WHITE PAPER

# State of the Practice - Connected/Automated Vehicles

## State of the Practice and Impacts to Long-Range Transportation Planning in Rhode Island



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# Table of Contents

# Executive Summary

## By the year 2040 between 20 percent and 40 percent of the vehicle fleet could be autonomous.

Connected and automated vehicles will significantly transform the traditional transportation landscape. Connected vehicles (vehicles that can wirelessly communicate with one another and the infrastructure) and automated vehicles (driverless cars) can provide many benefits such as enhanced safety, improved mobility, and new opportunities to collect and utilize data to improve decision-making. The greatest benefits of this evolving vehicle technology can be realized when connected vehicles and automated vehicles are merged.

The purpose of this paper is to review the state of the practice for connected/automated vehicles (CAVs) including a brief technical background, deployment projections, public opinion, potential applications, planning level policy and strategy needs, and opportunities for Rhode Island.

The following CAV actions are recommended for Rhode Island:

1. Identify a CAV Program Manager for the state and prepare a strategic action plan;
2. Monitor and participate in CAV research;
3. Enact the appropriate state legislation (licensing, enforcement, inspection, insurance, liability, etc.)

4. Integrate CAV considerations into long-range plans (including transit planning and freight/goods transport);
5. Identify funding opportunities (for example, highway safety funds);
6. Facilitate partnerships and technology development with private sector vendors and universities across the state;
7. Review and revise local/municipal laws and zoning ordinances;
8. Conduct an audit of infrastructure and communication needs to support piloting and testing opportunities (for example, traffic signal equipment capabilities, tolling infrastructure);
9. Initiate testing and pilot demonstrations; and
10. Initiate public education and training.

Deployment projections for CAVs vary widely. Level 2 automated vehicles, which rely on human assistance and human backup, are available today. While connected vehicles could be made available today there would not be enough other vehicles or connected infrastructure to provide any benefits. Some automakers are projecting that level 4 and level 5 automated vehicles will be on the market within five years or less. In the Northeast, Uber is piloting driverless rideshare vehicles in Pittsburgh, Pennsylvania and three companies are operating in the Boston Seaport: NuTonomy, Optimus Ride, and Aptiv.

While automakers appear enthusiastic to bring automated vehicles to the market, there is public skepticism. Almost 50 percent of consumers surveyed in 2018 expressed that CAVs were unsafe. While millennials are more likely than other generations to embrace autonomous vehicles, a 2017 study showed the following concerns were commonly expressed: loss of control, lack of trust for the technology, the technology will never work perfectly, and the technology is unsafe.

At this time, there are still many unknowns surrounding CAVs, the technology, and their deployment. One of the critical unknowns is that there is no singular standard by which all CAVs should be developed. While this has left a great deal of freedom for automakers and developers to build the technology, there also comes a point where many try to identify which path will move forward and which technologies will not have a place in the future market. It is not possible to project with any accuracy what will the future holds for CAVs. Rather, appropriate policies should be put in place to guide CAV implementation. This is a key recommendation for Rhode Island.

The potential impacts of CAVs are broad and could include: changes in vehicle ownerships, freight movement, household transportation costs, vehicle design, function of parking, congestion management, public transportation, labor, and land use. This paper considers some potential future scenarios that CAVs could present as well as several policy and strategy recommendations that could be considered to guide the development and deployment of CAVs in Rhode Island.

Certain actions can be taken now to begin preparing for a changing transportation environment that is somewhere on the horizon. CAVs should be taken into consideration during transportation planning efforts. In the long-term plans should consider how having CAVs on the road could impact the transportation network. In the short-term, planning efforts may want to consider infrastructure and communications needs to support piloting and testing opportunities to familiarize area professionals and the public with CAVs. Highway Safety Improvement Program (HSIP) funds could be an opportunity to assist with funding under the correct circumstances and the American Association of State Highway Transportation Officials (AASHTO) Signal Phasing and Timings (SPaT) Challenge could provide a foundation for an infrastructure needs assessment and deployment project. Finally, consideration for CAVs should not be limited to planning for automobiles. CAVs could transform transportation across all modes including public transportation and non-motorized travel.

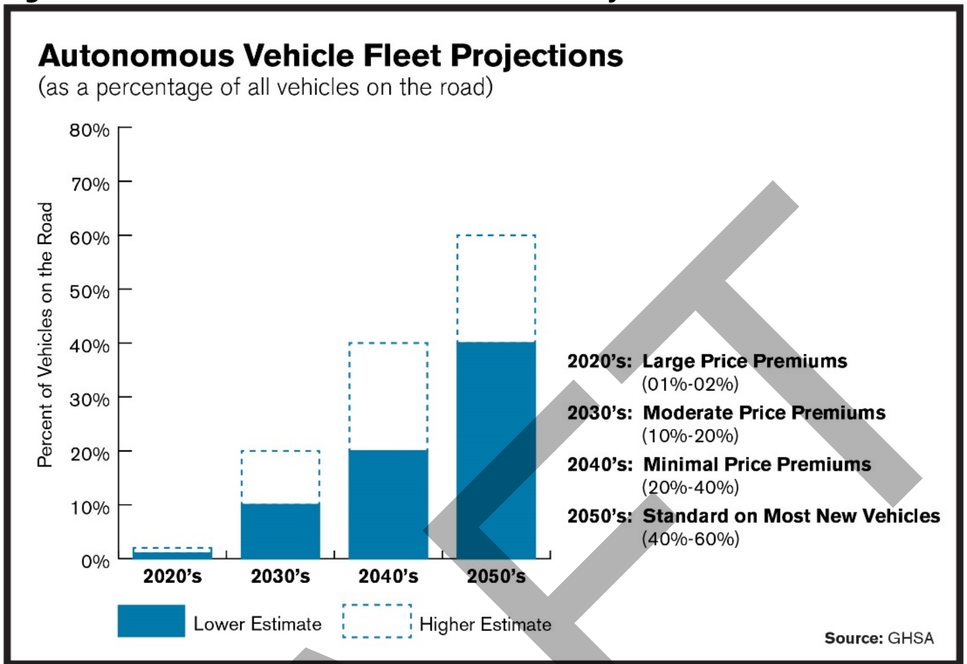
# 1

## Introduction

By some estimates, the most significant change that could be made in transportation over the next 20 years is the introduction of connected/automated vehicles. Looking out to the year 2040 such technology could become commonplace.

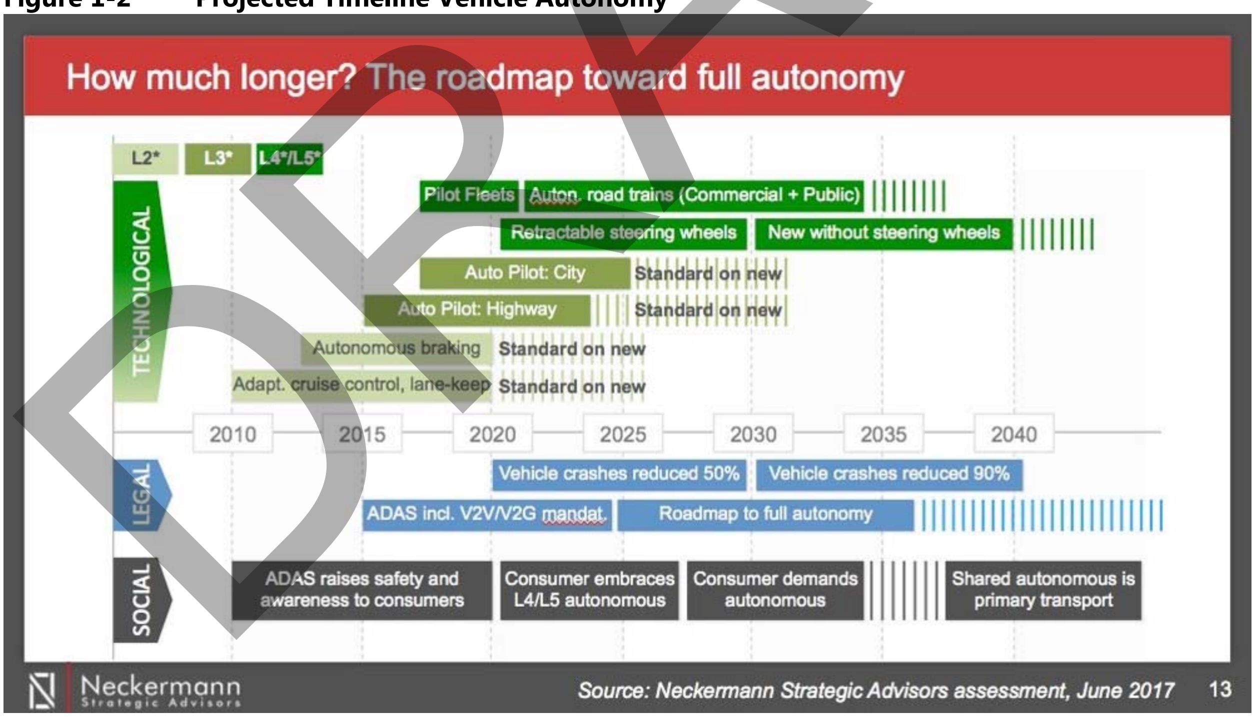
While the precise timeline over which connected/automated vehicle (CAV) deployment will take place is unclear, most sources would agree that they are coming and will transform transportation behavior and practices as they are today. The Governors Highway Safety Association published a research spotlight on autonomous vehicles in 2017. This document suggests that by the year 2040 between 20 percent and 40 percent of the vehicle fleet could be autonomous vehicles with a minimal premium on the price of the vehicle. Figure 1-1 and Figure 1-2 provide two timelines for automated vehicle deployment in the United States.

**Figure 1-1 Autonomous Vehicle Fleet Projections**




Source: Hedlund, James. Governors Highway Safety Association. Autonomous Vehicles Meet Human Drivers: Traffic Safety Issues for States. 2017.

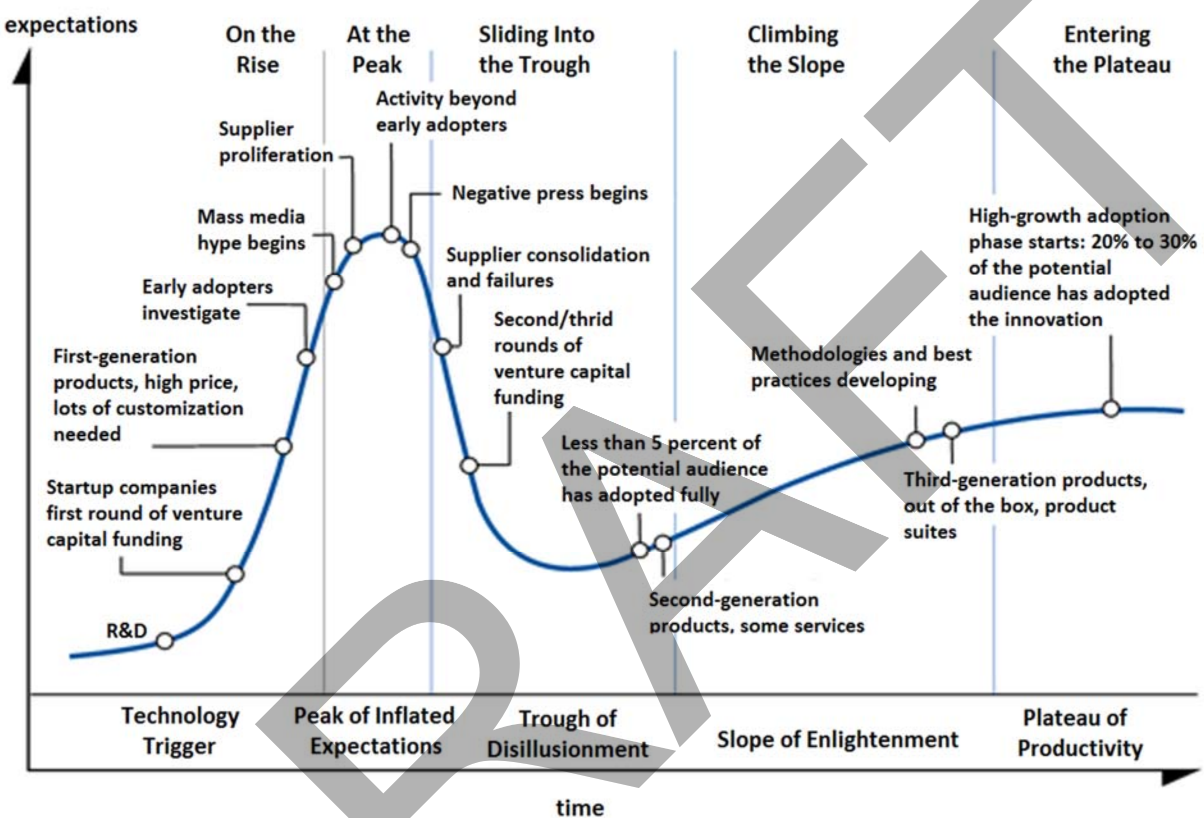
**Figure 1-2 Projected Timeline Vehicle Autonomy**




Source: Neckermann Strategic Advisors. Autonomous Vehicles Assessment. June 2017. http://www.neckermann.net/
L#: Level of Autonomy measured using the Society of Automotive Engineers ratings from 0 to 5 – Level 5 is Fully Autonomous.
ADAS: Advanced Driver Assistance Systems

There are numerous variables involved in projecting when CAV technology will become widely available to the public. One approach to predicting the timelines for CAVs is the Hype Cycle of Emerging Technologies. Figure 1-3 below shows the general hype cycle. An evaluation of emerging technologies found that Autonomous vehicles are at the Peak of Inflated Expectations. [1]

**Figure 1-3 General Hype Cycle of Emerging Technologies**




Source: Gartner Hype Cycle. Gartner, Inc. (2016). URL: gartner.com/SmarterWithGartner
Source (graphic): By NeedCokeNow - Own work, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=27546041

The purpose of this report is to provide an overview of connected and automated vehicle technologies, provide some context on the current state of deployment, and discuss the impacts that this emerging technology has on transportation planning practices, specifically as it applies to long-range transportation planning. Those topics will be discussed as follows:

- Chapter 2 Technical Background
- Chapter 3 State of Deployment and Adoption
- Chapter 4 Transportation Planning Impacts
- Chapter 5 Next Steps



[1] Top Trends in the Gartner Hype Cycle for Emerging Technologies, 2017. Gartner, Inc. (2017) URL: https://www.gartner.com/smarterwithgartner/top-trends-in-the-gartner-hype-cycle-for-emerging-technologies-2017/

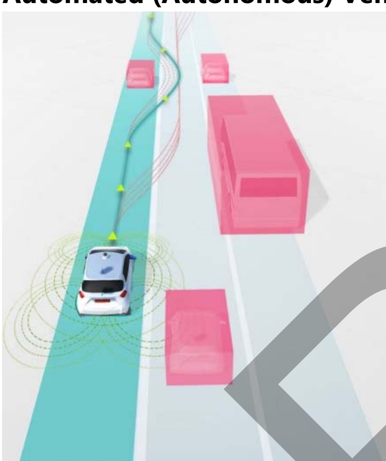
# 2

# Technical Background

Connected/automated vehicle technology is constantly evolving and changing as the body of research, pilots, and deployments continue to grow. The purpose of this section is to provide a snapshot of what connected/autonomous vehicle technology looks like today including the current standards, guidance, policy, and applications.

While sometimes used synonymously, connected vehicles and automated (autonomous) vehicles are each unique. The two technologies can each be implemented in the same vehicle allowing the technologies to compliment and build on one another. The basic types of connected and automated vehicles are defined in Table 2-1.

**Table 2-1 Connected/Automated Vehicle Types**

| Vehicle Types | Definition |
|---|---|
| **Connected Vehicle (CV)**<br><br>Source: USDOT | • Vehicle uses computing and sensing technology and wireless communication to collect and share information between vehicles (vehicle-to-vehicle, V2V), with infrastructure (vehicle-to-infrastructure, V2I), or with mobile devices (vehicle-to-anything, V2X) to enhance safety, operations, and mobility.<br>• All parties (vehicles, infrastructure, mobile devices) must possess computing, sensing, communications equipment to collaborate.<br>• Typical communication range of 3,000 feet (DSRC).<br>• Progress toward connected vehicle deployment is incremental based on application development. The pace and direction is dictated by vehicle manufacturers, technology, and academia/research. |
| **Automated (Autonomous) Vehicle (AV)**<br><br>Source: nuTonomy. http://www.nutonomy.com/ | • Vehicle transitions safety-critical driving tasks (steering, braking, decelerating) from the driver to the vehicle.<br>• The transition is going to be incremental as technology improves. The level of vehicle automation depends on the range of safety-critical driving tasks shifted to the vehicle and on the level of responsibility on the driver for monitoring the driving environment.<br>• Vehicles operate independently using cameras and sensors to navigate the driving environment. Knowledge of the environment is limited to what the vehicle can sense through sensors/RADAR/ LIDAR.<br>• Vehicle manufacturers partnered with technology firms have the highest level of control over the direction of progress on autonomous vehicle development and deployment with policy and legislation driven by the government. |
| **Connected/Automated Vehicle (CAV)**<br><br>Source: USDOT | • The functionality of a connected vehicle for communication and coordination in conjunction with driverless control of an automated vehicle.<br>• Takes advantage of wider communication range of 3,000 feet supplemented nearby by automated vehicle sensing.<br>• Reduced reaction times based on connected vehicle communication due to driverless vehicle control. |

## 2.1 Connected Vehicles

Connected vehicles use computing and sensing technology and wireless communication to collect and share information between vehicles, with the infrastructure, or with other mobile devices. The USDOT more broadly defines a connected vehicle as a vehicle containing an onboard unit (OBU) or aftermarket safety device (ASD). Such packages would enable the computing or sensing technologies and communication described.

### 2.1.1 Types of Connected Vehicles

**Vehicle-to-vehicle (V2V)**

V2V communication would allow vehicles to share driving information with one another. Such information could include location, proximity, speed, or direction of travel. As vehicles share and collect this information the driver or vehicle can make informed decisions and adjust their speed or trajectory accordingly.

For example, a Forward Collision Warning application would give a following vehicle advanced warning that a leading vehicle is slowing causing the following vehicle to slow down accordingly. If the leading vehicle stopped suddenly this application could prevent a rear end crash.

**Vehicle-to-infrastructure (V2I)**

V2I communication would allow vehicles to share driving information with the infrastructure and the infrastructure to share information, messages, or warnings with vehicles. Vehicle information could include location, proximity, speed, or direction of travel. Infrastructure elements could transmit a variety of messages or warnings such as warning about sudden changes in the roadway geometry (curve warning), warnings about sudden traffic signal queuing, or warnings about a work zone ahead. Once enhanced with communication equipment an element of the infrastructure could become part of the connected network such as a sign, traffic signal, or guardrail. As vehicles share and collect this information the driver or vehicle can make informed decisions and adjust their speed or trajectory accordingly.

For example, a Curve Speed Warning application could allow a curve warning sign to trigger a warning to a vehicle that they are traveling too quickly for the upcoming horizontal curve. If the vehicle has some autonomous capabilities the vehicle could go a step further and slow itself down to an appropriate speed based on information provided wirelessly by the curve warning sign.

**Vehicle-to-anything (V2X)**

The connected vehicle premise could be expanded to any wireless device (e.g. smart phones) allowing communication between vehicles and any transportation user (V2X) such as a pedestrian or bicyclist. This concept is the least developed of the three connected vehicle concepts described. The USDOT has not sponsored any V2X applications for research and deployment, however, preliminary concepts for such applications have been developed.

For example, a Pedestrian and Cyclist Intersection Safety application could allow a pedestrian or cyclist carrying a mobile device to passively place a call at a signalized intersection to cross as they approach the intersection. This would be the equivalent of pressing a pedestrian push button at a traffic signal while waiting at the crosswalk. What V2X could enable is for that call to be placed sooner, reducing delay for pedestrians and cyclists, or for a specialized call to be placed. If the pedestrian is elderly or mobility impaired a specialized call could be placed that would extend the walk time for the pedestrian facilitating a safe crossing.

### 2.1.2 Equipment

Connected vehicles require some additional equipment to track vehicle status such as trajectory, speed, proximity, and acceleration or deceleration. Generally, the collection of modules, displays, and communications equipment are referred to as the On-Board Equipment (OBE). The devices used specifically for transmitting and receiving messages are referred to as On-Board Units (OBUs). At times, these terms have been used interchangeably. This document will use the term on-board equipment (OBE) to refer to vehicle equipment necessary for the collection and communication of vehicle data for the purposes of connected vehicle operations.

Similarly, infrastructure requires certain equipment to enable data communication, computation, or storage. Any infrastructure element from a traffic signal equipment cabinet to a roadside sign could house equipment to connect into the V2I communication network. Such equipment packages are referred to as Roadside Units (RSUs) or Roadside Equipment (RSEs). This document will use the term roadside equipment (RSE) to refer to infrastructure equipment necessary for the collection and communication of data in a V2I communication network.

### 2.1.3 Communications

Vehicle-to-vehicle and vehicle-to-infrastructure connections are made through wireless communication. The three types of communication associated with connected vehicle technology are Wi-Fi, cellular data, and Dedicated Short Range Communication (DSRC).

**Wi-Fi**

Wi-Fi for connected vehicles is no different than the Wi-Fi communications that many portable and mobile devices use on a day-to-day basis. While Wi-Fi is an effective means for transmitting data, even large quantities of data, it is a short-range signal, typically of 150 to 300 feet. This does not lend Wi-Fi to communication with moving vehicles. Additionally, connection speed reliability could interfere with the ability to send and receive critical safety messages in a timely manner.

### Cellular data

Cellular data, such as the 3G or 4G that many mobile devices use to communicate, is another communication option. This connection may be appropriate over long distances and in a mobile application, however, communication latency may be too high for sending and receiving critical safety messages.

### 5G Wireless Communication

The wireless industry recently adopted its first standard for 5G wireless communications. The G in 3G, 4G and 5G refers to technological generations; 4G is prevalent across the country today. The main improvements with 5G will be higher data transfer speeds (up to 20 gigabytes per second, or Gbps), faster responsiveness (lower latency, 1 millisecond) and the ability to connect devices together. 5G will be hugely beneficial to CAVs, allowing them to interact with other vehicles and smart infrastructure and allowing for the effective network management of traffic.[2] 5G has not been widely tested and is not yet available in most places.

### Dedicated Short Range Communication (DSRC)

Dedicated Short Range Communication is the low to medium range communication medium that can provide low latency communication necessary for time critical messages between vehicles and the infrastructure. DSRC communication range is up to approximately 3,000 feet. What makes this communication medium particularly unique is that it has been set aside by the Federal Communications Commission for automotive communication applications. DSRC has generally been identified as the communication medium for connected vehicle technology with Wi-Fi and cellular data supporting a connected vehicle environment in other ways such as communication with DOTs or other big data support systems.

### Basic Safety Message

A Basic Safety Message (BSM) is a standardized message format and library used to communicate between vehicles and with infrastructure or devices. Message contents and transmission must comply with standards and protocols established by the Society of Automotive Engineers (SAE). Clear and consistent communication is critical as connected vehicles begin cooperating, sharing information, and making informed decisions.



[2] Segan, Sascha. "What is 5G?" www.pcmag.com. Feb 1, 2018. Web. Mar 03, 2018.

### 2.1.4 Applications

Connected vehicles have the ability to impact all areas of transportation. Research, development, and implementation is being undertaken on an application-by-application approach. The USDOT defines a connected vehicle application as "One or more pieces of software designed to perform some specific function; it is a configuration of interacting Engineering Objects. For example, a software program with an interface, enabling people to use a computer as a tool to accomplish a specific task."[3]

For example, Forward Collision Warning (FCW) is a V2V application that prevents a following vehicle from colliding with a leading vehicle. This application uses location, speed, and acceleration/deceleration information shared between vehicles to warning a following vehicle of the risk of a rear end collision. By knowing the instantaneous and projected locations of each vehicle a collision between the two vehicles could be avoided.

A Curve Speed Warning (CSW) application is an example of a V2I application. This application requires a connected vehicle equipped with an OBE and connected roadside infrastructure such as a curve warning sign that is equipped with RSE. The vehicle could share its location, speed, and acceleration/deceleration with the infrastructure who could respond with a warning if the vehicle is approaching the upcoming curve at an unsafe rate. A connected/automated vehicle that can both communicate with the infrastructure and has given the vehicle control of speed and braking could reduce its own speed in response to the warning from the infrastructure about the upcoming curve.

**Table 2-2** lists a range of connected vehicle applications. This is not an exhaustive list of all applications or possibilities that connected vehicles can open. Rather, it has served as a starting point for conversation on the possibilities.



3 "Glossary." *ARC-IT Version 8.0*, http://local.iteris.com/arc-it/html/glossary/glossary-a.html. August 2017.

**Table 2-2 USDOT Sponsored Connected Vehicle Applications**

| V2V SAFETY | ENVIRONMENT | MOBILITY |
|---|---|---|
| Emergency Electronic Brake Lights (EEBL) | Eco-Approach and Departure at Signalized Intersections | Advanced Traveler Information System |
| Forward Collision Warning (FCW) | Eco-Traffic Signal Timing | Intelligent Traffic Signal System (I-SIG) |
| Intersection Movement Assist (IMA) | Eco-Traffic Signal Priority | Signal Priority (transit, freight) |
| Left Turn Assist (LTA) | Connected Eco-Driving | Mobile Accessible Pedestrian Signal System (PED-SIG) |
| Blind Spot/Lane Change Warning (BSW/LCW) | Wireless Inductive/Resonance Charging | Emergency Vehicle Preemption (PREEMPT) |
| Do Not Pass Warning (DNPW) | Eco-Lanes Management | Dynamic Speed Harmonization (SPD-HARM) |
| Vehicle Turning Right in Front of Bus Warning (Transit) | Eco-Speed Harmonization | Queue Warning (Q-WARN) |
| | Eco-Cooperative Adaptive Cruise Control | Cooperative Adaptive Cruise Control (CACC) |
| **V2I SAFETY** | Eco-Traveler Information | Incident Scene Pre-Arrival Staging Guidance for Emergency Responders (RESP-STG) |
| Red Light Violation Warning | Eco-Ramp Metering | Incident Scene Work Zone Alerts for Drivers and Workers (INC-ZONE) |
| Curve Speed Warning | Low Emissions Zone Management | Emergency Communications and Evacuation (EVAC) |
| Stop Sign Gap Assist | AFV Charging / Fueling Information | Connection Protection (T-CONNECT) |
| Spot Weather Impact Warning | Eco-Smart Parking | Dynamic Transit Operations (T-DISP) |
| Reduced Speed/Work Zone Warning | Dynamic Eco-Routing (light vehicle, transit, freight) | Dynamic Ridesharing (D-RIDE) |
| Pedestrian in Signalized Crosswalk Warning (Transit) | Eco-ICM Decision Support System | Freight-Specific Dynamic Travel Planning and Performance |
| **AGENCY DATA** | | Drayage Optimization |
| Probe-based Pavement Maintenance | **ROAD WEATHER** | |
| Probe-enabled Traffic Monitoring | Motorist Advisories and Warnings (MAW) | **SMART ROADSIDE** |
| Vehicle Classification-based Traffic Studies | Enhanced MDSS | Wireless Inspection Smart Truck Parking |
| CV-enabled Turning Movement & Intersection Analysis | Vehicle Data Translator (VDT) | |
| CV-enabled Origin-Destination Studies | Weather Response Traffic Information (WxTINFO) | |
| Work Zone Traveler Information | | |

Source: US Department of Transportation, Intelligent Transportation System Joint Program Office. "Connected Vehicle Applications" https://www.its.dot.gov/pilots/cv_pilot_apps.htm [Accessed: August 18, 2017].



Taking applications a step further, the US Department of Transportation Architecture Reference for Cooperative and Intelligent Transportation (ARC-IT) provides a living warehouse of concepts for connected vehicle applications at all stages of development, not strictly those that have undergone some level of research and deployment.

ARC-IT "provides common basis for planners and engineers with differing concerns to conceive, design and implement systems using a common language as a basis for delivering ITS, but does not mandate any particular implementation. ARC-IT includes artifacts that answer concerns relevant to a large variety of stakeholders, and provides tools intended for transportation planners, regional architects and systems engineers to conceive of and develop regional architectures, and scope and develop projects."[4] This continually growing and evolving warehouse gives users the opportunity to share concepts for organizational relationships, processing logic, physical interactions between application components, and standards and protocols governing the application.

Continued development and deployment of connected vehicle technologies will likely continue on an application-by-application basis through government and academia research supported by automobile manufacturers who can ultimately bring the technology to users.

### 2.1.5 Key Challenges

One of the key challenges to connected vehicle technology is deployment and adoption. The benefits of connected vehicles rely on coordination and collaboration between all partners involved from vehicles to infrastructure to transportation managers (e.g. traffic management centers). Without broad deployment and adoption benefits and vehicle capabilities could be limited.

From the standpoint of policy, a key challenge that must be addressed is standardization across automobiles and products. To create a driving environment where all players are working together collaboratively all devices must work together on the same network. For example,

## 2.2 Automated Vehicles

Fully automated vehicles can operate the vehicle, navigate the driving environment, and make decisions without human intervention. Such vehicles are often referred to as autonomous vehicles, driverless cars, or self-driving cars.

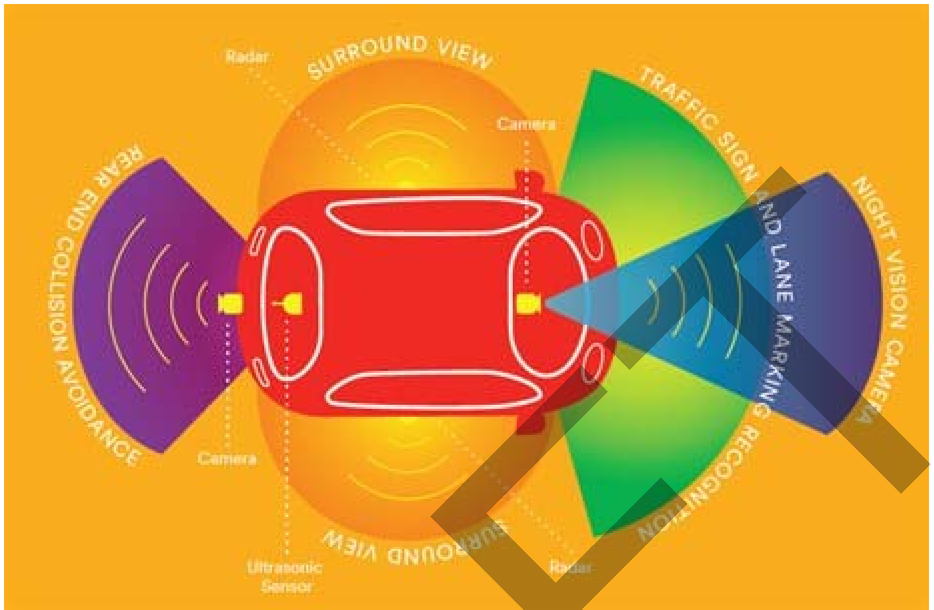
Autonomous vehicle development is driven by automobile and technology developers and manufacturers, and the vehicles themselves operate in an isolated way using several sensing devices to identify and read cues in the environment (for example: roadway striping, signs, other road users). Figure 2-1 shows an example of the range of sensors needed for autonomous operations.

Source: Google www.waymo.com



4 US Department of Transportation. "Architecture Reference for Cooperative and Intelligent Transportation" http://local.iteris.com/arc-it/index.html [Updated: July 27, 2017; Accessed: August 24, 2017].

**Figure 2-1 Autonomous Vehicle Sensing**




Source: ITS America. "3M Reflects on why CAVs need lines and signs" http://www.itsinternational.com/sections/nafta/features/3m-reflect-on-why-cavs-need-lines-and-signs/

### 2.2.1 Levels of Automation

The Society of Automotive Engineers (SAE) developed a definition for levels of vehicle automation which was adopted by the National Highway Traffic Safety Administration (NHTSA) in 2016. There are six levels starting with level 0 for vehicles with no automated driving components up to level 5 which is a fully automated vehicle that requires no human monitoring or back-up. A fully automated vehicle is responsible for all safety-critical driving tasks, monitoring the driving environment, and fallback driving tasks during an event under all driving conditions. The levels of automation are depicted in Figure 2-2 and a detailed description of how and when a human is needed is provided in Figure 2-3.

Currently, level 1 and level 2 vehicles are available on the market. Such vehicles could take over driving tasks from a human driver, however, a human is still needed to monitor the driving environment, act as a fallback should the vehicle need to relinquish control, and may need to take on all driving tasks in certain driving environments where the vehicle is not capable of taking on any safety critical tasks. All automated vehicles currently available on the market fall into level 1 or level 2.

Level 5 automated vehicles are fully autonomous vehicles that no not require a driver at all. Oftentimes, such vehicles are conceptualized as not even needing a steering wheel or having forward facing "driver" seat. Manufacturers have set broad goals for putting Level 5 vehicles on the road with some projecting as soon as 2020 and others looking out to the year 2030 and beyond.

Level 4 vehicles are fully autonomous in some situations, but not all. For example, a vehicle that may operate autonomously on a freeway, but not on city streets. This is a logical precursor to achieving full automation.

Level 3 automation is a gray area where the vehicle can take on many driving tasks, however, a human driver is still the required fallback should the vehicle give up control. Giving vehicles primary control and leaving humans as a fallback plan places humans in an unusual position and makes responsibility and liability difficult to pin down. Given the gray that this arrangement creates, it is possible, even likely, that many automakers will skip the incremental step of placing a level 3 automated vehicle on the road.

**Figure 2-2 Levels of Vehicle Autonomy**

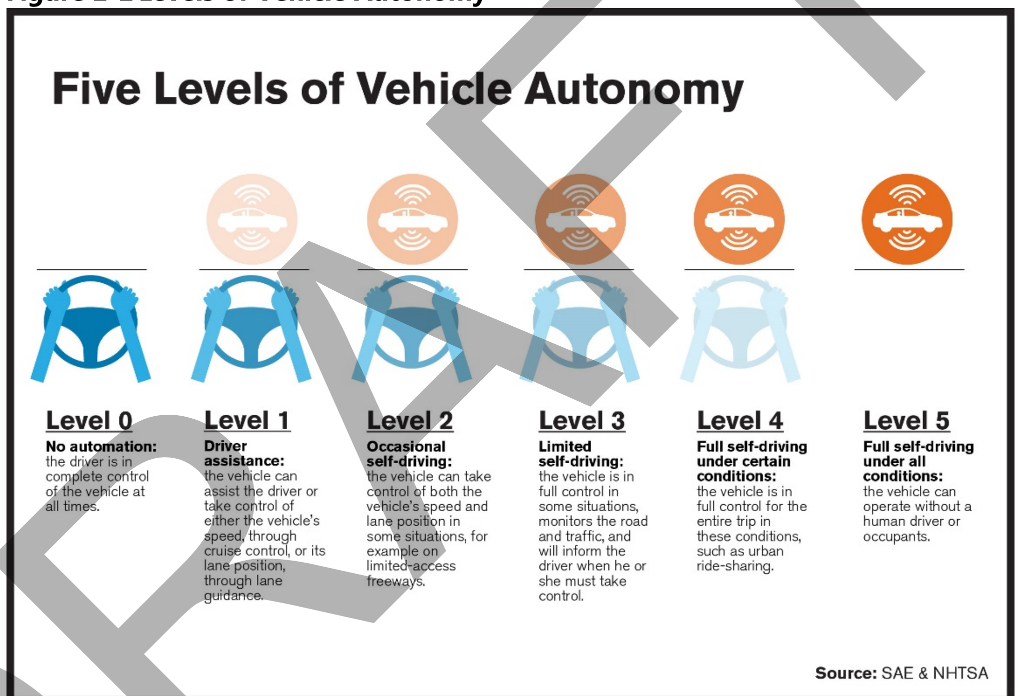


**Figure 2-3 Human verses System Role in the Levels of Automation**

| SAE level | Name | Narrative Definition | Execution of Steering and Acceleration/ Deceleration | *Monitoring* of Driving Environment | Fallback Performance of *Dynamic Driving Task* | System Capability *(Driving Modes)* |
|---|---|---|---|---|---|---|
| ***Human driver* monitors the driving environment** | | | | | | |
| 0 | **No Automation** | the full-time performance by the *human driver* of all aspects of the *dynamic driving task*, even when enhanced by warning or intervention systems | Human driver | Human driver | Human driver | n/a |
| 1 | **Driver Assistance** | the *driving mode*-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task* | Human driver and system | Human driver | Human driver | Some driving modes |
| 2 | **Partial Automation** | the *driving mode*-specific execution by one or more driver assistance systems of both steering and acceleration/ deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task* | **System** | Human driver | Human driver | Some driving modes |
| ***Automated driving system* ("system") monitors the driving environment** | | | | | | |
| 3 | **Conditional Automation** | the *driving mode*-specific performance by an *automated driving system* of all aspects of the dynamic driving task with the expectation that the *human driver* will respond appropriately to a *request to intervene* | System | **System** | Human driver | Some driving modes |
| 4 | **High Automation** | the *driving mode*-specific performance by an automated driving system of all aspects of the *dynamic driving task*, even if a *human driver* does not respond appropriately to a *request to intervene* | System | System | **System** | Some driving modes |
| 5 | **Full Automation** | the full-time performance by an *automated driving system* of all aspects of the *dynamic driving task* under all roadway and environmental conditions that can be managed by a *human driver* | System | System | System | **All driving modes** |



**Key definitions** in J3016 include (among others):

**Dynamic driving task** includes the operational (steering, braking, accelerating, monitoring the vehicle and roadway) and tactical (responding to events, determining when to change lanes, turn, use signals, etc.) aspects of the driving task, but not the strategic (determining destinations and waypoints) aspect of the driving task.

**Driving mode** is a type of driving scenario with characteristic *dynamic driving task* requirements (e.g., expressway merging, high speed cruising, low speed traffic jam, closed-campus operations, etc.).

**Request to intervene** is notification by the *automated driving system* to a *human driver* that s/he should promptly begin or resume performance of the *dynamic driving task*.

Source: SAE International, Standard J3016: Taxonomy and Definitions for Terms Related to On-Road Motor Vehicle Automated Driving Systems.

One difference in the development and deployment of autonomous vehicles compared to connected vehicles is the role of government and research compared to the role of automakers.

While connected vehicles are being approached incrementally on an application-by-application basis typically through academia, autonomous vehicles are being developed at a pace dictated by auto manufacturers and their technology partners. These partners are promising big, innovative leaps that will revolutionize driving and transportation. Most manufacturers have set goals and milestones linked to level 4 and 5 automation.

### 2.2.2 Key Challenges

One of the key challenges to automated vehicle deployment for auto makers will be developing a vehicle that operates in all driving environments (from freeways to local streets). This also means that vehicles can adapt to differences in roadway designs from location to location (e.g. slight variations in striping quality, signage sizes, signage color), and can operate in an environment where the vehicle fleet is made up of vehicles with and without autonomous capabilities.

On the policy and legislation side, one of the key challenges to deployment is resolving issues of liability. Today if two vehicles get into a crash the operators can be held responsible for their decisions. The premise behind autonomous vehicles is that responsibility is shifted away from human drivers and over to automated vehicles. When humans are no longer responsible for making decisions, it is unclear where the responsibility lies in a vehicle crash. Potentially, automakers are viewed as being responsible because their algorithms or their vehicle systems could have led to the crash. This is further complicated because in some circumstances drivers must serve as a fallback plan.

## 2.3 Connected/Automated Vehicles

As described in Table 2-1, a connected/automated vehicle could utilize both technologies in a complimentary way to enhance driving. The ability of an automated vehicle to take on tasks currently completed by humans including navigation and make decision-making can be enhanced with the wide and not easily obstructed communication range of a connected vehicle which can deliver data and messages earlier and faster than an automated vehicle can achieve alone.

The challenges faced by connected/automated vehicles are the same as those outlined for each connected and autonomous vehicle. The various benefits to implementing the technologies described are outlined in the following section.

## 2.4 Benefits

The four general benefits of connected/automated vehicles are safety, mobility, environmental, and improved data.

### 2.4.1 Safety

Some of the examples given in prior sections show the link between connected/automated vehicle technology and safety. Any technology that can reduce individual perception-reaction time to a situation can improve safety by reducing the severity of crashes and ultimately eliminating crashes. Looking beyond connected/automated vehicles to a network that incorporates cyclists and pedestrians using smart phone technology could yield safety benefits for these vulnerable user groups as well.

On the other hand, many agencies suggest that while certain safety issues may be resolved by connected/autonomous vehicle technology there will be new, currently unrecognized safety issues to address. This is a reminder of the importance of thoughtfully planning, deploying, and implementing such technologies.

### 2.4.2 Mobility

As these technologies encourage greater data sharing among all roadway users, individuals and system managers can take advantage of this data to manage and improve roadways utilization. Beyond traffic management, there are opportunities to increase the physical capacity of the roadway network in a connected environment by reducing space between vehicles in a lane (allowing a higher density of vehicles) and reducing the width of travel lanes (opening opportunities for more lanes on a facility).

### 2.4.3 Environment

CAV technologies that allow vehicles to control their speed could lead to greener driving habits. For example, applications that allow the infrastructure to better coordinate vehicle travel and harmonize speeds could result in fewer stops, less idling, and smoother speed profiles, all of which result in reductions in greenhouse gas emissions.

From a travel choice standpoint, greater sharing and travel coordination that can be achieved through rideshare and expanding transit services could encourage existing drivers to make new choices, such as carpooling or transit, that could reduce the number of trips being made and ultimately the number of vehicles on the road.

### 2.4.4 Data

CAVs turn every vehicle into a mechanism for data collection for a variety of measures, not limited to: travel speed, travel time, delay, operations, incident response, pavement condition, and so on.

# 3

# State of Deployment and Adoption

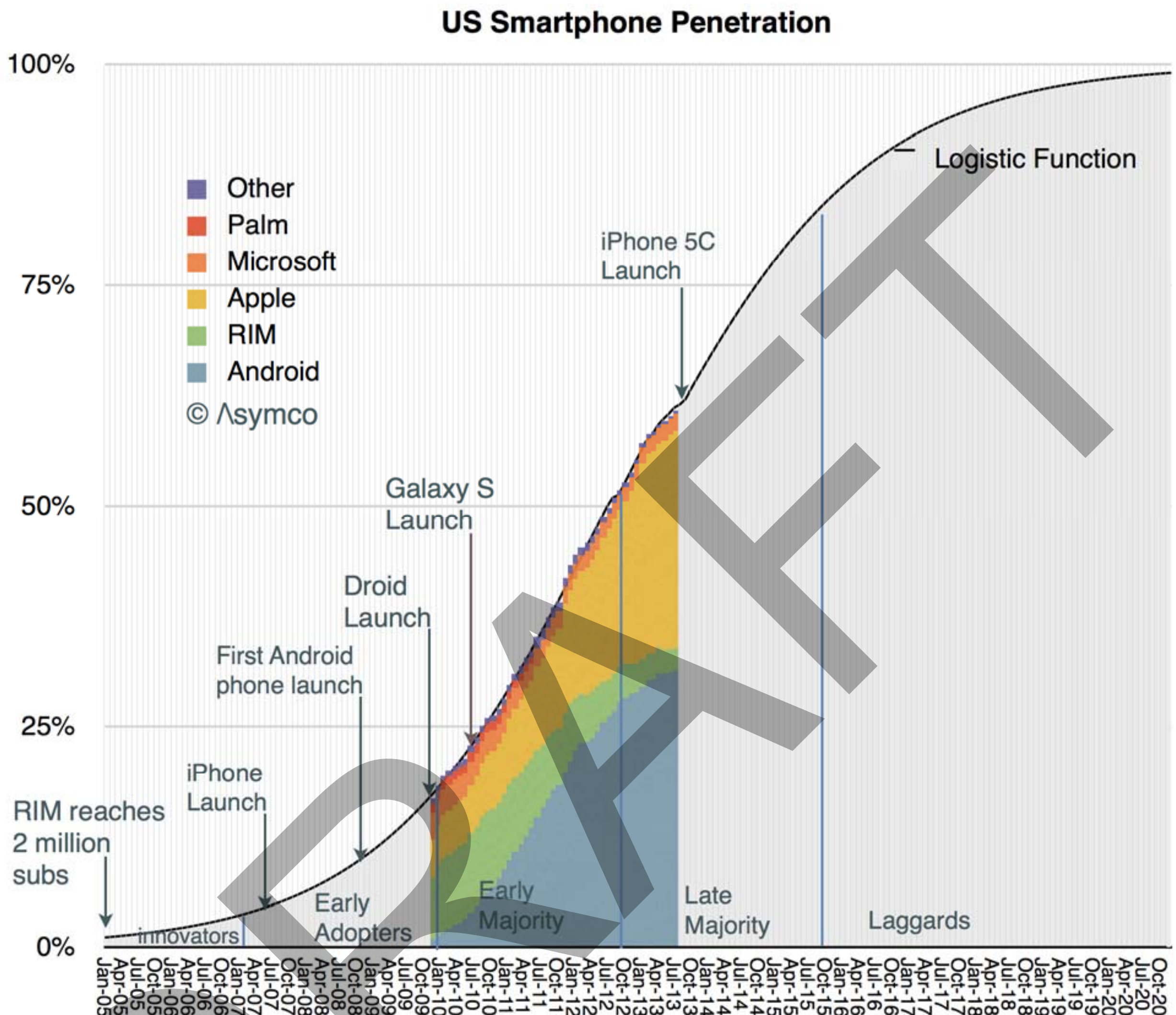
While the technology to bring connected and/or automated vehicles to reality is developing rapidly it is not the only hurdle to overcome before CAVs are on the road. Certain hurdles also exist to technology deployment and full-scale adoption by the public.

## 3.1 Deployment Timeline

As CAV technology seems so different than the enduring landscape of vehicle transportation for many decades, there is a tendency to assume that CAV adoption is a topic for the distant future. Recent trends indicate that introduction of these vehicles may be coming quite quickly. Vehicles that do not require a driver at all are already undergoing roadway testing and there are many players working hard to gain a foothold in this emerging market.

Adoption of smartphone technology in the US may offer some insight into the potential speed of adoption for other innovative and disruptive new technologies. Figure 3-1 shows the smartphone adoption curve in the US. Before the introduction of the Apple iPhone in 2007, smartphone use was virtually unknown in the US mobile phone market. Within three years, market penetration was at 25% of consumers, reaching 50% in five years. Today the US is near market saturation – everyone who wants a smartphone in the US likely has one.

**Figure 3-1  US Smartphone Adoption Curve**




Source: Dediu, Horace. *When will the US reach smartphone saturation?* http://www.asymco.com/2013/10/07/when-will-the-us-reach-smartphone-saturation/, published 10/7/13. Accessed 2/9/18.

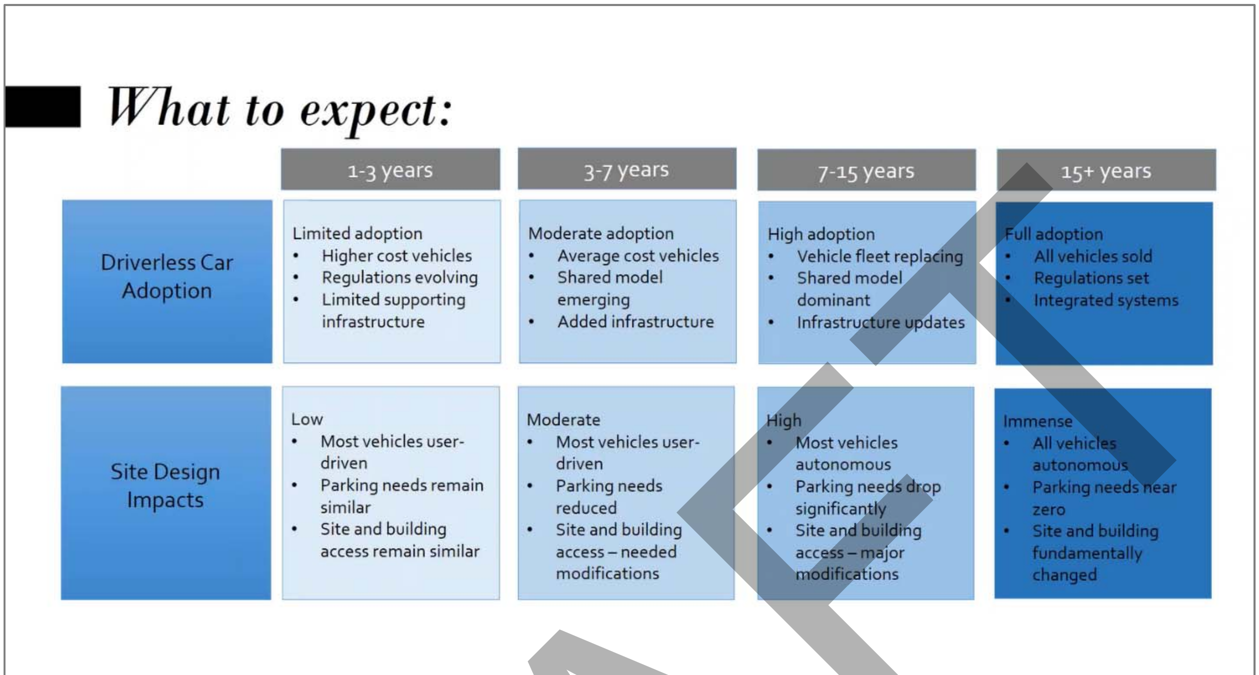
CAV adoption may not follow the same timeline and curve as smartphones, but by many estimates CAV introduction is coming, potentially sooner than many consumers and policymakers expect.

By one estimate, 95 percent of passenger miles travelled in the US by 2030 will be served by on-demand, autonomous electric vehicles owned by fleets.[5] This assumes that CAVs would have widespread approval for use on public roads by 2021. Figure 3-2 shows an estimated CAV adoption timeline and associated planning-related impacts, with moderate- to high-adoption possible within a seven-year timeframe.



5 Arbib, James & Tony Seba (2017). Rethinking Transportation 2020-2030: The Disruption of Transportation and the Collapse of the Internal-Combustion Vehicle and Oil Industries. ReThinkX.

**Figure 3-2 CAV Adoption Timeline and Site Design Impacts**




Source: Stein, Rick, Justin Robbins, Jason Sudy. (2017). "Thinking beyond the technology: How autonomous vehicles will change everything we know about cities." *American Planning Association, Ohio Chapter*. Retrieved February 8, 2018 from http://ohioplanning.org/aws/APAOH/asset_manager/get_file/156748/05.12.17_pdf.pdf.

Some projections for when an autonomous vehicle could be on the market are below as summarized by the Governors Highway Safety Association[6].

- There is broad consensus that Level 3-5 AVs will be commercially available to some buyers within five years. They may be operating on the road if appropriate laws and regulations are in place.
- On August 16, 2016, Ford announced its plans "to have a high-volume, fully autonomous SAE Level 4-capable vehicle in commercial operation in 2021 in a ride-hailing or ridesharing service"
- Fully autonomous vehicles are on the horizon from Tesla by 2018, Volkswagen by 2019, Toyota by 2020, and BMW by 2021.
- On October 19, 2016, Tesla announced that all Teslas produced after this date will have all the technology needed for Level 4 self-driving, though the software has not yet been activated.
- NuTonomy's self-driving taxis in Singapore began trial operations in August 2016. NuTonomy plans to have AV taxi fleets in 10 cities by 2020.
- Delphi and MobilEye plan to have a fully autonomous system on the market for use in a variety of cars in 2019.



6 Governors Highway Safety Association. (2017). *Autonomous Vehicles Meet Human Drivers: Traffic Safety Issues for States*. Washington, DC.

- Former Secretary of Transportation Foxx stated in 2015 that he expects AVs to be in use all over the world by 2025.
- GM plans to make its first autonomous vehicle electric, likely the 2017 Chevrolet Bolt EV, "and nearly anyone will be able to experience it through Lyft."
- The Central North America Trade Corridor Association is working to create a corridor that will allow autonomous vehicles for commerce along US 83 from Canada through North and South Dakota, Nebraska, Kansas, Oklahoma, and Texas to Mexico (CNATCA, 2016).

Even if adoption is a slower process than these estimates, it would be wise for governments and institutions to be well ahead of the curve to be able to realize the benefits from this technological change and minimize disruptions to the greatest extent possible.

### 3.1.1 Drivers of CAV Adoption

There are several reasons that CAV technology is likely to be introduced soon and quickly, including public safety and strong economic drivers.

#### 3.1.1.1 Public Safety

In 2016, there were 37,461 traffic crash fatalities in the United States, according to the National Highway Traffic Safety Administration (NHTSA). More than 2.4 million crash-related injuries were reported for 2015.[7] The vast majority of these crashes were the result of human error. CAVs present the possibility of reducing or removing human error from the equation. Given the high value of preserving lives and preventing injuries, coupled with the high cost to the economy of crash-related deaths, injuries and property damage (estimated at $242 billion nationally for all motor vehicle crashes in 2010 and $1.6 billion for Rhode Island in 2016)[8], the opportunity to significantly reduce these negative outcomes is highly desirable from a public policy standpoint.

#### 3.1.1.2 Economic Savings

In addition to reducing or eliminating crash-related economic losses, there are other strong economic drivers that lend confidence in near-term CAV adoption. One study

7 United States. US Department of Transportation. National Highway Traffic Safety Administration. Https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812451. N.p., Oct. 2017. Web. Feb. 2018.

8 ---. ---. ---. National Center for Statistics and Analysis. (2017, October). Summary of motor vehicle crashes (Final edition): 2015 data. (Traffic Safety Facts. Report No. DOT HS 812 376). Washington, DC. Web.
State of Rhode Island Highway Safety Improvement Program Fiscal Year 2018 Program Manual. DRAFT February 2018.

estimates that CAVs and the switch to an on-demand transportation sharing model could effectively end the current model of car ownership entirely, and save the average US household $5,600 per year on transportation costs. This could have positive impacts in many areas, from household savings to consumer spending. Individuals and households would no longer be required to drive, park, maintain, insure or fuel vehicles. Meanwhile, the costs of owning a traditional internal combustion vehicle could become increasingly more expensive and less convenient to operate. It is this cost differential that will be the main driver pushing adoption of CAVs by the general public.[9]

Why are on-demand, shared CAVs relatively so cheap to operate? The answer lies in their much higher utilization versus privately owned vehicles. An individually-owned vehicle sits idle the vast majority of every day. Shared vehicles would be available on-demand 24 hours per day, and utilization could be 10 times or more above that of an individually-owned vehicle. Much higher utilization, combined with the cost savings from decreased costs for insurance, maintenance, fuel and parking, results in the anticipated low cost of on-demand, shared CAV transport.[10]

The insurance industry and individual choices with respect to insurance would be a strong driver of a switch to CAVs. Insurance covers much of the costs of fatalities, injuries and property damage in the current car ownership-insurance model. The burden shifts entirely to the owner and operator of a vehicle that is automated. The insurance cost of a vehicle will become incorporated into the trip pricing model of shared use vehicles. Insurance will be much lower per vehicle as the risk of crashes decreases significantly and the numbers of consumers purchasing insurance products drops dramatically.

Consumers will be left with a decision in the future to keep their privately-owned and human-operated vehicle, pay the high insurance costs and the rising costs of a vehicle that is increasingly difficult to fuel and maintain.

### 3.1.2 Public Opinion of CAVs

Americans love to own and drive cars – so goes the long-standing cultural narrative surrounding automobiles in the US. This may be the case, but it is also true that we are price-responsive consumers and frequently make decisions based on cost. Society is also comprised of a wide variety of people, and our travel patterns are changing from previous generations, as are our opinions of cars.

At present, there is a healthy degree of public skepticism about CAVs. Figure 3-3 shows perceptions of safety concern regarding CAVs for a variety of world countries over the past two years. The authors note survey results showing that in 2018, 47 percent of US consumers feel that CAVs would be unsafe, which is down from 74

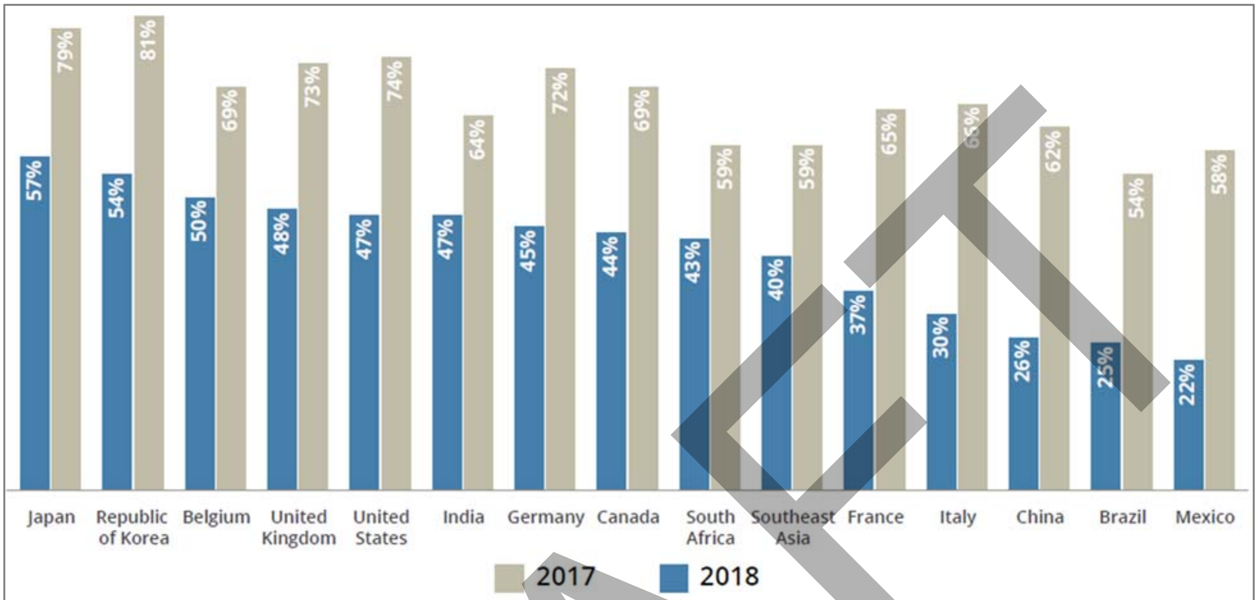


9 Arbib, James & Tony Seba (2017).

10 Ibid.

percent in 2017 survey results. This trend of decreasing worry about CAVs is mirrored in survey results from other countries.

**Figure 3-3 Percentage of Consumers Who Think that CAVs Would be Unsafe, 2017-2018**




Source: Deloitte Global Automotive Consumer Study, (2018). Retrieved February 8, 2018 from https://www2.deloitte.com/insights/us/en/industry/automotive/advanced-vehicle-technologies-autonomous-electric-vehicles.html.

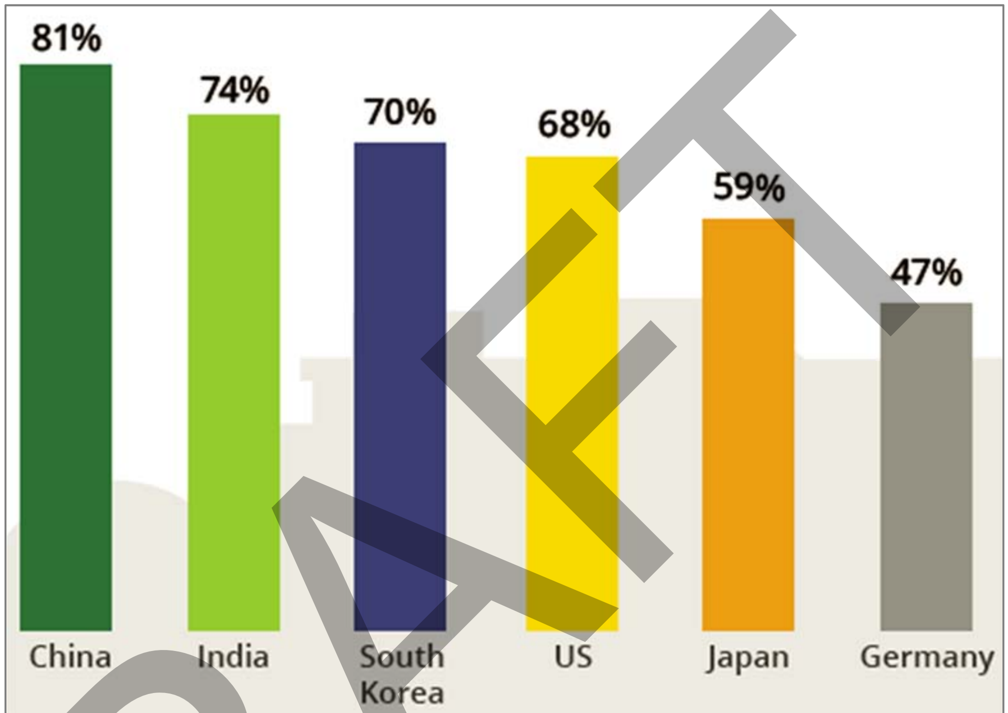
There remain significant concerns among the general public about CAVs. The basic theme of these concerns is anxiety about ceding human control to machines and fear that it may not work properly. A 2017 MIT study indicated that more than a 72 percent of survey respondents would *not* be comfortable with a car capable of Level 4 or 5 autonomy (see Figure 2-2). However, just 2 percent of the same respondents would want a vehicle with absolutely no automation. Some respondents indicated that they would *never* purchase a car capable of self-driving. Among the most prevalent concerns for this thinking:

- Loss of control (37%)
- I don't trust it (29%)
- It will never work perfectly (25%)
- It's unsafe (21%)
- It's too new (17%)
- I enjoy driving (17%)
- Technology is inferior to a human driver (12%).[11]

[11] Abraham, Hillary, Bryan Reimer, Bobbie Seppelt, Craig Fitzgerald, Bruce Mehler, Joseph Coughlin (2017). Massachusetts Institute of Technology Agelab. Consumer Interest in Automation: Preliminary Observations Exploring a Year's Change. Cambridge, MA, 2017. Web.

Most US consumers indicate that they are generally more likely to ride in an autonomous vehicle if an established track record of safety can be demonstrated, as shown in Figure 3-4.

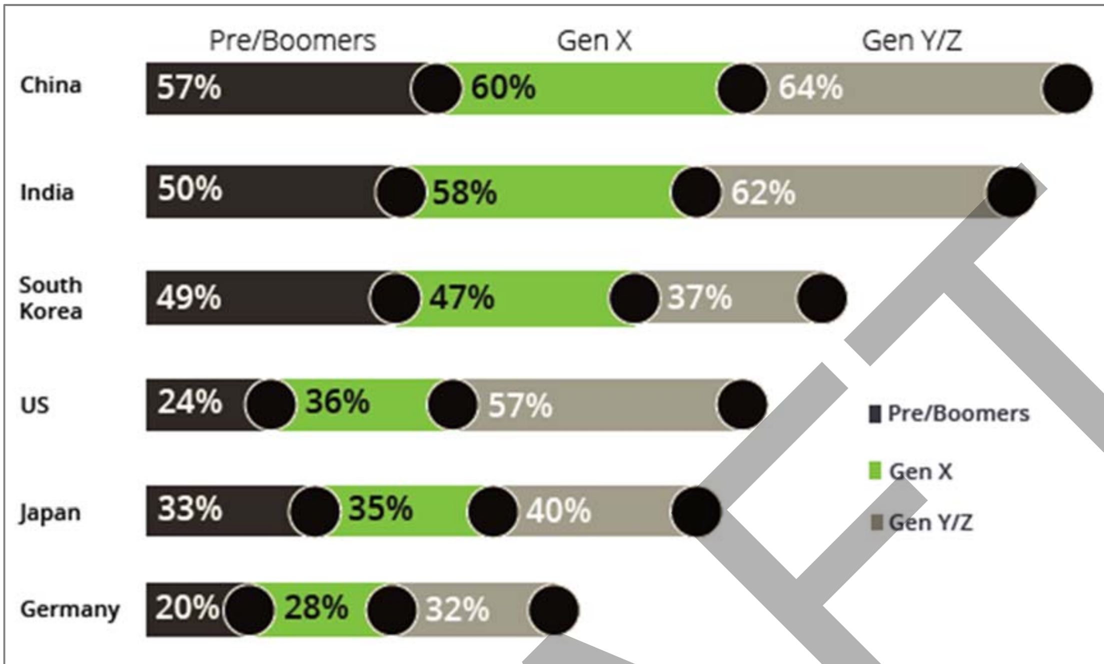
**Figure 3-4 Percentage indicating that an established safety track record would make it more likely for them to ride in an autonomous vehicle (2017)**




Source: Deloitte Global Automotive Consumer Study, (2017). Retrieved February 16, 2018 from https://www2.deloitte.com/content/dam/Deloitte/us/Documents/manufacturing/us-manufacturing-consumer-opinions-on-advanced-vehicle-technology.pdf.

There are generational differences in attitudes toward autonomous vehicles, just as there are generational differences in car ownership, acquisition of driver's licenses and use of ride hailing. Younger generations (Generations X and Millennials) are generally more interested in fully autonomous vehicles when compared with Baby Boomers and older generations (Figure 3-5). Looking forward, as Baby Boomers age and stop driving and start relying on alternative transportation options, they may stand to benefit from expanded use of autonomous vehicles for transportation.

**Figure 3-5 Interest in Fully Autonomous Vehicles, by Generation**




Source: ibid.

In summary, anxiety about CAV technology is still prevalent across the US and world, but is decreasing rapidly. Safety and loss of control appear to be the major concerns. People worldwide are becoming more comfortable with notion of autonomous vehicles, though they may not yet feel able to commit to using level 4 or 5 autonomy at present. Younger generations are more comfortable with highly automated vehicles than older generations. It is also important to note that China is amongst the nations with the least anxiety about CAV technology. China is a major driver of international products and consumption trends; widespread adoption in China would likely propel adoption elsewhere in the world.

## 3.2 Policy and Legislation

Policy and regulation are one of the main legs of the stool needed for widespread introduction of CAVs. Policy is scattershot at the moment, which makes it difficult for manufacturers of these vehicles and technology to effectively create systems that can be used across the US. This section reviews the current status of legislative and regulatory efforts with respect to CAVs at the federal and state level.

### 3.2.1 US Federal Policy

#### 3.2.1.1 2016 Automated Vehicles Policy

The USDOT issued its first Federal automated vehicle policy in September 2016. The policy was intended as guidance to states and industry. The policy set out vehicle performance guidance for automated vehicles, offered a model state policy, summarized NHTSA's current regulatory tools and considered new tools and authorities that may be applicable to the regulation of automated vehicles.[12]

#### 3.2.1.2 2017 Automated Vehicles Policy

A revision to the policy was published in September 2017.[13] It is comprised of two sections: Voluntary Guidance for Automated Driving Systems and Technical Assistance to States, Best Practices for Legislatures Regarding Automated Driving Systems. The Voluntary Guidance section contains 12 priority safety design elements, each with prescribed safety goals and approaches that may be used to achieve these goals. The policy is intended as a flexible framework for industry to use in addressing safety issues, and encourages (but does not require) entities engaged in testing and development of automated vehicles to publicly disclose voluntary safety self-assessments. The Best Practices section delineates Federal and State roles in regulation of the technologies involved and includes best practices for state highway officials. A framework is provided for States to develop policies and conditions for safe operation of these vehicles on public roadways.

#### 3.2.1.3 2018 Summit

USDOT has announced a summit to be held March 1, 2018 to seek input to a third automated vehicles policy revision (Version 3.0). The event has identified a focus area of key cross-modal issues important to the successful integration of automated vehicles into the transportation system. NHTSA has indicated that it is also looking for ideas to remove regulatory barriers to automated vehicles, particularly with respect to controls for a human driver.

#### 3.2.1.4 Commercial Vehicles

Commercial Vehicles such as buses and heavy goods vehicles fall under the regulatory jurisdiction of the Federal Motor Carrier Safety Administration (FMCSA), and so are not subject to the voluntary guidance of the 2017 NHTSA policy. The Federal Transit Administration is currently requesting comments on removing barriers to transit bus automation and its automated transit bus research program. The FMCSA held a listening session in April 2017 regarding highly automated commercial vehicles, but has not yet established any policy relating to them.

#### 3.2.1.5 Congressional Action

The US House passed autonomous vehicle legislation in September 2017 (the SELF Drive Act, H.R. 3388). The US Senate introduced legislation in late September 2017, the American Vision for Safer Transportation Through Advancement of

12 US Dept of Transportation. *Federal Automated Vehicles Policy: Accelerating the Next Revolution in Roadway Safety*. National Highway Transportation Safety Admin. 12507-091216-v9. Web.

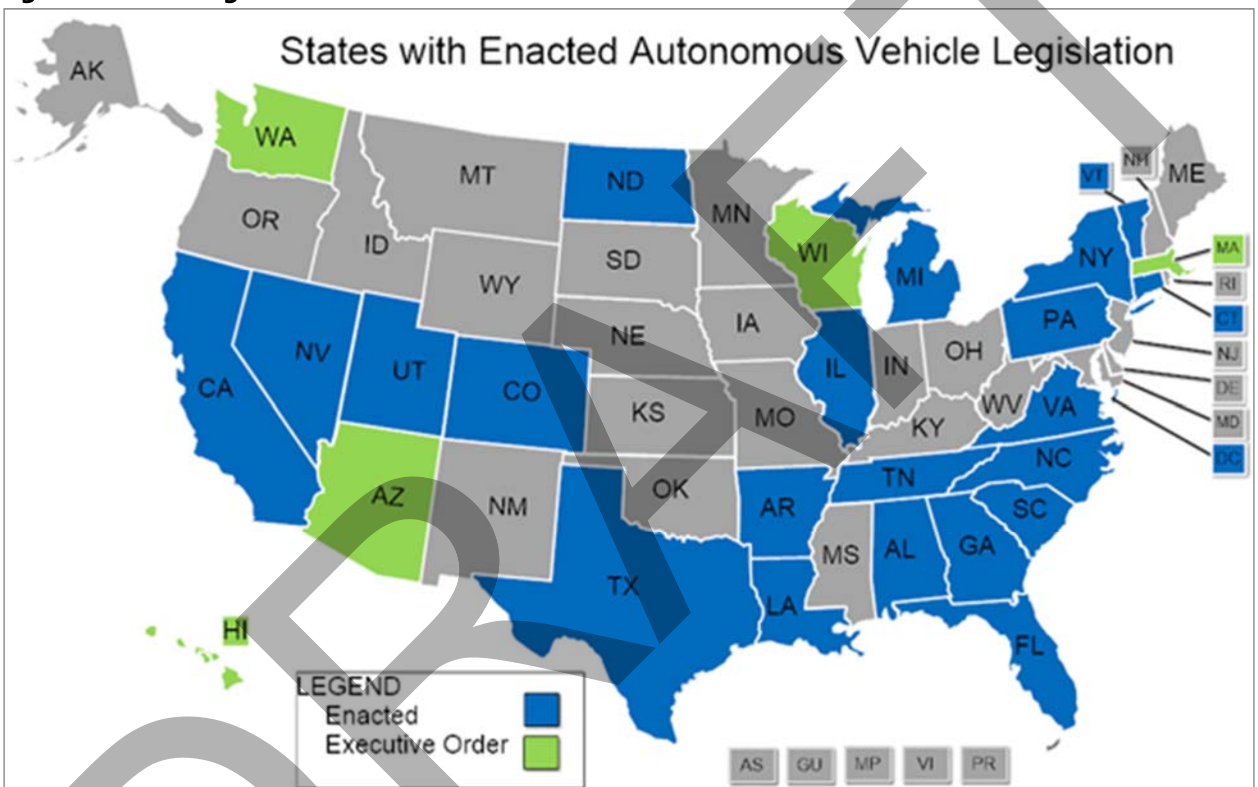
13 US Dept of Transportation. *Automated Driving Systems: A Vision for Safety 2.0*. National Highway Transportation Safety Administration. DOT HS 812 442.

Revolutionary Technologies Act, or AV START. This legislation stalled and has not been reintroduced at this time.

### 3.2.2 State Policies and Regulations

More than 20 states have enacted some amount of legislation (or executive orders) related to autonomous vehicles (Figure 3-4). Many of these establish advisory councils or committees to study the issue further, but some states – such as Nevada and California – authorize the operation or testing of vehicles to varying degrees.

**Figure 3-4 CAV Legislation Enacted**




Source: Autonomous Vehicles: Self-Driving Vehicles Enacted Legislation. (2018, January 2). National Conference of State Legislatures. Retrieved from http://www.ncsl.org/research/transportation/autonomous-vehicles-self-driving-vehicles-enacted-legislation.aspx.

## 3.3 Case Studies

### 3.3.1 National

The USDOT established 10 proving grounds for autonomous vehicles in January 2017. This was done in the waning days of the Obama administration, and no further mention of these proving grounds appears on USDOT's autonomous vehicle website or the current policy. It is unclear if this designation is still relevant. The ten sites were:

- City of Pittsburgh and the Thomas D. Larson Pennsylvania Transportation Institute (Pittsburgh, PA),
- Texas AV Proving Grounds Partnership (Texas),
- U.S. Army Aberdeen Test Center (Aberdeen, MD),
- American Center for Mobility (ACM) at Willow Run (Ypsilanti, MI),
- Contra Costa Transportation Authority (CCTA) & GoMentum Station (Contra Costa County, CA),
- San Diego Association of Governments (San Diego, CA region),
- Iowa City Area Development Group (Iowa City, IA),
- University of Wisconsin-Madison (Madison, WI),
- Central Florida Automated Vehicle Partners (Orlando, FL), and
- North Carolina Turnpike Authority (North Carolina).

### 3.3.2 Boston Seaport

Boston officially allows testing throughout the city, but has begun by allowing initial testing in a limited area of South Boston. This includes Raymond Flynn Marine Park and the South Boston Waterfront. Testing partners include Nutonomy, Optimus Ride and Aptiv. Testing must provide for human takeover from autonomous mode, emergency braking and emergency stopping capabilities and must demonstrate basic driving capabilities. Testing is phased, and Boston has allowed Nutonomy to expand its test zone over time and to pilot its vehicles in a variety of conditions.[14]

### 3.3.3 Pittsburgh

Uber began piloting self-driving taxis in Pittsburgh starting in September 2016. The self-driving vehicles operate with a safety driver present. It has operated a closed testing center in the city for several years prior to this.[15] Pittsburgh has become something of a center for autonomous vehicle research, due in no small part to the presence of Carnegie Mellon University.

### 3.3.4 Purpose-Built Test Facilities

Vehicle testing is underway at purpose-built closed testing facilities, such as Uber's Almono test facility in Pittsburgh and the MCity proving ground at the University of Michigan. These are meant to mimic the conditions of driving on public roads in more controlled conditions.

### 3.3.5 Ride Sharing

In addition to the Uber testing underway, both Ford and General Motors have intentions to launch major operations in autonomous ride sharing in the next several

14 Autonomous Vehicles: Boston's Approach. (2018, January 10). City of Boston, New Urban Mechanics. Retrieved from https://www.boston.gov/departments/new-urban-mechanics/autonomous-vehicles-bostons-approach.

15 Brewster, Signe (2016, Sept 14). "Uber starts self-driving car pickups in Pittsburgh." *Tech Crunch*. Retrieved from https://techcrunch.com/2016/09/14/1386711/.

years. GM intends to launch full autonomous ride sharing by 2019 in multiple cities through its Cruise self-driving car. Ford has plans to have fully autonomous vehicles on roads for ride sharing services in 2021.

**Figure 3-5 Autonomous Buses in Helsinki, Finland**


Source: Sisson, P. (2017, June 15). Driverless bus line coming to Helsinki this fall. Retrieved from https://www.curbed.com/2017/6/15/15810912/driverless-self-driving-bus-finland-helsinki-transportation.

### 3.3.6 Autonomous Bus Service

Helsinki, Finland started testing autonomous buses in August 2017. The small, electric buses carry up to 12 passengers along a fixed route, travelling at low speeds. An operator is on board to monitor service. This is believed to be the first instance of regular autonomous public transportation service. Helsinki has been active in a variety of efforts to increase public transit usage and decrease private car ownership. The city's public transport provider launched an on-demand public transit service that ultimately did not succeed, but autonomy may offer other options. These buses are considered an extension of the public transportation system and are intended to complement existing public transportation options.[16]



[16] Sisson, Patrick. (2017). "Driverless bus line coming to Helsinki this fall." Retrieved from https://www.curbed.com/2017/6/15/15810912/driverless-self-driving-bus-finland-helsinki-transportation.

The same buses used in Finland (made by Easymile) are set to be tested at the Bishop Ranch office park in San Ramon, California. Again, the buses will travel fixed routes at slow speeds. Shuttles can run in *transit* mode – stopping at every fixed stop – or in *bus* mode, stopping only when requested by a passenger. They are also capable of on-demand service. Service may be phased into more wider use as the vehicles demonstrate they are able to handle complex traffic scenarios.[17]

In 2017, transit operator Keolis partnered with French autonomous technology company NAVYA to launch a short, automated, public bus test in Las Vegas, NV. The test area was limited to three blocks, and the small electric bus carried up to 12 passengers at a time for approximately 10 days in January. This is thought to be the first use of a self-driving bus along an American public road.[18]

### 3.3.7 Pedestrian and Cyclist Applications

Pedestrian and bicycling advocates have been hesitant about the rollout of autonomous vehicles. There is fear that autonomous vehicles may not successfully identify bicyclists and pedestrians in the street environment, and these vulnerable users are much more likely to be injured or killed in the event of a crash.

The League of American Bicyclists conducted a 2014 survey about perceptions of safety among bicyclists and pedestrians regarding autonomous vehicles. The results indicate that their study group anticipated *increased* safety (42 percent of respondents) more than decreased safety (14 percent). A large number indicated that they did not yet have enough information to make a determination either way (43 percent).[19]

The same survey asked respondents about their specific concerns about sharing the road with autonomous vehicles. When asked to pick one from a series of possible responses, the following were most prevalent:

- new technology might distract from efforts to promote biking and walking for transportation;
- the possibility of technology failures that will affect the safety of biking and walking; and
- the inability to communicate with the car (e.g. no eye contact with a driver).

Connected vehicle technology may have a role to play, enabling connected vehicles to identify and communicate with bicyclists and pedestrians. However, adoption of this technology by the walking and cycling community may prove difficult. The

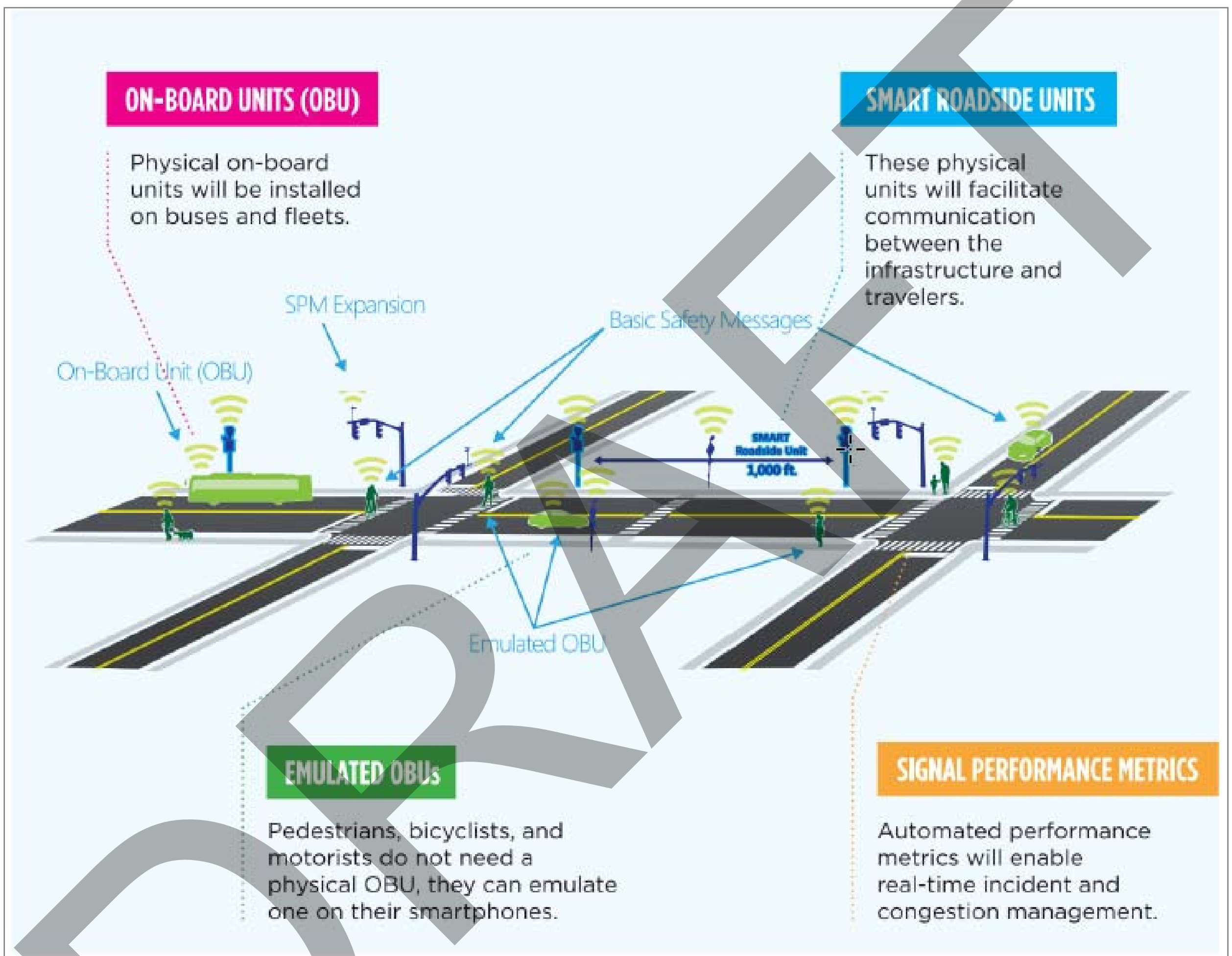
17 Levin. Adina. (2017, July 19). "Touring Bishop Ranch Autonomous shuttle pilot – what will it take to go mainstream? Retrieved from http://www.greencaltrain.com/2017/07/touring-bishop-ranch-autonomous-shuttle-pilot-what-will-it-take-to-go-mainstream/.

18 Granger, Jesse. (2017, Jan 11). "Self-driving shuttle bus launches test run along Fremont East, a first in the U.S." *Las Vegas Sun*. Retrieved from https://lasvegassun.com/news/2017/jan/11/self-driving-shuttle-bus-launches-test-run-along-f/.

19 McLeod, Ken. (2015, June 18). Will Automated Cars Make Bicyclists Safer? Retrieved from http://bikeleague.org/content/will-automated-cars-make-bicyclists-safer.

League of American Bicyclists survey also found that a sizeable portion of respondents said they would not be likely to wear a device able to communicate with cars. Some systems designers are looking to mobile phones or other devices for this purpose, though it may not be sufficient to assume that vulnerable users be able to self-identify their presence to CAVs, whether with a phone or other device.

**Figure 3-6 Florida DOT's PedSafe System**




Source: Florida DOT. (2017). Orlando Smart Community 2017 ATCMTD. Retrieved from http://www.fdot.gov/traffic/its/projects_deploy/cv/MapLocations/ATCMTD_Orlando.shtm.

Florida DOT is currently designing a collision avoidance system for bicyclists and pedestrians. PedSafe will use connected vehicle technology, dedicated short range communications, roadside units, onboard units, audible basic safety messages and advanced signal technology to identify vulnerable users and prevent crashes. It will be piloted around the University of Central Florida campus and its vicinity.

It is further possible that the typical game-of-chicken relationship between pedestrians and cars may be entirely upended by the introduction of CAVs. Whereas pedestrians currently have to weigh their options and make a cost-benefit calculation about crossing a street in a particular location, in the future they may have the benefit of an entire field of safety-first, law-abiding vehicles programmed to universally yield if a human steps into the street, regardless of location. This benefits pedestrians, but simultaneously could increase CAV travel times in places with high levels of pedestrian activity.[20] This type of pedestrian behavior would also slow transit and delivery vehicles and make for confusing relationships between cyclists and pedestrians.

Conversion to on-demand CAVs holds promise for a wholescale redesign of streets in ways that could benefit pedestrians and cyclists. Pedestrians may be able to cross a street almost anywhere in the future, for instance. CAVs may be managed to operate at safe and desirable speeds, also facilitating ease of crossing and a more comfortable environment for cyclists. As travel lanes may be narrower and parking or stopping would be in much less demand, the right-of-way of a typical street may be reapportioned to provide much more space for pedestrians, bicyclists and human-scale activity.[21]

It is difficult to precisely anticipate future interactions between pedestrians, cyclists and CAVs (and related smart infrastructure), but automated systems designers are testing their vehicles in mixed traffic environments today, and a high degree of safety is a central goal.

Safety must be paramount, and regulatory agencies must make certain this is codified in law. Bicyclists and pedestrian safety have the potential to improve significantly with the adoption of CAVs, as these vulnerable users are injured and killed in crashes each year at a rate much higher than their modal share. Taking motor vehicle drivers out of the crash equation may make the landscape much safer for bicyclists and pedestrians.

The valorous outcomes that could result with CAV introduction are by no means a given. Dystopian outcomes are also possible – more traffic, higher emissions, uncrossable streets and highly channelized pedestrian movement. Regulatory agencies must be prepared with plans and policies to guide CAV technology away from this potential future.

## 3.4 Rhode Island

The Rhode Island Department of Transportation (RIDOT) solicited a Request for Information (RFI) in mid-2017 regarding CAVs and other innovative transport systems. The goal of the RFI was to gather information that will enable the State to facilitate and expedite the adoption of CAV and other innovative transport system technologies.



20 Millard-Ball, Adam. "Pedestrians, autonomous vehicles and cities." *Journal of Planning Education and Research* 38:1 (2018): 6-12. Web.

21 NACTO (2017). *Blueprint for Autonomous Urbanism*. National Association for City Transportation Officials. Retrieved from https://nacto.org/wp-content/uploads/2017/11/BAU_Mod1_raster-sm.pdf.

RIDOT established the Rhode Island Transportation Innovation Partnership (TRIP), a collaboration between RIDOT and other state and local partners, with the intent to test automated, multi-passenger vehicles. Potential opportunities that have been proposed include:

1. *Woonasquatucket Corridor – CAV connectivity along the Woonasquatucket corridor and serving Providence's urban core, connecting new development in the corridor with transit-dependent residents in Olneyville and downtown Providence;[22]
2. Pawtucket/Central Falls – CAV connectivity around Pawtucket and to the potential new baseball stadium and upcoming Pawtucket/Central Falls Transit Center and to the intercity bus terminal in Providence;
3. *Providence Smart City – connectivity encompassing the new LINK District and intermodal transit hubs at the Providence Amtrak/MBTA Station and the Hospital District;
4. Quonset Business Park – employee transportation and business/manufacturing options to and within the business park district, the Port of Davisville, with potential connectivity to Wickford Junction Commuter Rail Train Station;
5. University of Rhode Island Kingston Campus – connectivity on the campus roadway network and to the Kingston and the Wickford Junction Commuter Rail Stations; and
6. Interstate Highway Shoulders – potential dedicated transit lanes using interstate highway shoulders throughout Rhode Island.[23]

RIDOT also hosted the Rhode Island Transportation Innovation Partnership Expo in September 2017. These meetings worked to facilitate discussion among experts and transportation industry leaders about the future of autonomous vehicles in Rhode Island.



22 RIDOT. "Trip Mobility Challenge: Bringing Next-Generation Mobility to Historic Providence" Retrieved from http://www.dot.ri.gov/projects/trip/docs/TRIP_Mobility_Challenge.pdf

23 RIDOT, (2017, June 6). "Connected and Autonomous Vehicles and Other Innovative Transport." Request for Information #7553496.

# 4

## Transportation Planning Impacts

"The onset of automated vehicles marks a critical and consequential turning point in the history of mobility – as important as the early 20th century rise of motordom. In the absence of ... policies [building a policy agenda and aspirational framework for the deployment of automated vehicles], transportation network companies and technology companies will shape urban transportation policy by default."[24]

While it is impossible to precisely forecast all the implications and timeline for the introduction of CAVs, some themes have been repeatedly amplified by researchers and transportation professionals thinking and writing on the subject. These include potentially large-scale changes to: the labor market, residential preferences, the auto-oriented supply chain (particularly for internal combustion vehicles), vehicle ownership, traffic safety, freight movement, household transportation costs, access to mobility services, vehicle form, need for parking, the form of roadways, traffic congestion and management, and public transportation.

These issues highlight the need for state and local governments to be proactive in their consideration of the implications of CAVs. Governments must look to build a

[24] NACTO. (Fall 2017). *Blueprint for Autonomous Urbanism*. New York: National Association of City Transportation Officials. Web.

policies, goals and objectives that can reap the rewards of this new technology and best serve the long-term needs of their residents.

## 4.1 Non-Transportation Impacts

Some potential impacts will not be directly associated with transportation, but are briefly mentioned here, as they will be part of the policy landscape pertinent to state and local government decision-making.

### 4.1.1 Labor

There are estimated to be approximately 3.5 million professional truck drivers in the US, and another 4 million employed in associated roles (e.g. warehousing).[25] The Bureau of Labor Statistics estimates that as of 2016 there are 305,000 professional taxi drivers (including ride-hailing and chauffeurs), 687,000 bus drivers, 1.4 million delivery truck drivers, and 682,000 material moving machine operators.[26] It remains to be seen what the effect or timing of CAV deployment will be on these jobs, but ride-hailing companies such as Uber are specifically crafting their technology to provide self-driving vehicles that replace taxi-type jobs. Traditional auto manufacturers including Ford, Volvo and General Motors are also moving in this direction, toward mobility-as-a-service models.

Professional drivers comprise a significant segment of the labor market. Should some – or all – of these jobs be replaced by automation, today's professional drivers will need re-training to continue work.

### 4.1.2 Residential choice

It's difficult to predict how CAVs may affect residential choice. It is possible that CAVs may propel low-density sprawl development even further, as they may be able to travel faster and more reliably, and let passengers engage in other activities while traveling. Conversely, the living in denser cities may become more desirable due to the changing form of urban streetscapes/landscapes – particularly as less space is required for vehicle movement, pedestrian and cycling facilities improve and plots of land become available for redevelopment.

## 4.2 Transportation Impacts

This section focuses on transportation-related impacts that will be relevant to state and local transportation planning and engineering agencies.



25 American Trucking Association (2018). "Reports, Trends and Statistics." Retrieved from http://www.trucking.org/News_and_Information_Reports_Industry_Data.aspx.

26 US Bureau of Labor Statistics. *Occupational Outlook Handbook*. Retrieved from https://www.bls.gov/ooh/.

US Dept of Transportation. *Federal Automated Vehicles Policy: Accelerating the Next Revolution in Roadway Safety*. National Highway Transportation Safety Admin. 12507-091216-v9. Web.

### 4.2.1 Auto-Oriented Supply Chain

A wide variety of businesses exist to support the private car ownership and operation market. This includes car dealerships, secondary car sales, gas stations, auto maintenance/repair facilities, parts manufacturers, etc. Even the oil industry at large is included within this supply chain. As more vehicles become electric and the market for shared CAVs grows, these businesses could enter a vicious cycle that could lead to decreased business and business closure.[27] Again, individuals employed in these sectors will require re-training. From a planning perspective, the closure of these businesses presents both serious land use challenges (e.g. corridors designated for a high volume of auto-oriented businesses) and opportunities for redevelopment as businesses close.

### 4.2.2 Vehicle Ownership

Vehicle ownership may decline significantly as CAVs become prevalent; shared-use CAV systems, in particular. This will largely be driven by the significant cost savings available as people begin purchasing mobility as a service. If lower-cost, high-quality, affordable and dependable alternatives exist to owning a private vehicle, the market will push people away from auto ownership. Some have predicted that shared-use CAVs will effectively end traditional automobile ownership as we know it.[28] This will have policy implications for vehicle registration and licensing operations and fees.

### 4.2.3 Traffic Safety

Traffic safety is predicted to significantly improve as reliable CAV technology is adopted. This is a simple acknowledgement of the high numbers of vehicular crashes in the US, and the associated deaths and injuries that result from these crashes. The vast majority of crashes are the fault of human error and inattention. Autonomy will remove the human driver from making choices that lead to crashes.

There remain fears that autonomy poses its own safety problems. There are questions still about the effectiveness of the technology to safely navigate a variety of complex transportation environments, and that this connected technology may be subject to hacking and outside interference. Regulatory agencies will need to hold the CAV service providers to account on these concerns, and providers must ensure that the systems operate in a safe and secure manner.



[27] Arbib, et al. (2017).

[28] Ibid.

### 4.2.4 Freight Movement

A large percentage of freight in the US is driven by professional truck drivers. Other major segments include parcel delivery, air, rail and sea freight sectors. Automation may have changes on all sectors. In March-April 2017, demonstration truck platoons travelled across Europe as part of the EU Truck Platooning Challenge. This demonstration used connected vehicle technology to allow trucks to platoon on roadways with very close following distances.[29] There is the possibility that trucks in the future may be able to operate with a lead truck and platooned drone trucks behind. It's conceivable that CAVs may come into play in other freight and freight handling industries on an increasing basis. How changes in freight and freight handling will require changes in the built environment or must be responded to by policy remain to be seen.

**Figure 4-1 Connected Truck Platooning**

Source: European Truck Platooning Challenge (2017).



### 4.2.5 Household Transportation Costs

Significant household cost savings may be realized through the switch to CAVs. Today's vehicle owners need to purchase, maintain, insure, park and fuel cars. In the future, these costs may be borne by a mobility service provider, whereby a consumer purchases on-demand service similar to ride-hailing or taxis today, but significantly

[29] European Truck Platooning Challenge. (2017). Retrieved from https://www.eutruckplatooning.com.

cheaper. The reason for the lower costs mainly lie in the cost savings mentioned above, but also in the vastly higher utilization of an on-demand, shared CAV when compared to a privately-owned vehicle.[30]

### 4.2.6 Access to Mobility Services

CAV introduction may provide much greater access to mobility services for some populations. If prices are affordable, it could provide effective transportation options to households without access to a car and the elderly, increasing mobility and access to jobs, education and health care. Policy makers will want to ensure that these valuable outcomes are realized as CAVs are introduced.

### 4.2.7 Vehicle Form

The traditional vehicle form may be subject to change as human drivers disappear and crashes become far less prevalent. Vehicles may come in a variety of forms and sizes to maximize utility. Laws and regulations will need to facilitate some of these changes, as they may be based on the premise of human drivers and crash safety/mitigation within the current transportation scenario.

### 4.2.8 Parking

In today's land use and development context, parking is often the single most important constraint for development to occur. CAVs may upend this supposition as mobility services deliver passengers to destinations and can leave the scene. A shared-use CAV could immediately engage in another trip. Development patterns of big box retail surrounded by an ocean of parking may become obsolete, freeing up a tremendous amount of space in most urbanized areas for potential redevelopment. Figure 4-2 demonstrates how the decrease in parking needs could impact upon the built form for a given space.

Curbside parking would be subject to major changes as well. Today, cities dedicate significant amounts of curb space to parking. The general convention is to allocate curb use based on adjacent land use, using meters and time limits to ensure turnover. In busy areas, vehicles may circle blocks and the nearby area hunting for parking. In the future, there will be opportunities to dynamically price for parking based on demand. Cities may be able to charge vehicles for time spent at a curb, and communicate where parking is available.[31]

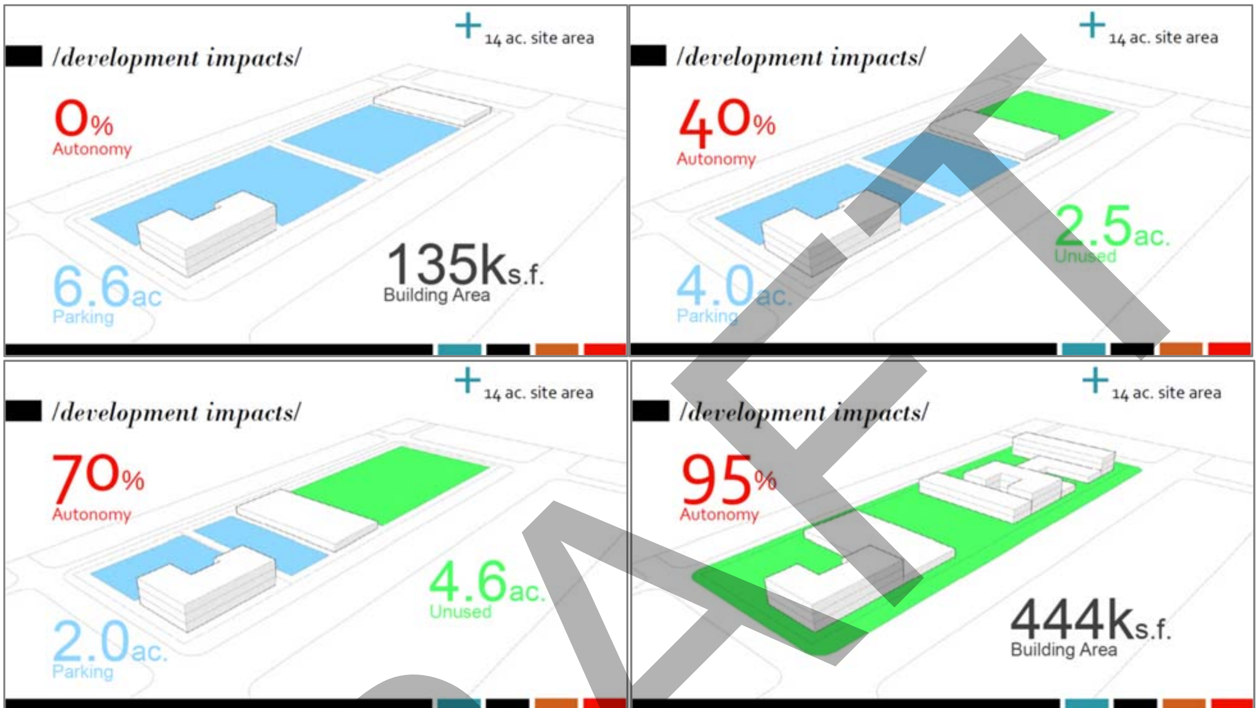
In general, far less curbside parking may be required in the future – this space may be available to reallocate to other uses.

Parking structures may also become a liability. Structures not designed in a way that they can be readily repurposed (e.g. parking structures with inadequate floor-to-

[30] Arbib, et al. (2017).

ceiling heights and ramped floorplates) may become obsolete. Public entities that own, operate or are considering construction of parking will need to consider their options carefully.

**Figure 4-2 Impact of Surface Parking Reduction on Development Patterns**




Source: Stein, R. et al (2017).

### 4.2.9 Roadway Form

CAVs may operate in a manner quite different than current transportation patterns. The National Association for City Transportation Officials (NACTO) anticipates that it may be possible to use emerging technology to increase the capacity of a travel lane substantially, which allows more people to move in less space. NACTO suggests that CAVs can move more people in fewer vehicles on less congested streets.[32] One estimate puts the number of passenger vehicles on American roads declining from 247 million to 44 million. This allows for a radical rethinking of public rights-of-way. The form of future streets will be up to policymakers and presents an important opportunity.

CAVs would effectively increase the capacity of every existing travel lane, so there may be less need to develop new roadway capacity.



32 NACTO (2017).

### 4.2.10 Traffic Congestion and Management

There are two schools of thought regarding how CAVs will affect traffic. The first, as has been stated multiple times previously in this report, is that far fewer vehicles will be required to carry people more efficiently. An alternate view is that as mobility will become so convenient and affordable, trip generation may be induced, and vehicles may occupy space on streets with no human occupants at times, as well.

CAVs are likely to facilitate reduced congestion in several ways. The first is through the reduced number of vehicles on roadways, as described above. CAV safety applications are also anticipated to significantly reduce crashes and associated delays, while CAV mobility applications may increase system efficiency through platooning behavior. This is maximized with widespread deployment of connective technologies in vehicles, alongside vehicle-to-infrastructure technologies, where the streets themselves become part of mobility management systems.[33]

CAVs provide an opportunity to manage traffic in a very different way in the future. Traffic may be managed in real-time, and cities may be able to use pricing mechanisms to incentivize shared and active modes over private trips.[34]

### 4.2.11 Public Transportation

The timeline for adoption of autonomous public transportation is similarly somewhat speculative. By one estimate, we may see level 3 autonomous vehicles on bus rapid transitways and high occupancy vehicle lanes within 5-10 years, level 4 operations on low speed mixed traffic city streets in 10-15 years, and level 4 and 5 operations in all environments in 15-20 years.[35, 36]

While autonomy may become available to public transport providers, it's also possible that private mobility service providers may begin to directly compete with traditional public transportation. In this scenario, some public benefits of CAVs may be achieved (e.g. improved mobility for those who don't own cars; less parking), but



33 National Academies of Sciences, Engineering, and Medicine. 2017. Advancing Automated and Connected Vehicles: Policy and Planning Strategies for State and Local Transportation Agencies. Washington, DC: The National Academies Press. https://doi.org/10.17226/24872

34 NACTO (2017).

35 Lott, J. Sam, (2017, Nov 16). "Impacts of Transit System Regulations and Policies on CV/AV Technology Introduction." Transportation Research Board Webinar. NCHRP 20-102 (02).

36 Some manufacturers are deciding to skip level 3 because it allows higher levels of automation, but still requires the driver to reengage should a problem arise that the vehicle cannot navigate. This could require a driver to receive a warning and would have about 90 seconds to re-acclimate and take back control of the vehicle. The issues surrounding this level are highly debated.

there is also possibility for additional traffic and replacement of high-capacity transit vehicles (trains and buses) with smaller, less space-efficient CAVs.[37]

CAVs may be able to complement other public transit systems (as is the intention with the Helsinki example described earlier), especially fixed assets like railways. In the future, buses may not run on fixed routes as they do today. Mobility may be provided door-to-door, hub-to-hub, on a flexible route or via a fixed route. The role of public transportation providers may change from owning and operating vehicles and assets to managing CAV providers to ensure high quality, affordable, equitable access to mobility-as-a-service.[38]

Public transit will continue to be important, as the sole resource able to realize large numbers or time-efficient trips in minimal space in dense urban environments. Shared CAVs of varying sizes would be able to reinforce high capacity core public transport networks. One policy document surmises that the benefits of this technology may only be possible if CAVs are introduced as shared fleets, well-integrated with high-quality public transport.[39] The appropriate regulatory frameworks need to be created by state and local governments in to ensure that CAVs can serve public policy goals.

As with other professional drivers, public bus and paratransit drivers may gradually be replaced by CAV technology, and retraining will be required. There will still be a workforce required to support these new types of vehicles, but it will be fewer people than the current model.

## 4.3 Key Policy Needs

State and local policymakers need to be proactive to prepare the ground for the coming CAV technological change. If they do not, then market forces and private actors will do this in their stead, and the outcomes may not be to the overall public benefit. Below are some key policy issues that public agencies may wish to address. Note that NHTSA's CAV policy includes model best practices for states.

### 4.3.1 Principles and Goals

NACTO's *Blueprint for Autonomous Urbanism* has proposed a series of principles that might be used to guide specific policies and regulations to facilitate the technology to benefit public needs first.[40] State and local governments might want to consider their own principles to inform policy choices regarding CAVs. NACTO's principles include:



37 International Association of Public Transport (UITP) (2017, January). "Autonomous vehicles: a potential game changer for urban mobility." Retrieved from http://www.uitp.org/news/autonomous-vehicles-urban-mobility.

38 Arbib, et al (2017).

39 UITP (2017).

40 NACTO (2017).

- Safety should be the Top Priority
- Mobility should be Provided for the Whole City
- Rebalance the Right-of-Way
- Manage Streets in Real Time
- Move More with Fewer Vehicles
- Ensure that Public Benefit Guides Private Action

### 4.3.2 Policy Recommendations[41, 42, 43]

**Encourage CAV Testing**

- Various technology firms are already testing in a variety of environments. Passing legislation to allow their operation locally makes the state and local governments partners in their development, and will facilitate local knowledge and familiarity with the technology as it changes.
- Some traffic laws may need to be reviewed and possibly revised to provide a legal basis for testing CAVs.

**Vehicle Regulation**

- Prepare the groundwork for CAVs. These vehicles will begin to blur the distinctions about the traditional role of federal, state and local governments with respect to vehicular operation. Vehicle and technology regulation should be left with NHTSA.
- Develop model state laws and regulations. Review the NHTSA model policy (Version 2.0, 2017) and subsequent iterations.
- Liability rules must be reviewed, as CAVs will not have a driver in the future, and may not be owned by its occupants.
- Establish regulations to identify CAVs. The data systems that track information on vehicle title and registration, driver licensing, etc. need to be able to identify CAVs.

**Include CAV Technology in Planning Processes and Documents**

- As planning documents are written and revised consideration must be given to the implications of CAV technology. This does not only apply to transportation-specific plans, but anywhere CAVs may have a role to play.

**Review and Revise Parking Codes**



41 Hedlund, James (2017). "Autonomous Vehicles Meet Human Drivers: Traffic Safety Issues for States." Governors Highway Safety Association. Retrieved from https://www.ghsa.org/sites/default/files/2017-01/AV%202017%20-%20FINAL.pdf.

42 NACTO (2017).

43 Stein, et al (2017).

- Any new parking garages must be able to be adapted to alternate uses.
- Parking requirements for new development should be reduced.

**Land Use Changes**

- Create land use overlay districts to anticipate future changes – auto-oriented service corridors, for instance.
- Consider plans for redevelopment of retail land that may become obsolete. Anticipate parts of communities most subject to change or outright market failure with the introduction of CAVs.
    - What will you do with excess retail areas, parking lots, corner lots?

**Develop Institutional Knowledge and Understanding Among Policymakers**

- Provide information and learning sessions to elected officials, planning commissions, etc.
- Provide educational content for governmental staff. Create a working group across departments and disciplines to review policies. Law enforcement must be included.

**Engage in Public Education**

- CAVs are not well understood by the public and public education efforts will be required. This will be particularly important during the transition period from partial autonomy to full autonomy, when CAVs will be sharing the road with human drivers.

**Transit**

- Invest strategically in transit. Modernize and strengthen transit on high volume routes. Strengthen the transit backbone.
- Ensure that transit agencies are considering their future position with respect to CAVs and planning appropriately.

### 4.3.3 Strategy Recommendations[44]

The following strategies have been identified for public officials to consider when trying to guide the direction of CAV impacts. Strategies are presented based on the outcomes they intend to achieve. Each strategy is evaluated using the following

[44] National Academy of Sciences, (2017) "Strategies to Advance Automated and Connected Vehicles: Briefing Document." Key findings from NCHRP Research Report 845: Advancing Automated and Connected Vehicles: Policy and Planning Strategies for State and Local Transportation Agencies. Accessed 2/16/18 from http://www.trb.org/Main/Blurbs/176508.aspx.

criteria. Effectiveness, Efficiency, Political Acceptability, and Operational Feasibility are rated on a scale from 1 (low) to 5 (high).

- **Effectiveness:** If the strategy is economic, how well does it internalize external costs into decision making by producers and consumers? If the strategy is not economic, how likely is it to achieve its desired policy outcome?
- **Efficiency:** If the strategy is economic, how well does it recover the costs from the externality? How likely is the strategy to produce a net-positive social benefit outcome?
- **Political Acceptability:** How likely is the general public to accept this strategy? Are any politically powerful stakeholders likely to oppose the strategy? How likely is the strategy to increase costs, place burdens on low income or socially disadvantaged groups, or result in social inequity?
- **Operational Feasibility:** How disruptive is implementation to the implementing agency? Are new or complex governing structures required? Is it expensive to implement? Are new workforce skills or infrastructure adaptation required?
- **Geographic Impact:** At what geographic scale does this strategy make the most sense?
- **Who:** What level of government would implement this strategy?
- **Hurdles:** Are there any notable barriers to implementation?

**Table 4-1 Mitigating Safety Risks Through Testing, Training, and Public Education.**

<table>
<tr><th>Strategy</th><th>Effectiveness</th><th>Efficiency</th><th>Political Acceptability</th><th>Operational Feasibility</th><th>Geographic Impact</th></tr>
<tr><td rowspan="2">Enact legislation to legalize autonomous vehicle (AV) testing</td><td>2</td><td>2</td><td>2</td><td>2</td><td>Urban, Suburban, Rural</td></tr>
<tr><td colspan="5">Who is responsible?<br>> Legislatures, and state and local transportation agencies<br>Key hurdles:<br>> Passing enabling legislation, Identifying funding sources for rulemaking and administration of testing requirements.</td></tr>
<tr><td rowspan="2">Enact Legislation to Stimulate CV or AV Texting</td><td>3</td><td>3</td><td>2</td><td>3</td><td>Urban, Suburban, Rural</td></tr>
<tr><td colspan="5">Who is responsible?<br>> Legislatures, and state and local transportation agencies<br>Key hurdles:<br>> Passing enabling legislation, upgrading or installing new infrastructure, creating new governmental agreements and partnerships</td></tr>
<tr><td rowspan="2">Modify Driver Training Standards and Curricula</td><td>3</td><td>3</td><td>3</td><td>2</td><td>State</td></tr>
<tr><td colspan="5">Who is responsible?<br>> Legislatures, State licensing/training agencies<br>Key hurdles:<br>> Operational issues</td></tr>
<tr><td rowspan="2">Increase Public Awareness of Benefits and Risks</td><td>3</td><td>4</td><td>4</td><td>4</td><td>Urban, Suburban Rural</td></tr>
<tr><td colspan="5">Who is responsible?<br>> State and local agencies<br>Key hurdles:<br>> Developing trusted messages given uncertainties in technology deployment, benefits and drawbacks</td></tr>
<tr><td rowspan="2">Subsidize Shared AV Use</td><td>1</td><td>3</td><td>2</td><td>3</td><td>Urban, Rural</td></tr>
<tr><td colspan="5">Who is responsible?<br>> Public transit agencies, Cities<br>Key hurdles:<br>> Implementation issues (subsidies needed only for special use cases)</td></tr>
<tr><td rowspan="2">Implement Transit Benefits for Shared AVs</td><td>3</td><td>3</td><td>4</td><td>4</td><td>Urban</td></tr>
<tr><td colspan="5">Who is responsible?<br>> Public transit agencies, Employers<br>Key hurdles:<br>> Regulatory: Congressional action is needed</td></tr>
<tr><td rowspan="2">Implement a Parking Cash-Out Strategy</td><td>3</td><td>2</td><td>5</td><td>4</td><td>Urban</td></tr>
<tr><td colspan="5">Who is responsible?<br>> Employers<br>Key hurdles:<br>> Institutional – few direct benefits for employers to implement</td></tr>
</table>

**Table 4-1 (Continued) Mitigating Safety Risks Through Testing, Training, and Public Education**

<table>
<tr><th>Strategy</th><th>Effectiveness</th><th>Efficiency</th><th>Political Acceptability</th><th>Operational Feasibility</th><th>Geographic Impact</th></tr>
<tr><td rowspan="2">Implement Location-Efficient Mortgages</td><td>1</td><td>2</td><td>3</td><td>3</td><td>Urban</td></tr>
<tr><td colspan="5">Who is responsible?<br>> Lenders<br>Key hurdles:<br>> Political</td></tr>
<tr><td rowspan="2">Implement Land Use Policies & Parking Requirements</td><td>3</td><td>3</td><td>3</td><td>4</td><td>Urban</td></tr>
<tr><td colspan="5">Who is responsible?<br>> Local government agencies, Metropolitan Planning Organizations (MPOs)<br>Key hurdles:<br>> Political, objections by private developers and local residents</td></tr>
<tr><td rowspan="2">Apply Road Pricing</td><td>4</td><td>5</td><td>1</td><td>3</td><td>Urban, Suburban, Rural</td></tr>
<tr><td colspan="5">Who is responsible?<br>> State and local agencies<br>Key hurdles:<br>> Public and political opposition</td></tr>
<tr><td rowspan="2">Implement a No-Fault Insurance Approach</td><td>3</td><td>2</td><td>2</td><td>3</td><td>Statewide</td></tr>
<tr><td colspan="5">Who is responsible?<br>> State legislatures, State insurance agencies<br>Key hurdles:<br>> Political feasibility, powerful stakeholder groups</td></tr>
<tr><td rowspan="2">Require Motorists to Carry More Insurance</td><td>4</td><td>5</td><td>3</td><td>5</td><td>Statewide</td></tr>
<tr><td colspan="5">Who is responsible?<br>> State legislatures, State insurance agencies<br>Key hurdles:<br>> Popularity with general public, enforcement of insurance minimums</td></tr>
<tr><td rowspan="2">Subsidize Connected Vehicles (CVs)</td><td>4</td><td>4</td><td>1</td><td>3</td><td>Urban, Suburban, Rural</td></tr>
<tr><td colspan="5">Who is responsible?<br>> State and local agencies<br>Key hurdles:<br>> Political feasibility: allocation of funds with unknown return on investment</td></tr>
<tr><td rowspan="2">Investment in CV Infrastructure</td><td>1</td><td>0</td><td>1</td><td>1</td><td>Urban, Suburban, Rural</td></tr>
<tr><td colspan="5">Who is responsible?<br>> State DOTs, Cities, Toll agencies, MPOs<br>Key hurdles:<br>> Funding availability, understanding benefits AV compatibility</td></tr>
<tr><td rowspan="2">Grant AVs and CVs Priority Access to Dedicated Lanes</td><td>3</td><td>4</td><td>2</td><td>2</td><td>Urban</td></tr>
<tr><td colspan="5">Who is responsible?<br>> State and local road operators<br>Key hurdles:<br>> Political, operational</td></tr>
</table>

**Table 4-1 (Continued) Mitigating Safety Risks Through Testing, Training, and Public Education.**

<table>
<tr><th>Strategy</th><th>Effectiveness</th><th>Efficiency</th><th>Political Acceptability</th><th>Operational Feasibility</th><th>Geographic Impact</th></tr>
<tr><td rowspan="2">Grant Signal Priority to CVs</td><td>1</td><td>2</td><td>2</td><td>4</td><td>Urban, Suburban</td></tr>
<tr><td colspan="5">Who is responsible?<br>> State and local transportation agencies that operate traffic signals<br>Key hurdles:<br>> Political</td></tr>
<tr><td rowspan="2">Grant Parking Access to AVs and CVs</td><td>1</td><td>3</td><td>2</td><td>4</td><td>Urban</td></tr>
<tr><td colspan="5">Who is responsible?<br>> Local government<br>Key hurdles:<br>> Effectiveness</td></tr>
<tr><td rowspan="2">Implement new contractual mechanisms with private-sector providers</td><td>2</td><td>4</td><td>2</td><td>2</td><td>Urban</td></tr>
<tr><td colspan="5">Who is responsible?<br>> Transportation agencies in urban areas (e.g. state DOTs, cities, toll authorities, public transit agencies)<br>Key hurdles:<br>> Viable business models, legal and governance, political acceptability</td></tr>
</table>

## 4.4 Key Infrastructure Needs

At present, automated vehicles are being tested on standard roads with no additional smart technology. NHTSA's autonomous vehicle policy states that vehicles will be required to adhere to all traffic control as outlined in the Manual on Uniform Traffic Control Devices (MUTCD).

In the future, if agencies want to have the data and traffic management benefits of connected vehicles, they will need to have communications technology and infrastructure that will allow that information to be collected.

Connected vehicles use computing and sensing technology and wireless communication to collect and share information between vehicles (V2V), with the infrastructure (V2I), or with other mobile devices (V2X). V2V enables crash prevention and platooning and vehicle-to-infrastructure technology (V2I) enables telecommunication, safety, mobility and environmental benefits. Infrastructure may also be able to communicate with non-vehicle devices, such as mobile phones or other devices. Dedicated short-range communication (DSRC) and 5G wireless communication can provide intercommunication with vehicles. At present, DSRC is already in place in some communities, but they only provide driver alerts.[45] Smart

[45] National Academies of Sciences, Engineering, and Medicine. 2017.

roadways will require the installation of roadside devices to enable these communications to take place.

Traffic management systems using these new integrated technologies will be another added infrastructure requirement. Many cities have invested in traffic management centers (TMCs) where they are able to dynamically communicate with traffic signal systems to improve vehicular movements. Next generation TMCs will be able to make use of intercommunication with vehicles and other transport network users to optimize these movements to a much higher degree.

Additional infrastructure improvements may be required to realize the public mobility promises of CAV technology. Strengthening core transit networks includes investing in planning and design, construction, transit vehicle acquisition and/or upgrades and ongoing maintenance. Shared CAVs will require designated pickup and drop-off zones to achieve the potential of reduced parking. Streets may need to be redesigned as fewer vehicles are needed. Freight vehicles will need designated spaces for loading as parking decreases. New bicycle and pedestrian facilities may need to be constructed as public right-of-way space is reallocated to other uses.

It is still questionable whether there will be a reduction in parking or fewer vehicles with the introduction of CAVs. Some think there will be more vehicles and those that still own a car or drive alone today will still ride alone in a CAV in the future. This will depend on how public outreach is pursued and the trajectory/success of the shared use business model with the travelling public.

Like all infrastructure improvements, maintenance will be required for these systems. Even with fewer vehicles, roadways conditions will need to improve. CAVs will require high quality pavement conditions, pavement markings and signs. Redesigned roadways with more space for transit, pedestrians or bicycles will nonetheless require ongoing maintenance investments, as well.

### 4.4.1 Technology Uncertainty

While it is becoming very clear that connected/automated vehicles are becoming a reality, there is still a great deal of uncertainty in precisely how or which technologies will be on the road in 10 to 20 years.

Unlike ridesharing and other shared mobility practices, connected/autonomous vehicle technology is in the earliest stages of adoption with a great deal of development and policy making yet to come. How driving trends could change over the next 20 years is unclear. The Victoria Transport Policy Institute offers several predictions for possible scenarios (see Table 4-2).

Many of these trends lend themselves to increased vehicle travel, parking needs, and roadway costs. Additionally, studies typically agree that there are opportunities to enhance traffic safety through connected/autonomous vehicles due to their ability to perceive dangerous situations and react quickly; reducing perception reaction times typical of human drivers, particularly those who are distracted. Table 4-3 summarizes some of the possible benefits and costs of autonomous vehicles.

**Table 4-2 Some Possible Future Autonomous Vehicle Scenarios**

| Scenario | Travel Impacts | Infrastructure Impacts |
|---|---|---|
| **Independent mobility for non-drivers**<br>Jake is an affluent man with degenerating vision. In 2026 his doctor convinced him to give up driving. He purchases an autonomous vehicle instead of shifting to walking, transit and taxies. | Increased vehicle travel and external costs | Increased residential parking and roadway costs |
| **Vehicle cost savings**<br>Bonnie lives and works in a suburb. She can bike to most destinations but occasionally needs to travel by car. In a city she could rely on taxis and car sharing, but such services are slow and expensive in suburbs. However, starting in 2030 a local company started offering fast and affordable automated taxi services. | Reduced vehicle ownership and travel | Reduced residential parking and roadway costs |
| **Improved home location options**<br>Malisa and Johnny have two children. Malisa works at a downtown office. After their second child was born in 2035, they shopped for a larger home. With conventional cars they would only consider houses within a 30-minute drive of the city, but more affordable new autonomous vehicles let them consider more distant homes, with commutes up to 60-minutes, during which Malisa could rest and work. | Increased vehicle ownership and travel | Increased residential parking and roadway costs |
| **Avoids driving drunk and associated consequences**<br>Garry is hard-working and responsible when sober, but a dangerous driver when drunk. By 2040 he had accumulated several impaired citations and caused a few accidents. With conventional cars Garry would continue driving impaired until he lost his drivers' license or caused a severe crash, but affordable used self-driving vehicles allow lower-income motorists like Garry to avoid such problems. | Less high-risk driving, more total vehicle travel | Increased residential parking and roadway costs |

Source: Litman, Todd. Victoria Transport Policy Institute. "Autonomous Vehicle Implementation Predictions: Implications for Transport Planning". September 8, 2017.

**Table 4-3 Autonomous Vehicle Potential Benefits and Costs**

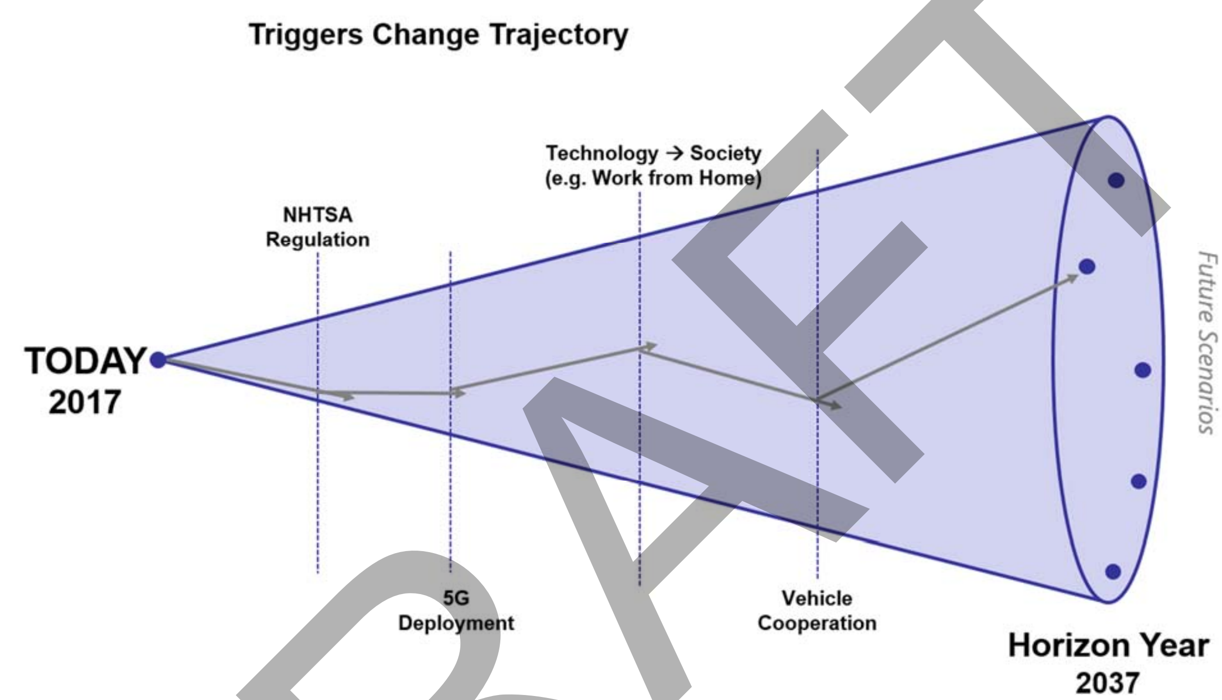
| Benefits | Costs/Issues |
|---|---|
| **Reduced driver stress.** Reduce the stress of driving and allow motorists to rest and work while traveling. | **Increases costs.** Requires additional vehicle equipment, services and maintenance, and possibly roadway infrastructure. |
| Reduced driver costs. Reduce costs of paid drivers for taxis and commercial transport. | **Additional risks.** May introduce new risks, such as system failures, be less safe under certain conditions, and encourage road users to take additional risks (offsetting behavior). |
| **Mobility for non-drivers.** Provide independent mobility for non-drivers, and therefore reduce the need for motorists to chauffeur non-drivers, and to subsidize public transit. | **Security and Privacy concerns.** May be used for criminal and terrorist activities (such as bomb delivery), vulnerable to information abuse (hacking), and features such as GPS tracking and data sharing may raise privacy concerns. |
| **Increased safety.** May reduce many common accident risks and therefore crash costs and insurance premiums. May reduce high-risk driving, such as when impaired. | **Induced vehicle travel and increased external costs.** By increasing travel convenience and affordability, autonomous vehicles may induce additional vehicle travel, increasing external costs of parking, crashes and pollution. |
| **Increased road capacity, reduced costs.** May allow platooning (vehicle groups traveling close together), narrower lanes, and reduced intersection stops, reducing congestion and roadway costs. | **Social equity concerns.** May have unfair impacts, for example, by reducing other modes' convenience and safety. |
| **More efficient parking, reduced costs.** Can drop off passengers and find a parking space, increasing motorist convenience and reducing total parking costs. | **Reduced employment and business activity.** Jobs for drivers should decline, and there may be less demand for vehicle repairs due to reduced crash rates. |
| **Increase fuel efficiency and reduce pollution.** May increase fuel efficiency and reduce pollution emissions. | **Misplaced planning emphasis.** Focusing on autonomous vehicle solutions may discourage communities from implementing more cost-effective transport solutions such as better walking and transit improvements, pricing reforms and other demand management strategies. |
| **Supports shared vehicles.** Could facilitate car sharing (vehicle rental services that substitute for personal vehicle ownership), which can provide various savings. | |

Source: Litman, Todd. Victoria Transport Policy Institute. "Autonomous Vehicle Implementation Predictions: Implications for Transport Planning". September 8, 2017.

One key takeaway of these possible future scenarios is that policy making and transportation investment in a network that prioritizes multiple types of shared mobility presents the best opportunity to leverage connected/autonomous vehicles to reduce vehicle travel and transportation costs.

One outlook for the future is that each future technology trigger will begin to paint a clearer picture of what the future of CAVs will be. It is important to remain aware of and stay engaged with emerging technologies and be prepared to react to changes. Figure 4-3 provides examples of technologies triggers to be aware of, however, many other triggers will influence the evolution of CAVs, many that we are not even aware of yet.

**Figure 4-3 Technology Trigger Impacts on CAV Development Trajectory**




Source: Adapted from Hardy, Matthew. American Association of State Highway and Transportation Officials. "Planning for the Hype" Rhode Island Transportation Innovation Partnership (TRIP) Expo. September 2017.

# 5

# Next Steps

While connected/automated vehicles are not yet mainstream, there are key transportation planning steps and decisions that can be made now.

## 5.1 Key Issues

The following are issues that will be important as CAV technology progresses:

- Unclear timeline – Estimates range from highly automated vehicles being available in the next five years to decades into the future. This presents issues for planning and infrastructure delivery; for instance, capital planning and installation of V2I technologies or redesign of streets to anticipate lower vehicular volumes. Public agencies may want to focus on policies and regulations being in place to guide a coherent vision for CAVs, rather than particular capital planning to respond to this new technology.
- Formulating a clear public vision: In the absence of a policy and regulatory framework for achieving the positive outcomes envisioned for CAVs, manufacturers and technology companies will fill that space. Public agencies should set out their visions to best harness this emerging technology for positive social and public outcomes.
- Phased deployment – CAVs will not simply arrive on the road in large fleets, fully autonomous. They will phase in with varying levels of human driver responsibility, and these vehicles will be sharing the road with human drivers

with less autonomous vehicles. This will be a confusing time for the public; public agencies will have a role to play in effective communication about expectations and public safety.

- Insurance and Liability: legal mechanisms must be robust to clarify issues such as insurance and liability.
- Cybersecurity and Privacy – Systems must be in place to ensure that the security of vehicles and their operational capabilities are maintained. There are also significant issues relating to privacy and the collection of personal data on travel behavior. Robust privacy protections must ensure that individuals are able to safeguard their data if they so desire.

## 5.2 Opportunities

Autonomous vehicle technology is advancing quickly, but we are at an excellent point in time to set out positive public visions for how this technology can benefit society. Planning for CAVs now will reap rewards in the future. This shift in transportation technology offers a moment to reconsider long-standing thinking about how streets operate and cities manage traffic.

**Long-Range Transportation Plan** – RI Statewide Planning is currently updating its Long-Range Transportation Plan. This is the comprehensive transportation document meant to guide transportation decisions across the State for 20 years. Including CAVs at this time is an excellent opportunity to start the conversation about how this technology can be incorporated into planning, policy and regulatory processes.

**Highway Safety Improvement Program (HSIP)** – With the authorization of the FAST Act vehicle-to-infrastructure equipment (such as DSRC) is considered an eligible activity for HSIP funding. As the state refines its vision for connected/automated vehicles it will be able to identify appropriate safety projects for equipment integration.

**AASHTO SPaT Challenge** – AASHTO has put out a challenge to each state to identify and implement a signal phase and timing (SPaT) enhanced corridor of up to 20 intersections by the year 2020. This would involve installing communications hardware (such as DSRC) in traffic signal cabinets to communicate traffic signal timings to vehicles. The motivations behind this challenge include exposing states to connected vehicle technologies to get them familiar with it and offering a travel corridor that connected vehicle owners can travel to take advantage of their vehicle features.

## 5.3 Next Steps

Lessons and examples from this document should be incorporated into other relevant sections of the Rhode Island Long Range Transportation Plan (LRTP). This will ensure that this emerging technology is included in consideration of all traffic systems covered by this document.

Rhode Island planners and policymakers must decide to what extent the State wishes to facilitate both the testing and near-term adoption of CAVs. Table 5-1 sets out some of the documents and actions that would benefit from the inclusion of CAV policies.

**Table 5-1 Plans and Impacts on Planning Products and Processes**

| **Planning Document** | **Impact on Products & Processes** |
|---|---|
| Long-Range Visioning | > Crash reduction; closer spacing may negate the need for additional roadway capacity.<br>> Alternative futures analysis must consider various technological, economic and land use outcomes and scenarios. |
| Statewide LRTP | > CAV visioning closely tied to long-range planning, including alternative futures analysis.<br>> LRTPs must consider crash reduction and capacity improvements. New forecasting required to address alternative futures and risk assessment of various investments.<br>> Must evaluate alternatives for CV deployment, with capital planning implications.<br>> Deployment to rural areas may be a challenge. Opportunities to incorporate investments should be identified. |
| Transportation Improvement Program | > Cost estimates for CAV technology deployment.<br>> Decision-makers and the general public must be educated about the need for these investments.<br>> CAV investments must be incorporated into the TIP prioritization process.<br>> Models/tools must incorporate the impacts of increased wireless communication into project evaluation. |
| Short-Range Transportation Plan | > Models/tools must incorporate the impacts of increased wireless communication into project evaluation.<br>> Planning agencies must identify supporting technology and services related to DSRC and V2I operation, such as security, back-office processing capability and maintenance.<br>> Decision-makers and the general public must be educated about the need for these investments.<br>> CV-related safety investments will require a greater level of cooperation among different governmental units. |
| Congestion Management Plan | > Incorporate CAV technology in to planning process.<br>> Apply criteria/performance measures for congestion mitigation to CAV alternatives.<br>> Tools will be needed to evaluate CAV deployments on congestion, addressing mobility and travel time.<br>> Look for opportunities to combine CAV technology with other CMP projects. |

| | |
|---|---|
| Asset Management Plan | > CAVs will enable gather of data on infrastructure condition, which may provide new opportunities for data analysis and utilization, as well as new expectations.<br>> CAV technology must be assessed for collecting operational and asset data in the corridor, such as travel speeds, weather condition and pavement condition.<br>> Public education will be required to explain the technology, what data is transmitted. |
| ITS and Operations Plan and ITS Architecture | > Need to identify a path from current use and technology to those compatible with CAV technology.<br>> Identify supporting technologies and services related to DSRC and V2I operation such as security, back-office processing capability, and maintenance.<br>> Update ITS Strategic Plan and ITS Architecture using latest tools incorporating CAV elements.<br>> Develop familiarity with CAV elements of ITS architecture and engage new stakeholders.<br>> Operations planning may change as a result of crash reduction and may switch to system maintenance as opposed to incident management. |
| Strategic Highway Safety Plan, Highway Safety Improvement Program | > More detailed simulation tools required to estimate safety impacts of CAV deployment.<br>> Incorporate assessments of safety impacts of increased CAV deployment as well as technology advances.<br>> CAV-related safety investments will require a greater level of cooperation between municipalities since consistency is critical to safety.<br>> CAV-related safety investments will require a greater level of cooperation among different levels of local government. |
| State Implementation Plan | > Tools required to identify impacts of V2I deployments on air quality.<br>> Implementation of USDOT's AERIS program has potential to generate environmentally relevant transportation data supporting green transportation choices by system users and operators. |
| Transit Development Plan | > Evaluate ridership expectations based on CAV technology impacts.<br>> New modeling tools may be required to estimate demand changes.<br>> Evaluate alternatives for deployment of CAV technology and how they are packaged with transit improvements.<br>> Assess use of CAV technology for collecting operational and asset data on transit corridors, such as travel speeds, parking availability, weather conditions, bus capacity and on-board condition. |
| Transportation Demand Management Plan | > Evaluate the efficiency improvements and traffic demands with CV investments. New modeling and tools may be required.<br>> Evaluate alternatives for deployment of CAV technology. This may generate data that can increase use of existing facilities and make them more efficient, such as parking, transit availability and travel time information. |
| Nonmotorized Transportation (Bicycle and Pedestrian) Plan | > Consider specific V2I elements for nonmotorized users, such as travel times and other travel information.<br>> Assess use of CV technology for collecting data, such as facility usage, travel speeds, weather conditions and the condition of non-motorized facilities. |

| | |
|---|---|
| | > Evaluate and track crash rates and the impact of CAV-related changes on infrastructure needs. |
| Corridor Studies | > Assess need for and feasibility of incorporating DSRC technology into improvements.<br>> Detailed simulation tools will be needed to estimate the safety impacts of CAV deployments.<br>> Knowledge-base must be adequate to understand the physical and operational requirements of V2I technology in order to develop reasonable cost estimates. |
| Public Involvement Plan | > Educate decision-makers and the public about the need for CAV-related investments.<br>> New stakeholders must be brought into planning processes to understand how CAV technology will operate and what relationships will be required.<br>> CAV-related safety investments will require greater cooperation between MPO member municipalities. This may be a wider group than are typically involved with transportation-related projects. |
| Freight Plans | > Evaluate the impact of V2V and V2I technologies on commercial vehicle operation and safety. Models will be needed to assess truck platooning and partial automation.<br>> Tools and data collection will be needed to properly evaluate impacts of reduced delay and idling on air quality.<br>> Re-evaluate future port-related infrastructure needed to service ports due to CAV technology introduction. New modeling may be required.<br>> Coordinate with vehicle enforcement personnel to identify how CAV technology can be used for more cost-effective enforcement. |
| Financing Plans | > New public-private partnerships may be required to fund key elements of this system.<br>> Identify criteria and evaluation tools for assessing the costs and benefits of CAV deployments in TIPs, short-range and long-range plans.<br>> Provide cost estimates for deployment of CAV technology.<br>> Educate decision makers and the public about the need for CAV-related investments. |

Source: US Dept. of Transportation, (2015, January 28). "Connected Vehicle Impacts on Transportation Planning, Technical Memorandum #2: Connected Vehicle Planning Processes and Products and Stakeholder Roles and Responsibilities." Federal Highway Administration. FHWA-JPO-15-246