Impact of autonomous vehicles on public transport sector

February 2017

Contents

Executive summary

With the emergence of autonomous vehicles, the government/public transit agencies need to take a leadership position in the market through disruptions such as the launch of self-driving public transport. They also need to prepare themselves for technology disruptions in the industry through innovations in revenue collection, infrastructure and data policies, with regulations being the overarching enablers

Key disruptor → Launch of self-driving shuttles and pods to supplement public transport, solutioning the first-mile/last-mile problem

Key enablers

- Innovative means of revenue collection, such as road-user pricing schemes, parking schemes and multimodal ticketing (with private vehicles supplementing public transport)
- Intelligent infrastructure development such as sensor technology in public infrastructure to facilitate public and commercial vehicles
- Collaboration with industry on R&D, test and validation facilities for being pioneers in capturing the AV market
- Managing data to enable improved transport planning, solutioning congestion as well as multimodal journey planning

Regulatory updates relating to autonomous vehicles

— **The US** has been active in introducing and updating its legislation on autonomous vehicles — nine states passed legislation and two states issued executive orders in 2016.

— **The European countries** also updated their laws on driverless cars — **Germany, Sweden, France, the Netherlands and Austria.**

— **The UK government** is encouraging OEMs, start-ups and technology companies to test their autonomous vehicles and has also invested in key projects such as GATEway, MOVE_UK and Atlas.

— **Other countries** such as Japan, Singapore and Australia showed an active participation in the autonomous technology space.

Key emerging trends in autonomous vehicles

1. Investments in R&D to develop autonomous technologies
2. OEMs partnering with mobility service providers
3. Government supports OEMs — invests in self-driving projects
4. Autonomous technologies challenges the Insurance industry
5. Non-traditional OEMs eye autonomous technology
6. Electric self-driving vehicles likely to run future cities

Emergence of autonomous vehicles (AVs)

- **Industry overview**
- **Autonomy timeline**
- **Advantages**
- **Disadvantages**
- **AV ecosystem**

Emergence of AVs
Industry overview

The challenges in the transport system of the future such as increased congestion and greater road fatalities, coupled with the various benefits of AVs, make self-driving vehicles the future of mobility and transport

Drivers for AV adoption

Safety — one of the key drivers for AV adoption

9th
leading cause of deaths globally: road accidents —
1.3 million deaths in 2012

90 percent
road accidents caused due to human error

Increased congestion — driving the market for AVs

2X
increase in the number of vehicles by 2035 — from 1.2 billion to 2 billion

33 percent
increase in world population by 2050 —
66 percent urban dwellers

Mitigating costs — increasing economic benefits

US$3 trillion
is the annual cost of road crashes

GBP51 billion
is the ~economic benefit of connected and autonomous cars by 2030

AV market opportunity

Price premium for SDVs — likely to reduce by 2035

US$7,000–10,000 is the price premium for the SDC electronics technology **in 2025**

US$3,000 is the price when no driver controls are available **in 2035**

Market growth of AVs

US$42 billion worth market size by 2025, according to Boston Consulting Group

54 million self-driving cars in use by 2035, according to a 2014 IHS automotive survey

25 percent market penetration of AVs by OEMs by 2035

Geographical adoption

North America: **29 percent** of sales of SDVs at Level 4 and Level 5 in 2035 (3.5 million vehicles)

China: **24 percent** of sales of SDVs at Level 4 and Level 5 in 2035 2.8 million vehicles)

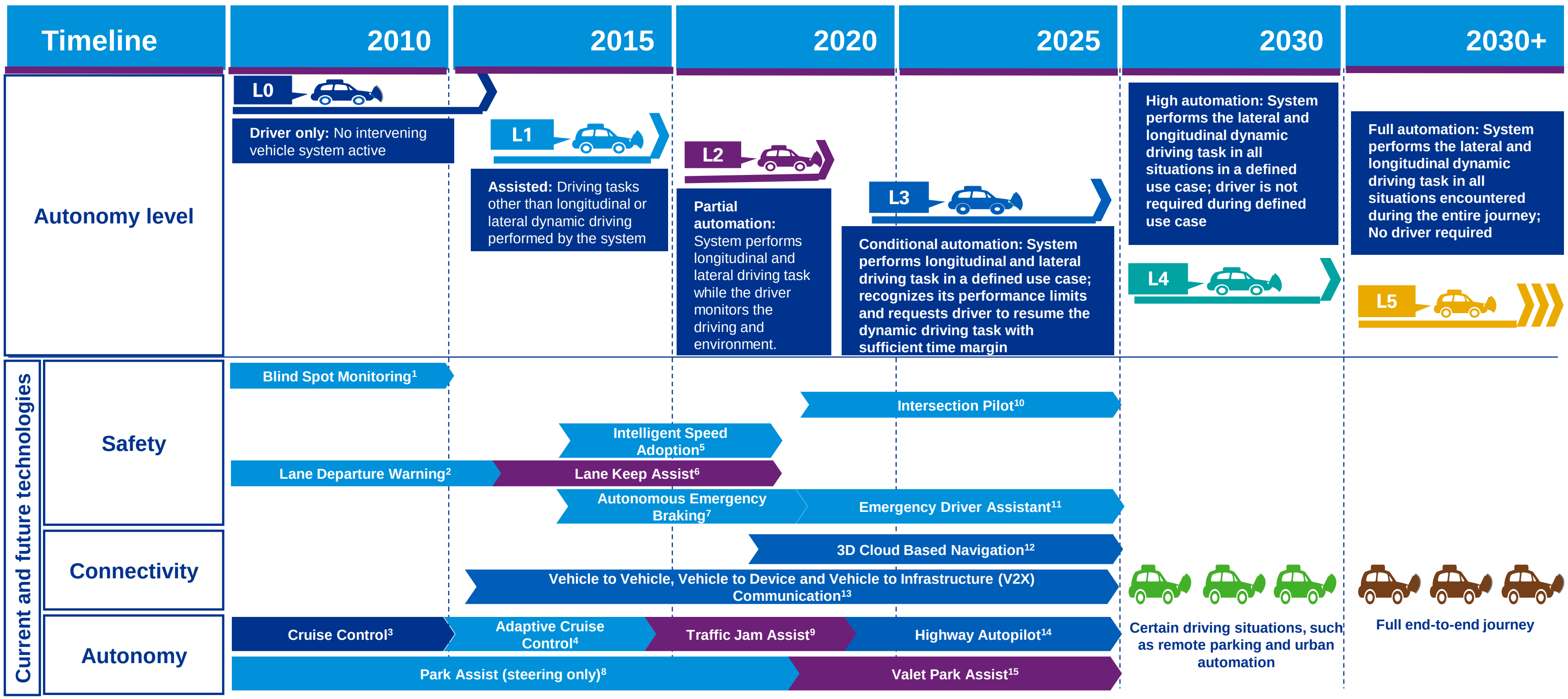
Western Europe: **20 percent** of sales of SDVs at Level 4 and Level 5 in 2035 2.4 million vehicles)

Source(s): The top 10 causes of death, May 2014, WHO website; 1.2 Billion Vehicles On World's Roads Now, 2 Billion By 2035: Report, 29 July 2014, Green car reports website; Human Error Accounts For 90 percent Of Road Accidents, April 2011, Alert Driving website; World population projected to reach 9.7 billion by 2050, 29 July 2015, UN website; World Urbanization Trends 2014, UN website; Self Driving Cars, June 2015, University of Berkley website; Are we ready for self-driving cars?, 24 November 2015, WEF Forum website; Turns Out the Hardware in Self-Driving Cars Is Pretty Cheap, 22 April 2015, Wired website; Will You Ever Be Able To Afford A Self-Driving Car?, 31 January 2014, Fast Company website; Self-Driving Cars Moving into the Industry's Driver's Seat, 2 January 2014, HIS website, accessed on 28 April 2016

Emergence of AVs

Autonomy timeline

In the past decade, technology has shaped the automotive industry for the adoption of AVs. With an increased integration of vehicle assist systems in premium vehicles, analysts project complete automation of vehicles by 2035



Note: Refer appendix for notes

Source(s): Connected and Autonomous Vehicles, March 2015, KPMG website, accessed on 28 April 2016

Emergence of AVs

Advantages

AVs are expected to significantly reduce travel cost, time and congestion, while increasing safety. Additionally, AVs could provide societal benefits such as mobility for aged/disabled individuals, create job opportunities and supplement public transport

— **Societal benefits/increased safety:** Since more than 90 percent of road accidents are caused by human error, AVs would play a major role in reducing that risk. In the US alone, adoption of AVs could eliminate over 30,000 road fatalities annually. Additionally, aged/disabled individuals, who have to rely on public transportation or assistance from others to travel, could benefit from AVs, which offer enhanced human-independent mobility.

— **Lower insurance and healthcare costs:** The US Department of Transportation estimates each human life to be worth US$9.2 million. Therefore, adoption of AVs would result in significant cost savings in different venues such as insurance and healthcare costs associated with accident recovery alone.

— **Reduction in fuel consumption and travel time:** AVs are expected to increase efficiency in terms of fuel consumption and time. In the US, AVs may cut travel time by up to 40 percent, recover up to 80 billion hours lost to commuting and congestion, and reduce fuel consumption by up to 40 percent. These cost/time-saving benefits are expected to be worth about US$1.3 trillion in the country. Other potential cost-saving domains include reduced manpower — drivers and law enforcers.

— **Reduced congestion:** Driverless systems are expected to expand roadway capacity and reduce congestion by using GPS technologies to efficiently route vehicles through traffic jams. Specifically, when congestion occurs, computerized systems will divert a certain percentage of vehicles off the highways and onto surface streets. Vehicle platooning can also improve traffic conditions and congestions. AV systems will likely adjust routing patterns for trucks and other heavy vehicles to avoid vulnerable infrastructure, thereby cutting costs and preserving the lifespan of critical roadways and bridges.

— **Better city planning due to lesser need for parking:** AVs remove commuters' demands for street and lot parking. Some cities devote a third of their land to parking and AVs could free up significant real estate for other uses, from parks to residences to office space. For personal AVs, commuters may be dropped at a location and the vehicle would park itself away from the destination, where space is available. Cutting back on the land used for parking might even reduce real estate costs.

— **Supplementing public transport:** Larger cities have the problem of providing adequate public transportation. Many lack the appropriate infrastructure to support the needs of their residents, a void that could partially be filled by self-driving cars. AVs could potentially supplement public transport, solving the first-mile-last-mile problem.

— **Job creation:** Analysts predict that the increase in the AVs would result in skilled jobs such as AV design and development, and jobs in infrastructure.

Source(s): Autonomous Vehicle Technology: A guide for policy makers, Rand website; Realising the benefits of autonomous vehicles in Australia, October 2014, Accenture website; Accident rates of self-driving cars: A critique of the Sivak/Schoettle study, 17 January 2015, Driverless future website; The pros and cons of a driverless future, 29 January 2015, Gizmag website; Top 20 Pros and Cons Associated With Self-Driving Cars, Auto-insurance website; The Massive Economic Benefits Of Self-Driving Cars, 8 November 2014, Forbes website, accessed on 28 April 2016

Emergence of AVs
Disadvantages

While the potential benefits of AVs surpass the disadvantages, there are various barriers to AV adoption such as public safety and privacy concerns possible equipment failures and cyber security threat is another major area of concern

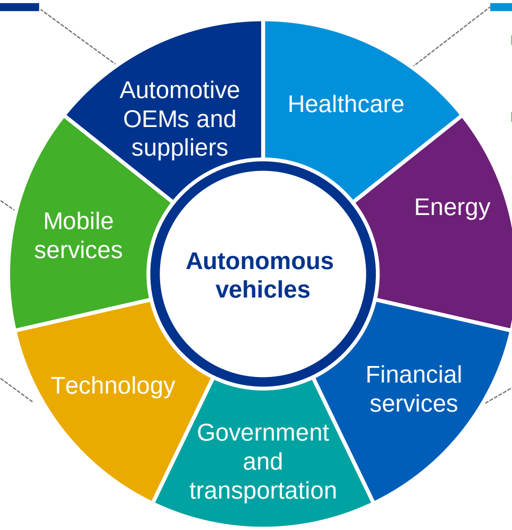
- **Technicalities and driver education:** According to Teletrac, a software as a service company, just having the ability to operate a self-driving car would require an education on the driver's part. While the computer takes over once the vehicle is operational, the driver would still be required to maintain some knowledge about how to operate it safely.
- **High vehicle costs:** The cost of implementing the new technology could be one of the factors keeping it out of reach for many. Currently, the engineering, power and computer requirements, software and sensors add up to more than US$100,000.
- **Security and technical risks:** According to the Guardian, the very security behind self-driving cars could be a major obstacle, especially because of the possibility of vehicles being hacked. There may be system failures due to driving conditions (heavy rain can damage laser sensors) or glitches in the equipment.
- **Impact on public transport:** Cost-efficient self-driving cars could change commuter preferences away from conventional public transport, which could affect government revenues. Reduced public transport would impact the transport convenience for the masses.
- **Reduced employment and business activity:** Jobs for drivers could decline and there may be less demand for vehicle repairs due to reduced crash rates.
- **Impact on gasoline industry:** With companies such as Tesla launching affordable electric vehicles such as the Model 3, electric vehicles are expected to replace internal combustion engines in the future. The gasoline industry could suffer because the upcoming AVs are likely to be electric in nature.
- **Potential litigation:** Equipment failure is high on the list of barriers identified. The cost to equip the vehicle fleet with adaptive cruise control and roadways with necessary sensors was seen as enormously expensive and would likely take decades.
- **Lack of clarity of partially implementation of AVs:** In a mixed population of driverless and non-autonomous cars — which certainly would be the case for most cities during any transition — the potential benefits of automation are less clear. For one thing, they won't necessarily cut down on traffic or help more people get from point A to point B.
- The **environmental implications** are also unclear. Driverless cars would still produce emissions, either through the tailpipe or through the power plant that charges their batteries, until local utilities begin to rely fully on renewable energy sources.

Source(s): Autonomous Vehicle Technology: A guide for policy makers, Rand website; Realising the benefits of autonomous vehicles in Australia, October 2014, Accenture website; Accident rates of self-driving cars: A critique of the Sivak/Schoettle study, 17 January 2015, Driverless future website; The pros and cons of a driverless future, 29 January 2015, Gizmag website; Top 20 Pros and Cons Associated With Self-Driving Cars, Auto-insurance website; The Massive Economic Benefits Of Self-Driving Cars, 8 November 2014, Forbes website, accessed on 28 April 2016

Emergence of AVs

AV Ecosystem

Autonomous vehicles are expected to have an impact across sectors. AVs, being an upcoming technology, brings in massive opportunities and has a potential to create major shifts within sectors



Automotive OEMs and suppliers

- Increased demand for sensors and equipment would increase revenues.
- Additional experience-based features such as infotainment systems and interactive gadgets could see a higher demand.

Mobile services

- Increased demand for connectivity and reliability could result in additional bandwidth requirements.

Technology

- AVs would require a highly accurate and efficient mapping technology.
- User data and analytics could be used to enhance the entire AV experience.
- Greater time availability could increase multimedia and information consumption.
- It could lead to increased advertising and subscription revenue opportunities.

Healthcare

- Fewer auto-related accidents and fatalities could reduce the costs for emergency medical services.
- In case of accidents, vehicles would be able to raise an alarm.

Energy

- Increased mobility and rise in the number of individuals traveling could lead to greater gasoline usage.
- Increased efficiency could reduce demand for gasoline.
- Transition to alternate fuels could adversely impact the petroleum industry.

Financial services

- Growth in fleet financing presents opportunities for financial firms.
- Shift away from personal vehicles could lead to decrease in auto loans and leasing.
- There are potential opportunities for experience-based insurance products.
- Reduction in accidents could lead to a decrease in insurance sales.

Government and transportation

- Reduced number of vehicles could decrease the current revenues (e.g., fuel tax, licensing fee, road fines, etc.)
- New taxation models, such as consumption-based dynamic taxation, could offset tax revenue decline.
- Potential change in use of public transportation — while some analysts speculate that rise in AVs would reduce public transport usage, authorities could supplement public transport through AV adoption, solving the first-mile/last-mile problem.
- Requirement of smart cities could result in greater government spending in improving infrastructure.
- Real-time data could be analyzed to improve traffic conditions, infrastructure and public experience.
- To facilitate AV adoption, authorities need to review and implement new regulations and policies as well as collaborate with industry players.

Effect/impact categorization:

- Positive
- Neutral
- Negative

Source(s): Ten ways autonomous driving could redefine the automotive world, June 2015, McKinsey website; Realising the benefits of autonomous vehicles in Australia, October 2014, Accenture website; Connected and Autonomous Vehicles, March 2015, KPMG website, accessed on 28 April 2016

Role of government/public transit agencies

- **Overview**
- **Need for changing regulations and policies**

Role of government/public transit agencies

Overview

The government agencies need to act swiftly to implement new programs and policies instead of being a hindrance to ensure the smooth adoption of AVs

— **There is growing need for implementation of new regulations and policies to facilitate AV adoption**
  - The government needs to develop a regulatory framework that addresses issues around privacy and cybersecurity, safety of public by developing standards and architecture around new technologies, ensuring new standards for vehicle and driver licensing as well as for emerging business models such as ride sharing.

— **Government need to further increase its collaboration with industry players in various areas.**
  - Incentivizing the adoption of alternative-fuel and electric vehicles by freight companies
  - Supporting services such as bike sharing, car sharing and ride sourcing to supplement public transport
  - Supporting research into automation technologies

— **To be prepared for the full adoption of AVs, the government needs to improve its future transportation planning.**
  - Integrating land use and transportation planning to support sustainable and efficient development patterns
  - Incorporating freight planning into transportation planning and regional economic development decisions
  - Supporting design and planning choices that support alternatives to vehicle travel.

— **The government also needs to be prepared for facing a potential decline in its revenues.**
  - Using congestion pricing to manage demand
  - Lifting the federal restriction on the tolling of interstate highways

— **Increased investments and funding is required in R&D of AVs as well as in infrastructure to enable it to be suitable for AVs.**
  - Supporting investments in transportation technologies and operational strategies that can reduce congestion
  - Increasing investments in roadway capacity to address congestion in metropolitan areas
  - Restructuring federal surface transportation programs to enable targeted, demand-driven, mode-neutral investments
  - Establishing strategic freight funding programs that target freight bottlenecks
  - Encouraging private investments in freight and passenger infrastructure

Source(s): Autonomous Vehicles, 8 April 2016, National Conference of State Legislatures website; The US Department of Transportation is trying to fix self-driving rules before they break, 14 January 2016, The Verge website; California wants to keep autonomous cars from being autonomous, 16 December 2016, The Verge website; Automated Driving: Legislative and Regulatory Action, Cyber Law website, accessed on 26 April 2016

Role of government/public transit agencies

Need for changing regulations and policies

The AV industry is evolving rapidly, whereas the policy and institutional aspect is moving at a glacial pace. The governments need to ensure that regulation keeps pace with technology development to avoid undesired delays in AV adoption

Current international treaties

- International traffic regulations (for example, the 1968 Vienna convention) must be adjusted to allow operation of AVs on public roads. Such operation is at present illegal in many jurisdictions.
  - The 1968 Vienna Convention on Road Traffic, which has been ratified by 73 countries including all EU member states (excluding the UK and Spain; the US is also not a signatory), was amended on 23 March 2016 to incorporate the transfer of automated driving technologies to the vehicle, provided that these technologies comply with the UN vehicle regulations or can be overridden or switched off by the driver. However, a second major regulatory aspect around the introduction of technical provisions of self-steering systems currently remains under discussion.

Certifications

- Vehicle and technology certification standards must evolve to allow AVs' market introduction. Current standards such as the IEC61508 (Functional Safety of Electrical/Electronic/Programmable Electronic Safety-related Systems) and the ISO 26262 (Road vehicles: Functional safety) may need to be updated so as to incorporate the potential safety issues of AVs. New international certifications and standards may need to be formulated to homogenize AV requirements around the world.

Burden of liability

- Liability for accidents is a controversial topic across nations experimenting with AV technology with confusion around whether AV owners, manufacturers (vehicle or sensor) or software companies should be held liable in case of an accident. Industry opinion tilts towards manufacturers or OEMs taking ownership of liability in case of accidents, such as the announcement by Volvo owning the burden of liability.
- However, currently no regulations around liability ownership have been formalized so far.

Source(s): Why You Shouldn't Worry About Liability for Self-Driving Car Accidents, 12 October 2015, IEEE Spectrum website; Certification for autonomous vehicles, 8 April 2015, University of North Carolina; UNECE paves the way for automated driving by updating UN international convention, 23 March 2016, UNECE website; Autonomous Vehicles, 8 April 2016, National Conference of State Legislatures website; The US Department of Transportation is trying to fix self-driving rules before they break, 14 January 2016, The Verge website; California wants to keep autonomous cars from being autonomous, 16 December 2016, The Verge website; Automated Driving: Legislative and Regulatory Action, Cyber Law website, accessed on 26 April 2016

Geographic adoption of AVs

- The US
- Europe
- The UK
- Others

Geographic adoption of AVs — (1/6)

The US

In the next 30 years, changes in freight demand, shipping, manufacturing, logistics, technology and energy production are poised to transform the economics of transportation yet again

Trends driving AV adoption in the US

Population growth and demographic shifts

70 million
Will be added to the US population between 2015–45

77 percent
Increase in population over 65 years by 2045, with one-third with a disability

Financial costs from accidents and congestion

US$33 billion
In work lost costs resulting from US$18 billion in medical costs from crash injuries

US$121 billion
Is a annual financial cost of congestion, with over 40 hours spent stuck in traffic

Shifts in megacities and income disparity

11 megacities
Will represent over 75 percent of the population and employment

10 percent
Of the population earns one-third of the national income, with transport as the second-largest expense for US households

Increasing exports and US energy boom

US$2.3 trillion
Recorded in US exports in 2013

50 percent
Increase in crude oil production since 2008

45 percent
Increase in freight volume by 2040 to 29 billion tons

125 percent
Increase in value of freight by 2040 to US$39 trillion

43 percent
Increase in freight by trucks (primary mode) by 2040

US$27 billion
Wasted on time and fuel annually due to truck congestion

30,000 miles
Of highways to be clogged on a daily basis by 2040

Source(s): Beyond Traffic: US DOT's 30 Year Framework for the Future, 24 November 2015, Transportation.gov website, accessed on 26 April 2016

Geographic adoption of AVs — (2/6)

The US

In the next 30 years, changes in freight demand, shipping, manufacturing, logistics, technology and energy production are poised to transform the economics of transportation yet again

Current state of infrastructure in the US

65 percent
Of US roads in less than good condition

25 percent
Of US bridges need significant repair

50 percent
Of locks and chambers are over 50 years old

D+
Overall infrastructure grade

8th (2008)
World standing on quality of roads

16th (2014)
World standing on quality of roads

Investments required to improve transportation

US$83.1 billion
Current annual spending at all levels of government

US$120 billion
Investments required between 2015–20 on just highways and bridges

US$17.1 billion
Current annual capital spending on public transport

US$43 billion
Investments needed for public transportation

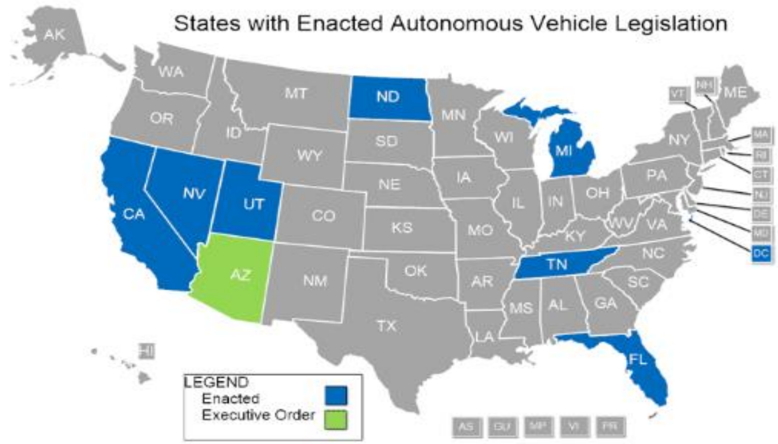
Source(s): Beyond Traffic: US DOT's 30 Year Framework for the Future, 24 November 2015, Transportation.gov website, accessed on 26 April 2016

Geographic adoption of AVs – (3/6)

The US

State governments in the US are speeding up the roll-out of regulations to address the potential impacts of self-driving vehicles (SDVs), however, there is a need for a unified national legislation to enable SDVs to operate across state boundaries

Bill	Title	Introduced	Last Action	Status
HR 3879	Autonomous Vehicle Privacy Protection Act of 2015	2 November 2015	3 November 2015	Committee
HR 22	Fixing America's Surface Transportation (FAST) Act	6 January 2015	4 December 2015	Enacted



Policies shaping the adoption of AVs in the US

- In **January 2016**, the US Transportation Secretary, Anthony Foxx, announced a **new policy** that updated the National Highway Traffic Safety Administration's (NHTSA) 2013 preliminary policy statement on AVs.
- The policy was designed to ease concerns that overly restrictive regulations would inhibit automakers and suppliers from effectively testing and producing self-driving cars.
- Within six months, NHTSA is expected to propose guidance to industry on establishing principles of safe operation for fully autonomous vehicles.
- **NHTSA also committed nearly US$4 billion over the next 10 years** to accelerate the development and adoption of safe vehicle automation as well as introduce unified nationwide rules regarding AVs.
- **Sixteen states introduced legislation related to AVs in 2015**, up from 12 in 2014, nine states and DC in 2013 and six states in 2012.
  - Nevada was the first state to authorize the operation of AVs in 2011.
  - Currently, **California, Florida, Michigan, North Dakota and Tennessee and Washington DC** have also passed legislation related to AVs.
  - Arizona's governor issued an executive order related to AVs, while in June 2015, Virginia's governor announced a partnership allowing R&D for AVs to take place in the state through 'Virginia Automated Corridors'.
  - In April 2016, Florida state legislation allowed the driving of AVs on its roads and begun preparation for a truck platooning test.

Source(s): Autonomous Vehicles, 8 April 2016, National Conference of State Legislatures website; The US Department of Transportation is trying to fix self-driving rules before they break, 14 January 2016, The Verge website; California wants to keep autonomous cars from being autonomous, 16 December 2016, The Verge website; Automated Driving: Legislative and Regulatory Action, Cyber Law website; Beyond Traffic: US DOT's 30 Year Framework for the Future, 24 November 2015, Transportation.gov website, accessed on 26 April 2016

Geographic adoption of AVs – (4/6)

The US

The US government needs to develop a regulatory framework that encourages innovation, rather than hinders it and places priority on ensuring the safety of the overall transportation system

Concerns around disparity in legislations across states

— With each state implementing its own research and legislation, there is growing concern in the industry about the disparity across the states.

— In December 2015, **California's Department of Motor Vehicles issued draft regulations that raised concerns for Google**'s steering wheel-less autonomous car, as well as any use of AVs without a human inside.

- California required vehicles be tested and certified by third-party testing bodies that don't currently exist and that AV operators should hold a special "operating certificate" in addition to a traditional driver's license.
- Google criticized the proposal stating that California's restrictive regulations put a ceiling on the potential for fully self-driving cars.
- On the other hand, cars without any humans inside are legal on Texas roads. Hence, companies are shifting business away from California due to friendlier and cheaper business environment.

Investments required to improve transportation

— **Privacy and cybersecurity** is another area that needs to be adequately addressed in the consideration and adoption of new technologies.

— **Standards and architecture** needs to be developed for the application of **connected vehicle technologies** to derive the full benefits of V2V technologies.

- This presents significant technical and policy challenges to public agencies and private partners and will require substantial investments to install and maintain these roadside equipment.
- **Government needs to collaborate more closely with automakers** to develop and deploy V2V systems, however, technical, legal and regulatory challenges remain.

— Federal and state agencies need to address new challenges related to **human safety and risks to the natural environment,** resulting from the transportation of natural gas and petroleum. **Policies** need to be implemented for **shifting freight demand** to safer, more environmentally sustainable modes.

— The recent **emergence of ride sourcing businesses** demonstrates a key challenge for governments as it enables the use of the Internet and mobile apps to allow individuals to monetize underutilized space, assets and skills.

- Ride sourcing services such as Lyft and Uber can also help to **supplement transit service in urban areas** by providing direct service for short trips and service during transit system off-hours.
- The **legal and regulatory landscape needs to adapt** quickly to the new business models.

Source(s): Autonomous Vehicles, 8 April 2016, National Conference of State Legislatures website; The US Department of Transportation is trying to fix self-driving rules before they break, 14 January 2016, The Verge website; California wants to keep autonomous cars from being autonomous, 16 December 2016, The Verge website; Automated Driving: Legislative and Regulatory Action, Cyber Law website; Beyond Traffic: US DOT's 30 Year Framework for the Future, 24 November 2015, Transportation.gov website, accessed on 26 April 2016

Geographic adoption of AVs — (5/6)

The US

In 2016, about 20 states-introduced legislations — nine states passed legislations and two states issued executive orders relating to autonomous vehicles

Update[1]

— In December 2016, US DOT (Department of Transport) proposed a regulation that would mandate vehicle-to-vehicle (V2V) communication technology on light-duty vehicles, to avoid car accidents. The department's Federal Highway Administration also seeks to introduce guidance for Vehicle-to-Infrastructure (V2I) communications that will help reduce congestion and improve mobility and safety.

Florida — April 2016

— Permits the operation of autonomous vehicles on public roads by individuals with a valid driver's license; also eliminates other provisions related to vehicle operation for testing purposes

- Eliminates the requirement of a driver to be present in the vehicle
- Requires autonomous vehicles to meet the applicable federal safety standards and regulations

— Defines autonomous technology and driver-assistive truck platooning technology; identifies the need for further research on the use and safe operation of driver-assistive truck platooning technology; expected to permit any pilot project

Louisiana — June 2016:

— Defines 'autonomous technology' according to the Highway Regulatory Act

Michigan — December 2016:

— Permits operations of autonomous vehicles under certain conditions even without a driver; specifies requirements such as maintaining a minimum distance of 500 feet in commercial vehicles does not apply to vehicles in a platoon

- Establish mobility research centers where automated technology can be tested
- Provide exemptions for mechanics and repair shops from the liability of fixing automated vehicles

Note: [1]The regulations mentioned above have not been reworded and relevant provisions have been updated as specified in the NCSL (National Conference of State Legislatures) document
Source(s): Autonomous — Self Driving Legislation, 12 December 2016, National Conference of State Legislatures; U.S. DOT advances deployment of Connected Vehicle Technology to prevent hundreds of thousands of crashes, 13 December 2016, NHTSA (National Highway Traffic Safety Administration) website, accessed on 06 February 2017

Geographic adoption of AVs — (6/6)

The US

In 2016, about 20 states introduced legislations — nine states passed legislations and two states issued executive orders relating to autonomous vehicles

Update[1]

Tennessee

— **April 2016:** Redefined 'autonomous technology' for preemption purposes, along with defining 'driving mode' and 'dynamic driving task'

— **March 2016:** Permitted motor vehicles to be operated or equipped with an integrated electronic display visible to the operator while the motor vehicle is engaged in autonomous technology

Utah — March 2016:

— Established the need for further research on autonomous vehicles, including evaluating NHTSA and AAMVA standards and its best practices; evaluating appropriate safety features, regulatory strategies and developing recommendations

Virginia — April 2016

— Permitted viewing of a visual display while the vehicle is being operated autonomously

Programs and initiatives

— In October 2016, Charlie Baker, Governor, Massachusetts, signed an executive order — **'To Promote the Testing and Deployment of Highly Automated Driving Technologies.'** As an initial step, an AV working group was created. It will closely work with experts on vehicle safety and automation, members of the legislature and support agreements entered between the AVs and Massachusetts Department of Transportation (MassDOT).

— In September 2016, California authorized the Contra Costa Transportation Authority to conduct a pilot project for testing autonomous vehicles that are not equipped with a steering wheel, a brake pedal, an accelerator or an operator inside the vehicle. The testing is to be conducted only at specified locations and operated at specified speeds limits.

— In January 2016, Anthony Foxx, Transportation Secretary, US, announced a new policy — an update on the National Highway Traffic Safety Administration's (NHTSA) 2013 preliminary policy statement on autonomous vehicles. With the new policy, NHTSA **announced a commitment of about US$4 billion over the next 10 years**, to develop and adopt safe autonomous vehicles. In the next six months, the NHTSA is also expected to propose guidelines on establishing fully autonomous vehicles.

Note: [1]The regulations mentioned above have not been reworded and relevant provisions have been updated as specified in the NCSL (National Conference of State Legislatures) document
Source(s): Autonomous — Self Driving Legislation, 12 December 2016, National Conference of State Legislatures; Governor Baker Signs Executive Order to Promote the Testing and Deployment of Automated Vehicles, 20 October 2016, 2017 Commonwealth of Massachusetts website, accessed on 06 February 2017

Geographic adoption of AVs — (1/4)

Europe

Countries such as France, Italy and the UK are planning to operate transport systems for driverless cars and Germany, the Netherlands, France, Sweden and Austria have been at the forefront of AV testing and adoption

Initiatives

Germany:

- The BMVI (Federal Ministry of Transport and Digital Infrastructure) recently announced the establishment of a test field for connected and automated driving on the A9 motor way in Bavaria. In June 2015, the research program 'New Vehicle and System Technologies' was published by the German Federal Ministry of Economic affairs and Energy.
- This program sets a framework for funding in the areas of automated driving and innovative vehicles. The Federal Ministry for Education and Research recently launched an R&D funding program related to the links of electric mobility and automated driving.
- **Update:**
  - In December 2016, an amendment was made in the Vienna Convention on Road Traffic relating to autonomous vehicles that was later applicable even in Germany. The amendment will allow the transfer of driving tasks to the vehicle if the technologies used in the vehicles are in line with the regulations specified by the United Nations.
  - In October 2016, Germany updated its traffic rules to include autonomous cars. According to the primary draft legislation, cars will require a steering wheel and a driver on the driving system ready to intervene when required.

Sweden:

- The joint initiative 'Drive Me — Self driving cars for sustainable mobility', endorsed by the Swedish Government, was launched with the aim to have 100 self-driving Volvo cars on public roads in Gothenburg in 2017.
- Beside the Volvo Car Group, the Swedish Transport Administration, the Swedish Transport Agency, Lindholmen Science Park and the City of Gothenburg are involved in this pilot project..
- **Update:**
  - In April 2016, a proposal for changes in the legislation of driverless cars was presented to the Swedish Minister of Infrastructure — likely to be passed into a law by May 2017. The proposal suggests that the Swedish Transport Agency should be responsible for authorizing permits to carry out trails of autonomous cars.
  - Volvo is expected to start its 'Drive-Me' initiative, a public autonomous driving experiment in Gothenburg, in 2017. The project will involve Volvo XC90 SUV self-driving vehicle, first in the series of autonomous vehicles being driven by real families on public roads.

Source(s): Connected & Autonomous Vehicles, October 2014, Atkins Global website; Driverless cars take to the road, 21 January 2013, Cordis website; UK to allow driverless cars on public roads in January, 30 July 2014, BBC website; accessed on 29 April 2016; Sweden proposes a progressive legislation , 11 April 2016, Drive Sweden website; Volvo Begins Autonomous Driving Project in Sweden, 09 September 2016, Electronics 360 website; Germany: Road Regulations Amended to Allow Autonomous Vehicles, 15 December 2016, Library of Congress website; Germany paves the way for autonomous vehicles, 30 October 2016, The Financial Express website, accessed on 07 February 2017

Geographic adoption of AVs — (2/4)

Europe

Countries such as France, Italy and the UK are planning to operate transport systems for driverless cars and Germany, the Netherlands, France, Sweden and Austria have been at the forefront of AV testing and adoption

Initiatives

France:

— In this framework, the 'Autonomous Vehicle plan', led by Carlos Ghosn, CEO of Renault/Nissan, is aimed at making the French Automotive and Road Transport industry one of the pioneers in designing mainstream AVs.

— **Update:**

- In August 2016, the French Government permitted autonomous car manufacturers to test cars on public roads. The new amendment is likely to provide an opportunity for non-French manufacturers to test their cars on French roads.

Netherlands:

— The Dutch government has created new innovative and adaptive legislations to make large-scale testing possible for self-driving vehicles on Dutch public roads. Field Operational Tests (FOTs) with automated driving is allowed on all public roads in the Netherlands.

— With the emergence of cooperative systems and participation in the European projects CVIS and SAFESPOT, the first steps were taken toward incorporating C-ITS in a national policy. The Netherlands started the Dutch Automated Vehicle Initiative (DAVI), a public private partnership initiated by TU Delft, Connekt30 and TNO. The role of DAVI is to investigate and demonstrate automated driving on public roads.

— In April 2016, the European Truck Platooning Challenge, organized by the Dutch Ministry of Infrastructure and the Environment, was completed successfully. It involved trucks from six European manufacturers — DAF Trucks, Daimler, IVECO, MAN, Scania and Volvo.

— **Update:**

- **The Amsterdam Declaration**, a new technology agreement, was signed by transport ministers of 28 EU member states at the informal meeting of the Transport Council in April 2016. The agreement highlights the necessary steps to be undertaken for the development of self-driving technology in the EU.

Source(s): Connected & Autonomous Vehicles, October 2014, Atkins Global website; Valeo Autonomous iAV Car Driving System CES, 5 January 2015, YouTube website; Automated Driving Roadmap, 21 July 2015, ERTRAC website, accessed on 29 April 2016; EU ministers to try out self-driving cars in Amsterdam, 14 April 2016, The Netherlands EU Presidency 2016 website; Press Release: AVL Testing Autonomous Vehicle, 29 December 2016, AVL company website; France gives green light on autonomous car trials, 06 August 2016, Read Write website; France gives green light on autonomous car trials, 06 August 2016, Read Write website, accessed on 07 February 2017

Geographic adoption of AVs — (3/4)

Europe

Countries such as France, Italy and the UK are planning to operate transport systems for driverless cars and Germany, the Netherlands, France, Sweden and Austria have been at the forefront of AV testing and adoption

Initiatives

Austria:

— Austria is a committed driver of ITS and C-ITS, preparing the path for connected and automated driving through projects such as TESTFELD TELEMATIK and ECo-AT (European Corridor — Austrian Testbed for Cooperative Systems) and testing interoperability with neighboring countries and regions. The country has been emphasizing the importance of a properly equipped infrastructure for more than eight years, with COOPERS (2006–2010 FP 7) as the cornerstone for fail-proof V2I communication.

— **Update:**

- In December 2016, AVL List GmbH, a company involved in development, simulation and testing of technology in powertrains and passenger cars completed the trial of its autonomous vehicle on the Pyhrnautobahn highway in Styria, Austria. The drive was officially authorized by the Federal Ministry for Transport, Innovation and Technology.

Source(s): Automated Driving Roadmap, 21 July 2015, ERTRAC website, accessed on 29 April 2016; Press Release: AVL Testing Autonomous Vehicle, 29 December 2016, AVL company website, accessed on 07 February 2017

Geographic adoption of AVs – (4/4)

Europe

Europe has been at the forefront of formulating and implementing regulations and policies related to AVs. However, it needs to further strengthen its current efforts on standardizing its policies

AV regulatory landscape in Europe

Standardization of technical certifications across the EU

- Under the European vehicle *type approval system*, manufacturers can obtain approval for a new vehicle type in one EU Member State if it meets the EU technical requirements. The manufacturer can then *market it EU-wide with no need for further approval tests or checks in other Member States*. The approval is granted by a national authority in charge of type-approval. The completion of the type-approval examination results in issuance of a Certificate of Conformity, which is a statement by the manufacturer that the vehicle conforms to the relevant legal requirements as stipulated by EU legislation.

Collaborations fostering data protection

- In July 2014, the *Alliance of Automobile Manufacturers* formed a voluntary information sharing and analysis center (Auto ISAC) for the industry, to target the threat of hackers. The *European Automobile Manufacturers Association* (ACEA) has agreed on principles of data protection in relation to connected vehicles and services.

Need for regulations on liability issues

- In the EU product liability is strongly harmonized by the Directive on liability for defective products (Council Directive 85/374/EEC).
- There is currently *no framework in place harmonizing the rules on liability for damages caused by accidents* in which motor vehicles are involved – the regulation of liability of the holder of a vehicle or of the driver differ between the Member States. The new possible causes created by automation might interfere with the objective of liability regimes to apportion risks, therefore an adaptation of liability law to the new technologies and a European harmonization of the regimes concerning the liability of owners and/or drivers of automated vehicles is necessary.

Initiatives enabling standardization and interoperability of technical standards

- *iMobility Support* is a 3-year support action that fosters the deployment of intelligent mobility in Europe by organizing the iMobility Forum activities, including stakeholder networking, deployment support, awareness raising and dissemination of results of ICT for smart, safe and clean mobility.
- *C-ITS* uses technologies that allow road vehicles to communicate with other vehicles, with traffic signals and roadside infrastructure as well as with other road users. The systems are also known as vehicle-to-vehicle communications, or vehicle-to-infrastructure communications. The C-ITS Platform and/or its Sub-Groups will integrate inputs from relevant on-going initiatives on C-ITS in Europe supported at European, national, regional or local levels, in order to bring in the knowledge and experience into the development of the Deployment strategy in the EU.

Source(s): About iMobility Support, iMobility support website; C-ITS Platform, January 2016, EC Europa website; Automated vehicles in the EU, January 2016, European Parliament website, accessed on 29 April 2016

Geographic adoption of AVs – (1/3)

The UK

The Government is developing a light touch/non-regulatory approach to the testing and development of these technologies – as set out in this review

Programs and initiatives

Programs:

— In February 2016, the UK government awarded **GBP20 million to eight new projects** to develop next generation autonomous vehicles. The projects are to be funded from the government's **GBP100 million Intelligent Mobility Fund**.

- The funding is expected to help strengthen the UK as a global center for the fast-growing intelligent mobility market, estimated to be valued at GBP900 billion per year globally by 2025.

Initiatives:

— In March 2016, the government announced that driverless cars would be tested on UK motorways from 2017.

- It is building a **GBP15 million 'connected corridor' between London and Dover** to enable vehicles to communicate with infrastructure and other vehicles as part of the trials.
- The government announced it would also launch a consultation to remove regulatory barriers within this parliament to allow driverless cars on England's major roads. The trials would be funded from the government's Intelligent Mobility Fund.

Source(s): Driverless cars will be tested on UK motorways in 2017, 16 March 2016, Wired website; Driverless cars technology receives £20 million boost, 1 February 2016, UK government website, accessed on 27 April 2016

Geographic adoption of AVs — (2/3)

The UK

The government is encouraging start-ups and technology companies to develop and test their autonomous vehicles — a market likely to be worth US$1.1 trillion by 2025. Key driverless projects in the UK include GATEway, MOVE_UK and Atlas

Programs and initiatives

Update

— As part of its GATEway initiative, in September 2016, the first wind tunnel test was carried out in the UK. The test was conducted by Westfield Sportscars Ltd. and supported by the Niche Vehicle Network — seeking to improve the aero-dynamic efficiency and confirm safety standards in automated shuttles.

- The GATEway project, led by the UK TRL (Transport Research Laboratory), is likely to see trails of fully electric and fully automated shuttles in Greenwich, in 2017.

— In August 2016, the UK Government launched a competition contributing an additional GBP30 million from the Intelligent Mobility Fund (in February 2016, GBP 20 million was contributed) toward research and development of connected and autonomous vehicle technologies. An additional GBP19 million fund is expected to be invested on driverless car projects in Greenwich, Bristol and a joint project in Milton Keynes and Coventry.

— In April 2016, Highways England announced its investment of GBP150 million during 2016–21, on developing new technologies, including trails of driverless technology on motorways. It also laid out its Innovation Strategy, which specifies an array of plans to keep in pace with the developing technologies. The strategy also includes trail run of radar technology on motorways and in tunnels to enhance the detection of breakdowns.

— In March 2016, the Atlas initiative, an association of UK businesses, was designed to study critical data relating to the operation of driverless cars. The association consists of key businesses such as Ordnance Survey, Satellite Applications Catapult, the Transport Research Laboratory (TRL), Sony Europe, two UK specialist SMEs in autonomous and navigation systems — GOBOTIX and OxTS — and the Royal Borough of Greenwich.

Source(s): Driverless vehicles are headed to the UK, 10 October 2016, The Business Insider website; Driverless car news, 14 December 2016, Tech world website; Trials of wirelessly connected vehicles , 05 April 2016, UK Government website; Innovation, Technology and Research Strategy , 05 April 2016, UK Government website; New measures to help Britain lead the way, 11 July 2016, UK Government website; UK in the driving seat of driverless cars, 01 March 2016, Electronic Specifier website; World's first autonomous vehicle wind tunnel test carried out in UK, 01 September 2016, Gateway website, accessed on 06 February 2017

Geographic adoption of AVs – (3/3)

The UK

The Government is developing a light touch/non-regulatory approach to the testing and development of these technologies – as set out in this review

Legal and regulatory framework needs to be reviewed and amended in a number of areas:

— **Changes are expected to be made to the European standards (known as type approval) with which mass production vehicles are required to comply prior to sale**, as well as to ISO standards such as that on symbols and driver warnings. Developing these standards is likely to take several years.

— The Government published a **Code of Practice** in 2015 for those wishing to test driverless vehicles on UK roads, in collaboration with key stakeholders.

- This would facilitate long distance and large area public road testing as the Code of Practice approach can be applied across the UK, unlike many other countries which offer only selected roads or small, restricted geographical areas.

— The Government, working with the devolved administrations, would review and amend domestic regulations by summer 2017 to accommodate driverless vehicle technology. Following are their key areas of concern:

- **Clarification of liabilities** – There needs to be greater certainty around criminal and civil liability in the event of an automated vehicle being in a collision. Under the current legal framework these issues would be dealt with on a case by case basis by the Courts. We will aim to provide additional clarity and certainty in legislation, to provide a sound basis upon which to allocate criminal and civil liability.

- **Amending regulations on vehicle use** – Existing regulations governing how vehicles are used and maintained will need to be revised to allow the use of automation technology without a test driver and to ensure that the technology is maintained correctly. This may involve changes, for example, to the MOT test to check roadworthiness. It may also be appropriate to revise The Highway Code to include a section on automated vehicle technologies.

- **Promoting safety** – Safety is of paramount importance. The Government will consider whether a higher standard of "driving" should be demanded of vehicles operating in an automated mode than would be expected of a conventional driver. Government will also consider how the existing regulatory framework may be developed to ensure automated vehicle technologies are protected from possible cyber threats.

Source(s): Driverless cars will be tested on UK motorways in 2017, 16 March 2016, Wired website; Driverless cars technology receives £20 million boost, 1 February 2016, UK government website, accessed on 27 April 2016

Geographic adoption of AVs — (1/2)
Other countries

Other countries that have seen high involvement of government authorities for the development of AV technology are Singapore, Japan and Australia

Initiatives

Japan:

— The Japanese Government stresses the importance of communication between vehicles and infrastructure for the introduction of automated vehicles; it introduced the 'ITS spot' technology, which enables such communication with high bandwidth.

— In Japan, 1,600 'ITS spot' locations have been installed with appropriate transmitters and over 100,000 vehicles communicate with them. They already provide information and warnings on traffic and will, in future, be combined with lane-keeping assist and adaptive cruise control, to avoid traffic congestion.

— **Update:**

- Japan Inc. seeks to develop a leading transportation system by 2020 by using autonomous and connected-car technologies. With car makers clearing the automated driving tests on highways and unmanned driving test on public roads, the initiative is said to gain momentum in 2017. The government seeks to commercialize these services by 2020, popularize autonomous driving by 2025 and bring traffic accidents nearly to zero by 2030.

Singapore:

— To explore the opportunities and challenges of automated driving, the Land Transport Authority of Singapore (LTA) has signed a five-year Memorandum of Understanding with the Agency for Science, Technology and Research (A*STAR) for starting a joint partnership, 'The Singapore Autonomous Vehicle Initiative' (SAVI).

— SAVI will provide a technology platform for managing R&D (autonomous vehicles, autonomous mobility system and automated road system) and diverse trials for automated driving for public and industrial stakeholders.

— Besides SAVI, there are several ongoing trials for automated driving on Singapore's roads, for instance between MIT and the National University of Singapore (NUS). Within this project, a fleet of autonomous golf buggies is currently tested for car-sharing concepts.

— **Update:**

- In August 2016, Singapore Land Transport Authority (LTA) formed a strategic partnership with Delphi Automotive PLC to implement autonomous mobility concepts. Delphi is expected to provide fully autonomous vehicles and will also develop a cloud-based mobility-on-demand software (AMOD). Singapore's LTA pilot program is expected to be operational by 2022.

Source(s): Connected & Autonomous Vehicles, October 2014, Atkins Global website; Driverless cars take to the road, 21 January 2013, Cordis website; Roadmap to the autonomous car, PSA website; UK to allow driverless cars on public roads in January, 30 July 2014, BBC website; Valeo Autonomous iAV Car Driving System CES, 5 January 2015, YouTube website; Automated Driving Roadmap, 21 July 2015, ERTRAC website, accessed on 29 April 2016; Japan Inc. steps up autonomous-drive push, 06 November 2016, Automotive News website; Delphi Selected by Singapore for Autonomous Vehicle Program, 01 August 2016, CLEPA website, accessed on 07 February 2017

Geographic adoption of AVs – (2/2)

Other countries

Other countries which have seen high involvement of government authorities for the development of AV technology include Singapore and Japan and Australia

Initiatives

Australia:

— In January 2016, the Canberra Government released a draft legislation for testing of self-driving vehicles; a trial demonstration of Volvo's driverless cars in South Australia in November had raised public awareness of the emerging technology, creating an opportunity for Canberra to take it to the next level.

— The Association of Australian and New Zealand road transport and traffic authorities (Austroads) endorsed the C-ITS Strategic Plan to prepare its roads for automated cars and the advent of C-ITS equipped vehicles.

— **Update:**

- In October 2016, the South Australian Government announced an investment of US$10 million to enhance testing and R&D of connected and autonomous vehicle technologies in South Australia. The government will invite companies, research institutes and other organizations to submit proposals that will enhance the development of connected and autonomous vehicle technologies.

Source(s): Connected & Autonomous Vehicles, October 2014, Atkins Global website; Driverless cars take to the road, 21 January 2013, Cordis website; Roadmap to the autonomous car, PSA website; UK to allow driverless cars on public roads in January, 30 July 2014, BBC website; Valeo Autonomous iAV Car Driving System CES, 5 January 2015, YouTube website; Automated Driving Roadmap, 21 July 2015, ERTRAC website, accessed on 29 April 2016; US$10 million Government investment, 10 October 2016, Jay Weatherill website, accessed on 07 February 2017

Trends impacting autonomous vehicles

- Investments in R&D to develop autonomous technologies
- OEMs partnering with mobility service providers
- Government supports OEMs — invests in self-driving projects
- Autonomous technologies challenges the Insurance industry
- Non-traditional OEMs eye autonomous technology
- Electric self-driving vehicles likely to run future cities

Trends impacting autonomous vehicles — (1/3)

R&D investments and OEMs, suppliers and technology providers' partnerships have witnessed an increase in the recent past in the latest self-driving technologies

Investments in R&D to develop autonomous technologies

- According to IHS Automotive, autonomous vehicles are expected to reach 21 million by 2035, owing to multi-million investments in quality control and R&D across the automotive industry.
- In December 2016, Ford Australia opened its new Asia Pacific Development Center in Melbourne — which is expected to have a high-tech 3D virtual studio. It also announced a 50 percent rise in the local R&D budget.
- In August 2016, JLR announced its partnership with Harvard University to conduct research on connected and driverless cars.
  - JLR will provide Harvard University grants of ~US$6 million to research in areas of soft robotics, advanced materials and sensor technology.
  - The partnership was announced following the company's plan to create ~100 research vehicles in the next four years to develop and test its CAV technologies.
- Over the next five years, Kia and Hyundai have announced R&D investments of US$9.8 billion for driverless cars and seek to develop fully autonomous cars by 2030.

OEMs partnering with mobility service providers

- Automakers are expanding alliances and collaborating with start-ups, mobility service providers and others to develop and commercialize their autonomous technologies.
- In February 2017, Daimler signed an agreement with Uber in which it will supply self-driving vehicles for Uber's ride-hailing services in the coming years.
- In August 2016, Ford announced its strategy of focusing on mobility service providers for a positive return on investment on driverless cars. It also announced mass-production of fully autonomous cars for mobility service providers by 2021.
- In August 2016, Volvo and Uber invested US$300 million in a joint venture, under which Volvo will install self-driving technologies to its vehicles and sell it to Uber, which will use it to offer driverless taxis.
- Volkswagen invested US$300 million in Gett, a ride-sharing service provider. It seeks to invest or acquire companies that support ridesharing toward autonomous taxis, which is likely to generate revenue in billions by 2025.
- Fiat Chrysler Automobiles (FCA) is said to be in talks with Uber and Amazon on the development of self-driving cars, potentially providing test cars to the two companies.
  - Fiat seeks to be the main supplier for Uber's self-driving taxi fleet, while for Amazon it is focused on providing self-driving cars, facilitating faster delivery.

Source(s): 21 million autonomous cars on road by 2035: IHS Automotive, 09 June 2016, Telematics Wire website; Toyota to Invest $50 Million in New Artificial Intelligence, Partner With Stanford and MIT, 04 September 2015, Recode website; Ford to spend $450m on R&D in Australia, 22 December 2016, Drive website; Hyundai to develop fully autonomous cars by 2030, 19 November 2015, ZD Net website; With Harvard University, Tata's JLR hopes to soon steer fleet of driverless cars, 29 August 2016, The Business line website; Uber, Daimler strike partnership for self-driving vehicles, 02 February 2017, Alabama news center website; Ford Autonomous Vehicle Plan Targets Mobility as a Service, 24 August 2016, Gartner website; Uber and Volvo collaborate over self-driving taxis, 18 August 2016, Financial Times website; Gett gets investment from Volkswagen in self-driving bid?, 25 May 2016, Readwrite website; GM invests $500 million in Lyft, sets out self-driving car partnership, 05 January 2016, Thomson Reuters website; Fiat Chrysler Eyes Uber, Amazon Self-Driving Pacts After Google Deal, 06 August 2016, Investor's Business Daily website, accessed on 08 February 2017

Trends impacting autonomous vehicles — (2/3)

To support the driverless car revolution, governments at the local and regional levels are proactively establishing regulations, polices and plans; with driverless cars projected to reduce insurance costs, traditional insurance offerings will certainly undergo significant change

Government supports OEMs — invests in self-driving projects

- OEMs are tapping academic and government research institutes for technical expertise through partnerships and joint development agreements.
- China's Ministry of Industry and Information Technology is expected to lay out plans for extensive highway driving by 2020 and fully autonomous urban driving by 2025.
  - The Chinese Government has set up three test sites for connected and self-driving cars in Shanghai, Beijing and Chongqing, which seeks to support R&D and policy formulation for connected car technology.
- The UK has invested in over eight new projects to develop autonomous technologies. It has also equipped over 40 miles of roads in Coventry with technologies to support the testing of autonomous vehicles.
- The National Highway Traffic Safety Administration (NHTSA) is supporting research in autonomous vehicles and has also established a classification for different levels of automation.
- As part of the GBP5.5 million UK CITE project, JLR, along with the government, is investing and seeks to create ~100 research vehicles in the next four years.

Autonomous technologies challenges the Insurance industry

- According to research from Swiss Re and HERE, a mapping company, the upcoming driverless technologies, such as collision warning system and blind spot information, will reduce accidents by 28 percent.
  - It also highlights that reduction in accidents is likely to reduce car insurance premiums by US$20 billion over the next five years.
- Insurance companies are likely to face challenges in developing polices and will need to consider potential risks to drivers (if semi-autonomous) and passengers, and consider who or what will be held responsible for any damage/accident.
- Currently, personal auto insurances products are purchased by vehicle owners as the drivers are held responsible for accidents. With the shift toward self-driving cars, their exists ambiguity on who will be held responsible for accidents and malfunctions — if it is the driver, manufacturer, technology provider or all the three.
- As OEMs are seen developing non-autonomous, semi-autonomous and fully autonomous vehicles, insurers will have to create enhanced products and specific services to cater to each of the above segments.

Source(s): Why China Will Win The Race For Supremacy In Autonomous Vehicles, 02 June 2016, Forbes website; Autonomous driving & the next generation of transport in China, December 2016, Business Sweden website; UK driverless car projects get government green light, 01 February 2016, BBC News website; Jaguar Land Rover Says It Will Test Over 100 Autonomous Cars, 13 July 2016, Fortune website; Government's role in driverless cars: today and tomorrow, 2016, Parsons Brinckerhoff website; Insurance industry welcomes proposals for driverless cars cover, 18 May 2016, The Financial Times website; Implications of Driverless Cars on the Insurance Industry, 27 April 2016, The Huffington Post, Top five predictions for how autonomous vehicles will change the insurance industry and auto claims in the next 10 years, 08 August 2016, Gowling WLG website; Driverless Cars: Time for Insurers to Shift Gears, August 2016, Cognizant report, accessed on 08 February 2017

Trends impacting autonomous vehicles — (3/3)

Companies such as Uber and Google are making robust investments in self-driving technologies and seek to develop vehicles that are fully autonomous; growing incentives offered by governments and stringent environmental regulations have made way to electric autonomous vehicles

Non-traditional OEMs eye autonomous technology

- According to Boston Consulting Group, the autonomous technology market is expected to grow to US$42 billion by 2025 and by 2035 self-driving cars is likely to account for a quarter of the global sales.
- With traditional OEMs developing self-driving capabilities, companies such as Google seek to generate fully autonomous vehicles and offer them for use in ride-hailing services.
- In December 2016, Alphabet, Google's parent company, announced that its autonomous vehicle project, Waymo, would operate as a stand-alone company and that its autonomous technology will be put to public use in 2017.
- Uber does not seek to make its own vehicles, but align with automakers to develop self-driving technologies.
  - In August 2016, Uber acquired self-driving truck start-up Otto and formed an alliance with Volvo worth US$300 million to develop self-driving cars.
  - In May 2016, it announced testing of its self-driving system, a modified hybrid Ford Fusion on the streets of Pittsburgh, Pennsylvania.
  - In February 2016, Uber announced its expansion of R&D in Pittsburgh, Pennsylvania, where the company will conduct research on self-driving technology and construct roadways for testing.

Electric self-driving vehicles likely to run future cities

- Shared fleet services of electric and autonomous vehicles are likely to be been seen as a rising trend in the futuristic urban transportation.
- The Renault–Nissan alliance plans to launch more than 10 new electric vehicles with autonomous driving technologies over the next four years.
- General Motors' (GM) first fully autonomous vehicle is expected to be electric and the company seeks to launch its self-driving cars on the Lyft platform.
  - In January 2016, GM invested US$500 million in Lyft, a ride-sharing company, to tap the network of on-demand autonomous vehicles.
- BMW also seeks to launch its first electric autonomous car iNEXT by 2021.

Source(s): Billions are being invested in driverless cars that Americans don't want, 05 May 2016, Automotive News website; Why car and tech companies have different visions for self-driving cars, 05 January 2017, Vox website; Uber to kick off first autonomous car test in Pittsburgh, 20 May 2016, Readwrite website; Apple's Latest $1 Billion Bet Is on the Future of Cars, 14 May 2016, The Wall Street Journal website; Uber buys self-driving truck startup Otto; teams with Volvo, 19 August 2016, Economic Times website; Google Parent Company Spins Off Self-Driving Car Business, 13 December 2016, The New York Times website; Google's Waymo Unit Close To Putting Self-Driving Cars On Public Roads In 2017, 19 December 2016, Forbes website; Renault-Nissan to launch more than 10 vehicles, 07 January 2016, Renault Nissan website, GM's first fully autonomous car will be electric and launch on Lyft, 19 July 2016, The Business Insider website; BMW Plans Electric, Self-Driving Car For 2021, 13 May 2016, Information Week website accessed on 08 February 2017

Trends impacting adoption of AVs on public transport sector

- **Transforming cost and revenue models**
- **Need for collaboration between government and industry**
- **Need for improved infrastructure**
- **Real time data**
- **Emergence of self-driving public transport**

Transforming cost and revenue models

Impact

AVs are expected to have a disruptive effect on the conventional road revenue generation. While the technology may help in decreasing costs in some areas, a requirement of improved infrastructure would add to the public spending

Impact on costs

— Infrastructure requirements such as ideal roads, smart cities, sensors embedded in the roads etc., would add to public cost.

— According to a National Highway Traffic Safety Administration (NHTSA) report, seven percent of vehicle crash costs in 2010 were paid for by public revenues in the US, costing US$18 billion. Given the AVs' potential for safety, accidents could be reduced dramatically.

— Driverless technologies would eliminate other inefficiencies within transportation systems — congestion, unrealized safety improvements that waste valuable resources etc. According to Brookings, an American think tank, the financial impact of these inefficiencies is about US$100 billion just in the US.

Impact on revenue

— Governments rely on revenues generated through human errors — towing fees, speeding tickets, driving under influence, etc. According to 2014 statistics from NHTSA, about US$6.2 billion is paid in speeding tickets alone annually in the US. In an ideal condition, driverless innovations would result in error free driving.

— New innovations in transportation decrease federal and state revenues. For example, public sector entities have incurred financial losses due to eco-friendly and electric vehicles, even though federal gas tax has remained at US$0.184 per gallon (unadjusted for inflation) since 1993. With a significant number of analysts anticipating that AVs would use electric-drive technology, governments dependent on revenue from fuel would be critically impacted.

Source(s): Driving Citation Statistics, 8 July 2014, Statistic brain website; Autonomous vehicles will have tremendous impacts on government revenue, 7 July 2015, Brookings website; Self-driving cars will reduce government revenue, 12 January 2016, Financial Review website; Self-Driving Cars May End the Fines That Fill City Coffers, 14 July 2015, Wired website; The year is 2045, 2 February 2015, US Department of Transport website; Beyond Traffic 2045, 2 February 2015, US Department of Transport website, accessed on 27 April 2016

Transforming cost and revenue models

Areas of improvement/solutions

Government authorities will probably have to explore new means of road revenue generation and revisit some of the existing models

Per-mile driving charge

- To supplement (or replace) diminishing money provided by gas taxes and vehicle registration fees, consumption based dynamic taxation such as a per-mile driving charge could be imposed.
- In the US, Oregon is one of the states seeking new revenues to make up for transportation shortfalls. In 2012, a program in Oregon was completed wherein the participants paid 1.56 cents per mile driven rather than a state tax of 30 cents per gallon of gasoline.

Value capture

- Some localities in the US have experimented with value capture strategies which can include a variety of mechanisms to capture a portion of the value generated by increases in land value near transportation improvements. For example, property owners and businesses can agree to pay annual fees to fund a transportation improvement; a portion of future property taxes resulting from increased property values could be used to pay for infrastructure.

Multimodal ticketing

- Commuters in the future may use multiple means of autonomous transport to travel, including both public and private means. This presents a challenge for billing commuters without a human to oversee the payment.
- Multimodal ticketing involves a single means of payment across different modes of transport. This would create a centralized system for revenue collection.

Tolls

- Not only can tolling be used to generate revenues to fund the construction or maintenance of highway capacity, it can also be used to manage congestion on a facility. Dynamic tolling, in which toll rates change based on the time of day or level of congestion, is particularly well suited to this role. Tolling remains an effective way of revenue generation. In the future, authorities may need to adapt to the requirements of AVs and accordingly tax vehicles.

Source(s): Driving Citation Statistics, 8 July 2014, Statistic brain website; Autonomous vehicles will have tremendous impacts on government revenue, 7 July 2015, Brookings website; Self-driving cars will reduce government revenue, 12 January 2016, Financial Review website; Self-Driving Cars May End the Fines That Fill City Coffers, 14 July 2015, Wired website; The year is 2045, 2 February 2015, US Department of Transport website; Beyond Traffic 2045, 2 February 2015, US Department of Transport website, accessed on 27 April 2016

Need for collaboration between government and industry

Impact

The potential opportunities and disruptions caused by the advent of autonomous vehicles has resulted in collaborations both in private and public sector. Authorities in the UK, Netherlands and Singapore are among the more proactive ones

UK

- In October 2015, Engineering and Physical Sciences Research Council (EPSRC) in partnership with Jaguar Land Rover (JLR) announced a GBP11 million autonomous vehicle research program.
  - The research is to take place at ten UK universities and the Transport Research Laboratory.
  - As part of its partnership with JLR, EPSRC issued a joint call for research proposals that focused on developing autonomous cars: Towards Autonomy - Smart and Connected Control. Five projects were selected and JLR would lead the collaboration with these successful research groups.

Netherlands

- In March 2013, Delft University of Technology, TNO (a nonprofit applied and contract research), the RWD (Dutch Vehicle Authority), Connekt (an independent network of companies and government agencies, linking stakeholders to achieve sustainable improvements in mobility) and other Dutch and selected international partners launched the Dutch Automated Vehicle Initiative (DAVI), a public private partnership which aims at the investigation, improvement, evaluation and demonstration of automated driving on public roads.

Singapore

- In August 2014, the Land Transport Authority and the Agency for Science, Technology and Research, a public sector agency, signed a five-year Memorandum of Understanding to set up the Singapore Autonomous Vehicle Initiative (SAVI). SAVI provides a technology platform with a joint program office to oversee and manage research and development and test-bedding of AV technology.
- In 2007, the Massachusetts Institute of Technology (MIT) in partnership with the National Research Foundation of Singapore (NRF) established Singapore-MIT Alliance for Research and Technology (SMART), a research enterprise, which developed Singapore's first locally-developed driverless car.

Source(s): Driving Citation Statistics, 8 July 2014, Statistic brain website; Autonomous vehicles will have tremendous impacts on government revenue, 7 July 2015, Brookings website; Self-driving cars will reduce government revenue, 12 January 2016, Financial Review website; Self-Driving Cars May End the Fines That Fill City Coffers, 14 July 2015, Wired website; Government, A*STAR website; SMART launches first Singapore-developed driverless car designed for operations on public roads, SMART website; About SMART, SMART website; Jaguar Land Rover and EPSRC announce £11 million autonomous vehicle research programme, 9 October 2015, EPSRC website; Daimler Gets Moovel-ing on Mobility As A Service, 18 April 2016, Driverless transportation website, accessed on 27 April 2016

Need for collaboration between government and industry

Areas of improvement/solutions

The ongoing experimentation of AVs has been undertaken predominantly by private companies. Some government authorities have realized the potential threats and opportunities of AVs have started collaborating with various organizations

Continued collaboration

— While government authorities in some countries have realized the potential of autonomous vehicles, most of the testing and experimentation of AVs is currently being undertaken by private firms. Government involvement in the development through collaborations and partnerships will enable the authorities to understand the requirements and effects of the AV technology and it will help them prepare better for the future.

- Ride sourcing services, such as Lyft and Uber, are disrupting and augmenting traditional taxi service by using mobile apps to connect for-hire drivers to riders. Ride sharing services are growing rapidly and government authorities could partner with firms specializing in this domain to apply the model to public transport.
- A public-private partnership, in which automakers, tech companies and public agencies test solutions together, will be the ideal way to ensure that a safe and effective transportation system is co-designed.

Supplementing public transport

— There exists a gap in the current public transportation model — inability to transport commuters door-to-door. With the upcoming AV technology, governments could employ smaller vehicles/pods which could bridge this gap and enable transportation between public transport stations and commuter home/destinations.

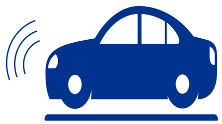
- In April 2016, Daimler launched a Mobility as a Service (MAAS) firm in North America called moovel, which would offer a choice of transportation options to commuters using a smartphone application. Moovel helps transit agencies with last mile/first mile options and has collaborated with various services, agencies and authorities in Chicago and California.

Source(s): Driving Citation Statistics, 8 July 2014, Statistic brain website; Autonomous vehicles will have tremendous impacts on government revenue, 7 July 2015, Brookings website; Self-driving cars will reduce government revenue, 12 January 2016, Financial Review website; Self-Driving Cars May End the Fines That Fill City Coffers, 14 July 2015, Wired website; Government, A*STAR website; SMART launches first Singapore-developed driverless car designed for operations on public roads, SMART website; About SMART, SMART website; Jaguar Land Rover and EPSRC announce £11 million autonomous vehicle research programme, 9 October 2015, EPSRC website; Daimler Gets Moovel-ing on Mobility As A Service, 18 April 2016, Driverless transportation website, accessed on 27 April 2016

Need for improved infrastructure

Impact

AVs are highly dependent on inputs from the surroundings. Better quality and accuracy of input would increase the efficiency of the vehicles. For AVs to function efficiently, smart infrastructure may be required



Self-contained AV

- AVs are highly dependent on inputs from the surroundings. Currently self-contained AVs are prevalent in the experimentation. These vehicles use an array of sensors to gather information about the surroundings and process the data within the vehicle. The vehicle then acts upon the processed data to maneuver.
- As self-contained AVs depend on data collected from sensors such as Lidar and cameras, the inputs need to be standardized and of high quality. For example, a highway may have demarcations for the lanes but city streets may not. These demarcations are one of the important guiding points for an AV. Without these, the vehicle may not know how to act and in a worst case scenario, it may cause an accident.
- For the successful implementation of self-contained AVs, government authorities will have to ensure standardization and maintenance of roads and traffic signs and rules.

Interconnected AV

- Interconnected AVs would use V2X communication, where ‘X’ could be infrastructure (V2I) or another vehicle (V2V). The information collected by the vehicle’s sensors directly could be complemented by V2X communication.
- V2I communications would allow infrastructure, such as traffic signals, to communicate with vehicles.
  - V2I systems could be used to send warnings to drivers about weather conditions, traffic, upcoming work zones and even potholes.
  - V2I communications could also create a variety of operational and regulatory benefits, such as enabling wireless roadside inspections and helping truckers to identify parking spots.
- V2I technology demands the creation of smart infrastructure by adding sensors and transmitters to roads, pavements traffic signals etc.

Source(s): Infrastructure and the autonomous vehicle, December 2014, ITS international website; Beyond Traffic 2045, 2 February 2016, US Department of Transport website; Drivers of change, 12 July 2013, Roads Bridges website; Autonomous Vehicles Adapt to Infrastructure Challenges, Direct industry website, accessed on 27 April 2016

Need for improved infrastructure

Areas of improvement/solutions

Authorities may not only have to improve the infrastructure by improving and standardizing roads and signs, but they may also have to make add additional equipment to create smart infrastructure for V2I communication

Smart infrastructure concepts

- Highly visible lane striping and pavement markings may be required to keep autonomous vehicles in their proper lanes.
- Some experts have suggested embedding machine readable components such as magnets or RFID chips into the road paint.
- Consistent roadway signage will be required so that AVs can correctly understand the sings.
- Traffic signals may be required to communicate directly with the AVs as the cameras may not be able to see the lights in certain conditions.

Scalability

- The requirement for creating close-to-perfect driving conditions, with adequate driving signs, embedded sensors and additional equipment to communicate with AVs would require a large public investment. However, considering that AVs would dramatically change the current transportation models, it is important for government authorities to upgrade the existing infrastructure and make them scalable so as to prepare for the opportunities and challenges.
- The potential benefits of investing in smart infrastructure are not limited to private and public transport. The commercial transport sector will benefit from smart infrastructure. Automation is already affecting ports. At major container ports around the world, the process of transferring containers from ships to docks, trucks and trains is becoming highly automated, reducing reliance on human operators. Live tracking, reduced congestion, any-time delivery are some of the potential benefits of smart infrastructure. Hence scalability it is an important aspect to be considered while upgrading the infrastructure.

Source(s): Infrastructure and the autonomous vehicle, December 2014, ITS international website; Beyond Traffic 2045, 2 February 2016, US Department of Transport website; Drivers of change, 12 July 2013, Roads Bridges website; Autonomous Vehicles Adapt to Infrastructure Challenges, Direct industry website, accessed on 27 April 2016

Real time data

Impact and areas of improvement/solutions

Statistical data directly collected from AVs can be used to study various parameters of driving such as traffic and road conditions. Analyzing these parameters could help achieve increase efficiency and reduce travel time and costs

Impact

— The sensors on the self-driving Google car generate about 1 gigabyte of data every second. In a year, the car would generate about 2 petabyte of data if it drives for 600 hours a year (the time it takes an average American). With a projected 54 million autonomous cars in 2035, there would be a large amount of data generated.

— This data can be utilized by government authorities, vehicle manufacturers and other companies to improve vehicles, traffic, infrastructure and consumer services.

— While the information received from AVs would be useful, data security and privacy issues would be major areas on concern. Cyber threats could jeopardize the AV model. Regulators and other data users will need to establish agreements and systems to protect certain data and maintain privacy.

Areas of improvement/solutions

— Transport authorities could use the data collected by autonomous vehicles to schedule vehicle movements at off-peak times, enhancing productivity and traffic throughput.

— The routes for vehicles could be altered dynamically on the basis of demand. For instance, a commuter could use a mobile application to call an autonomous bus and the bus would automatically incorporate the pick-up/drop point while choosing a suitable route. While this could increase the trip time but it would provide a door to door service which is rare in current public transport models.

— Some initiatives to implement V2X and monitor and analyze the data generated by AVs include ‘Pathway to Autonomous Commercial Vehicles’ and ‘i-MOTORS’ (programs undertaken by the UK government).

Source(s): Self-driving Cars Will Create 2 Petabytes Of Data, What Are The Big Data Opportunities For The Car Industry?, Datafloq website; How Autonomous Cars Will Make Big Data Even Bigger, 8 January 2015, Datafloq website, accessed on 27 April 2016

Emergence of self-driving public transport

Impact

With a potential threat of autonomous cars reducing public transport use and the benefits of automating vehicles, public .authorities need to increase experimentation on public autonomous transport. Some benefits are discussed in this section

Reduced fuel consumption

— In 2011, use of the US public transportation saved about 865 million hours in travel time and about 450 million gallons of fuel in 498 urban areas. Using autonomous vehicles, a greater efficiency can be achieved.

Reduced congestion

— Autonomous public vehicles may allow platooning (vehicle groups traveling close together), narrower lanes and reduced intersection stops, reducing congestion and roadway costs.

Higher capacity

— In Australia, currently 15,000 people are carried by a bus in the space of one road lane per km per hour on a freeway. If autonomous buses were to replace the conventional buses, the capacity would increase to about 25,000 people per hour.

Source(s): Going down the same old road: driverless cars aren't a fix for our transport woes, 2 December 2015, The Conversation website; Autonomous Vehicle Public Transportation System: Scheduling and Admission Control, 20 September 2015, Arxiv website; Public transportation reimagined: Electric, modular and autonomous, 9 October 2015, move-forward website; China's Self-Driving Bus Shows Autonomous Tech's Real Potential, 10 July 2015, Wired website; Public Transportation Benefits, Apta website; Autonomous Vehicle Implementation Predictions, 10 December 2015, Vtpi website, accessed on 26 April 2016

Emergence of self-driving public transport

Areas of improvement/solutions

As most AVs being tested are cars, the future of autonomous public transport remains uncertain. The authorities could increase experimentation in order to prepare for disruptions/opportunities. Some autonomous public models are discussed below

Electric driverless pods

— Soon to be implemented experimental models of self-driving public transport include pods with passenger capacities of 6–10.

Full-sized driverless buses

— While tests are being conducted on full-sized buses, they are limited in number due to the complexity involved in handling a heavy vehicle.

Innovative concept for greater efficiency

— More innovative concepts include a fleet of compact electric modules capable of seating 10 passengers, which can adapt to the capacity and journey based on the passenger demands. These modules would have the ability to connect and disconnect to other modules as per requirement.

Source(s): Going down the same old road: driverless cars aren't a fix for our transport woes, 2 December 2015, The Conversation website; Autonomous Vehicle Public Transportation System:; Scheduling and Admission Control, 20 September 2015, Arxiv website; Public transportation reimagined: Electric, modular and autonomous, 9 October 2015, move-forward website; China's Self-Driving Bus Shows Autonomous Tech's Real Potential, 10 July 2015, Wired website; Public Transportation Benefits, Apta website; Autonomous Vehicle Implementation Predictions, 10 December 2015, Vtpi website, accessed on 26 April 2016

Emergence of self-driving public transport

Case examples

Existing experimental public transport models include pods capable of carrying 6–15 passengers. Chinese manufacturer Yutong developed the first full-sized autonomous bus in September 2015

WEpod

Country: The Netherlands

Type: Electric driverless shuttle

Capacity: Maximum of six passengers

Speed: 25 kmph

Description: The WEpod is capable of driving on regular roads in public traffic. Initially, the vehicle is expected to drive on a fixed route in the Netherlands, expanding to more routes and regions May 2016 onward.

Yutong self-driving bus

Country: China

Type: Diesel self-driving bus

Capacity: Maximum of ~40 passengers

Speed: 68 kmph

Description: In September 2015, Yutong, a Chinese bus manufacturer, announced that its self-driving bus had successfully handled 26 traffic signals, several lane changes and at least one passing maneuver during a 20-mile drive.

Navya

Country: Switzerland

Type: Electric driverless shuttle

Capacity: Maximum of nine passengers

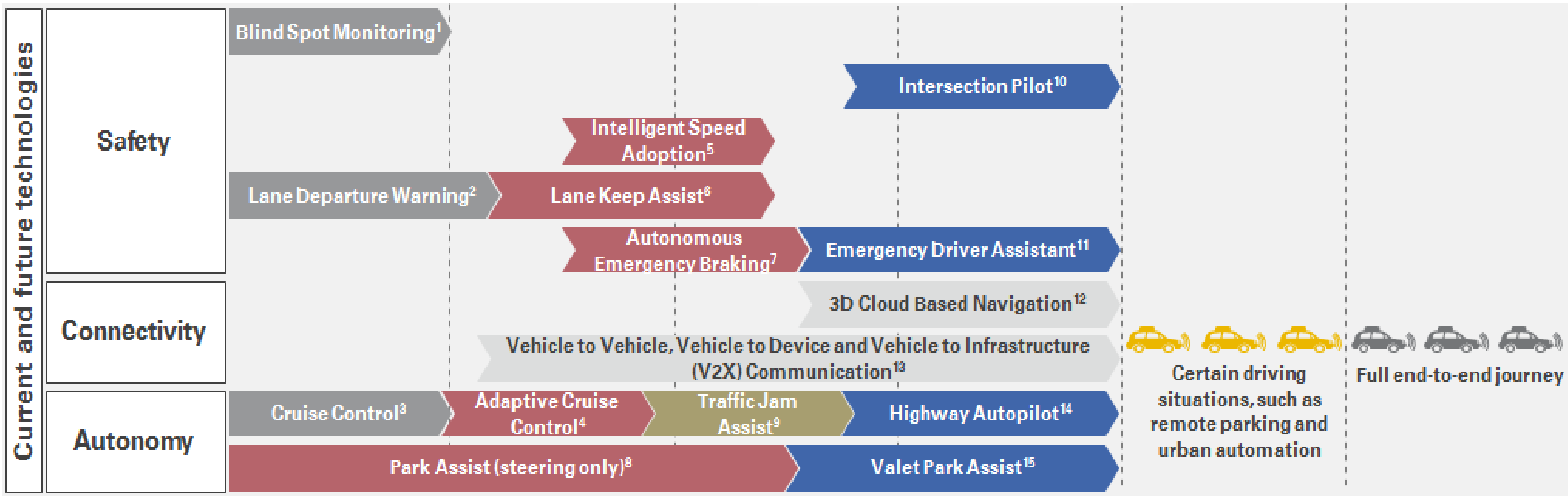
Speed: 45 kmph

Description: In November 2015, BestMile, a Swiss start-up, announced that it would commence trials of its autonomous bus system starting 2016. The buses are produced by Navya, a French autonomous vehicle company.

Source(s): First driverless buses travel public roads in the Netherlands, 28 January 2016, Telegraph website; China's Self-Driving Bus Shows Autonomous Tech's Real Potential, 10 July 2015, Wired website; Baidu expects autonomous buses to become first wave of self-driving vehicles, 31 January 2016, Driverless-future website; The World's First Autonomous Buses Will Debut In Switzerland In Spring 2016, 7 November 2015, Digital Trends website, accessed on 26 April 2016

Appendix

Appendix



Notes:

1. The blind spot monitor is a vehicle-based sensor device that detects other vehicles located to the driver's side and rear.
2. Lane departure warning system is a mechanism designed to warn the driver when the vehicle begins to move out of its lane.
3. Cruise control is a system that automatically controls the speed of a motor vehicle.
4. Adaptive cruise control is an optional cruise control system for road vehicles that automatically adjusts the vehicle speed to maintain a safe distance from vehicles ahead.
5. Intelligent Speed Adaptation is any system that ensures that vehicle speed does not exceed a safe or legally enforced speed.
6. Lane Keep Assist is a feature that in addition to Lane Departure Warning System automatically take steps to ensure the vehicle stays in its lane.
7. Autonomous emergency braking is an autonomous road vehicle safety system which employs sensors to monitor the proximity of vehicles in front and detects situations where the relative speed and distance between the host and target vehicles suggest that a collision is imminent.
8. Park assist (steering only) technology assists drivers in parking their vehicle while the driver controls the throttle and braking.
9. Traffic Jam Assist automatically resumes driving the vehicle from standstill to creep with stop and go traffic.
10. Intersection pilot informs the driver locally about traffic nodes located ahead. It supports the driver with optimal driving maneuvers and simultaneously enables improved traffic light switching by routing vehicle information.
11. Emergency Driver Assistant monitors driver behavior. In case of a medical emergency, if the system concludes that the driver is no longer able to safely drive the vehicle, the car takes the control of the brakes and the steering until a complete stop.
12. 3D Cloud Based Navigation is an autonomous navigation system which uses a real-time 3D point cloud (a set of data points in 3D).
13. V2X communication is the passing of information from a vehicle to any entity that may affect the vehicle and vice versa.
14. Highway autopilot uses sensors and advanced machine vision technology to keep the vehicle in its lane and at a safe distance from the car in front of it.
15. Valet Park Assist parks the vehicle in a spot automatically.

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Government

Developed by Uday Singh, Jenitha B.V. and Nandini Tare

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