AUTONOMOUS/ CONNECTED VEHICLE READINESS PLAN

JULY 2019

CITY OF ELK GROVE
PROUD HERITAGE. BRIGHT FUTURE.

FEHR PEERS

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AN AV/CV READINESS PLAN FOR ELK GROVE

Autonomous vehicle (AV) and connected vehicle (CV) technology can transform how Cities manage and operate their streets.

What can the City of Elk Grove do to best prepare for the future arrival of autonomous and connected vehicles on City streets? This AV/CV Readiness Plan provides background on current AV and CV technology and offers recommendations for the City.

EXECUTIVE SUMMARY

WHAT IS A READINESS PLAN?

A readiness plan provides recommendations to help the City plan for the future arrival of autonomous vehicles (AVs) and connected vehicles (CVs) operating on City streets. This plan provides background, examines potential effects of AVs and CVs on the City of Elk Grove, and provides recommendations for AV/CV readiness.

WHAT ARE AVS AND CVS?

Autonomous vehicles (AVs) are equipped with on-board software and hardware that are capable of driving the vehicle instead of a human operator. They are also referred to as self-driving, driverless, or automated vehicles. Connected vehicles (CVs) are able to communicate wirelessly with its surroundings and other vehicles to share and receive information regarding the transportation system. Today, many new vehicles include autonomous technology, such as adaptive cruise control, self-parking capabilities, and vehicle route navigation. These features offer the ability to maintain safe and efficient vehicle spacing and flow and are intended to ultimately operate autonomously without requiring driver attention.

WHEN ARE AVS/CVS ANTICIPATED TO BE AVAILABLE?

Some autonomous technology is readily available today, but full automation is still to come. Despite rapid advances in AV and CV technology, there is still substantial uncertainty associated with the implementation of AVs and CVs for public use. Estimates range from several years for a highly autonomous vehicle to never for a fully autonomous vehicle (i.e., without the need for a human driver). Even after highly and fully autonomous vehicles are available, it will likely take some time before they represent a significant percentage of the vehicle fleet.

WHAT EFFECTS WILL AVS/CVS HAVE ON TRANSPORTATION AND THE BUILT ENVIRONMENT?

AVs and CVs could result in significant changes in travel. These range from benefits such as reduced collision rates, more stable traffic flow, increased access to mobility, and reduced driving stress; potential side effects such as increased vehicle travel and traffic congestion; to potential greater demand for suburban development.

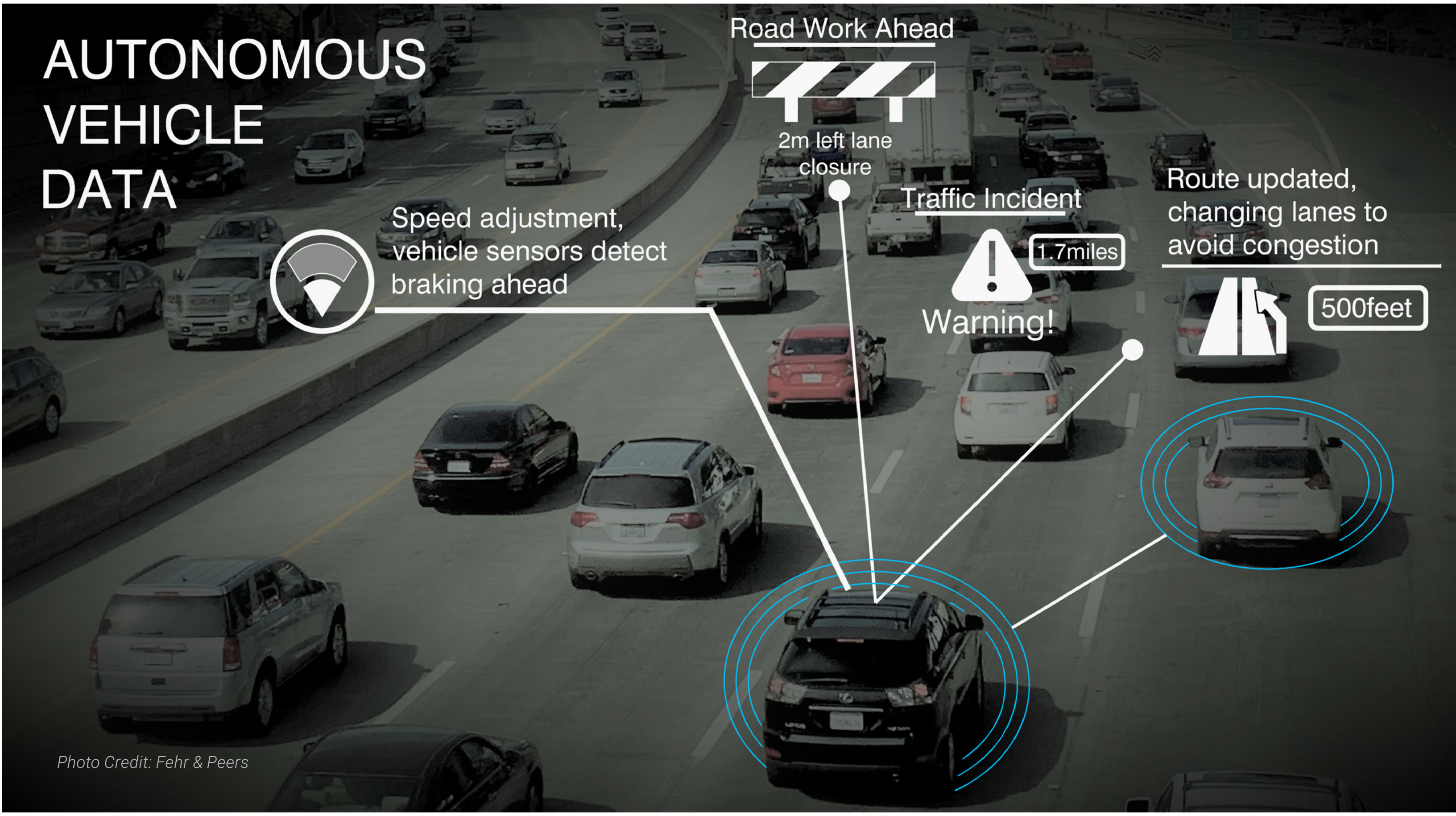


Photo Credit: Fehr & Peers

WHAT IS RECOMMENDED TO GET READY?

AVs will be capable of operating on City streets without any major changes to current practices. Therefore, the City does not need to invest in new or upgraded infrastructure for AVs to function.

However, there are investments and policies the City can consider to better prepare for an AV and CV future. These investments should also consider their utility beyond AVs and CVs, particularly given the uncertainty of when AVs and CVs will become available and how quickly they will be adopted into our transportation landscape. The near-term recommendations include: asset management, roadway striping, fiber optic infrastructure, and data management. Long-term investments to support CVs are not reommended at this time, but may include: smart street lighting, cloud based networks, and CV infrastructure at intersections.

Government actions, regulations, and standards could influence or even dramatically alter the effects AVs and CVs have on travel and the built environment. Therefore, this plan recommends the City consider the following policy actions:

- Local community and stakeholder outreach and engagement
- Monitor regulatory developments at the state and federal level
- Lobby for data sharing and effective communication protocols for AVs, CVs, and mobility service providers at the state and federal level
- Apply cost structures to manage effects and encourage desired outcomes
- Restructure transit service in the City
- Modify zoning regulations to respond to reduced parking demand, increased land values in established areas, and potential demand for new development at the edge of the City

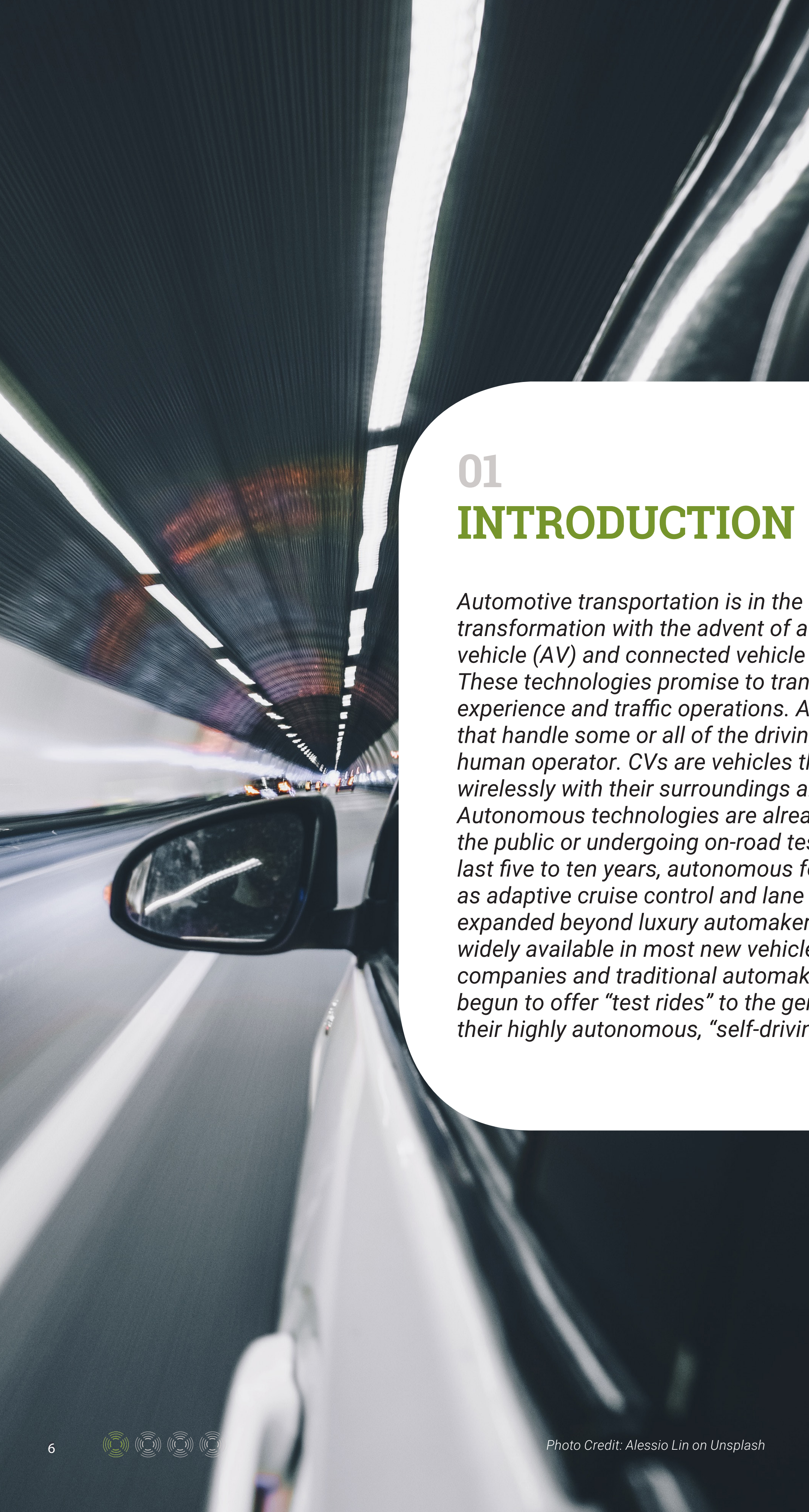


Photo Credit: Alessio Lin on Unsplash

01 INTRODUCTION

Automotive transportation is in the midst of a radical transformation with the advent of autonomous vehicle (AV) and connected vehicle (CV) technology. These technologies promise to transform traveler experience and traffic operations. AVs are vehicles that handle some or all of the driving instead of a human operator. CVs are vehicles that communicate wirelessly with their surroundings and other vehicles. Autonomous technologies are already available to the public or undergoing on-road testing. Within the last five to ten years, autonomous features such as adaptive cruise control and lane keeping have expanded beyond luxury automakers to become widely available in most new vehicles. Technology companies and traditional automakers alike have begun to offer "test rides" to the general public in their highly autonomous, "self-driving" vehicles.

WHAT IS A READINESS PLAN?

The purpose of this readiness plan is three fold:

1. Provide background on the status of AV and CV technology
2. Identify the potential effects of AVs and CVs on transportation and the built environment of Elk Grove
3. Propose potential ways to leverage the opportunities afforded by this technology while managing potential impacts

Overall, this plan aims to answer the following key question based on what is known today:

How should the City of Elk Grove plan for the future arrival of autonomous and connected vehicles operating on City streets?

The recommendations in this plan consider the following questions:

» What capital investments in the City's infrastructure should the City of Elk Grove consider?

» What policy or legislative efforts should the City consider to proactively address potential effects of AVs and CVs?

This plan includes the following chapters:

Background
Provides an overview of AVs and CVs and the status of this technology as of 2019. Includes current forecasts of AV and CV availability.

Effects
Identifies what effects AVs and CVs will have on transportation and the built environment. Defines how AVs and CVs will potentially change the way we travel, and how this may affect our transportation system and the built environment.

Recommendations
Proposes recommendations for actions and investments that can be considered to capitalize on the opportunities provided by AVs and CVs or reduce and manage potential impacts.

02
BACKGROUND

Autonomous and connected vehicle technology is developing quickly and is anticipated to become common in vehicles on the road within the next two to thirty years. Some of these technologies are available in vehicles today and include: adaptive cruise control, traffic incident and lane departure warnings, driver attentiveness detection, vehicle route navigation and congestion avoidance, eco-driving optimization, and self-parking capabilities. These technologies offer the ability to maintain safe and efficient vehicle spacing and flow, and are intended to ultimately operate autonomously without requiring driver attention.

WHAT ARE AUTONOMOUS VEHICLES?

In short, an autonomous vehicle (AV) is one where the vehicle's on-board software and hardware handles the driving task instead of a human operator. This could range from only controlling certain aspects at the direction of a human driver, such as speed with adaptive cruise control, to fully driving the vehicle without any need for a human operator.

The U.S. Department of Transportation (US DOT) defines autonomous vehicles as those that "rely on sensors and software that allow an expansive view of the environment across a range of lighting and weather conditions. They can quickly learn and adapt to new driving situations by learning from previous experience through software updates."[1] US DOT recognizes that the lexicon describing AVs is varied and potentially confusing: "To date, a variety of terms (e.g., self-driving, autonomous, driver less, highly autonomous) has been used by industry, government, and observers to describe various forms of automation in surface transportation."[1] This plan uses "autonomous vehicles" to describe vehicles that have these technological abilities.

1 "Preparing for the Future of Transportation - Automated Vehicles 3.0", US Department of Transportation, April 2019

Pictured: Google's Autonomous Vehicle
Photo Credit: David Wasserman , Fehr & Peers

LEVELS OF AUTOMATION

The Six Levels of Automation

The Society of Automotive Engineers (SAE) International developed a classification system of six levels of automation, ranging from no automation to full automation. This classification system has been adopted by US DOT and the United Nations, and is illustrated in Figure 1.

Levels 1-3 offer assistance to the driver, who needs to remain aware and able to intervene at a moment's notice. Levels 4 and 5 offer full driving capabilities, and do not require an on-board operator.

Level 1 and Level 2 vehicles are commercially available and include branded feature packages such as Honda Sensing, Toyota Safety Sense, Tesla Auto Pilot, and Cadillac Super Cruise. The more sophisticated versions of this technology have features that allow a driver to take their hands off the wheel while the vehicle maintains a steady speed. Recent updates to Tesla Autopilot also allow the vehicle to change lanes and steer the vehicle towards highway exits autonomously when the driver engages the turn signal and under limited circumstances.

Level 3 vehicles are not commercially available in the U.S. However, Audi's Traffic Jam Pilot system released this year claims to be the first Level 3 automation included in commercially available vehicles, and is available in Europe. This system, when activated by the driver, will take over driving the vehicle in slow-moving traffic on freeways and highways when travel speeds are less than 37 mph. With this system activated, the driver can take their hands off the steering wheel and focus on a different activity until prompted by the vehicle to resume control.

In some ways, this is similar to Level 2 technology, and it can be difficult to differentiate between Level 2 and Level 3 technology. There is also debate in the industry whether Level 3 automation is safe or desirable since drivers may be required to shift quickly from not monitoring the drive when automation is engaged to taking over control when prompted.

Examples of Vehicle Automation Technologies

Speed control (i.e., acceleration and braking). Adaptive cruise control (ACC) is an example in which the vehicle accelerates and brakes based on the desired speed and traffic flow conditions. ACC is often limited (i.e., above certain speed thresholds for use on freeways or expressways, and may not be intended for use on city streets). However, functions such as collision avoidance and "traffic jam chauffeur" exemplify how this technology could be expanded to apply at all travel speeds and conditions, including stop-and-go traffic on city streets.

Steering (i.e., autonomous lane keeping, turning maneuvers, etc.). Lane centering is an example where the vehicle detects lane markings and steers the vehicle to maintain its position in a lane. In more sophisticated AVs that are currently testing, this also includes the ability to make turn movements and change lanes based on the ultimate destination.

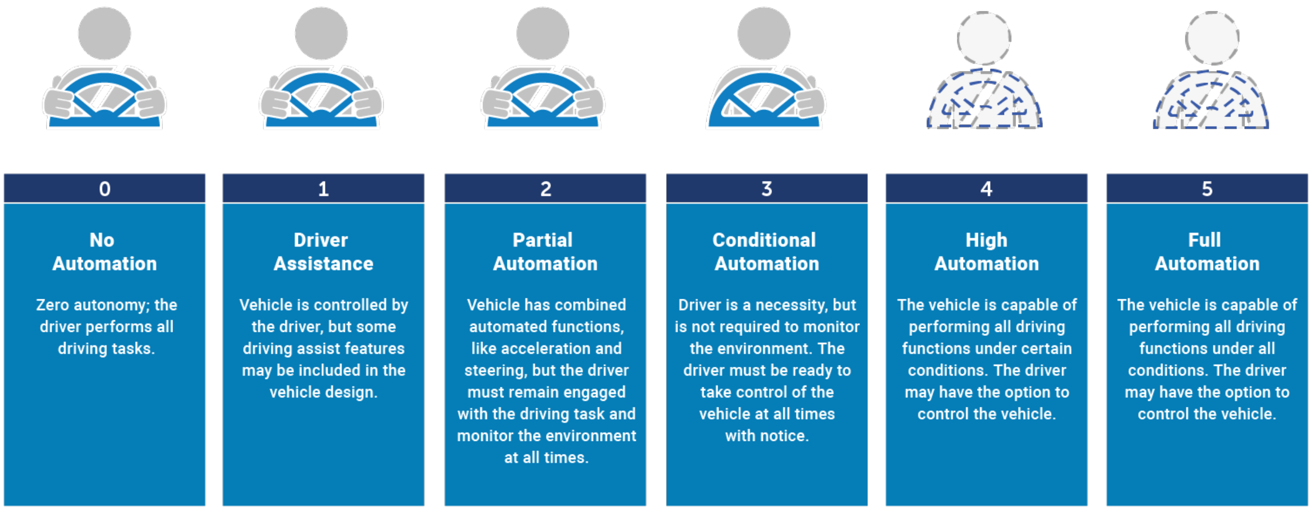


Figure 1: Levels of Autonomous Vehicles
Image Source: SAE & NHTSA

Level 0 (No Automation) represents a vehicle with no automation. The vehicle responds only to drive inputs but can provide warnings about the driving environment like blind spot warning. The driver must do all driving.

Level 1 (Driver Assistance) represents a vehicle that can provide basic driver assistance like emergency braking or lane keeping support. The driver must do all driving.

Level 2 (Partial Automation) represents a vehicle that can automatically steer, accelerate and brake in limited situations (such as adaptive cruise control and lane-keeping). The driver must stay fully alert even when the vehicle assumes some basic driving tasks.

Level 3 (Conditional Automation) represents a vehicle that can take full control over steering, acceleration, and braking under some conditions. Unlike Level 2, the driver does not need to monitor the drive when automation is engaged; however, the driver must always be ready to take over control of the vehicle if prompted.

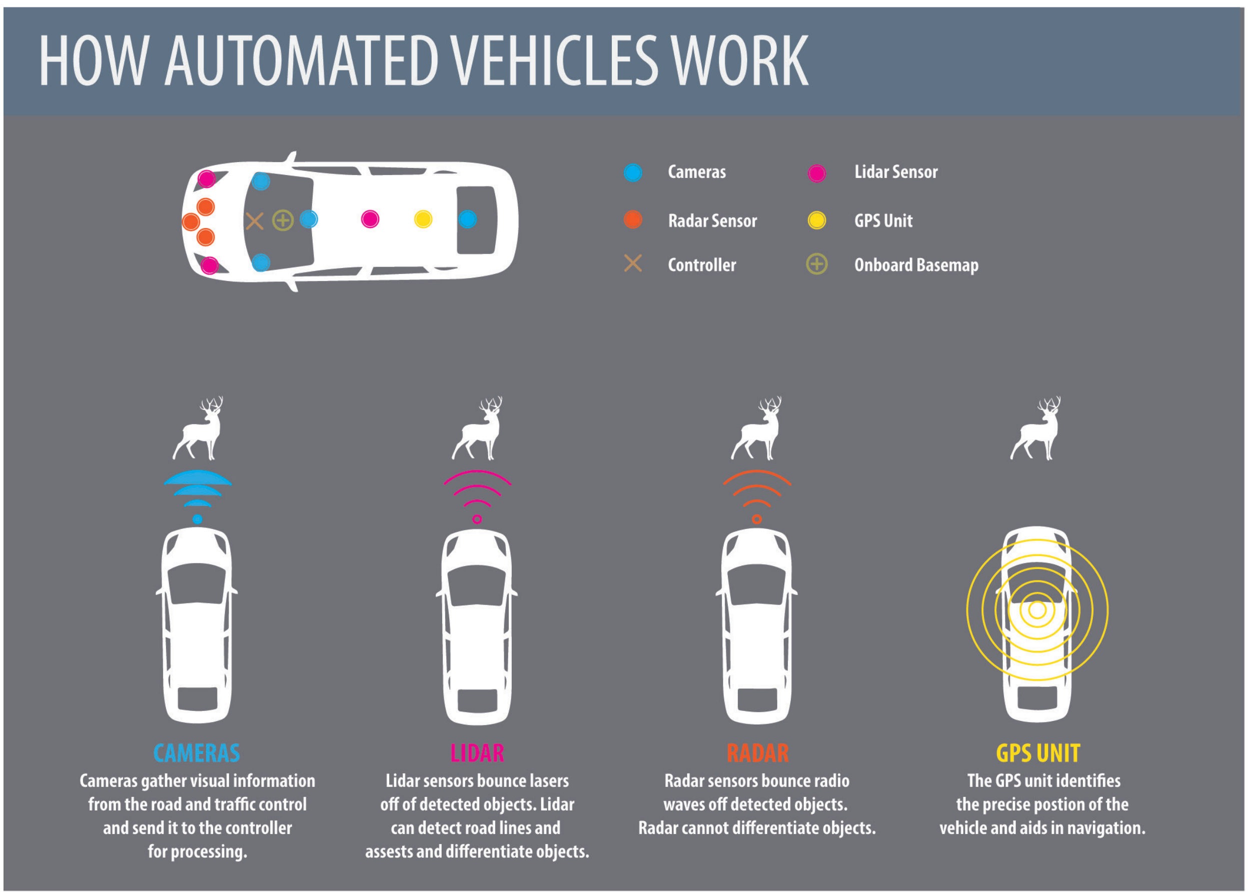
Level 4 (High Automation) represents a vehicle that can assume all driving tasks under most conditions. The driver is required to take control when the autonomous system is unable to continue (such as blizzard conditions). There are currently no commercially available Level 4 vehicles.

Level 5 (Full Automation) represents a vehicle that can operate in all environments without human intervention. A Level 5 vehicle would not require a steering wheel. There are currently no commercially available Level 5 vehicles.

HOW DO AUTONOMOUS VEHICLES WORK?

Level 4 and 5 AVs use an internal high-definition map of their surroundings. The map is informed by various sources, starting with a static map either generated by the manufacturer or bought from a third party, supplemented with information supplied by the wide array of sensors that exist on the vehicles. The sensors typically consist of lasers, radar, lidar, high-definition cameras, and sonar. These sensors capture images of signs, striping, traffic signals, temporary traffic controls, pedestrians, bicyclists, and of course other vehicles. The sensors themselves do not provide any control inputs to the vehicle.

That task is the responsibility of software that processes the various inputs, interprets the information, and directs the vehicle (i.e., provides acceleration, braking and steering inputs) along a path based on what it perceives. This software is often referred to as "Artificial Intelligence" (AI) and is continuously updating how it interprets objects it detects and how it reacts based on that information. Most AVs also include rules to avoid obstacles and differentiate between objects (like a bicycle and pedestrian). That along with the aforementioned AI allows the vehicles to obey traffic laws and navigate around obstacles.



Pictured: How Autonomous Vehicles Work
Image Source: Fehr & Peers

WHAT ARE CONNECTED VEHICLES?

It is important to distinguish Connected Vehicles (CV) from Autonomous Vehicles (AV). Currently, AV manufacturers and developers do not necessarily regard CV as a required component of AV and vice-versa.

The “Connected Vehicle” is one that can communicate wirelessly with its surroundings and other vehicles. Several acronyms are used to describe this communication:

“V2X” (vehicle-to-everything) is the umbrella term indicating vehicle-to-anything connections.

“V2V” (vehicle-to-vehicle) describes the technology for vehicles to communicate with each other.

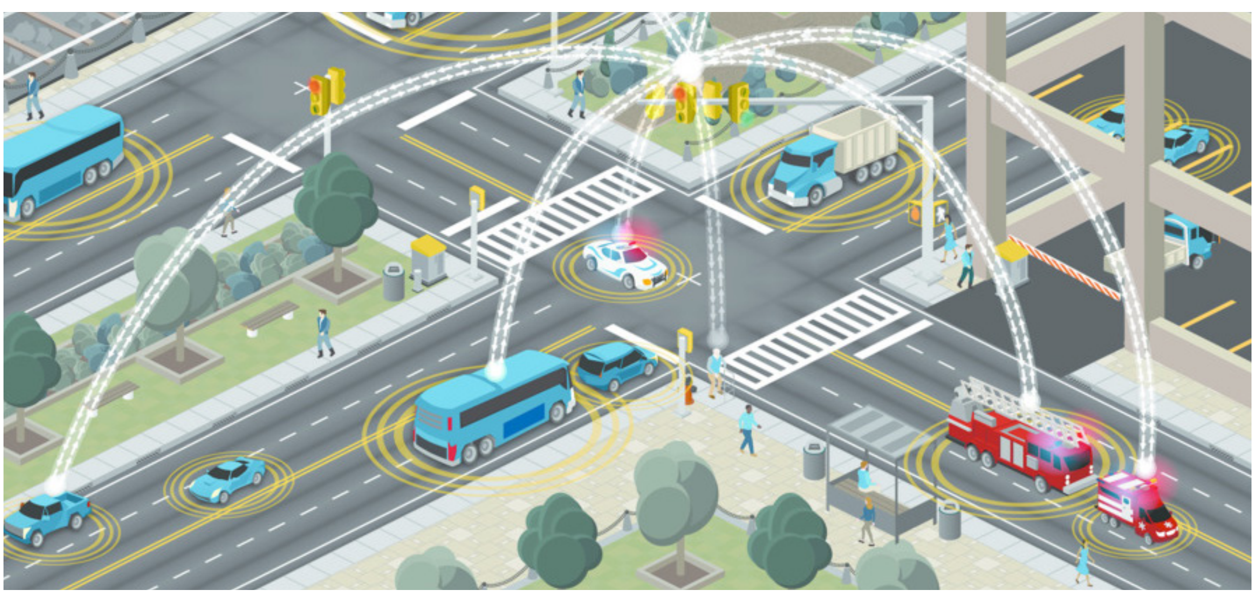
“V2P” (vehicle-to-pedestrian) describes the technology for vehicles to communicate with pedestrians.

“V2B” (vehicle-to-bicycle) describes the technology for vehicles to communicate with bicycles.

“V2I” (vehicle-to-infrastructure) describes the technology for vehicles to communicate with roadway infrastructure, such as traffic signals and tollbooths.

Sensors, wireless bandwidth, and traffic signals are examples of hardware that are involved in this communication.

Note that many vehicle manufacturers use the term “Connected Vehicle” to describe a vehicle with a connection to the internet; while that is certainly valuable to vehicle owners and can provide a means to communicate vehicle interactions with a public agency, connection to the internet is not required by any standards-making body and is not a characteristic of a CV as we describe it in this document.



Pictured: An Illustration of "V2X"
Image Source: US DOT

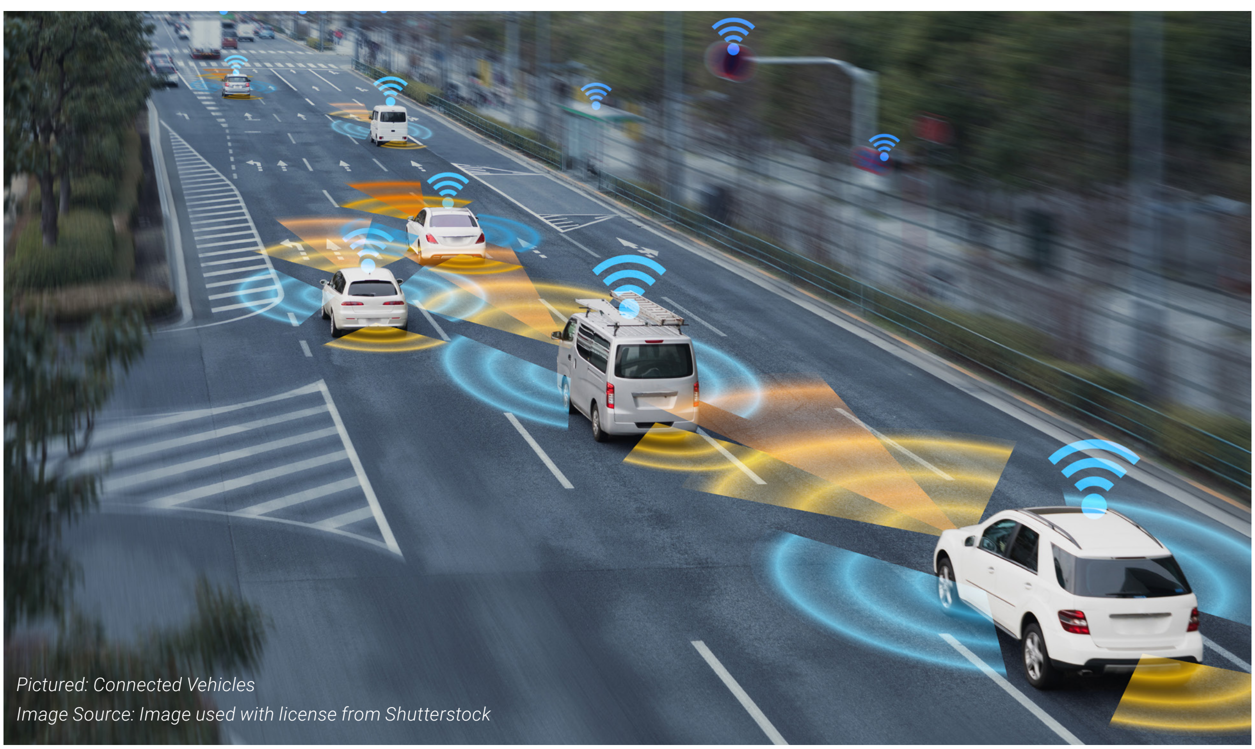
HOW DO CONNECTED VEHICLES WORK?

As an emerging technology, CV terminology and infrastructure elements are varied, and defined by several entities. At a high level, V2I communication is exemplified by communication between a moving vehicle and a stationary element of roadway infrastructure.

CVs communicate wirelessly with Dedicated Short Range Communication radios (DSRC) and/or Cellular V2X (relying on 4G and emerging 5G networks) as the two primary methods for wireless communication of V2X messages. Both utilize the same 5.9 GHz frequency band, which the Federal Communications Commission (FCC) has classified as protected bandwidth for transportation data only. DSRC has been in development longer, has been tested for V2X, but has little other organic demand. That is not the case for 5G, though it has far less deployment experience at this time.

It is important to note that DSRC communications are the only FCC approved devices allowed to operate in the automotive safety spectrum. Currently, the FCC does not allow cellular networks to operate in the automotive safety spectrum. However, the 5G Automotive Association (5GAA), a global, cross-industry organization of automotive, technology, and telecommunications companies, is working to prove to the FCC that cellular networks can provide the reliability and data transmission speeds capable of supporting automotive safety features. If successful, the 5GAA hopes to have the FCC allow 5G cellular networks to operate in the automotive safety spectrum.

Therefore, there is no current consensus on what will become the future wireless communication standard for CVs. These two options (DSRC versus 5G) could become a situation similar to BetaMax versus VHS or HD DVD versus BluRay, where the two methods compete to become the dominant industry standard.

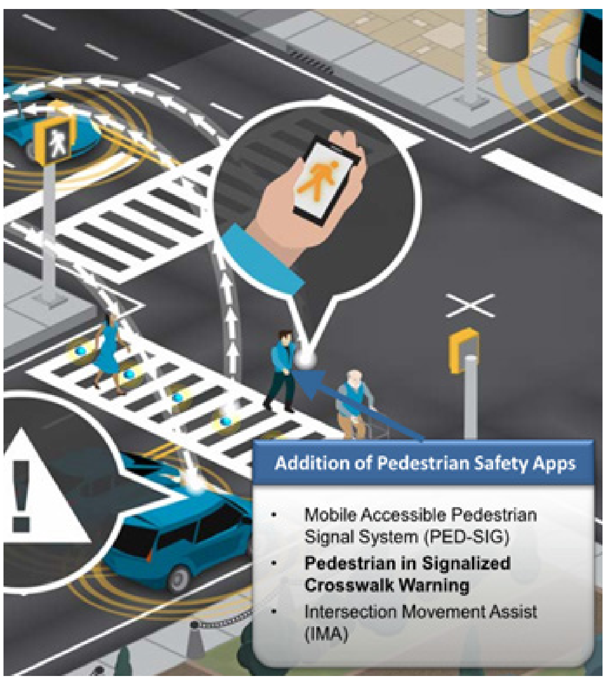


Pictured: Connected Vehicles
Image Source: Image used with license from Shutterstock

CONNECTED VEHICLE APPLICATIONS

Safety applications center on the basic safety message (BSM), a packet of data that contains information about vehicle position, heading, speed, and other information relating to a vehicle's state and predicted path. The BSM contains no personally identifying information.

From transportation infrastructure, messages are likely to include signal phase and timing (SPaT) from traffic signal systems, similar signal status messages, and geometric map messages describing lane geometry and other elements of the traffic signal system.



Pictured: Connecting Pedestrians
Image Source: ITS, US DOT PWX Presentation, 2016
Kenneth Leonard, Director, ITS Joint Program Office, OST-R

For CVs, as more vehicles, pedestrians and cyclists become connected, applications will be developed to improve characteristics of our current transportation system. Broadly, those applications are grouped into several categories:

Safety
Examples: Curve Speed Warning, Red Light Violation, Forward Collision Warning, Pedestrian in Signalized Crosswalk

Mobility
Examples: Intelligent Signal System, Transit Priority, Dynamic Ridesharing

Environment
Examples: Eco-signal approach, Connected Eco-Driving, where connected automated vehicles minimize starts and stops to minimize vehicle emissions

Agency Data
Examples: Work Zone Traveler Information, and a variety of probe data applications

Road Weather
Examples: Motorist Advisories and Warnings, Weather Response Traffic Information

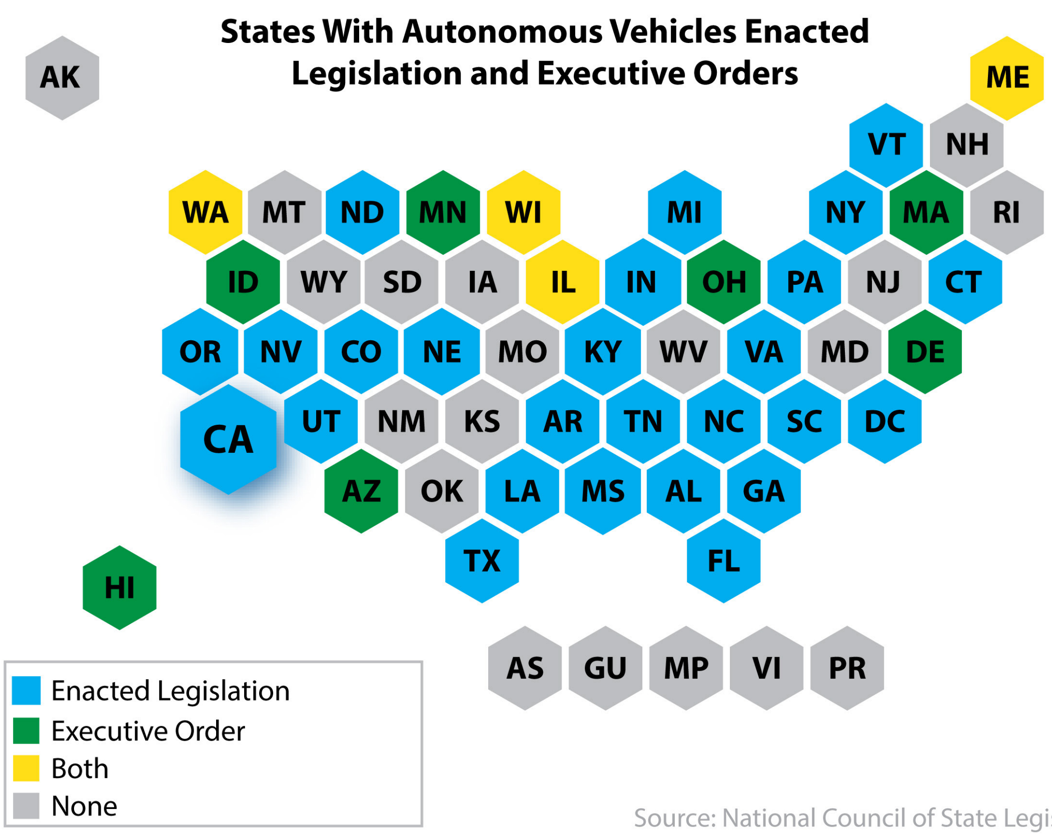
Smart Roadside
Examples: Smart Truck Parking, or the ability for trucks to see parking availability at upcoming rest stops and reserve their spots

CURRENT AV AND CV REGULATIONS

At the Federal level, responsibilities include development of Motor Vehicle Safety Standards, which are developed and enforced by the National Highway Traffic Safety Association (NHTSA). Those rules govern the requirements for all vehicles, autonomous or not.

States and local agencies have the responsibility to develop and enforce rules for testing and operation of AVs on public roadways. The figure below illustrates which states have begun that development (as of April 2019).

California, Vehicle Code (CVC) Section 38750 requires the California Department of Motor Vehicles (DMV) to adopt regulations governing both the testing and public use of autonomous vehicles on California roadways. The DMV has three autonomous vehicle permit options. A manufacturer can apply for a testing permit (which requires a driver), a driverless testing permit, and then a deployment (public use) permit. Through adoption of regulations effective on April 2, 2018, the DMV has the authority to issue permits for driverless testing or deployment of autonomous vehicles.



Source: National Council of State Legislatures

Roadside Hardware and Software

Generally speaking, the role of US DOT is to educate, provide training, conduct research and provide funding for CV projects through competitive grants and research opportunities. US DOT (Largely the Federal Highway Administration (FHWA))-funded research projects tend to produce results and findings that get incorporated by standards-writing bodies. For example, FHWA-sponsored research into how traffic signal controllers can communicate with each other over DSRC might result in proposed changes to SAE standards for V2V and V2I communication.

The SAE, who also defines levels of autonomy for AVs, defines the message format for messages that are to be passed between vehicles and anything else. Most of the standards mentioned here are encapsulated within SAE standard J2735.

The Institute of Electrical and Electronics Engineers (IEEE) defines the communication standards for how those SAE messages are passed back and forth, just as they do for messages passed through Ethernet, Bluetooth, WiFi, etc. In this case, the communication standards are within the IEEE 1609 family of standards dealing with "Wireless Access in Vehicular Environments" (WAVE). Specific to traffic signal systems, the SAE messages need to be compliant with already-developed national standards for communication between traffic signal and systems known as the The National Transportation Communications for Intelligent Transportation System Protocol (NTCIP). The NTCIP was co-developed by the Institute for Traffic Engineers (ITE), the American Association of State Highway Officials (AASHTO) and the National Electrical Manufacturer's Association (NEMA).

Outside of what was previously described, the development of other public works will continue to be completed according to local or state standards for roadway infrastructure.

Road Rules and Licensing

Generally speaking, and as discussed in previous sections, road rules and licensing requirements are the responsibility of states and local governments. In California, the DMV regulates both the testing and public use of autonomous vehicles through a permitting process. (Note that the California DMV refers to automated vehicles as "Autonomous Vehicles" for their permitting). AV and CV pilot tests are also subject to these rules for anything involving autonomous vehicles, from pilot tests to large-scale deployments. Cities have limited power to enact additional regulations for CVs being used with their jurisdiction.

CVs, the Internet of Things, and "Smart City"

The "Internet of Things" or IoT refers to the ever-growing collection of devices that are connected to the internet. The IoT generally includes any system of inter-related computing devices that are able to transfer data over a network without requiring human-to-human or human-to-computer interaction. AVs and CVs fit within the IoT.

A "Smart City" generally refers to cities that capture the data from their assets within the IoT to help improve City services and prioritize funding needs. For example, a Smart City might utilize Internet-equipped garbage containers to be able to summon garbage collection vehicles on-demand. It might utilize Internet-connected Street Lights to summon maintenance vehicles and reduce response time or collect data about its surroundings to inform City services, address safety, or address current environmental conditions. With respect to AVs and CVs, a Smart City could establish dynamic rules for parking allocation, pricing of lane use, traffic control closures, etc.

IMPLEMENTATION TIMELINE

Although some autonomous, driver assist technology is readily available today, full automation is still to come.

The current availability of AV technology by SAE Automation Level is as follows:

- » Level 1 and Level 2 vehicles with autonomous features such as adaptive cruise control and lane keeping are commercially available today.
- » Level 3 and Level 4 vehicles (i.e., highly autonomous vehicles) are being tested and in limited cases are offering test rides through mobility service providers, in select markets, such as Waymo's Early Rider test program in Phoenix, Arizona.
- » When (or if) vehicle manufacturers are able to develop and successfully deploy Level 5 (i.e., fully autonomous/driverless) is uncertain. Estimates range from 15 years to never.

Even after highly and fully autonomous vehicles (i.e., Levels 3, 4, and Level 5) are available, it will take some time before they represent a significant percentage of the vehicle fleet. How quickly these vehicles enter the fleet in large numbers will be based on a number of factors, including:

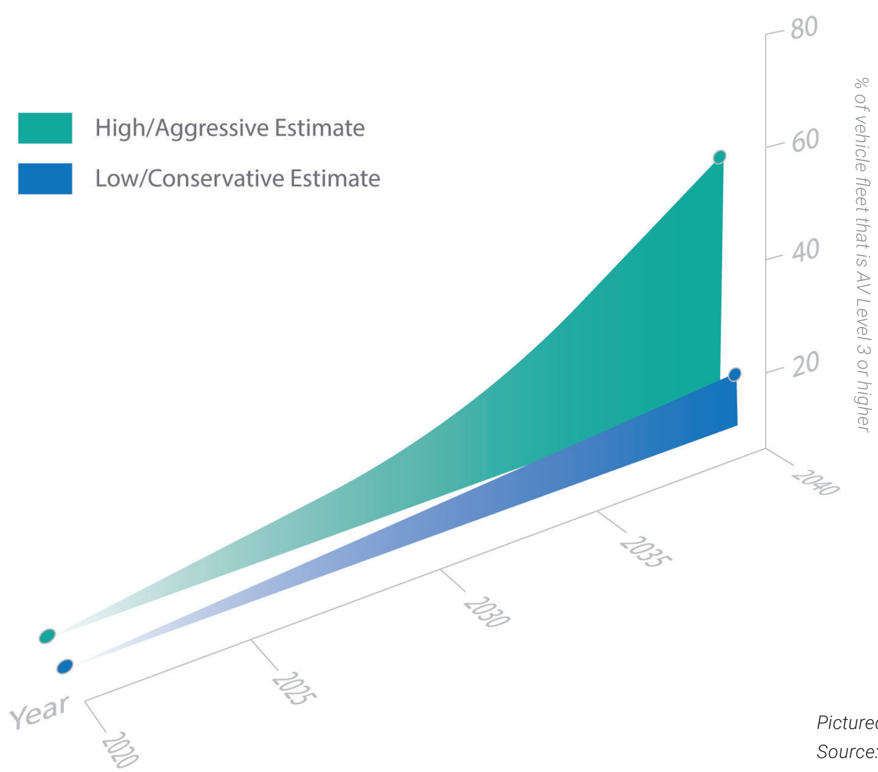
- » **Perfection of fail-safe technology:** AV technology is continually being tested and perfected, at first in controlled settings, and more recently as "real-world" test services for volunteer riders.
- » **Safety and licensing:** A major barrier will be licensing AVs to determine when they are ready for the road. AVs will need substantial testing to assuage the concerns of regulators and consumers that they can operate safely in the great number and variety of circumstances where judgment is needed.
- » **Legal issues and liability:** In case of a collision, who will be liable? How does (or should) the AV prioritize the safety of people in its vehicle versus other crash-involved parties?
- » **Privacy and security issues:** AVs and CVs will gather, share, and store a lot of data to operate. There may be concerns about how and with whom this data is shared as well as the security of the computer systems involved either from a software glitch or intentional sabotage.
- » **Personal preferences:** How willing or resistant will people be to forfeit control of their vehicles or their enjoyment of driving? How willing will people be to share the road with highly autonomous vehicles?
- » **Cost and equity:** Like most new technology, initial use of AVs may be expensive and privately owned AVs may only be affordable to those with high incomes initially before the cost becomes more affordable to the masses.
- » **Infrastructure implementation:** Until AVs constitute a substantial portion of the vehicle fleet, their roadway operational benefits may be limited when mixed with traditional vehicles. Does this create incentives for or necessitate separate facilities or designated lanes for AVs in the interim when the vehicle fleet is a combination of AVs and traditional vehicles?

A few pivotal AV issues may include:

- When and to what degree will the National Highway Traffic Safety Administration (NHTSA) permit and then ultimately require the use of AV capabilities?
- When (or will) people's personal mobility preferences or economics result in a shift from the current vehicle ownership and leasing model to a subscription-based car possession or mobility service model?

These factors will influence how quickly the public adopt AV and CV technology in their everyday travel. Since many of these factors are dependent on highly variable characteristics such as technological advancement, regulatory response, societal acceptance, and economic viability, it is difficult to predict how quickly these factors and issues will be resolved to the approval of the driving public. Therefore, there is a wide range of predictions for when highly autonomous vehicles become prevalent on public roadways.

With highly autonomous vehicles (Level 3 and Level 4) beginning to serve passengers through pilot projects, some are confident that highly autonomous vehicles are nearing the point of full operation and will be adopted quickly, particularly through mobility service providers such as Uber and Waymo. Others believe the general public may be more wary and resistant to AV travel based on the factors described above, and therefore believe AV technology will not experience widespread adoption quickly. This variability and uncertainty is illustrated in the figure below.



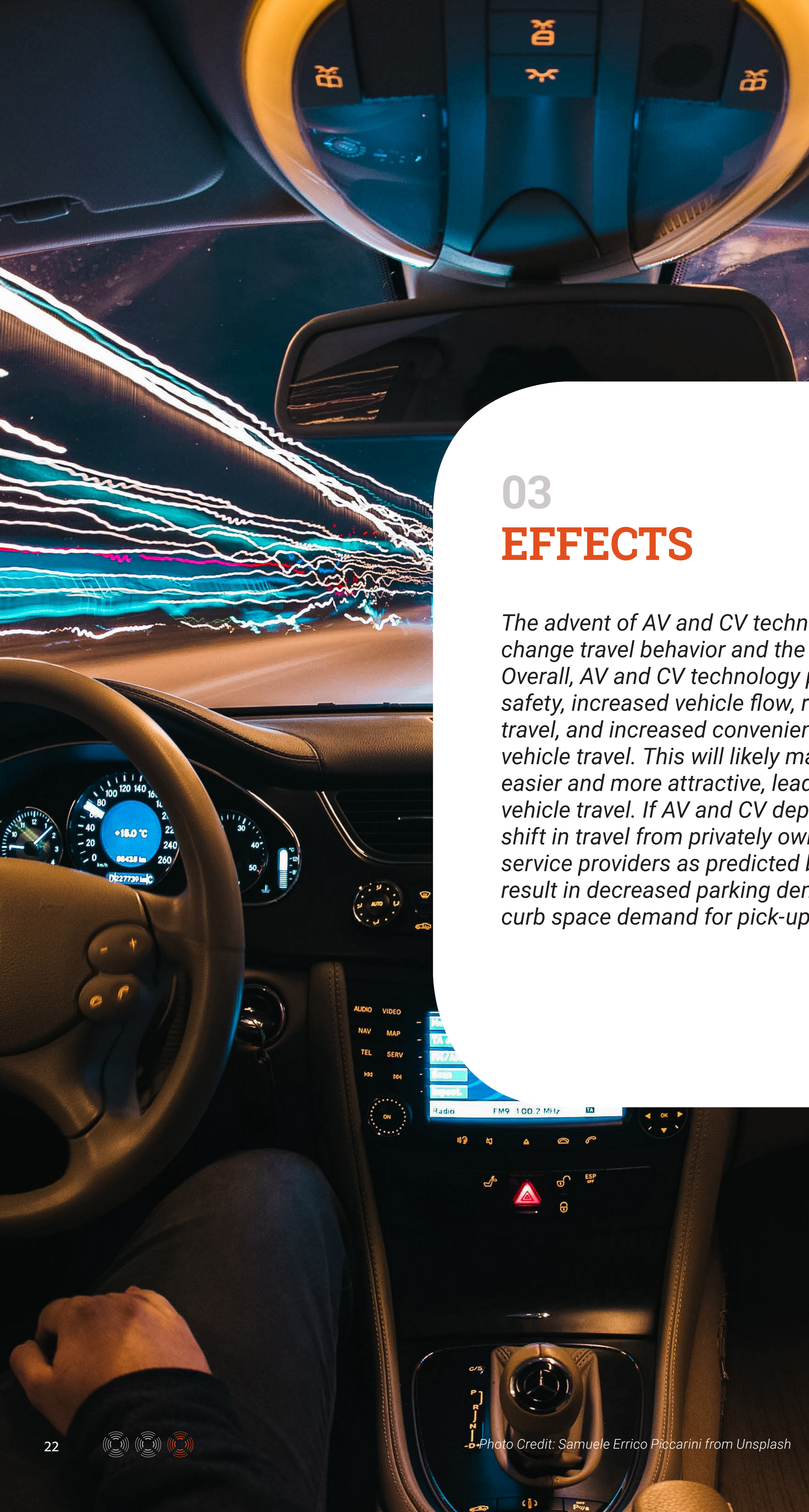
Pictured: AV Adoption Timeline
Source: Fehr & Peers

FUTURE CONVERGENCE OF AVs AND CVs

While AV and CV technology are not seen as required components of each other, it is likely that these technologies will begin to converge as they continue to develop and mature. Vehicles with AV technology will greatly benefit from communicating with the roadway infrastructure and users of the transportation network rather than just relying on on-board sensors and a static starting map to understand the conditions of the roadway. Similarly, CVs without automation technology may provide drivers with alerts about upcoming roadway conditions, similar to blind spot warnings, but adding automation will more effectively eliminate potential human error.

This convergence would result in connected autonomous vehicles (CAVs). Highly autonomous CAVs would operate without the direct need of a human operator as well as benefit from communicating with the roadway infrastructure and other users (i.e., bicycles, pedestrians, transit, freight, etc.) to better anticipate forthcoming interactions and roadway conditions.

Source: CC BY 2.0



03
EFFECTS

The advent of AV and CV technology could drastically change travel behavior and the built environment. Overall, AV and CV technology promises improved safety, increased vehicle flow, reduced cost for vehicle travel, and increased convenience and access for vehicle travel. This will likely make travel by vehicle easier and more attractive, leading to an increase in vehicle travel. If AV and CV deployment facilitate the shift in travel from privately owned vehicles to mobility service providers as predicted by some, it would also result in decreased parking demand but increased curb space demand for pick-up/and drop-off activity.

Photo Credit: Samuele Errico Piccarini from Unsplash

AV AND CV EFFECTS ON TRANSPORTATION

How significantly this technology affects the traveling public will be dependent on how effectively AV technology is introduced to consumers and how quickly the public responds and adopts the use of AV and CV technology. Will AV and CV technology roll out like smart phones or the Internet, becoming widely adopted by the public and seamlessly influencing our everyday lives within a relatively short time frame? Or will they be more like segways or smart glasses: technology that was extensively promoted by their developers and media outlets when leading up to their public debut, but to date only serve niche markets without mass adoption? While the outcome is still uncertain, the answers to these questions will likely become clearer in the next five to ten years as highly autonomous vehicles begin to hit the road.

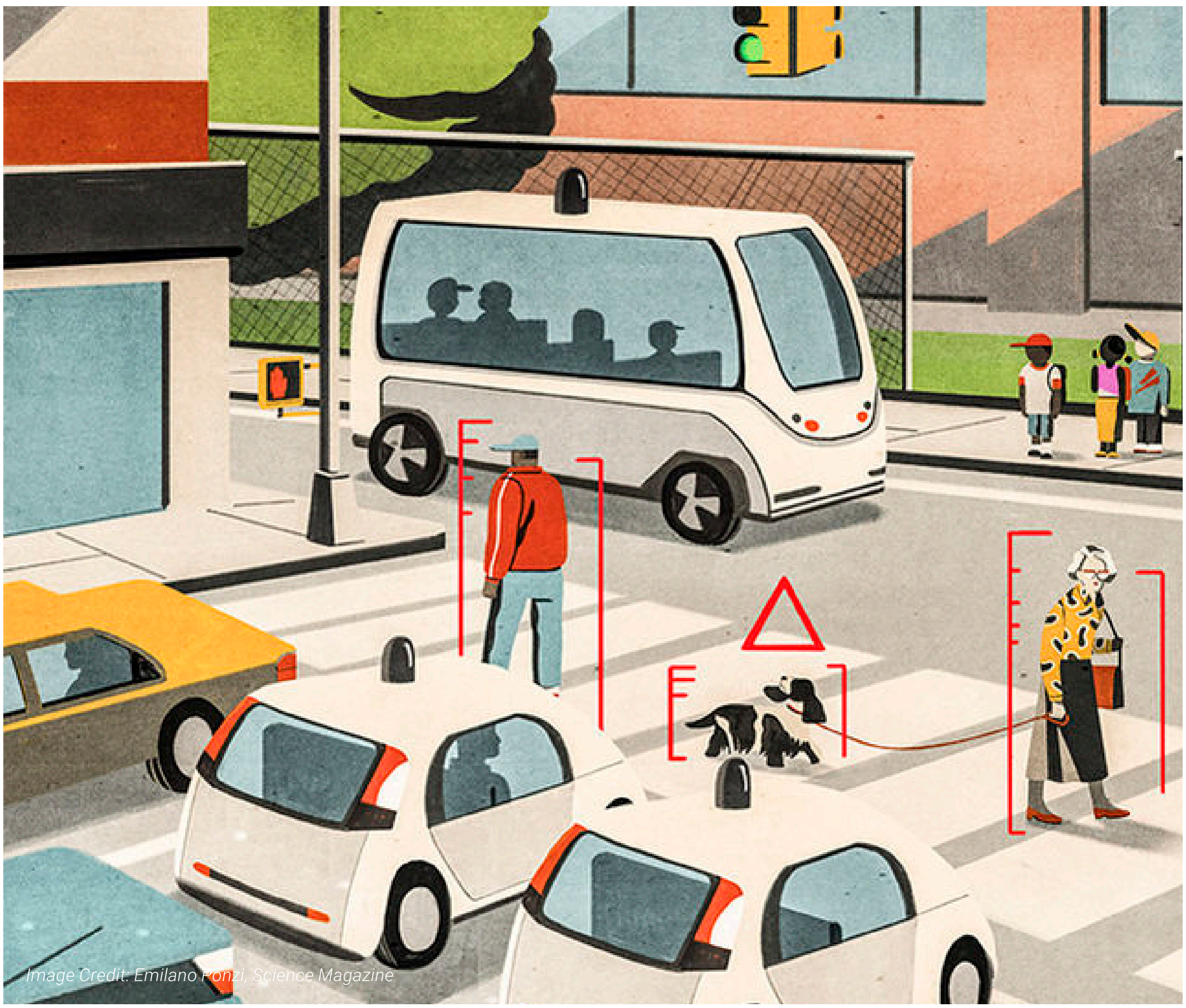


Image Credit: Emilano Ponzi, Science Magazine

CHANGES IN DRIVING CONDITIONS

By shifting some or all of the responsibility of driving from human operators to the vehicle computer, AVs could create several significant changes for drivers and the traveling public, including:

Reduced potential for collisions

The use of computer and sensor-aided travel is intended to reduce or eliminate human factors that contribute to collisions, such as lack of visibility, slow reaction times, inattention, influences of alcohol and drugs, etc. When combined with CV technology, vehicles can have even greater awareness of their environment to reduce the risk of collisions.

Traffic flow benefits

As vehicles become more autonomous and connected, they offer greater potential to result in more stable traffic flows. This could potentially increase roadway capacity by creating shorter headways, (i.e., spacing between vehicles), less weaving, and more predictable and coordinated movements, particularly on freeways and expressways.

Eliminated burden of driving

In highly autonomous vehicles, time that was originally spent driving is now available for other purposes. It also could reduce driving-related stress, particularly the stress of long-distance driving or the frustration of driving in congested conditions. If traveling via a mobility-as-a-service (MaaS) provider, such as transportation network companies (TNCs) (i.e., Uber, Lyft, etc.), or in a fully autonomous vehicle that is able to drive itself, it would also eliminate the need to find parking.

Increased access and travel options

AVs, particularly in conjunction with transportation network companies (TNCs) such as Uber and Lyft, may provide increased travel options for those who currently cannot drive, such as the young, elderly, and those unable to drive due to physical disabilities.

Reduced travel costs

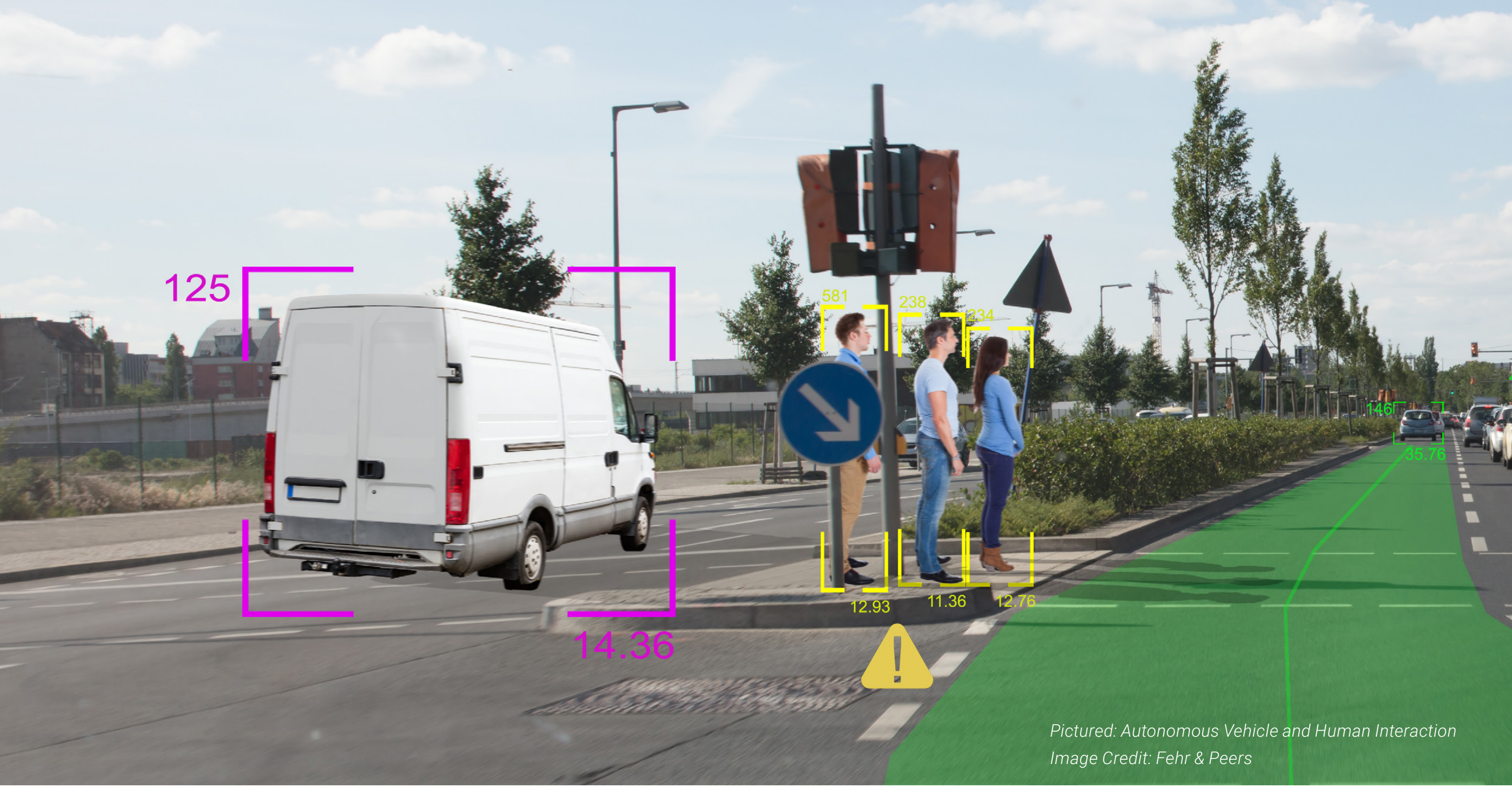
The ability to do other tasks and reduced stress as a result of automation may result in intrinsic "time cost" savings for travelers. More directly, as AVs complement the MaaS and TNC service-based model, eliminating the driver components of these services would likely lower the actual out-of-pocket cost of this service. As providing MaaS becomes less expensive and more convenient, it becomes a more attractive model compared to the costs of private ownership.

Optimized travel routing

Based on data provided to the vehicle computer, AVs will be able to use real-time data to determine and use the most optimal travel route to get passengers to their destinations. While some drivers today already use smart phone applications, such as Google Maps and Waze, to identify optimal routes, AV and CV technology will make these optimal route choices even more seamless and no longer dependent on drivers.

Increase in vehicle miles of travel (VMT)

The combined effect of the above factors is that traveling via automobile would likely become more convenient. Absent any other intervening factors (i.e., regulatory restrictions or added cost), our research shows that this results in increased vehicle travel and therefore, increased VMT. Furthermore, as vehicle travel becomes more accessible, less costly, and more convenient, transit ridership is likely to decline.



Pictured: Autonomous Vehicle and Human Interaction
Image Credit: Fehr & Peers

URBAN PLANNING IMPLICATIONS OF AVS AND CVs

By increasing the convenience and reducing the burden of driving, increased vehicle travel and reduced travel costs are likely to have several implications on transportation planning and the built environment. These effects may include:

Reduced Parking Demand

The magnitude of reduced parking demand will depend on a number of factors, including whether vehicles continue to be privately owned or facilitate a shift towards Mobility-as-a-Service (MaaS). Under the former scenario, privately-owned AVs may act as "chauffeurs," and still require parking after dropping off their owners. However, parking areas could be located further from activity centers (where demand and land values are the highest) to areas with surplus space and lower land values. Under the latter scenario, AVs will facilitate the shift toward MaaS resulting in an increased use of TNCs as the removal of drivers decreases costs and mobility services become more competitive with private ownership. This would reduce parking demand as MaaS vehicles would become a shared resource for mobility with an economic incentive to be continually driving passengers and not parked in a lot or structure.

Increased Curb Activity

While an increased use of MaaS or privately-owned AVs acting as chauffeurs dropping off their passengers at their destinations would reduce parking demand, it would also result in increased curb space demand for drop-off and pick-up activity. In Elk Grove, this may lead to re-purposing parking areas at shopping centers or office parks from places for temporary vehicle storage to areas designed for convenient and dedicated passenger pick-up and drop-off, similar to schools.

Potential for Increased Development Density

With less parking demand, current parking areas could be developed into higher value uses, such as employment, services, retail, residences, or public spaces. This would result in increased development densities, particularly in existing or planned activity centers where land values are the highest and develop able land is the most scarce. In Elk Grove, this could facilitate long-term redevelopment of existing retail centers and office parks that are surrounded by large surface parking lots, or result in reduced parking requirements which would possibly lead to increased development densities for new commercial developments.

Potential for Increased Suburban Development

AVs could induce additional demand for suburban development further from urban areas. Currently, traffic congestion and travel times from employment centers create a de facto limit on suburban development based on how long people are willing to commute. However, with AVs reducing the stress and burden of driving combined with potential traffic flow benefits and increased capacities on freeways, AVs could enable additional low-density development further from existing employment and activity centers.

Increased Vehicle Travel

As described above, AVs will likely make traveling via automobile more convenient by reducing the stress, burden, and cost of driving and increasing access to vehicles. Absent any other intervening factors (i.e., regulatory restrictions or added cost), our research shows that this results in increased vehicle travel and therefore, increased VMT. Since existing service providers, such as TNCs, are privately operated, there will be further incentive to increase vehicle travel to generate revenue. This increase in vehicle travel would conflict with statewide, and potentially local, goals of sustainability and reducing vehicle use.

Increased Congestion

The increase in vehicle travel caused by improved convenience as well as "deadheading" (i.e., zero-occupant vehicles traveling to pick up their next passenger or to a parking area until it is needed) will likely result in increased traffic congestion. While AVs will likely provide some traffic flow efficiency improvements by reducing vehicle headways and collisions, the increased travel demand would likely exceed any operational benefits, particularly on local arterial streets where intersections will continue to be the constraint on roadway network capacity. Furthermore, in activity centers or areas with increased development density, increased pedestrian activity could result in additional vehicular delay. If AVs are pre-programmed to have 100% yield compliance to ensure pedestrian safety, intersections with high pedestrian activity could become a source of increased delays, street congestion, and vehicle user frustration.

Possible Increase in Neighborhood Cut-through Trips

Combining increased travel demand and congestion on arterials with vehicle computers that can identify optimal routes to reduce travel time (i.e., avoid congestion) may result in an increase in traffic on local streets. This may be particularly noticeable on local roadways that run parallel to congested arterials, which were previously unknown or too cumbersome for most drivers to deviate to and navigate through.

Decreased Transit Ridership

As AVs and mobility services provided by AVs become more available, the attractiveness of inexpensive point-to-point transportation will likely result in decreased demand for mass transit, absent any regulatory intervention, incentives, or a MaaS structure that intentionally channels riders to mass transit service along trunk lines.

04
RECOMMENDATIONS

The recommendations presented in this plan provide ideas for the City to consider in proactively responding to the future arrival of AVs and CVs. These recommendations provide a wide range of strategies and consider the potential utility of these actions beyond serving AVs and CVs. This is important given the uncertainty regarding the specific timing and the potential magnitude of the effects AVs and CVs will have on our transportation network and built environment.

Photo Credit: CC BY 2.0

HOW TO PREPARE FOR THESE CHANGES?

AVs will be capable of operating on City streets without any major changes to current practices. Therefore, local agencies should not need to invest in new or upgraded infrastructure for AVs to function on their streets.

However, there are infrastructure investments that the City can consider that would better prepare it to take advantage of an AV future, as well as support and facilitate AV and CV effectiveness. Furthermore, there are opportunities for local agencies to proactively identify policies and future actions to align AV and CV travel to reflect the overall goals and values of the local community.

Using this framework, the recommendations presented in this plan address two overarching topics:

1. **Infrastructure**

   Manage existing and invest in strategic infrastructure to support effective future travel by AVs and CVs. Prepare the City to maximize the potential benefits from this technology.

2. **Policy**

   Consider future policy efforts that would clarify the community's values and expectations regarding future AV and CV travel in Elk Grove. Manage the effects of AVs and CVs on the Elk Grove community.

The National League of Cities (NLC) recommends that local agencies consider the following four overarching steps to prepare for AVs:

Start Planning for AVs Now

This Readiness Plan demonstrates Elk Grove's commitment to starting this planning process. The NLC emphasizes that early stakeholder and community engagement and education are helpful first steps to lay the groundwork for future policy discussions.

Policy Development Framework

Begin considering how AVs may fit into long range plans and initiate discussions about how to develop critical policies and priorities for the safe operation of AVs.

Track and Monitor Federal & State Developments

Federal and state entities have typically played a significant role in regulating transportation. However, the profound effect AVs will have on cities makes it critical for cities to stay apprised of federal and state policy and legislative development. Cities should voice their interests, objectives, and concerns, and ensure new policy guidance, regulation, or legislation considers the issues that are important for cities.

Plan Infrastructure Needs & Build Data and Computing Capacity

Consider long-term infrastructure needs, such as data storage and processing capacity, to better position the City to support and integrate AV and CV technology.

INFRASTRUCTURE STRATEGIES

The following outlines steps that the City of Elk Grove can take to prepare for the coming AV and CV future. The recommendations outlined below consider the substantial uncertainty associated with the evolution of technology and policy direction at the State and Federal levels. The recommendations focus on actions that the City can take that will be beneficial for an AV and CV future, but will not waste City resources on actions that may become obsolete or antiquated as AV and CV technology and policy become more certain.

1. Asset Management

Maintaining roadway infrastructure features, such as signs, lights, lane markings, and curb space, so they are reliably detectable and discernible by AV sensors is important to the safe operation of automated vehicles. The City's recent addition of the computerized maintenance management system is a powerful and convenient tool for tracking and maintaining existing City infrastructure. The computerized maintenance management system can be used to track and manage assets that are relevant to future AV and CV operations on City streets. Examples of computerized maintenance management system AV readiness categories:

AV Ready Assets

- » 6" reflective thermoplastic striping.
- » Roadway signage meeting current standards for size, message and retro-reflectivity.
- » Intersection pavement markings exist, are legible and constructed with retro-reflective material.
- » Traffic signal controllers that support connected vehicle technology and operate in high speed communication networks.
- » Inventory of existing electronic infrastructure (traffic signals and CCTV cameras) connected to the existing fiber optic system, wireless or mobile network.

Assets for Immediate Upgrade to AV Ready Status

- » 4" striping to be upgraded to 6" reflective thermoplastic striping.
- » Signage not meeting current messaging standards and reflectivity requirements.
- » Legacy traffic signal controllers that do not support connected CV technology.
- » Legacy copper and wireless networks (maintain as backup and install new fiber optic backbone).

Assets for Future Upgrade as Technology Becomes Available

- » Prioritize signage to be replaced with machine readable signs for future AV use.
- » Corridors and intersections that have high definition mapping available for future AV use.
- » Identify traffic signals with unique operations, including traffic signals using electronic blank out signs to restrict turn movements, signals operating protected/ permissive left turns, right turn overlaps, flashing yellow arrow movements. Tracking these signals will help to prioritize the installation of vehicle to infrastructure (V2I) hardware once a V2I communication technology is selected in the future.

RECOMMENDATION

Use the computerized maintenance management system to manage and track the status of AV ready assets. Identify existing AV ready assets, assets that can be immediately upgraded to AV ready without the implementation of new technology, and assets set aside for future upgrade as the technology becomes available.

COST

Cost is equal to staff time with no associated hardware or infrastructure costs required for inclusion of AV asset management into existing computerized maintenance management system.

2. Roadway Striping

In 2018, the Federal Highway Administration (FHWA) conducted a survey to determine what infrastructure was needed to support autonomous driving systems. One of the top themes from the survey was "Greater uniformity and quality in road markings and traffic control devices would enable automation. Having greater consistency in road markings and traffic control devices and an improved state of good repair benefits all road users, including ADS."

The Marking Technical Committee of the National Committee on Uniform Traffic Control Devices (NCUTCD) developed criteria to help cameras (and humans) detect markings in otherwise challenging conditions such as worn markings, wet conditions, glare, etc. The suggestions include standardizing the width of edge-lines at 6-inches (previous standard was 4-inches). Caltrans has adopted 6-inch wide markings and new reflective standards in 2018 as a way to accommodate autonomous vehicle technologies.

RECOMMENDATION

Identify and prioritize corridors to become AV ready. Update striping along these corridors to follow Caltrans current 6-inch striping width and reflective standards.

COST

6-inch thermoplastic reflective striping @ $0.85 per lineal foot, compared to $0.75 per lineal foot for 4-inch thermoplastic reflective striping.

3. Fiber Optic Infrastructure

CAVs are estimated to produce nearly 11 Terabytes of data per day. It is estimated that a CAV will upload 25 gigabytes of data every hour to external networks. CAVs will upload data about everything including its route, its speed, the wear and tear on its components, and even road conditions. Vehicles today have about 40 microprocessors and dozens of sensors that collect telematics and driver behavior data, and that data can be analyzed in real-time to keep the vehicle's performance, efficiency, and safety in check. It also provides vital feedback for local and state agencies about traffic volume and roadway design.

The challenge is transmitting the large volume of vital data to the City's TMC. Existing copper wire based networks are not sufficient for collecting and reliably transmitting the volume of data a CAV has to offer that is essential to manage traffic and improve safety.

The City's existing fiber optic communications network consists of 7.2 miles of fiber optic cable and 42.6 miles of legacy copper signal interconnect cable. The City's fiber optic network currently includes a fiber optic cable trunk (backbone) located along Laguna Springs Drive, Laguna Boulevard, Elk Grove-Florin Road, and Bond Road that connects the City Hall Campus buildings and the City Corporation Yard.

RECOMMENDATION

Expand the existing fiber optic network. As part of an AV readiness strategy, the City should continue expansion of its fiber optic system to replace existing legacy copper. Priority corridors include the following:

- Laguna Boulevard – Harbour Point Drive to Big Horn Boulevard
- Harbour Point Drive – Maritime Drive to Elk Grove Boulevard
- Elk Grove Boulevard – Harbour Point Drive to Waterman Road
- Bruceville Road – Kammerer Road to Sheldon Road
- Sheldon Road – Bruceville Road to Elk Grove Florin Road
- Elk Grove Florin Road – Bond Road to Calvine Road
- Big Horn Boulevard – Amber Creek Drive to Laguna Boulevard (including Lewis Stein Road from Big Horn Boulevard to W Stockton Boulevard)
- Franklin Boulevard – Bilby Road to Big Horn Boulevard
- Whitelock Parkway – Franklin Boulevard to Bruceville Road
- Promenade Parkway – Kyler Road to Kammerer Road
- Grant Line Road – Promenade Parkway to Waterman Road
- Power Inn Road – Geneva Pointe Drive to Sheldon Road
- Kammerer Road – Grant Line Road to I-5

COST

$3.00 per foot. Additional costs for installation may vary by location and include: trenching, conduit, splice closures, new switches, etc. The Elk Grove Traffic Congestion Management Plan 2019 notes that build out of the City's fiber optic network is estimated to exceed $15,000,000, but the actual cost is unknown at this time.

Pictured: Fiber Optic System Expansion
Credit: Fehr & Peers

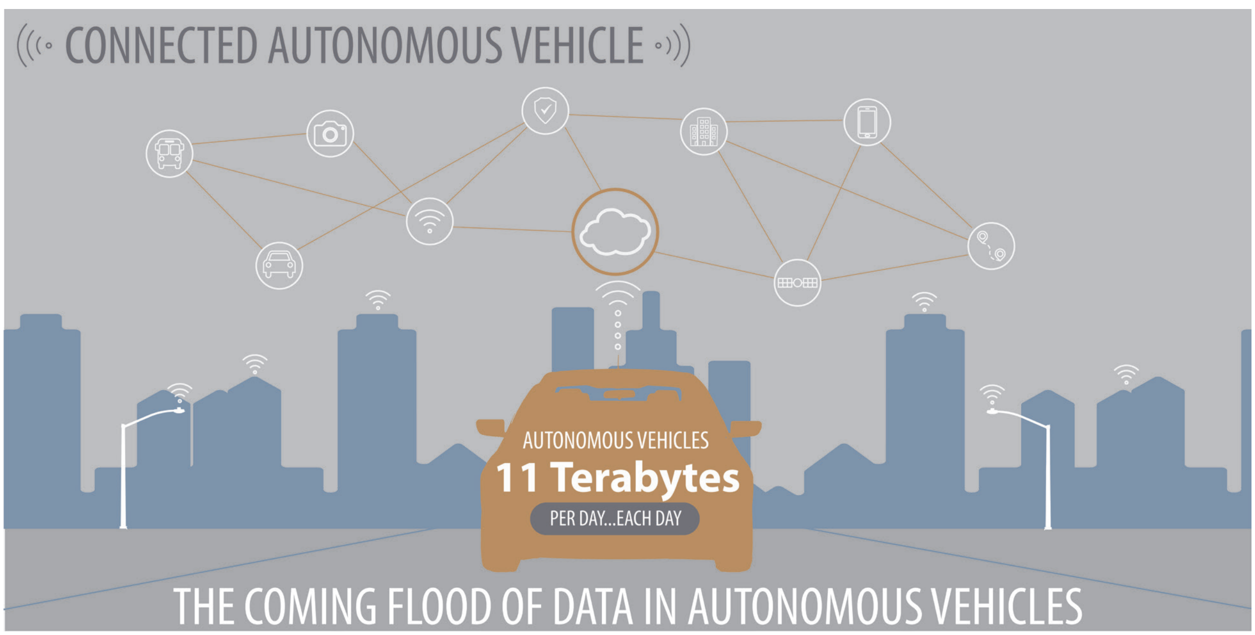
Pictured: Elk Grove
Credit: Fehr & Peers

4. Data Management

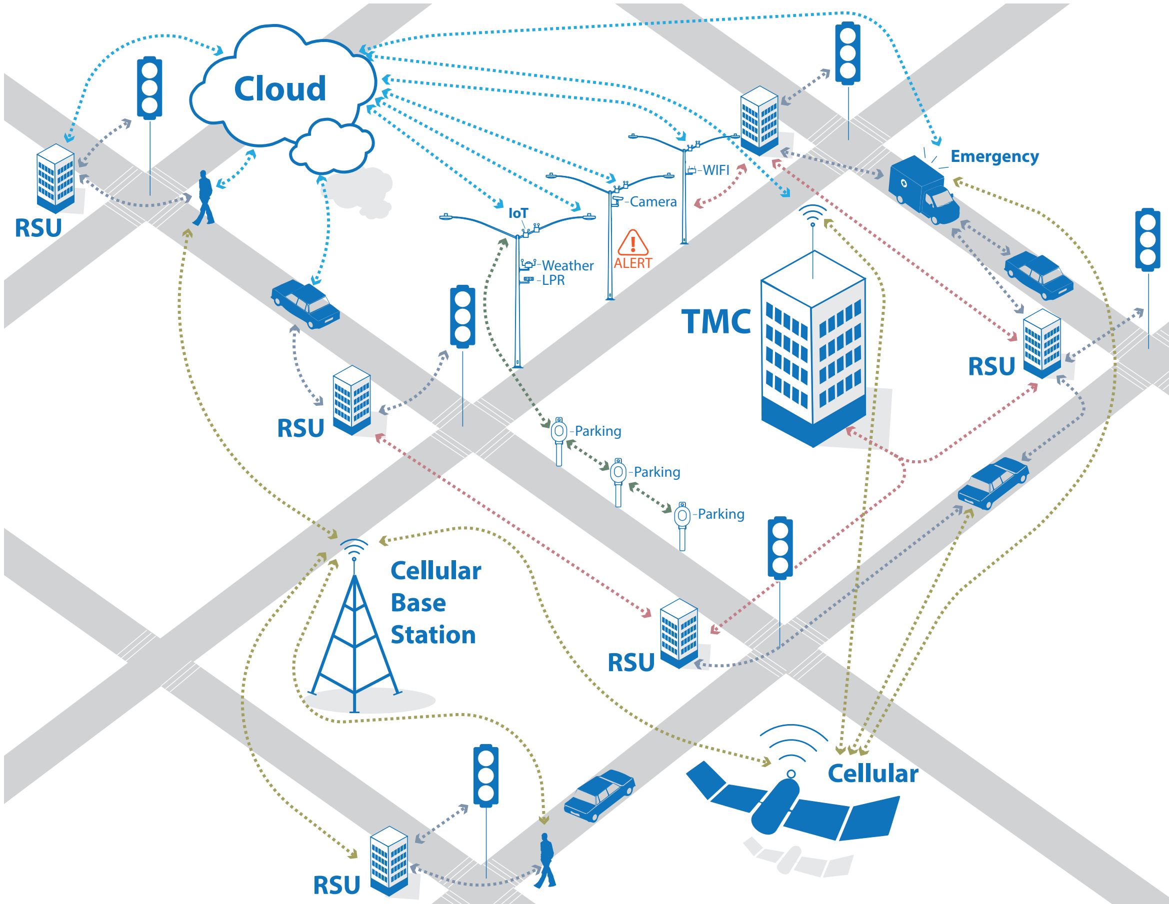
Effective traffic management relies on data from intelligent transportation systems (ITS) to monitor and control dynamic message signs, traffic cameras, streaming video, adaptive traffic signals, etc. Data provides access to congestion information for freeways and local arterials as well as weather data, which impacts local transportation and travel times. CAVs will produce vehicle specific data such as vehicle speed, route, wear and tear on the vehicle, and road conditions. CAV and ITS data can be used for a variety of purposes: safety, emergency response, traffic signal optimization, traffic volume, transit efficiency, mobility, and more. In addition to producing data, CAVs will also utilize data to plan routes, access high definition maps, avoid congestion and more. Real-time data generated by CAVs and ITS infrastructure can be provided to third-party app developers.

Data collection, data aggregation, and data sharing is becoming a mission critical function for CAVs. Historically, data processing and analysis has taken place within the TMC.

Modern systems make increasing use of edge or cloud computing, where the analysis takes place in the field or transmitted to computers and servers in a third-party cloud. This strategy reduces the burden on communication systems to transmit all data back to the TMC. Regardless, it is important to develop a data management plan that addresses how to organize data provided by hardware and software in the field. Development of a data management center takes time and involves system planning, developing operational strategies, performing system design, implementing hardware, and developing cyber security protocols. Beginning the process now will accelerate AV implementation within the City and provide TMC staff with modern transportation management tools that have immediate benefits.



Pictured: The Coming Flood of Data in Autonomous Vehicles
Image Source: Fehr & Peers



Pictured: Traffic Management Center Data Collection
Credit: Fehr & Peers

RECOMMENDATION

Develop a scalable data architecture within the City's TMC. Use the reference designs for CV systems, provided by the Department of Transportation, to begin building a data center architecture that is capable of scaling to handle the huge volume of data that will be generated by CAVs and smart infrastructure assets that will all be communicating with each other. Build a multi-service network that is capable of integrating different technologies and disparate data sources onto one platform. This will allow everything from the traffic signals to CAVs on the road to weather data and data from transit systems to all function on the same infrastructure within the TMC.

COST

Unknown. This will involve network and communications system design and systems integration consultants. Cost will be dictated by the complexity of the initial data management architecture.

5. Smart Street Lighting

Utilizing Internet of Things (IoT) technology, streetlights can communicate with AVs about upcoming traffic patterns, relay crash avoidance data, or guide them to use a preferred route. Streetlights can gather data from roadway sensors, traffic cameras, transit vehicles, and emergency vehicles. TMC staff can use street light sensor data to manage transportation throughout the city.

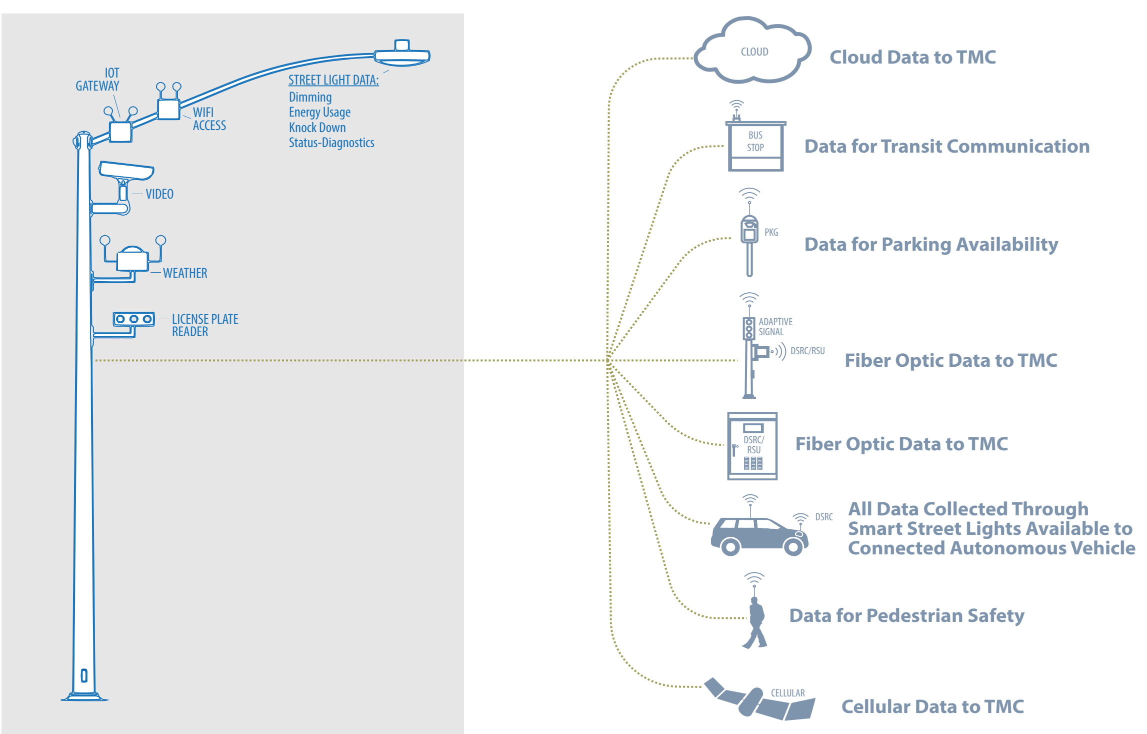
There are many transportation benefits to implementing smart street lighting. One example of an Elk Grove smart street lighting application: Complete the fiber optic installation from Harbour Point Drive and Maritime Drive to Elk Grove Boulevard and Waterman Road as described in the fiber optic recommendations above. Use the fiber optic cable to connect bus stops along Elk Grove Blvd to the internet, turning them into WiFi access points. These, in turn, connect with WiFi-enabled street lamps that monitor traffic flow and air quality.

RECOMMENDATION

Recommended with phased implementation of fiber optic infrastructure and operational data management resources where appropriate to monitor and collect traffic data.

COST

Approximately $100,000-$200,000 per mile for base units on each street light (assuming street lights on both sides of an arterial street at 150-foot spacing). May require additional cost to retrofit existing lighting fixtures to be compatible. Installation, integration costs, and additional sensors, such as cameras, license plate readers, etc. would be in addition to the base unit cost and could initially far exceed the cost for the base units.



Pictured: Traffic Management Center Data Collection
Credit: Fehr & Peers

6. Cloud Based Network

Cloud based traffic solutions have the ability to collect data from CAV sensors, road cameras, traffic feeds, IoT enabled infrastructure, smart street lights, weather stations, and mobile devices, and process the data in AVs. The processed data is transferred to the cloud, aggregated, and sent back to other CAVs, smartphones, and the TMC almost instantly.

A cloud based solution can link CAVs, road infrastructure, TMC staff, and people through cloud-based Vehicle to Vehicle (V2V), Vehicle to Everything (V2X), and Vehicle to Infrastructure (V2I) channels almost instantaneously.

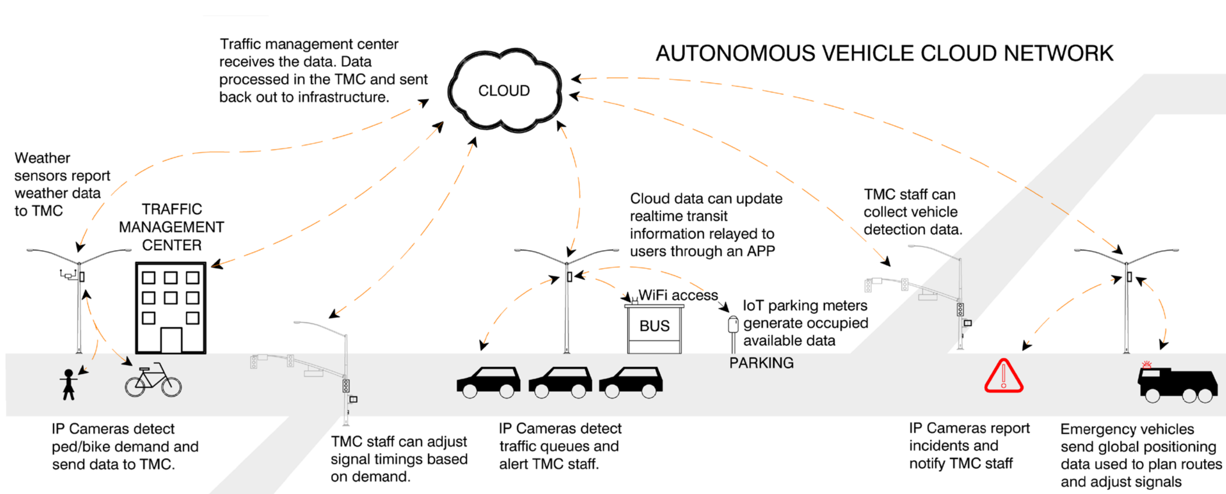
Using a cloud based network will likely play a role in the future of Elk Grove's traffic management center but only after data architecture and cybersecurity protocols are in place.

RECOMMENDATION

Not recommended to develop a cloud network at this time due to uncertainties in the hardware technology and specifications associated with data format.

COST

Unknown. Cost will depend on the extent of infrastructure linked to a cloud-based network, frequency of data access, and how much cloud-based data capacity is needed.



Pictured: AV Cloud Network

Source: Fehr & Peers

7. Deploy Connected Vehicle Infrastructure at Intersections

Deploy CAV equipment and establish vehicle to infrastructure communication (DSRC radios or cellular network equipment) at signalized intersections or other key locations throughout the City. The DSRC radio strategy would initiate a pilot program and would require procuring CAV equipment that would need to be installed at signalized intersections by the City. This strategy does not include the push of specific CAV data to vehicles using the system, but rather making the CAV infrastructure data available for agencies or the region to utilize when CAV software and data are more robust and available. The National Operations Center of Excellence has developed a SPaT (Signal Phase and Timing) challenge to help cities procure and implement CAV infrastructure. The SPaT is a challenge to state and local public sector transportation infrastructure owners and operators to cooperate together to achieve deployment of DSRC infrastructure with SPaT broadcasts in at least one corridor or network (approximately 20 signalized intersections) in each of the 50 states by January 2020. DSRC communications are the only FCC approved devices allowed to operate in the automotive safety spectrum.

Deploying cellular network infrastructure to communicate with CAVs offers benefits over the DSRC radio strategy. To enhance the safe and effective operation of CAVs, cellular networks can provide fast, always-on network connectivity. Network connectivity allows CAVs to see beyond the line of sight provided by on-board sensors and roadside DSRC radio units. This connectivity increases the range of basic safety messages to enable CAV crash avoidance systems to respond earlier. Pedestrians and vulnerable road users also benefit from wireless connectivity which can enable safety messages from vehicles and infrastructure. Cellular networks offer the ability to support client devices which are roaming at high speeds across large areas as many AVs will do.

Currently, the FCC restricts cellular networks from operating in the automotive safety spectrum. The 5G Automotive Association (5GAA) is a global, cross-industry organization of companies from the automotive, technology, and telecommunications industries, working together to develop end-to-end solutions for future mobility and transportation services. 5GAA's goal is to prove to the FCC that cellular networks can provide the reliability and data transmission speeds capable of supporting automotive safety features and be allowed to operate in the automotive safety spectrum.

RECOMMENDATION

Not recommended to deploy connected vehicle infrastructure due to the uncertainty associated with competing technologies (DSCR vs. Cellular) and FCC regulations prohibiting cellular technology from using 5.9 Ghz frequency.

COST

Typical roadside unit is approximately $10,000 per intersection. Installation, integration costs, and additional equipment (i.e., cameras, radio devices, etc.) would be in addition to the basic roadside unit and could far exceed the $10,000 cost for the base unit with the initial implementation (i.e., later implementation could be less expensive once system is setup and integrating new units is less complicated).

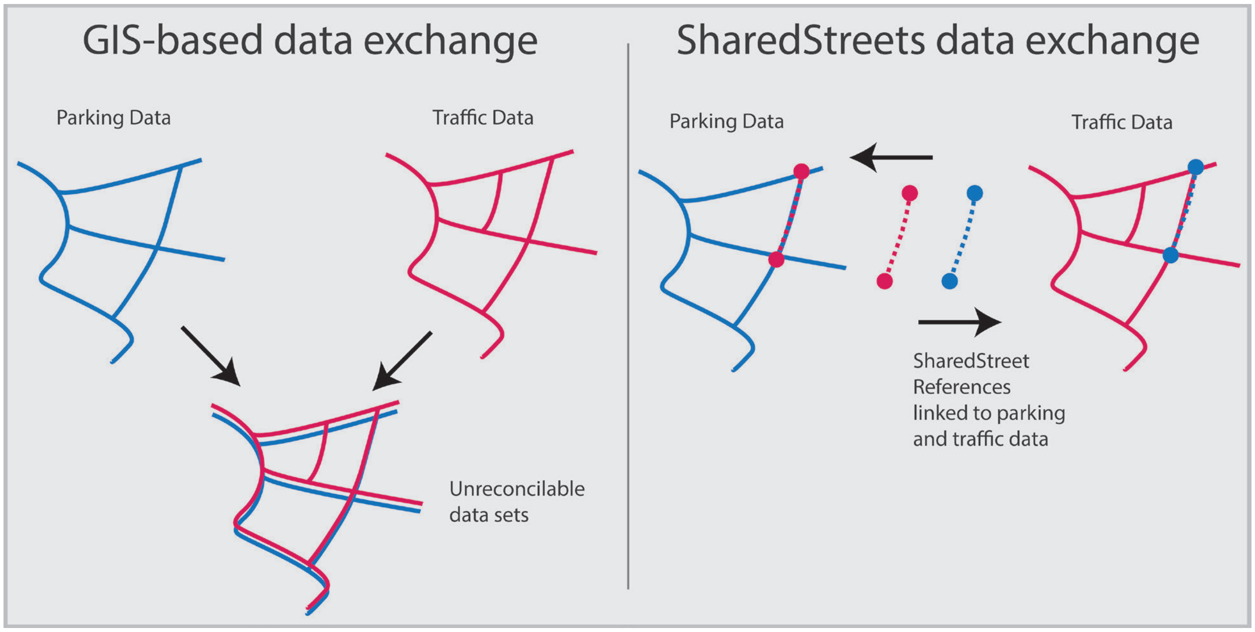
WHAT ROLE CAN LOCAL AGENCIES PLAY?

Vehicle sensors on AVs are certainly capable of "seeing" a wide array of roadside infrastructure and other vehicles. Therefore, local agencies could literally "do nothing" and AVs would be able to operate on City streets.

However, there is a limit at this time (barring technological advances that are not on the horizon) to AVs ability to interpret some roadside infrastructure such as dynamic signs, vehicle occupancy requirements, and temporary traffic controls. The need to supplement high-definition maps with other road rules has prompted the development of other data repositories as means by which public agencies can provide information to vehicle manufactures and companies that provide Mobility-as-a-Service (MaaS). Two examples of efforts that local agencies are undertaking to support AV travel are provided.

City of Los Angeles Mobility Data Specification

The City of Los Angeles Mobility Data Specification (MDS) is a "data standard and application programming interface (API) specification for mobility-as-a-service providers, such as Dockless Bikeshare, E-Scooters, and Shared Ride providers who work within the public right of way. Inspired by the General Transit Feed Specification (GTFS) and the General Bikeshare Feed Specification (GBFS). Specifically, the goals of the MDS are to provide API and data standards for municipalities to help ingest, compare and analyze mobility as a service provider data. The specification is a way to implement real-time data sharing, measurement and regulation for municipalities and mobility as a service providers. It is meant to ensure that governments have the ability to enforce, evaluate and manage providers. Implementing a data standard in this way will allow Elk Grove to standardize key aspects of data exchange between the City and different AV providers.



Pictured: NACTO/Open Transport Partnership SharedStreets Data Exchange
Source: NACTO and Fehr & Peers

NACTO/Open Transport Partnership SharedStreets Standards

The SharedStreets data standard (launched in February 2018) is a first-of-its-kind transportation data standard and platform for public-private partnerships that allows cities to work with companies to manage streets, and prepare for the unprecedented technological advancement emerging in cities' transportation networks. The SharedStreets web portal is accessed at http://sharedstreets.io/.

For example, the SharedStreets portal might contain a Street and curb inventory where Cities produce detailed curb inventories including parking regulations and physical assets, using internally managed linear referencing systems (LRS), or latitude/longitude coordinates not linked with streets. Internal LRS data can be translated to SharedStreets references to allow interoperability with other city or external data sets.

For Incident/road closure reporting, transport authorities share data about street conditions in real-time with consumer applications. SharedStreets references can be used to streamline reporting procedures by providing a shared, non-proprietary format for describing roadway incidents and closure events.

POLICY RESPONSES

The infrastructure strategies presented would help the City of Elk Grove be better prepared to serve AVs and CVs and provide opportunities to share and receive valuable data from these vehicles. They would also prepare the City's infrastructure to communicate with CVs and CAVs. This could provide opportunities for the City to manage potential increased roadway congestion by modifying signal operations, communicating directly with vehicles to avoid certain roadways, or alert vehicles to unique situations, such as the approach of an emergency response vehicle. However, by themselves, these infrastructure strategies do not fully address or mitigate the potential effects AVs and CVs could have on travel and the built environment.

On the other hand, government actions, regulations, and standards could influence and even have a dramatic effect on these outcomes. Policy and regulatory responses could be used to balance the incentives of the private market and desired outcomes that reflect community values and the public good. These responses could cover a range of topics. The following topics are intended to provide the City with an initial idea of possible options, and could be modified or expanded upon as needed.

Community & Stakeholder Outreach & Engagement

As recommended by the NLC, initial planning for AVs should include early stakeholder and community engagement and education to lay the groundwork for future policy discussions. This engagement should reflect the key topics discussed in this plan. For example, it should include educating the public on the current status of AVs and CVs, what the City can do to prepare for them as they begin hitting the streets of Elk Grove, the approximate time frame and uncertainty of their deployment, and the potential effects they may have on travel and the built environment. This engagement process should also be used to understand the community's values, desires, and concerns regarding AV and CVs. What are the benefits that the community and stakeholders are most eager for and what actions can the City take to encourage and support those beneficial outcomes? What are the biggest concerns, and how can the City begin to plan and develop a strategy for mitigating those effects now before they become an issue?

Understanding the community's values and desires are also important when prioritizing AV and CV-focused infrastructure projects. Each infrastructure investment should be evaluated against the community's desires, and those that would bring about outcomes that most closely align with those values should be prioritized. For example, if congestion management is a concern, investments that reduce congestion whether they be infrastructure related (i.e., interconnected signal systems using fiber or CV infrastructure) or through demand management strategies that could be enhanced with CV infrastructure (i.e., prioritizing HOVs, rideshare vehicles, etc.).

Lobbying for Data Sharing & Effective Communication Standard

Historically, technology companies and automobile manufacturers have been resistant to sharing data collected through vehicle computers, particularly related to the testing of AV technology. As AV and CV use become more widespread generating terabytes of data along the way, it will become beneficial, if not critical, for cities to have access to appropriate levels of this data and for their infrastructure to effectively communicate with private vehicles. For example, if the City wants to inform private vehicles about an emergency response vehicle approaching or establish parameters to reduce neighborhood cut-through traffic, it may be dependent on the ability of the City's TMC to communicate effectively with private vehicles. How this data sharing and communication protocol is established is likely to be determined through state or federal regulations and standards. Therefore, it is recommended the City monitor developments at state and federal agencies and legislatures and collaborate with other local agencies to encourage this data access.

Applying Cost Structures or Infrastructure Priorities to Manage Effects & Encourage Desired Outcomes

Managing increased traffic levels can occur through a variety of strategies including:

- Pricing AV travel to encourage higher occupancy travel. For example, working with MaaS providers to set up a fee structure that results in higher user costs for zero-occupancy (i.e., a surcharge for "deadheading") or single-occupancy vehicles and lower costs for shared rides and high-occupancy vehicles. Furthermore, a surcharge could be applied for traveling during peak periods compared to off-peak periods to encourage peak spreading.
- Using infrastructure, including possibly leveraging CV technology, to prioritize higher occupancy vehicles. For example, during congested conditions, infrastructure receiving information from CAVs could have high occupancy vehicles travel at a higher speed in their own travel lane while single occupancy or zero occupancy vehicles are relegated to slower travel lanes.

Restructuring Transit

Transit travel times are often much slower than automobile travel, and with AVs expanding access to door-to-door service, whether through private vehicles or through service providers such as TNCs, transit will become less competitive. However, mass transit is still more efficient on a passenger density basis for highly traveled routes between major origins and destinations. Therefore, to facilitate transit in light of an AV future, transit service and experience may need to substantially change to remain competitive. This could include:

- Automating transit service: adopting autonomous vehicle technology into transit vehicles could offer several benefits. Savings on labor could be redirected to expanding core services, which would result in increased frequency on the lines in most demand. When combined with technology that matches riders with common destinations, autonomous rapid transit (ART) service could improve travel times by allowing the ART vehicle to skip stations. This would be further enhanced by transit only or high-occupancy travel lanes.
- Better match vehicle types with transit demand: TNCs/MaaS offer expanded options for demand response service in low-demand areas. These services can connect to traditional or ART service provided on trunk lines that experience higher demand.
- Increasing service frequencies: increasing frequency reduces wait times and provides flexibility for passengers to use transit without needing to be concerned about schedules
- Transit-Only lanes: particularly with the potential for increased vehicle travel and congestion associated with AVs, designating lanes for transit vehicles on designated transit corridors would allow transit vehicles to be travel time competitive with automobile travel.

Land Use Strategies

AVs are likely to affect development pressure, with the potential for redevelopment of parking areas, reduced parking demand, and increased attractiveness for residential development at the urban edge. Therefore, zoning changes may be necessary to either harness or restrict these changes, as desired by the community. For example, as parking demand is reduced, minimum parking requirements could be updated to allow fewer parking spaces, freeing up more land for development or conversion to public spaces. There could be additional demand for new development at the edge of the city that are not yet zoned for development. The community and decision makers should weigh the benefits and challenges of this increased development demand and how to respond in a way that reflects the community values.

APPENDIX A

Traffic Management Center Upgrades

The city's current TMC signal control system software is not equipped to incorporate the variety of data generated from CAV's and IoT enabled infrastructure. To increase connectivity and data sharing, the city will need to build out both the technology infrastructure (data centers, cloud infrastructure, power, fiber optic cable, switching and routing infrastructure, and cybersecurity), as well as the hardened, physical infrastructure assets (IoT-connected traffic signals and sensors along roadways). Using the reference designs for connected and autonomous vehicle systems provided by the Department of Transportation, the city can start small and build a data center architecture within the TMC that is capable of scaling to handle the huge volume of data that will be generated by CAV's and smart infrastructure assets that will all be communicating with each other. The goal should be to build a multi-service network that is capable of integrating multiple different technologies and disparate data sources onto one platform. This will allow everything from the traffic signals to CAV's on the road to weather data and data from mass transit systems to all function on the same infrastructure within the TMC.

Agencies looking to move forward into the era of connected autonomous transportation and mobility may want to begin by focusing on the following data topics:

» Data for Safety: Communicating with roadside infrastructure and accessing video feeds from IP cameras, connected autonomous vehicles can be alerted to accidents, work zones or construction areas or other road hazards ahead. With the deployment of Dedicated Short Range Communication (DSRC) radios CAV's can communicate with traffic signals to know if they are about to change and adjust speed accordingly, or even alert the CAV to slow down when they are entering a school zone. By monitoring CAV data exchanged at the radio locations, the TMC can make adjustments to traffic flows by adjusting signal timings based on speed data. All these examples can help reduce the number of crashes and fatalities on our roadways.

» Data for traffic signal preemption: Emergency response vehicles equipped with the proper sensors and exchanging real-time data, allows the city to prioritize emergency responders and police, allowing them to preempt the traffic signals and arrive on scene faster. Emergency vehicle preemption on a common, converged IP infrastructure and using standards-based dedicated short range communications enables the reuse of this architecture for many other applications with reduced incremental cost. Transit signal priority is another example that can take advantage of DSRC data. Deploying CAV infrastructure at traffic signals and at key locations throughout the city can yield enormous value through unlocking new data sets.

» Data for Mobility: With all the different transportation options available today, people want a seamless mobility experience when it comes to optimizing planning, scheduling, wayfinding and paying for their trips across different modes of transportation, and they want to be able to do it all from one platform. For example, if a person's journey combines multiple modes of transportation such as bus, train and car-sharing, they should be able to easily schedule and pay for all those services from one platform or interface rather than accessing multiple different applications, scheduling and ticketing systems. To do this, the city will need the ability to connect different modes of transportation, each with varied types of data, from multiple different transportation infrastructure assets and through the TMC integrate it all in one common platform.

» Data as a revenue source: As autonomous, connected and ridesharing vehicles increase in prevalence, more people are moving toward Mobility as a Service (MaaS) and the importance of owning a personal vehicle is diminishing. This trend, coupled with the fact that more electric vehicles are hitting the roadways, means that state and local governments are gathering less revenue from gas taxes, tolls and other forms of vehicle-related recurring revenue that help them maintain roadways and infrastructure. The city can look to recoup these losses and find new revenue streams by offering new conveniences and monetizing the data collected through CAV's and connected infrastructures.

- Data for transit efficiency: Asset utilization and the ability to gain benefit out of the common infrastructure assets already in place are important goals for many cities. By connecting existing infrastructure assets to a multi-service IoT network and enabling greater data-sharing capabilities, central operations centers for mass transit systems can monitor their fleets in real time, adding capacity and re-routing or making adjustments as needed. They can also provide riders with real-time alerts on scheduling changes for greater efficiency and reduced operational costs.

Cybersecurity

- Infrastructure Cybersecurity: The Federal Highway Administration (FHWA) is working on multiple fronts to improve the cybersecurity resilience of surface transportation infrastructures. Outreach and awareness efforts are underway in cooperation with the National Highway Institute, engineering organizations, and transportation agencies to demonstrate how cybersecurity risks can affect their operation. Tools are being created to help interested agencies improve their infrastructure, processes, and organizational structures to more effectively address risk to their cyber physical systems. FHWA's efforts have focused on customizing risk mitigation materials, originally developed by the National Institute of Standards and Technology (NIST), for operating engineers in the highway transportation sector. FHWA is also working closely with the ITS JPO and its modal partners to explore, assess, and mitigate additional risks that potentially could stem from increased connectivity between vehicles and infrastructure.

- ITS Architecture and Standards Security: The USDOT's vision is to build uniform, end-to-end security into the system architecture to protect the integrity and privacy of the data traveling throughout the CAV environment. This security approach ensures that vehicles exchanging data as they travel down a highway, vehicles receiving data from infrastructure at traffic signals or work zones, and all other components and participants in the CAV system can rely on the integrity of the CAV data received. The US DOT has supported and participated in the development of voluntary consensus standards critical to the trust/authentication model of security for connected vehicle environments. Organizations such as the Institute of Electrical and Electronics Engineers and the Society of Automotive Engineers develop voluntary consensus standards in cooperation with industry and installers. The foundational standards required for the USDOT's connected vehicle security solution have been published and are publicly available. The ITS JPO will continue to support and work with these organizations to evolve these foundational standards and develop additional security standards required to ensure security in the connected vehicle environment.

APPENDIX B GLOSSARY OF TERMS, ABBREVIATIONS, AND ACRONYMS

AASHTO	American Association of State Highway Officials
ACC	Adaptive Cruise Control
AI	Artificial Intelligence
API	Application Programming Interface
AV	Autonomous Vehicle
BSM	Basic Safety Message
CAV	Connected Autonomous Vehicle
CV	Connected Vehicle
DSRC	Dedicated Short Range Communication
FCC	Federal Communications Commission
FHWA	Federal Highway Administration
GBFS	General Bikeshare Feed Specification
GTFS	General Transit Feed Specification
IEEE	Institute of Electrical and Electronics Engineers
IoT	Internet of Things
ITE	Institute for Traffic Engineers
MaaS	Mobility as a Service
MDS	Mobility Data Specification
NCUTCD	National Committee on Uniform Traffic Control Devices
NEMA	National Electrical Manufacturer's Association
NHTSA	National Highway Traffic Safety Administration
NLC	National League of Cities
NTCIP	National Transportation Communications for Intelligent Transportation System Protocol
SAE	Society of Autonomous Engineers
SPaT	Signal Phase and Timing
TNC	Transportation Network Company

US DOT	United States Department of Transportation
VMT	Vehicle Miles of Travel