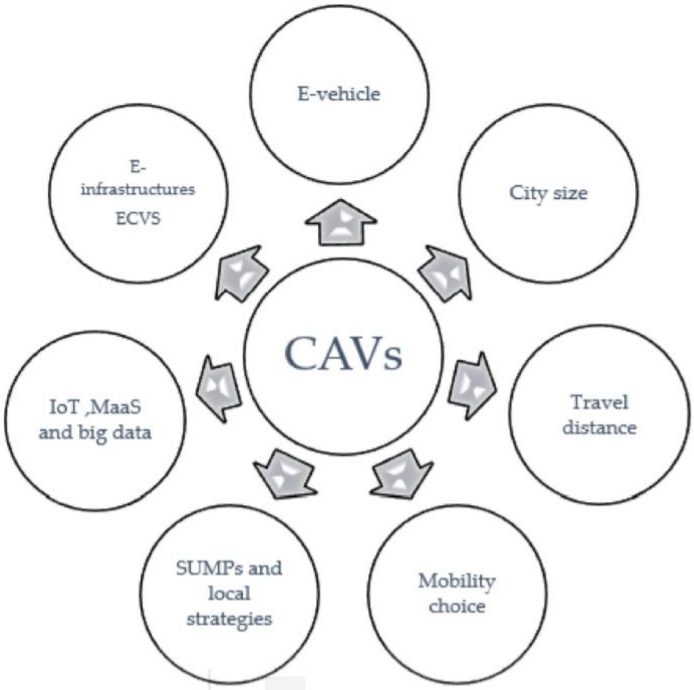


Figure 10.6: Components of CAVs

The rise of linked and autonomous vehicles supports greater flexibility in transportation services, as well as a reduction in alcohol-related accidents and human mistake or distraction. These technologies also enable the optimization of vehicle flow efficiency, the reduction of pollution, and the expansion of social inclusion possibilities for individuals with impairments, including those with physical, cognitive, or motor disabilities.

Individuals with motor issues, such as the elderly (a rising population), people with disabilities, and marginalized groups, would benefit from self-driving automobiles. The value of mobility as a service is projected to be in the billions of dollars. will reduce the cost of a ride to less than the cost of a public transportation ticket, therefore assisting in the reduction of social barriers. Similarly, the growth of connected and autonomous vehicles has the potential to help the community in a number of ways. It may be quantified in both direct and indirect ways.

i) Traffic volume,

ii) Transportation expenses,

iii) Total parking space, and

iv) Energy consumption and travel time are all critical indications for maximizing the service of connected and autonomous vehicles in metropolitan settings. 2021. Different components of CAVs are shown in Figure 10.6.

10.9 EFFECT OF CONNECTED AND AUTONOMOUS VEHICLES ON THE AUTOMOTIVE INDUSTRY

The automobile industry is one of the manufacturing sector's most powerful pillars. The development of self-driving automobiles has the potential to impact the global automotive sector significantly. The Automotive Sector is undergoing a digital innovation. The industry transition to autonomous, connected, electrified, and shared (ACES) vehicles has the potential to boost technological development and economic activity in traditional manufacturing Countries, bridging the gap between high-tech innovation hubs and historically industrialized regions.

Autonomous vehicles may provide a way for entrants with strong information technology skills to enter and disrupt the existing automobile business. A number of variables combine to make this a good opportunity, but it also presents a unique challenge for existing businesses. The following are the most significant of these factors:

The automobile industry is already in upheaval as it faces the prospect of a steady increase in electro-mobility. This tendency calls into question the value and distinguishing potential of established automotive firms' current core competencies. New suppliers can strive to break into the market with new technologies, but incumbent businesses can also improve their market position by acquiring new technological expertise.

Competence in digital networks: Companies like Apple and Google have a lot of experience developing digital products and apps, as well as networking subsystems, cars, and infrastructures. Applying this experience to automotive applications can provide you a considerable advantage in terms of digital networking and autonomous driving, assuming you have the appropriate vehicle-related knowledge. Competencies can be brought in from suppliers or manufacturers.

Data competence: The capacity to manage huge volumes of data enables new digital business models, and this is a type of competency that is highly developed in digital-based technology firms. The creation and utilization of enormous data sets (big data) holds a lot of promise for entrepreneurs looking to create new, yet-to-be-discovered business models centered on individual mobility.

Capital strength: The two firms in this industry with the greatest stock market values worldwide are Google (or, more particularly, Alphabet) and Apple. Uber, although being a relatively new firm, has a significant market capitalization. This demonstrates not just investors' favorable expectations, but also the firms' substantial investment potential thus establishing a new market potential would be difficult for new entrants.

10.10 BENEFITS OF AUTONOMOUS VEHICLES

Deployment

From the perspective of the population as a whole, AVs would significantly improve road safety, ameliorate traffic congestion, and reduce the emission of greenhouse gases and other pollutants. On an individual level, AVs offer large efficiency benefits—increasing access to ridesharing and public transportation as well as reducing travel time. Many benefits, such as improved traffic management and road safety, would provide immediate, tangible benefits to both individuals and society as a whole. Others, such as reductions in emissions and average vehicle miles traveled, may only become apparent over a longer period of time.

Efficiency

Route optimization: AI allows for route optimization and optimized matching of drivers and riders, which is already being explored by Uber and Lyft. This technology includes predictions of upcoming delays and instantaneous rerouting. Jacksonville's planned AV-based 10-mile urban transit network would embrace this technology to allow transit vehicles to be automatically rerouted to less busy areas to reduce wait time.

Traffic management: Many AVs will instantaneously communicate with transportation infrastructure, including "smart" traffic lights, which has already shown promise in reducing stoppages and wait times. Pittsburgh's "SurTrac" pilot program, which installed intelligent traffic signals at 50 intersections in Pittsburgh, reduced travel times by 25 percent due to less stopping (30 percent decrease), and when stopped, less waiting time (40 percent decrease). Less advanced systems have also been proven to improve traffic management. The utilization of adaptive cruise control and AI-based monitoring of traffic flow increased traffic speed by 8–13 percent. Uptake of vehicles with automated assistance in navigation, parking, and crash aversion (adaptive cruise control) could increase the effective capacities of roadway lanes by up to 80 percent, depending on how widespread AVs are adopted. A single shared AV could replace about 10 privately owned vehicles, significantly reducing congestion and parking requirements.

Incident management: Traffic congestion on busy roads and highways is often exacerbated by improper incident management. AVs would be able to reduce the duration of incident-caused congestion by instantaneously alerting ambulances and emergency services, and the volume of congestion by immediately alerting oncoming traffic of the incident and optimally rerouting.

Safety

Road safety: AVs would drastically reduce the potential for road accidents. Automobile crashes were estimated to have a societal cost of $836 billion in 2010 alone. Ninety-four percent of crashes are attributable to human error, which autonomous systems even below level five would guard against. Sensors and computers cannot fall asleep, drive under the influence, or become distracted. Real-world data backs the safety theory. A 2017 trial showed that Tesla's crash rate fell almost 40 percent after the cars were equipped with autopilot.

Traffic management: Improved traffic management, especially in conjunction with artificially intelligent transport system (ITS) infrastructure, such as "smart" traffic lights, could significantly improve road safety by avoiding congestion. Some argue, however, that automation could increase the number of vehicles on the road and worsen congestion, especially if consumers opt not to embrace ridesharing and if skepticism toward autonomous vehicle technology persists. Research from the University of Adelaide, for example, found that traffic congestion could increase over the next 30 years if commuters switch to AVs but are averse to ridesharing. A drop in both vehicles on the roads and vehicle trips eventually occurs in scenarios where commuters remain skeptical of AVs, but commuter aversion delays the transition.

Environment

Reduction of greenhouse gas and air particulate emissions: Route optimization decreases travel time and therefore decreases emissions from internal combustion vehicles or required energy production to charge EVs. Improved traffic management decreases stoppages and idling time which would further reduce emissions and energy needs. Truck platooning (coupling of several heavy goods vehicles led by one human driver, simultaneously accelerating or braking) increases fuel efficiency by operating closer, reducing stops and air resistance.

Sustainability: AV-based public transport systems were found to be the most sustainable strategy in dense urban areas to shift the heavy trip load from private vehicles. Ridesharing in urban areas could allow for a “greenification” of cities, introducing green spaces and improving inner-city safety by reallocating space for bike lanes and safer pedestrian zones. More immediately, self-parking AVs are able to occupy parking spaces 15 percent tighter than normal cars, allowing for a significant reduction in parking infrastructure in urban areas. On average, U.S. vehicles sit idle for 95 percent of their lifetime. Autonomous ridesharing and public transportation solutions would allow for 24/7 use of vehicles, further reducing parking needs and opening up space for pedestrians and green micro mobility options, like bicycles and scooters.

10.11 IDENTIFYING THE IMPACT OF CAVS ON USERS AND MOBILITY

Autonomous driving is a hot issue in smart cities that aims to change mobility. A lot of research has gone into the development of self-driving vehicles, and several testing and real-world demonstrations have been recorded in recent years. The initial expectations were fairly high. Researchers and the general public projected a significant positive impact on traffic congestion, travel time, and other mobility issues. However, new research casts doubt on these exclusively optimistic assumptions, claiming that autonomous driving might have a beneficial or negative impact depending on city policy.

In order to acquire a better grasp of the general public's expectations regarding the implications of autonomous driving, the need for user perception surveys will always be there in future.

The surveys will intend to get the insights of how the population is perceiving the CAVs and its benefit and implication to their mobility, thus a adequate survey should address:

- Familiarity with autonomous vehicles and general opinion
- Expected benefits of autonomous vehicles
- Concerns about employing driverless vehicles
- Concerns about autonomous vehicles' safety in unforeseen situations
- Concerns about cyber security issues
- Concerns regarding various self-driving vehicle implementations
- Overall interest in autonomous vehicle technology and readiness to pay for it

10.11.1 Survey Design

The survey questionnaire can be subdivided into groups as such:

- Socio-Economic-Demographic Characteristics of the Population.
- Expected Impacts and implications of autonomous vehicles in cities. (Safety, Congestion etc)
- Integration into a city (e.g., sensitivity to public space sharing, sensitivity to diverse modes' priorities)
- Transition from the current condition to one where autonomous vehicle are more prevalent.
- Perception regarding concerns and potential issues.

10.11.2 Case of Perception study of public opinion about autonomous and self-driving vehicles in the U.S., the U.K., and Australia

This case study looked at public perceptions of self-driving vehicle technology in three major English-speaking countries: the United States, the United Kingdom, and Australia. The poll received valid responses from 1,533 people aged 18 and more is shown in Table 10.2.

Table 10.2: Public opinion about Autonomous and Self driving Vehicles in the U.S, the U.K and Australia

Demographic aspect		Percent			
		U.S. (N=501)	U.K. (N=527)	Australia (N=505)	*Total (N=1,533)*
Age group	18 to 29	29.2	23.7	26.6	*26.5*
	30 to 39	21.6	24.5	22.8	*23.0*
	40 to 49	19.2	21.0	21.6	*20.6*
	50 to 59	23.2	21.4	22.6	*22.4*
	60 to 69	7.0	8.7	6.5	*7.4*
	70 or older	0.0	0.6	0.0	*0.2*
Gender	Female	52.1	52.9	51.7	*52.2*
	Male	47.9	47.1	48.3	*47.8*
Education	Less than bachelor degree	56.3	59.0	51.3	*55.5*
	Bachelor degree	29.5	23.5	32.1	*28.4*
	Graduate degree	14.2	17.5	16.6	*16.1*
Employment	Employed full-time	46.5	42.7	43.6	*44.3*
	Employed part-time	17.0	19.4	19.6	*18.7*
	Not currently employed	20.6	20.1	17.4	*19.4*
	Retired	9.0	8.5	9.5	*9.0*
	Full-time student	6.0	8.9	8.3	7.7
	Part-time student	1.0	0.4	1.6	*1.0*
Vehicle type driven most often	Passenger car	55.3	66.4	74.1	*65.3*
	Minivan I van I MPV	7.0	6.3	2.4	*5.2*
	Pickup truck	8.0	0.6	2.8	*3.8*
	SUV	16.8	4.0	11.1	*10.6*
	Motorcycle I scooter	0.4	1.1	0.8	*0.8*
	Do not drive	12.0	21.2	8.7	*14.0*
	Other	0.6	0.4	0.2	*0.4*
Autonomous-	Level 0	47.7	49.7	45.3	*47.6*

vehicle technology installed on vehicle(s)	Level 1	25.5	16.7	29.7	*24.0*
	Level 2	4.6	3.6	4.4	*4.2*
	Do not know	6.4	5.5	4.6	*5.5*
	Do not own vehicle	15.8	24.5	16.0	*18.8*

10.11.3 Findings

10.11.3.1 Knowledge of and opinions toward autonomous and self-driving cars

Prior to the study, the majority of respondents in each of the three countries had heard of autonomous or self-driving vehicles (Figure 10.7). The United States had the largest percentage of people who have heard of autonomous or self-driving vehicles (70.9%), followed by the United Kingdom (66.0%) and Australia (66.0%). (61.0 percent).

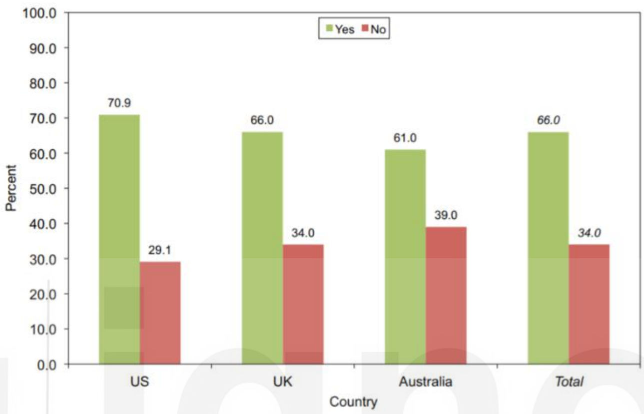


Figure 10.7: % of Knowledge on Autonomous and Self Deriving Cars

Table 10.3 shows a full breakdown of responses by nation, whereas Figure 10.8 shows collapsed summaries (positive responses versus negative responses). The majority of respondents were enthusiastic about the technology, with Australia (61.9 percent) having the most positive comments, followed by the United States (56.3 percent) and the United Kingdom (47.3%). (52.2 percent).

Only a small minority of respondents reported negative feelings, with the United States (16.4%) having the highest rate, followed by the United Kingdom (13.7%) and Australia (11.3 percent). In each country, almost 30% of respondents expressed a neutral impression of autonomous and self-driving vehicles.

Table 10.3: Percentage of people and their opinion about CAVs

Response	U.S.	U.K.	Australia	*Total*
Very positive	22.0	13.9	16.2	*17.4*
Somewhat positive	34.3	38.3	45.7	*39.4*
Neutral	27.3	34.2	26.7	*29.4*
Somewhat negative	12.4	11.2	8.3	*10.6*
Very Negative	4.0	2.5	3.0	*3.2*

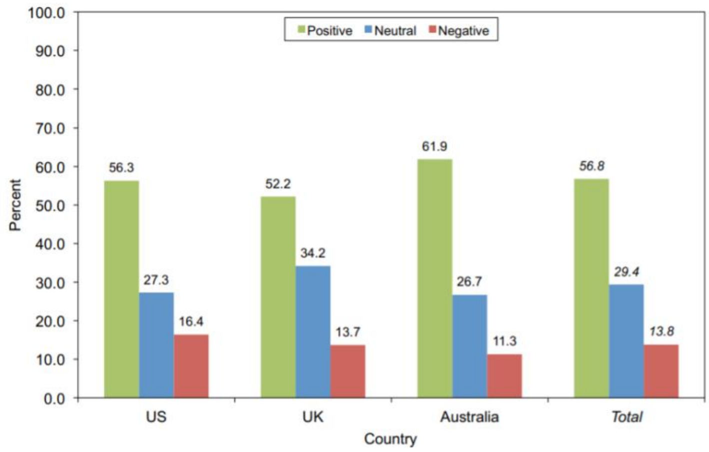


Figure 10.8: Collapsed Summary on CAVs

10.11.3.2 Expected benefits of self-driving vehicles

"How probable do you think the following benefits will occur while utilising entirely self-driving vehicles (Level 4)?" respondents were asked. They were asked to rate each item on a list of projected benefits for entirely self-driving vehicles as "extremely likely," "very likely," "slightly unlikely," or "very unlikely" (Level 4). Table 10.4 shows a full breakdown of responses by nation, whereas Figure 3 shows collapsed summaries (likely responses versus unlikely responses). In all three countries, "rather likely" was the most common response for all items. With the exception of less traffic congestion and shorter travel times (which a majority of respondents thought were unlikely to occur), the majority of respondents believed that each of the projected benefits would be likely to materialize with self-driving vehicles. Better fuel economy was the most likely outcome (when collapsed, 72.0 percent thought it was "likely"), while shorter travel times were the least likely outcome (43.3 percent said it was "likely").

Table 10.4: User perception towards benefit of CAVs

Expected benefit	Response	U.S.	U.K.	Australia	*Total*
Fewer crashes	Very likely	26.1	23.5	24.2	*24.6*
	Somewhat likely	41.7	47.6	48.1	*45.8*
	Somewhat unlikely	22.2	21.6	21.4	*21.7*
	Very unlikely	10.0	7.2	6.3	*7.8*
Reduced severity of crashes	Very likely	25.0	21.8	23.6	*23.5*
	Somewhat likely	43.9	50.9	49.9	*48.2*
	Somewhat unlikely	20.8	20.9	20.2	*20.6*
	Very unlikely	10.4	6.5	6.3	7.7
Improved emergency response to crashes	Very likely	32.5	18.8	23.0	*24.8*
	Somewhat likely	39.1	41.4	45.7	*42.1*
	Somewhat unlikely	21.2	29.6	24.4	*25.1*
	Very unlikely	7.2	10.2	6.9	*8.1*
Less traffic congestion	Very likely	19.2	15.2	15.2	*16.5*
	Somewhat	30.5	32.1	32.3	*31.6*

	likely				
	Somewhat unlikely	32.9	37.4	36.2	*35.5*
	Very unlikely	17.4	15.4	16.2	*16.3*
Shorter travel time	Very likely	16.8	11.0	13.3	*13.7*
	Somewhat likely	29.1	28.3	31.5	*29.6*
	Somewhat unlikely	36.9	44.2	40.2	*40.4*
	Very unlikely	17.2	16.5	15.0	*16.2*
Lower vehicle emissions	Very likely	21.2	23.0	16.8	*20.3*
	Somewhat likely	42.3	44.2	45.5	*44.0*
	Somewhat unlikely	26.1	26.4	27.5	*26.7*
	Very unlikely	10.4	6.5	10.1	*9.0*
Better fuel economy	Very likely	25.3	27.5	21.0	*24.6*
	Somewhat likely	44.7	48.4	49.1	*47.4*
	Somewhat unlikely	21.2	19.7	22.6	*21.2*
	Very unlikely	8.8	4.4	7.3	*6.8*
Lower insurance rates	Very likely	22.6	18.0	16.6	*19.1*
	Somewhat likely	30.9	40.2	38.0	*36.4*
	Somewhat unlikely	27.9	27.7	28.9	*28.2*
	Very unlikely	18.6	14.0	16.4	*16.3*

Similar studies can be carried out in regular interval to assess the operational necessities of CAVs with respect to users so that regular monitoring and improvement in infrastructure can be facilitated based upon the demand.

APPENDIX1: MODEL QUESTIONNAIRE FOR ASSESSMENT OF CAVS IMPACT ON MOBILITY

Opinions Concerning Autonomous and Self-Driving Vehicles

We're conducting a survey to assess public sentiment on autonomous and self-driving automobiles. On the following page, you'll find a general explanation of what autonomous and self-driving vehicles represent. Before continue with the survey, please take a time to read that description carefully.

Autonomous vehicles are ones that function without direct driver input in at least some components of a safety-critical control (such as steering, throttle, or braking). Autonomous vehicles are those that give drivers safety alerts (for example, a forward-crash warning) but do not take control of the vehicle. Autonomous vehicle technologies range from those that handle simple operations like cruise control to fully self-driving vehicles that don't require a human driver. On-board sensors, cameras, GPS, and telecommunications may be used to gather data in order enable autonomous vehicles to make judgements about safety-critical circumstances and act properly by taking control of the vehicle to some extent

Q1) Had you know anything about of autonomous and/or self-driving vehicles before hand?
Yes No

Q2) What are your thoughts on autonomous and self-driving vehicles in general? Please give us your view based on the description you just read, even if you had never heard of autonomous or self-driving vehicles before taking this poll.

- Very positive
- Somewhat positive
- Neutral
- Somewhat negative
- Very negative

There are numerous tiers of self-driving vehicle technology. Some of these technologies are presently available, while others will be available in the future. Below are descriptions of each level of autonomous car technology. Before continue with the survey, please take a minute to read each description attentively.

Technology at present:

0th level. There is no technology for self-driving cars.

1st level One or more safety-critical functions are controlled by the vehicle, yet they operate autonomously. Overall control is still in the driver's hands.

2nd level. This level includes two or more technologies from Level 1, yet they work together in unison. Overall control is still in the driver's hands.

Technology for future:

Level 3 offers only a limited amount of self-driving technology. The driver will be able to delegate control of all safety-critical operations to the vehicle, with the driver only having to intervene on rare occasions.

Level 4: Vehicle that is completely self-driving. For the duration of the journey, the car will control all safety-critical functions.

Q3) Which of the following autonomous-vehicle technologies, if any, do you have on the vehicle(s) that you own or lease?

Please select one response only. If you have more than one vehicle with this technology, please select the most advanced level installed on your vehicles.

Do not currently own a vehicle.

level 0

There is no automation. At all times, the driver has total and exclusive control of the principal vehicle controls (brake, steering, and throttle), and is solely responsible for keeping an eye on the road and ensuring the vehicle's safe functioning. Vehicles with certain driver assistance or convenience systems but no steering, braking, or throttle control are still classified as Level 0 vehicles. Systems that just provide alerts (forward collision warning, lane departure warning, blind spot monitoring), as well as systems that provide automated secondary functions like as wipers, headlights (turn signals in the US, indicators in the UK/Australia), hazard lights, and so on.

Level 1:

One or more principal vehicle controls (brake, steering, or throttle) are automated at this level; if multiple controls are automated, they operate independently from one another. The driver maintains overall control and is solely responsible for safe operation, but he or she can choose to delegate some control to the vehicle (for example, cruise control); or the vehicle can automatically control a function (for example, electronic stability control); or the vehicle can provide additional control to assist the driver in certain situations (such as dynamic brake support in emergencies).

Although the vehicle may aid the driver in controlling one of the controls—steering, braking, or throttle—each function is managed independently of the others. Automatic braking and automatic lane maintaining are two further examples of Level 1 technologies.

Level 2:

At least two key vehicle controls (brake, steering, and/or throttle) are automated to relieve the driver of control of those operations. In certain limited driving scenarios, vehicles with this level of automation can share control with the driver. The driver is still in charge of keeping an eye on the road and ensuring safe operation, and he or she must be accessible for control at all times and on short notice. The driver must be prepared to take control of the vehicle safely if the system relinquishes control without notice.

I do not know if my vehicle has any of these technologies

Q4) Level 3 vehicles are likely to offer just a limited amount of self-driving capability. Under specific traffic situations, vehicles of this level allow the driver to relinquish control of all safety-critical tasks and rely on the vehicle to monitor for changes that need resuming driver control. The driver will be expected to be available for control on occasion, but with adequate transition time. A self-driving car, for example, may detect when the system is no longer capable of supporting automation, such as in a construction zone, and then tell the driver to take control of the vehicle with enough time to react safely.
The main difference between Level 2 and Level 3 vehicles is that at Level 3, the driver is not required to constantly monitor the roads while driving.
How concerned would you be if you were driving or riding in a car equipped with this degree of self-driving technology?

Very concerned
Moderately concerned
Slightly concerned
Not at all concerned

Q5) Level 4 vehicles are projected to deliver fully automated self-driving capabilities. For the duration of the trip, the car will be designed to execute all safety-critical driving operations and monitor road conditions. The "driver" will input the destination or navigation, but will not be expected to take control at any point throughout the journey. Both occupied and unoccupied automobiles are included. The automated vehicle system is responsible for safe operation by design. How concerned would you be about riding in a vehicle with this level of self-driving technology?

Very concerned
Moderately concerned
Slightly
concerned

Not at all concerned

Q6) How likely do you think it is that the following benefits will occur when using?completely self-driving vehicles (Level 4)?Please select one response per row.

	Very likely	likely	unlikely	Somewhere unlikely
a. Fewer crashes	D	D	D	
b. Reduced severity of crashes	D	D	D	D
c. Improved emergency response to	D	D	D	D
d. Less traffic congestion	D	D	D	D
e. shorter travel time	D	D	D	D
f. Lower vehicle emissions	D	D	D	D
g. Better fuel economy	D	D	D	D
h. Lower insurance rates	D	D	D	D

Q7)How concerned are you about the following issues related to completely **self- driving vehicles (Level 4)?**

	Very Concerned	Moderately Concerned	Slightly Concerned	Not at all concerned
a. Safety consequences of equipment failure or system failure				
b. Legal liability for "drivers"/owners				
c. System security (from hackers)				
d. Vehicle security (from hackers)				
e. Data privacy (location and destination tracking)				
f. Interacting with non-self-driving vehicles				
g. Interacting with pedestrians and bicyclists				
h. Learning to use self-driving vehicles				
i. System performance in poor weather				

Q8) H o w concerned are you about the following possible scenarios with **completely self-driving vehicles (Level 4)?**
Please select one response per row.

	Very Concerned	Moderately Concerned	Slightly Concerned	Not at all concerned
a. Riding in a vehicle with no driver controls available (no steering wheel, no brake pedal, and no gas pedal/accelerator)				
b. Self-driving vehicles moving by themselves from one location to another while unoccupied				
c. Public transportation such as buses that are completely self-driving				
d. Taxis that are completely self-driving				

Q9) How interested would you be in having a **completely self-driving vehicle (Level 4)** as the vehicle you own or lease?

Very interested
Moderately interested
Slightly interested
Not at all interested

Q10) How much EXTRA would you be willing to pay to have **completely self-driving technology (Level 4)** on a vehicle you own or lease in the future? (Please enter 0 if you would not be willing to pay extra for this technology.)

Q11) Ifyou were to ride in a **completely self-driving vehicle (Level 4),** what do you think you would use the extra time doing instead of driving?Please select one response only.

Text or talk with friends/family
Read
Sleep
Watch movies/TV Play games
Work
Watch the road even thoughwould not be driving
Iwould not ride in a completely self-driving vehicle Other (please specify):______

Q12) Now we would like to know some basic background information about you. What is your gender?

Female
Male

Q13) What is your age?

18 to 24
25 to 29

30 to 34
35 to 39
40 to 44
45 to 49
50 to 54
55 to 59
60 to 64
65 to 69
70 or older

Q14) What is the highest level of education you have completed?
Less than bachelor degree
Bachelor degree
Graduate degree
Doctorate
Post Doctorate

Q15) What is your current level of employment? Please select only ONE option that best describes you.
Employed full-time
Employed part-time
Not currently employed
Retired
Full-time student
Part-time student

Q16) What kind of vehicle do you use most often? Please select one response only.
Passenger car (any type or size)
Minivan *I* van *I* MPV (multipurpose vehicle) Pickup truck
SUV (sport utility vehicle) Motorcycle *I* scooter
I do not drive
Other (please specify):______________

SAQ 1

(a) Define Autonomous Vehicle.
(b) Define the degrees at which a vehicle could be made autonomous.
(c) Differentiate between a Connected and an Autonomous vehicle.
(d) What will be the impacts of Autonomous vehicles on transport sector?
(e) Describe the challenges of Autonomous vehicles briefly.

10.12 SUMMARY

This unit deals with explaining the concept of autonomous vehicles, challenges of autonomous vehicles and various application of autonomous vehicles in transportation systems. It also discuss about the connected vehicles and its different applications. The difference between connected vehicles and autonomous vehicles also explained in detail. The unit also describes CAV's impact on transportation systems.

10.13 KEYWORDS

1. **Autonomous Vehicles:** AV's or self driving vehicles that move without the investment of human driver are reffered to as autonomous of self driving vehicles.
2. **CAV's: Connected and Autonomous Vehicle:** CAV's are nothing but the autonomous cars having additional facility, which is connected to the other cars, back office and other infrastructure with a wifi network.

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