Establishing a Regional Planning Framework for Connected and Automated Vehicles

New York State Association of Metropolitan Planning Organizations (NYSAMPO)
Transportation System Management and Operations (TSMO) Working Group

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Executive Summary

In recognition of the potentially transformative impacts that Connected and Automated Vehicles are anticipated to have on transportation infrastructure and community development trends, the New York State Association of Metropolitan Planning Organization's Transportation Systems Management and Operations Working Group prepared this white paper to serve as a guide for MPO board members, staff, and member agencies to use when developing a planning program for the deployment of these vehicles.[1] Rather than trying to forecast what the specific impacts of Connected and Automated Vehicle technologies will be, this white paper encourages communities to articulate how they see these technologies contributing to the realization of community goals in areas such as public safety, access and mobility, land use and civic design, economic and workforce development, environmental protections, and transportation system efficiency and reliability. In addition, this paper seeks to establish a coordinated policy framework for Connected and Autonomous Vehicle deployment planning across all of the New York State's Metropolitan Planning Organizations.

In an attempt to clarify the meaning of commonly used terms, this white paper offers the following definitions for Connected, Automated, and Autonomous Vehicles:

- *Connected Vehicles* are vehicles that use two-way short- to medium-range wireless communications, known as Dedicated Short-Range Communication (DSRC), to interface with other vehicles and roadside infrastructure;
- *Automated Vehicles* are vehicles with one or more functions (such as steering, acceleration, or braking) that operate independently of a human driver (i.e., "automatically");
- *Autonomous Vehicles* are vehicles that operate without any connections or communications with other vehicles or roadside instrumentation (i.e., "autonomously" from roadside infrastructure).

A clear definition and understanding of these terms is critical because each vehicle type will have different impacts. A connected vehicle future is very different from an autonomous vehicle future in terms of the range of capabilities and benefits that can be achieved with connected over autonomous vehicles. Federal and state policy-makers generally agree that the greatest benefits will come from *connected* rather than *autonomous* vehicles because connected vehicles enable full integration between vehicles and infrastructure, thus realizing the maximum potential safety, efficiency, and reliability improvements.

This paper briefly summarizes the history of Connected and Automated Vehicle technology development (pages 4-6); outlines the anticipated benefits of this technology including safety, mobility, and environmental improvements (pages 7 through 12); discusses the potential timing and barriers to adoption (pages 13 and 14); and offers high-level observations on the potential impacts of these technologies on the built environment, including both transportation infrastructure and land uses (pages 15 through 18).

However, the core of this paper is Section 7 (pages 19 through 24), which provides a series of bulleted recommendations for decision-makers, planning and technical staff members, and

[1] For questions and comments on this white paper please contact Joseph Bovenzi, Working Group Chairperson, at jbovenzi@gtcmpo.org or at (585) 232-6240.

other interested stakeholders to draw on when considering how to integrate Connected and Automated Vehicle-related policies into their planning products including long range transportation plans, congestion management processes, freight and goods movement plans, travel demand models, and transportation improvement programs. The emphasis of these recommendations is on the importance of articulating how Connected and Automated Vehicle technologies will enable communities to address public safety, expand mobility and accessibility opportunities, enhance environmental protections and alternative fuel sources, improve transportation system efficiency for all stakeholders including commuters, freight shippers, and others, and integrate these technologies into community policies regarding Complete Streets, Access Management, and other civic design functions.

Section 8 (page 25) provides a list of twelve questions on key topics for agency staff to use as a jumping-off point for discussions (among themselves, technical agencies, community stakeholders, and others) about the potential impacts of Connected and Automated Vehicle technologies on their communities. These questions are intended to raise awareness of issues such as public policy revisions, infrastructure adaptions, and changing travel demand and behavior that Connected and Automated Vehicle technologies will enable.

Given the statewide (let along nationwide) reach of Connected and Automated Vehicle technologies, this paper suggests a uniform approach among New York's Metropolitan Planning Organizations in terms of planning for the deployment of these technologies, and stresses the importance of ensuring that these technologies are harnessed towards realizing community goals. To that end, the appendix summaries the current language (as of Summer 2017) in each of New York State's 14 Metropolitan Planning Organizations Long Range Plans to provide a snapshot of the current treatment of these technologies in those foundational policy documents.

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1. Introduction

Connected and Automated Vehicle (CAV) technologies have the potential to dramatically improve the safety and efficiency of the national transportation system. CAV technologies are expected to be deployed within the timeframe of many Metropolitan Planning Organization (MPO) long range plans currently under development, so it is important for MPOs and their member agencies to be aware of and consider the impacts of these technologies in their planning processes. While the full impact of CAV technologies on transportation infrastructure and services, travel patterns, and community development trends are unknown, MPOs can nevertheless begin acknowledging the these impacts in their planning products, including long range plans, congestion management processes, and travel demand models. Looking ahead, the greatest challenge facing MPOs and their member agencies will be ensuring that the benefits of CAV technologies are applied to achieving broad community goals including but not limited to public safety, access and mobility, land use and civic design, economic and workforce development, environmental protections, and transportation system efficiency and reliability.

This white paper was prepared for the New York State Association of Metropolitan Planning Organization Transportation Systems Management and Operations Working Group. It seeks to generate discussion about the impacts of CAV technologies among New York State MPOs and their member agencies. The white paper's intended audience is MPO and member agency staff, board and committee members, and local officials and members of the general public interested in the impacts of CAV on the transportation planning process. This paper is not intended to be a definitive overview of CAV capabilities, benefits, and drawbacks, and does not focus on the technical, legal, and economic challenges of adopting CAV technologies.

The National League of Cities analyzed urban and regional transportation plans for 68 metropolitan areas for its *City of the Future: Technology & Mobility* report, published in 2015. Only six percent of metropolitan areas had plans that considered the impacts of driverless vehicles and only three percent had plans that considered the impacts of privately operated Transportation Network Companies (TNCs) that provide ridesharing services.[1] Of Florida's 26 MPOs, 17 of them do not mention automated vehicles in their long range planning documents.[2] These figures reveal an alarming omission in the regional transportation planning process across the United States.[3] This white paper is an attempt to address this omission by informing discussions among transportation planning agencies as to what they can do now to prepare for the deployment of CAV technologies and how they can better align the mission and purpose of their agencies and communities with these emerging technologies.

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[1] *City of the Future: Technology & Mobility*. Pages 1-2. This report analyzed city and regional transportation planning documents from the 50 most populous cities in the United States and the largest cities in each state, for a total of 68 metropolitan areas.

[2] *Surveying Florida's MPO Readiness to Incorporate Innovative Technologies into Long Range Transportation Plans*. Pages 3-4.

[3] *Door to Door*. Page 306.

2. Definitions

Connected Vehicles are vehicles that use two-way short- to medium-range wireless communications, known as Dedicated Short-Range Communication (DSRC)[4], to interface with other vehicles and roadside infrastructure. These wireless interfaces send and receive data regarding vehicle position, speed, direction, and other factors to other vehicles (vehicle-to-vehicle or V2V), roadside infrastructure (vehicle-to-infrastructure or V2I), and other transportation system elements (vehicle-to-everything or V2X). These communications allow connected vehicles to maintain situational awareness of the surrounding driving environment at all times, provide real-time information and alerts to drivers, and interface with other vehicles and roadside infrastructure to operate safely and efficiently.

Automated Vehicles are vehicles with one or more functions (such as steering, acceleration, or braking) that operate independently of a human driver (i.e., “automatically”). Automated vehicles may be connected; i.e., they have a wireless connection to other vehicles or roadside infrastructure, or they may be autonomous; i.e., they operate independent of vehicle or infrastructure connections. Automated vehicles are sometimes referred to as “driverless vehicles” or “self-driving vehicles,” and the most advanced types (Highly Automated Vehicles) rely on a package of computers, sensors, and associated software to safely navigate to their destination. Automated vehicles have a range of capabilities and are not a single technology; any discussion of these vehicles should clarify the level of automation and specific capabilities under consideration.[5]

Autonomous Vehicles are vehicles that operate without any connections or communications with other vehicles or roadside instrumentation. Like automated vehicles, autonomous vehicles are sometimes referred to as “driverless vehicles” or “self-driving vehicles.” Autonomous vehicles function like automated vehicles in the sense that the most advanced types are capable of self-driving to a destination. However, unlike Connected Vehicles, Autonomous Vehicles operate

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[4] V2V wireless communications use the 5.9 (5.85 – 5.925) gigahertz (GHz) band.

[5] The USDOT *Federal Automated Vehicles Policy*, published in September 2016, identifies a six-level automated vehicle spectrum, summarized below:

- Level 0: A human driver conducts all driving tasks and monitors the driving environment at all times;
- Level 1: One or more automated systems (i.e., anti-lock brakes) sometimes assist a human driver conduct some driving tasks;
- Level 2: An automated system conducts some parts of the driving task while a human driver monitors the driving environment;
- Level 3: An automated system conducts some parts of the driving task and monitors the driving environment, but a human driver must be ready to take control when the automated system requests;
- Level 4: An automated system conducts the driving task and monitors the driving environment, but the automated system can only operate the vehicle under certain conditions and otherwise the human driver must take over;
- Level 5: An automated system is capable of self-driving, i.e., navigating and traveling from an origin to a destination without the input of a human driver (other than to specify the destination) in all conditions; there is no need for the human occupant to operate the vehicle.

This policy refers to Level 3 – 5 automated vehicles as “Highly Automated Vehicles.” These are distinguished from Level 0 – 2 vehicles because an automated system, not the human driver, is responsible for monitoring the driving environment.

without wireless connections to other vehicles or roadside infrastructure; all of the instrumentation required to operate an autonomous vehicle is located on board the vehicle.

This white paper uses the phrase "Connected and Automated Vehicle (CAV) technology" as a catch-all term for the full range of transportation technologies required to operate connected and automated vehicles.[6] They include the vehicles themselves; the cameras, sensors, computers, software, and interfaces required for V2V, V2I, or V2X communications; mobile devices such as smartphones and their associated apps that provide access to travel data and services; and lastly the roadside Intelligent Transportation Systems (ITS) infrastructure required to support these systems and services.[7]

[6] Another approach to understanding the differences in connected and autonomous vehicle technology is provided by Professor Alain Kornhauser at Princeton University, who has identified three categories, "Safe-Driving," "Self-Driving," and "Driverless," to help understand the differences in these technologies. Safe-Driving vehicles are those with capabilities that focus on safety enhancements and are designed to intervene with a human driver to prevent unsafe lane changes, speeding, collisions, etc. Self-Driving vehicles include the aforementioned safety features, but also enable some hands/feet off driving in certain locations under certain conditions. Lastly, Driverless vehicles include features of Safe-Driving and Self-Driving vehicles, but are designed to operate independently of human control at all times.

[7] See *Surveying Florida's MPO Readiness to Incorporate Innovative Technologies into Long Range Transportation Plans*, page 38, for a discussion of terminology. Table A3.4 on pages 44-45 provides a helpful summary of the definitions of Automated/Autonomous Vehicles in various state legislation.

3. Brief History of Connected and Automated Vehicles

Prototype CAV technologies were developed by inventors in the 1920s. In 1925, Francis Houdina constructed a radio-controlled car which was demonstrated in New York City by maneuvering through traffic on Fifth Avenue and Broadway. This car was controlled by an operator who rode in a second vehicle following the first car and who could change its direction by means of a radio signal.[8] In December 1925, Charles Adler demonstrated a safety device he hoped would reduce crashes on dangerous road sections, including tight curves and steep inclines. Adler embedded magnetic plates in the pavement, and as a car equipped with a speed governor passed over the plates, the magnets activated the speed governor and automatically slowed the car to a safe speed.[9]

Adler's experiment revealed the need to modify public infrastructure to support his invention. A 1932 *Popular Mechanix* article described a proposed system of carrier waves that could be broadcast from telephone wires and picked up by antennas attached to a car. Drivers would tune in to these carrier waves, much like tuning a radio to a specific frequency, which would guide them along a specific route and alert them if they deviated from that route.[10] While these early experiments and proposals did not lead to further development of CAV technologies, they are important because they demonstrate not only that attempts to enhance vehicle safety and performance through advanced technologies have been underway for nearly a century, but that the need to adapt transportation infrastructure to support these technologies has been present for that time as well.

During the mid-twentieth century, futuristic visions of the nation's transportation system were presented to the public. The 1939 New York World's Fair featured General Motors' immensely popular *Futurama* exhibit, which displayed a model of the city of 1960, depicting automated highways speeding travelers in safety and comfort through lush landscapes with gleaming skyscrapers. Futurama's designer, Norman Bel Geddes, expanded on these concepts in his 1940 book *Magic Motorways*, which described technical innovations that would make driving safer and more efficient. In 1958, Disney's *Magic Highway USA* program envisioned a future of mobility that included not only technological applications that are now readily available, such as navigation systems and rear-view cameras, but showed how transportation infrastructure could be modified to enhance safety, mitigate congestion, and provide navigation services. The 1964 New York World's Fair included an updated Futurama exhibit, which again depicted automated highways as well as specialized technologies including bus-trains and freight conveyor belt systems.

These utopian visions imagined profound changes in the built environment due to advances in transportation technology, but they did not consider the socioeconomic changes that could occur as a result of these advances. The lives and activities of the people featured in these programs were essentially reimagined versions of mid-twentieth century middle-class lifestyles; advances in transportation technology were envisioned as a way of enhancing those lifestyle patterns rather than bringing about fundamental changes in social patterns of living, working, and playing.

[8] *Radio-Controlled Automobile*. Page 592.
[9] *The Man Who Invented Intelligent Traffic Control a Century Too Early*. Page 1.
[10] *Tourists Can't Lose Road in Radio Guided Automobile*. Page 1.

Research and development programs provided a real-world application, even if only in prototype form, of the visioning exercises described above. During the 1950s, a joint research project by General Motors (GM) and the Radio Corporation of America (RCA) resulted in a prototype electric highway system, which used car-length detection loops and a guidance cable buried just beneath the pavement and detection circuits set up along the roadside to connect with the detection loops to guide vehicles along the center of the traffic lane.[11] This system was developed by RCA engineer Vladimir Zworykin, who identified safety improvements as a key motivation behind this project.[12] At Stanford University in the 1960s, a robotic cart was constructed that could be remotely operated; over time, upgrades to the cart's sensing and intelligence capabilities allowed it to navigate across a room cluttered with furniture without human interaction. In Japan in 1977, technicians equipped a car with cameras and computers that allowed it to drive at speeds up to 18.6 miles per hour along a guide rail.[13] However, meaningful advances in self-driving capabilities really took off during the 1980s.

The RAND Corporation's *Autonomous Vehicle Technology: A Guide for Policymakers* report identified three phases of CAV development that built on early research and development advances described above. During the first phase, from 1980 to 2003, foundational research at various university research centers focused on two main areas of CAV development: the design of automated highway systems, where vehicles relied on roadside infrastructure to operate, and the development of semi-autonomous and autonomous vehicles that could operate without connecting to roadside infrastructure. In the 1980s a research team led by Dr. Ernst Dickmanns at Bundeswehr University Munich constructed a prototype autonomous vehicle that was able to reach speeds of 60 miles per hour on roads without traffic.[14] Around the same time a research team at Carnegie Mellon University lead by Dean Pomerleau developed ALVINN (Autonomous Land Vehicle In a Neural Network), a vehicle that used camera images and a laser range finder to determine the direction it should travel in to follow the road.[15] These prototypes were followed by a number of pioneering research programs and field tests in the 1990s; in August 1997, the Demo '97 project brought together public, private, and university stakeholders to demonstrate how an automated highway might work by successfully testing a vehicle platooning system on a section of I-15 in San Diego.[16]

The second phase, from 2003 to 2007, revolved around the "Grand Challenges" sponsored by the U.S. Department of Defense Advanced Research Projects Agency (DARPA) in which competing teams raced to complete various courses, both off-road and in urban settings, with their prototype autonomous vehicles. While no vehicles completed the 2004 course, held on rugged desert terrain, five vehicles completed the 2005 course. The 2007 challenge featured a 60-mile urban course where autonomous vehicles navigated alongside human-operated vehicles and followed traffic laws; eight vehicles completed this course. Lessons learned and connections forged between universities and auto manufacturers lead to the third phase, from 2007 to the present, which has emphasized the commercialization of CAV technology for mass consumption.[17]

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[11] *Tomorrow's Thruway is Here Today*. Page 28.
[12] *Self-Driving Cars Were Just Around the Corner-in 1960*. Page 2.
[13] *Autonomous Cars Through the Ages*. Page 3.
[14] *Autonomous Cars and Society*. Page 9. See pages 8-12 for a good summary of CAV research.
[15] *ALVINN, An Autonomous Vehicle in a Neural Network*. Page 1.
[16] *Self-Driving Cars Debuted on California's Highways 20 Years Ago*. Page 1.
[17] *Autonomous Vehicle Technology*. Pages 56-57.

Recent years have seen the first deployments of CAV-enabled vehicles in various roles throughout the country. In September 2016, Uber launched a pilot ride-hailing service in Pittsburgh using autonomous vehicles (albeit with human drivers), and followed up this program with similar pilots in San Francisco and Phoenix.[18] In June 2017 the University of Michigan announced that it would launch an autonomous shuttle service in the fall. Two 15-passenger electric shuttles will be deployed to run continuously along a two-mile route on the university's North Campus.[19] In August 2017, the Colorado Department of Transportation announced that it would deploy an automated crash truck at work zones. This driverless vehicle is designed to improve work zone safety for highway workers by eliminating the need for a human driver to operate the crash truck.[20] Work on adopting roadside infrastructure is also underway; 3M is developing road signage with embedded bar codes that can relay information like GPS coordinates or traffic conditions to connected vehicles.[21] Today, alliances between technology companies, automakers, and transportation network companies are currently working to deliver on the promises of greater safety, improved mobility, and reduced environmental impacts.

As noted above, one the key themes that emerges from even a cursory review of the history of CAV development is the need to modify transportation infrastructure to support these vehicles. While specific technical needs change over time and the digital connected and autonomous vehicles of today are a far departure from the radio-guided vehicles foreseen in the 1930s, the basic notion of vehicles and infrastructure operating holistically as a single package is as relevant as ever. Looking ahead, as the technical needs of CAV become clearer, one of the key considerations for MPOs and their partner agencies will be to integrate those needs into the continuing, comprehensive, and coordinated transportation planning process.

[18] *Pittsburgh Offers Driving Lessons For Uber's Autonomous Cars*. Page 2.
[19] *Driverless Shuttle Service Coming to U-M's North Campus*. Pages 1-2.
[20] *Colorado DOT Purchases World's First Automated Self-Driving Construction Vehicle*. Pages 1-2.
[21] *The Company that Invested Post-It Notes is Hiding Invisible Messages in Signs to Help Self-Driving Cars See the World*. Pages 1-2.

4. Capabilities and Benefits

Extensive commentary is available on the anticipated capabilities and benefits of CAV technology. This section summarizes the salient points for MPO staff to be aware of when making the case for the integration of CAV considerations into their planning programs and products.

4.1. Safety

As an USDOT abstract on Connected Vehicle research notes, the "past 50 years have been about *surviving* vehicle crashes, the next 50 will be about *preventing* them." This concept represents a fundamental shift in how MPOs and their member agencies approach the design, construction, and operation of their transportation infrastructure.

For good reason, safety improvements are among the most widely discussed benefits of CAV technology. In 2015, 35,092 people were killed and an estimated 2,443,000 were injured in crashes across the United States (1,121 fatalities occurred in New York State). The number of fatalities increased by 7.2 percent over the 32,744 people killed in 2014, the largest percentage increase in almost 50 years.[22] According to the United States Department of Transportation's most recent estimate, the total annual economic cost of crashes in 2010 was $242 billion while the total societal harm was $836 billion.[23] The National Highway Traffic Safety Administration (NHTSA) found that the critical reason for 94 percent of crashes was attributable to driver action.[24] These figures indicate that safeguarding the lives and property of transportation system users is a critical need, and explain why safety-related applications of CAV technology aimed at enhance a driver's situational awareness of traffic conditions have been a traditional focus of CAV research and development activities.

Safety-related CAV research and development activities have largely emphasized driver warning systems. Collision avoidance alerts warn drivers when vehicles ahead of them suddenly brake, change lanes, or make some other unexpected movement; intersection movement assist functions warn drivers if another vehicle is running a red light, making an illegal turn, or blocking the intersection; and proximity alerts when drivers approach work zones, incident scenes, dangerous curves, hidden intersections, or other special conditions and/or locations. Warnings for specific turning movements can be implemented, such as alerts that notify drivers making a left turn to wait for oncoming traffic to clear before turning, or let bus operators know when a vehicle is making a right turn in front the bus. In addition to warnings, safety features may function automatically; i.e., if a driver fails to heed a warning the vehicle may react independently of driver input to avoid a crash.

These safety features are not limited to Vehicle-to-Vehicle applications. Vehicle-to-Pedestrian (V2P) safety applications can alert drivers to the presence of pedestrians in crosswalks. Sensors can warn pedestrians if they are in danger of being hit by vehicles that may not be in their line

[22] *2015 Motor Vehicle Crashes: Overview*. Pages 2-3.
[23] *The Economic and Societal Impact of Motor Vehicle Crashes*. Pages 5 and 10.
[24] *Critical Reasons for Crashes Investigated in the National Motor Vehicle Crash Causation Survey*. Pages 1-2. For clarity, the term "Critical Reason" refers to the immediate reason for a pre-crash event that causes a crash. It includes recognition errors, decision errors, performance errors, and non-performance errors. Please consult the source materials for further detail.

of sight as they alight from a bus or cross a street, and can also warn bus operators if a pedestrian or bicyclist is in the path of the bus.

The future safety applications of CAV technology go far beyond driver warnings, which depend on drivers responding to them in a timely fashion to be effective. Vehicle platooning on expressways can reduce the number and severity of crashes in addition to improving operational efficiencies. Roadside sensors can monitor the condition of hazardous materials on trucks, alerting local emergency responders if a potentially dangerous cargo is passing through their jurisdiction. Sensors embedded in a vehicle's safety restraints could monitor a driver's health status and, if the driver experiences a sudden medical emergency, automatically slow and stop the vehicle while alerting first responders. Looking ahead, MPOs should identify the safety applications of CAV technologies as a means of achieving the safety-related goals for all regional modes of transportation.

4.2. Mobility and Accessibility

Mobility refers to the ability of people and goods to get to where they need to go. Accessibility refers to the ease with which those people and goods can interface with their destination once they arrive. Typically, a key theme of MPO planning activities is consideration of the transportation system's ability to provide mobility and accessibility for all users. Policies, programs, and projects aimed at enhancing mobility and accessibility are then developed and implemented.

MPOs will have to consider the impacts of CAV technologies on their mobility and accessibility-related policies, programs, and projects because the reduction in travel costs that these technologies may deliver have the potential to radically change demand for access to transportation infrastructure. According to a recent report commissioned by the Residential and Civil Construction Alliance of Ontario, *Ontario Must Prepare for Vehicle Automation*, the key governance issue for transportation system management is the demand for "automobility – how and whether we need mobility, how we consume it, how independent, personal, comfortable, private we demand it to be, how much we demand, and how it is supplied."[25] This observation supports a role for public planning agencies in determining how CAV technologies are applied to the regional transportation system and how they will contribute to maximizing community benefits instead of evolving on their own without broader coordination with the communities they serve.

4.2.1. Expanding Mobility Options

The American transportation system is designed to accommodate private automobiles over all other modes. In 2013, 76.4 percent of workers commuted to work by driving alone in an automobile while a further 9.4 percent commuted as part of a carpool. Only 5.4 percent of commuters used public transportation, 2.8 percent walked, and a mere 0.6 percent rode their bicycles to work.[26] These figures illustrate the primacy of the automobile, which when combined with public investments in roads, bridges, and other transportation infrastructure, has delivered unprecedented mobility to much of the American population.

[25] *Ontario Must Prepare for Vehicle Automation*. Page 22.
[26] *Who Drives to Work? Commuting by Automobile in the United States: 2013*. Page 1.

However, this mobility has come with costs that the aforementioned figures do not convey. In addition to the safety problems discussed above and the environmental costs described below, the reliance on automobiles has limited the mobility of many Americans, including those too old or young to drive, the disabled and others who are unable to drive due to health issues, those who cannot afford a vehicle and its attendant costs (fuel, maintenance, insurance, parking, etc.), and those who prefer not to drive due to lifestyle reasons.[27] In addition, an individual's transportation needs change through the course of his or her life; the transportation system that might have met their needs at one point in their life may no longer do so as they age through different life stages.

CAV are anticipated to greatly expand mobility options for the groups described above who are otherwise limited in their ability to directly access and benefit from the transportation system. Previous commentators have envisioned a broad range of scenarios in which autonomous vehicles are dispatched by parents to pick up their children from a friend's house, used by a disabled person to run errands, and relied on by senior citizens to reach a medical appointment. These technologies will enable people to have greater independence earlier and later in their lives than they currently do and provide expanded access to educational, employment, and recreational activities. Lastly, for communities concerned with providing equitable access to mobility services such as subscription-based ridesharing (see Section 4.2.4. below), ensuring the availability of these services for low-income residents and workers may become one of the key issues for planning agencies to address under Title VI and related social equity and anti-poverty initiatives.

4.2.2. Congestion Management

One of the major benefits of CAV is their ability to operate more efficiently than human-operated vehicles. While the adoption of CAV may lead to an overall increase in Vehicle Miles Traveled (VMT), this may not necessarily be bad for congestion management efforts as this increase will be combined with more efficient operational capabilities, including increased vehicle throughput and reduced incident-related delay, to minimize congestion.[28] CAV technologies can also be harnessed to transportation demand management initiatives to ensure that improvements in travel time and reliability are not swallowed up by increased VMT.

MPOs with a population of 200,000 people or more must develop and maintain a Congestion Management Process (CMP) that identifies the locations, causes, and potential remedies for congestion. This includes all types of congestion, including routine daily delays due to recurring congestion as well as non-recurring congestion caused by traffic incidents or special events such as road closures for a festival. MPOs will have to reconsider their congestion mitigation efforts to factor in the impacts of CAV on traffic operations and congested locations, as well to take advantage of the data generated by CAV to better understand the causes and locations of congestion.

Closely related to congestion management is the concept of reliability, which refers to the consistency and dependability of travel times across multiple days or times of day. It can also be understood as the absence of travel time variability. A transportation system, road or road segment, or travel route with good travel time reliability has consistent and dependable travel

[27] *Autonomous Vehicle Technology: A Guide for Policymakers*. Pages 16-17.
[28] *Autonomous Vehicle Technology: A Guide for Policymakers*. Page 17.

times for a given operating condition each time that condition is met. By establishing a communications network that allows vehicles to detect congestion and navigate around it, CAV technologies are anticipated to enhance system reliability by minimizing uncertainty over travel conditions.[29] While beneficial to all travelers, reliability is particularly important to freight carriers working under tight schedules to ensure on-time delivery of their cargoes. Truck platooning, the process by which two or more trucks are linked together by wireless communications so that the lead truck controls speed, direction, braking, and other functions while the following trucks react to the lead truck's movements, offers a range of potential efficiency and congestion-mitigation benefits, as well as associated safety and environmental benefits.

CAV may also mitigate congestion through enhanced navigation capabilities and services. While travelers are already accustomed to using their Global Positioning Systems (GPS) or smartphone devices to navigate to a destination, or using apps such as San Francisco's *SFpark* to locate available parking spots, CAV-enabled wayfinding can theoretically navigate a vehicle to an available parking location with minimum traffic disruption and time lost to searching for parking.[30]

4.2.3. Driver Behavior

As discussed above in Section 4.1, CAV have tremendous potential to improve transportation system safety. Driver inattention is a major safety problem, with about one third of crashes happening because of distracted driving. Behaviors such as talking, texting, manipulating an electronic device or even operating the vehicle radio all contribute to driver inattentiveness.[31] As Tom Vanderbilt noted in his 2012 article on autonomous cars, "maybe the problem is that driving distracts us from our digital lives."[32]

One of the fundamental promises of CAV technologies is that, in their final form of fully connected and completely automated operation, they will eliminate the need for drivers to manually operate vehicles. If so, this would mitigate the constant problem of driver distraction. Furthermore, when released from the need to manually operate a vehicle, motorists could invest this time into other uses. The average commute time in the U.S. is about 25 minutes; thus the typical commuter loses about 50 minutes a day to his or her commute.[33] This time could be invested in a range of activities related to work or recreation, thus potentially increasing both worker and personal productivity.

4.2.4. Vehicle Ownership

CAVs are anticipated to change vehicle ownership patterns. Instead of buying their own vehicles, consumers interested in accessing the benefits of CAV technologies will subscribe to an on-demand service that provides suitable mobility options when needed. Ridesharing services already provide this function in many large cities, where the costs of operating a vehicle can be prohibitive. The subscription model relieves the consumer of direct fuel,

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[29] *Self-Driving Cars: The Next Revolution*. Page 28.
[30] See sfpark.org for more information.
[31] *Social Science Studies the Most Hazardous Thing on the Road: You*. Page 2.
[32] *Let the Robot Drive*. Page 11.
[33] *Self-Driving Cars: The Next Revolution*. Page 29.

maintenance, insurance, and parking costs, while continuing to provide the flexibility and convenience that today's drivers are accustomed to have with their personal vehicles. A subscriber to an on-demand service would enjoy the benefits of automobile mobility without the costs of vehicle ownership. As for the vehicle, instead of sitting in a parking space most of the day it would be on the road, ferrying occupants to their destinations all day long.

As always, there will be exceptions. Many businesses and public agencies that operate specialized vehicles or fleets will require access to these vehicles; a building contractor or a utility provider cannot be expected to travel to job sites without their tools, equipment, and materials. Public and commercial fleets require specialized support services and equipment; these fleets may benefit from the application of connected and autonomous vehicle technologies but given their specific functions they will have to remain separate from general usage. Early deployments of these technologies have already occurred in the form of Automatic Vehicle Location (AVL) systems that track the location of snow plows as they proceed along their routes.[34]

Automated vehicles will require strict adherence to maintenance programs as the risks of deferred maintenance are much greater than on conventional vehicles; providing autonomous vehicles on a subscription-based or on-demand service model where the vehicle would be updated or replaced on a set schedule would help both manufacturers and regulating agencies ensure that these vehicles are properly maintained.[35] This would also speed up fleet turnover, ensuring that vehicles and their on-board technologies remain up-to-date.

4.3. Environment

The deleterious effects of the transportation system on the environment have been well documented. CAV technologies can support a community's environmental stewardship efforts by reducing vehicle emissions and fuel consumption through more efficient vehicle and infrastructure operations, by generating travel data that can inform environmentally-supportive decision-making by system users and operators, and by expanding access to and use of alternate fuels.

In 2015, the transportation sector was responsible for 27 percent of total greenhouse gas emissions in the United States. Transportation emissions rose by 16 percent during the 1990 – 2015 timeframe, mainly due to increased travel demand. Nationwide, VMT by light-duty vehicles (passenger cars and light-duty trucks) increased by 42 percent between 1990 and 2015 due to a range of factors, including population growth, economic growth, urban sprawl, and generally low fuel prices.[36] Globally, the transportation sector produces almost one quarter of the world's energy-related carbon dioxide emissions. Global carbon dioxide emissions more than doubled between 1970 and 2010 with about 80 percent of that increase coming from road vehicles. Given the growing demand for transportation services, worldwide GHG emissions could almost double by 2050 if no mitigation measures are implemented.[37]

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[34] Among other examples, see the City of Rochester's "PlowTrax" system at: http://www.cityofrochester.gov/PlowTrax/
[35] *Tomorrow's Transportation Ecosystem*. Page 1.
[36] *Inventory of U.S. Greenhouse Gas Emissions*. Page 2-28.
[37] *Chapter 8: Transport*. Pages 647-648.

As a result of the challenges of mitigating the impact of vehicle emissions on the natural environment and human health, a suite of potential CAV environmental applications was identified by the USDOT's Applications for the Environment: Real-Time Information Synthesis (AERIS) Program. This program identified a series of CAV applications designed to reduce fuel consumption and emissions. For example, an eco-traffic signal timing system can reduce vehicle emissions and fuel consumption by coordinating signal timing patterns with vehicle movements. A connected vehicle transmits data on its location, speed, direction, emissions, and other pertinent factors to receivers on the signal system, which in turn adjusts timing patterns to reduce fuel consumption and minimize emissions. Other examples of CAV environmental applications include connected eco driving, which provides motorists with real-time information on how to reduce fuel consumption and emissions while driving, and eco-routing, which would identify the minimum fuel consumption and emissions need to reach a certain destination. These applications are also good examples of Vehicle-to-Infrastructure integration.[38] The benefits of truck platooning include fuel savings; testing by C.R. England and Peloton in November 2013 indicated average fuel savings of 4.5 percent for the lead truck and ten percent for the following truck.[39]

While CAV technologies can be used to reduce fossil fuel emissions, they can also further the adoption of alternative energy sources. Electric vehicles (EVs) currently make up a mere 1 percent of the global vehicle fleet, but by 2040 they are anticipated to make up 15 percent to 35 percent of total new vehicle sales worldwide. Given that this is roughly the same timeframe that the widespread deployment of CAV are anticipated, it is worthwhile to consider the impacts of these technologies converging on the transportation system at around the same time. EVs are easier and cheaper to maintain and have more durable powertrains than vehicles with Internal Combustion Engines (ICE) because electric engines have fewer moving parts.[40] This makes EVs better suited to the constant use that CAV technologies enable, especially with regards to automated ride-sharing and ride-hailing services. Future CAV-supportive technology could include wireless charging systems that are integrated into roadside infrastructure, thus allowing vehicles to charge their batteries as they pass along the road.[41]

[38] *Module 13: Connected Vehicles*. Pages 25-26.
[39] *Platooning Test*. Page 6.
[40] *USB Evidence Lab Electric Car Teardown*. Page 27. UBS Corporation technicians conducted a "teardown" of a Chevrolet Bolt and compared it to a similar ICE vehicle (VW Golf). The Bolt's electric engine had only three moving parts compared to the Golf engine's 133 moving parts; in addition, the Bolt does not require oil or spark plug changes.
[41] *Future of Highways*. Page 21.

5. Timeline

The timeline for the deployment of CAV technology is uncertain. As noted above in the introduction, the deployment of CAV technologies are anticipated to become widespread by the middle of the century. However, there are many unknowns regarding the rate of adoption and the timing of the availability of specific CAV-enabled functions, as well as the nature of CAV applications (i.e., CAV-enabled vehicles available for consumer purchase, through a subscription service, or through an on-demand ride-sharing service).

A report by the Victoria Transport Policy Institute (VTPI) estimates that autonomous vehicles will become available with high price premiums in the 2020s. Price premiums are forecast to decrease during the ensuing decades until the 2050s, when autonomous vehicle technologies will become standard features. The market for autonomous vehicles will become saturated (i.e., everyone who wants one will have one) in the 2060s.[42] The report acknowledges that technical challenges may push out these dates even further, and that production costs, retail prices, security and privacy issues, and other considerations may discourage widespread adoption.

A Fehr and Peers report links the deployment of CAV technology to the enactment of federal mandates and adoption of subscription ownership models by the automotive industry. The report forecasts that 25 percent of vehicles on the road will be autonomous by 2035 and 50 percent will be autonomous by 2050. These percentages rise to 75 percent after 2035 and 95 percent after 2040, depending on federal mandates and/or the adoption of subscription ownership models that will increase vehicle turnover and the rate of introduction of new technologies.[43]

Other analyses suggest that the deployment of connected and autonomous vehicles will be sooner. IBI Group forecasts completely driverless vehicles will be available by the mid-2020s[44], and WSP/Parsons Brinckerhoff suggests that increasing numbers of driverless vehicles will be in service by the 2025-2030 time frame.[45] A report by IHS Automotive forecasts that almost 54 million self-driving vehicles will be in use world-wide by 2035, and that by 2050 almost all vehicles will be autonomous.[46] A 2013 Morgan Stanley bluepaper observes that the socioeconomic benefits of autonomous vehicles could accelerate their adoption and that widespread deployment of connected/autonomous vehicles and associated infrastructure improvements is possible by the mid-2030s.[47]

Technological, policy, and legal challenges aside, the widespread deployment of CAVs will depend on public acceptance of CAV technologies. In 2011 and 2012 the USDOT and partner agencies hosted a series of Driver Acceptance Clinics (DACs) to obtain feedback on a range of safety-related CV applications. The DACs indicate that there is widespread interest in and support for safety-related CV applications, with over 90 percent of participants in favor of V2V communications on their personal vehicles.[48] A survey of residents in the Austin area found that

[42] *Autonomous Vehicle Implementation Predictions*. Page 12.
[43] *Effects of Next-Generation Vehicles on Travel Demand and Highway Capacity*. Page 10.
[44] *A Driverless Future*. Page 1.
[45] *Driving Towards Driverless*. Page 7.
[46] *Self-Driving Cars Moving into the Industry's Driver's Seat*. Page 1.
[47] *Autonomous Cars*. Pages 42-43.
[48] *Public Perceptions of Connected and Automated Vehicle Technologies*. Pages 2-3.

about half of the respondents intended to use self-driving vehicles. Driver feedback indicated that a range of factors, including increased safety, stress relief for drivers, improved mobility for senior citizens, the ability to be productive while traveling, trust that the new technology will be thoroughly tested, comparability to public transit, and the simple attraction of using new technology all contributed to interest in self-driving vehicles.[49] The speed at which members of the general public comes to expect the benefits of CAVs as a normal feature of the transportation system in the same way that they do street lights, traffic signals, and roadside signage will be a significant determinant in the acceptance and adaptation of these vehicles.

Looking ahead, the salient point for MPO staff and their partner agencies to be aware of is that the impacts of CAV technologies will have to be considered within the time horizons of Long Range Plans currently in effect or under development. Given that many of these plans include recommendations looking ahead to 2040, 2050, or beyond, that MPO travel demand models look out several decades in advance, and that planning studies developed or sponsored by MPOs may also have an implementation horizon that extends over several decades, MPO staff members and their member agency colleagues should be discussing how best to consider the impacts of CAVs on the transportation system.

[49] *Revolutionizing Our Roadways*. Page 7.

6. Implications for the Built Environment

The impact of CAV technologies on the built environment will largely be driven by the realization of connected vehicle capabilities. In January 2017, the National Highway Traffic Safety Administration published a Notice of Proposed Rulemaking regarding the establishment of Federal Motor Vehicle Safety Standard No. 150 (Docket No. NHTSA 2016-0126), which would mandate vehicle-to-vehicle communications for new light vehicles and standardize the message and format of these communications. This rulemaking is important because, if adopted, it will establish a platform for future vehicle connectivity. The long-term impact of a failure to adopt this rule will be to limit future vehicles to autonomous capabilities; while still an improvement over current conditions, vehicle autonomy will not produce the full range of safety and efficiency benefits that are anticipated by combining vehicle connectivity with automated functions. The role of MPOs and their member agencies will be very different in an *autonomous* world than a *connected* world; agency support for autonomous vehicles will largely focus on maintaining existing infrastructure in a state of good repair, whereas support for connected vehicles will require a more in-depth reassessment of how the transportation system functions and what infrastructure modifications are required to support connected vehicle operations.

6.1. Transportation Infrastructure

With the exception of railroads, transportation infrastructure in the United States has traditionally been planned, funded, built, operated, and maintained by public agencies (state departments of transportation, public authorities, municipal departments of public works, etc.). However, the development of CAV technologies has been largely propelled by private interests and coordination will be required to ensure that it is compatible with public infrastructure.

As discussed above, the widespread use of Highly Automated Vehicles may not occur until the middle of the twenty-first century or later. However, it is possible that the targeted deployment of CAV technologies for specific uses and in certain areas may occur much sooner, including the 2025-2030 timeframe for freeway lanes and the 2035-2040 timeframe for arterials.[50] This means that transportation planners should concentrate their initial efforts on identifying the ways that CAV technologies can help realize community goals regarding safety, mobility, goods movement, etc. For example, specialized instrumentation that supports freight operations on expressways and access/egress to manufacturing, distribution, and warehousing sites may be an early emphasis of connected vehicle technology, and when viable models are demonstrated planners can include the deployment of these systems in their policy and planning documents as a means of enhancing community economic development efforts by improving the safety and efficiency of freight operations.

In addition to considering the impacts of CAVs on expressways, MPO planning efforts will have to consider their impact on local streets. Within densely built-up areas such as urban and village centers, it is anticipated that on-street parking will be at least partially replaced with drop-off/pick-up zones and associated infrastructure for both freight and passengers. This will fundamentally change traffic patterns as the need to provide and find parking is reduced and replaced by a need to ensure safe and efficient access to drop-off/pick-up zones.[51]

[50] *Effects of Next-Generation Vehicles on Travel Demand and Highway Capacity*. Page 9.
[51] A number of publications on CAV (see *Driving Towards Driverless* and *Envisioning Florida's Future*, among others) have discussed the potential for reducing lane widths because HAVs do not require as

The deployment of Highly Automated Vehicles is anticipated to significant changes to roadside infrastructure. New ITS field instrumentation designed to support CAV operation, such as transmitters to relay data between vehicles and infrastructure elements like traffic signals, will be deployed. Traditional roadside signage, traffic signals, and road striping will have to change to accommodate electronic rather than human drivers.[52] In addition, traditional ITS field instrumentation such as Dynamic Message Signs (DMS) may no longer be required as connected vehicle technology can display messages within vehicles. Roadside sensors that collect data on lane occupancy, vehicle speeds, and other operations data may be rendered superfluous by vehicle probe-based data; however, as discussed above having two parallel data sources would be beneficial for data validation and back-up purposes. In addition, while vehicle probe data might be ideal for understanding system-wide traffic patterns, roadside sensors might provide better data on traffic movements at specific locations such as an intersection. Traffic cameras, currently among the most ubiquitous ITS field instruments, may also become superfluous as there will be no reason for CAV to view camera feeds of traffic conditions. However, traffic cameras may survive as a legacy system that are useful mainly for human operators to monitor road conditions and travelers interested in visually checking road conditions prior to setting out on their trips.

The concept of “universal design,” traditionally viewed as designing infrastructure that is accessible to all users regardless of age or disability, will be broadened to accommodate design and technical considerations for CAV. The same will be true with the concepts of “complete streets” and “access management;” future examples of which will be designed to accommodate a range of systems and services enabled by CAV technologies. Planners and engineers traditionally responsible for road design and construction will have to deepen their coordination with information technology professionals who can ensure that the appropriate digital infrastructure is supplied. This will lead to the emergence of “infostructure,” where data collection, communication, and analysis capabilities are integrated into transportation facilities from the planning stage forward.[53]

Autonomous vehicle developers have focused on building vehicles that operate independently of roadside infrastructure. As previously discussed, autonomous vehicles function without a need for communications to other vehicles and infrastructure.[54] However, the greatest benefits of automated functions will be realized when combined with connected technology, and MPOs and their member agencies should emphasis the benefits of connected over autonomous transportation in their planning and policy reports.

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much space as human-operated vehicles; if this is true it will theoretically open up more right-of-way for alternate modes of transportation (or allow more vehicle travel lanes to be added). However, lane widths will have to accommodate both human-operated and autonomous vehicles during the transition period to HAVs, and even if lanes can be made narrower, a certain amount of buffer space may be needed for safety reasons. Lane widths will still have to accommodate larger vehicles and provide sufficient turning radii for trucks and buses. At the time of this writing, while infrastructure changes such as narrowing lane widths is a potential long-term impact of widespread CAV adoption, it should not be looked on as a certainty.

[52] *Automated Vehicles: The Coming of the Next Disruptive Technology*. Page 41. This report notes that the computerized management of vehicle merging may encourage the replacement of signalized intersections by roundabouts.

[53] *A Policymaker’s Guide to Digital Infrastructure*. Page 9.

[54] *Automated Vehicles: The Coming of the Next Disruptive Technology*. Page 39.

6.2. Land Use and Urban Design

The impacts of CAV technology is not limited to transportation infrastructure, and research on the potential influence of these technologies on the broader built environment is emerging. Reports such as *Driving Towards Driverless: A Guide for Government Agencies* and *Envisioning Florida's Future: Transportation and Land Use in an Automated Vehicle World* include findings and observations that are broadly applicable to metropolitan areas throughout the country.

For example, both these reports identify the reduction of parking requirements, redevelopment of parking facilities, and the relocation of parking away from urban centers as a potential redevelopment opportunity.[55] Land freed from parking could be redeveloped with residential or commercial spaces, or given over to community open space such as parks and playgrounds. Related to these opportunities will be the need for municipalities to reconsider their site and urban design requirements. Site planning will shift away from a specific need to provide parking to a broader need to ensure safe and efficient accessibility to the site, while building layout and design will shift from a focus on accessibility via parking to accessibility via drop-off/pick-up zones.[56] In a connected world, site planning and development review procedures will also have to consider the aforementioned "infostructure" capabilities needed to support HAVs.

One of the greatest uncertainties regarding CAV technology is whether it will lead to the continued expansion of development on the urban fringe or reinforce efforts to redevelop downtown and other urban areas.[57] While these trends should not be viewed as mutually exclusive and the focus of regional transportation planning programs should always be to enhance safety across all modes and strengthen linkages among all parts of a metropolitan area, the agencies responsible for land use planning and development review will have to find ways to ensure that CAV technology supports broader community development goals. Connected vehicles may increase low-density, sprawling development patterns on the urban fringe by making travel time more productive, thereby reducing travel time costs.

However, connected vehicles may reinforce efforts to redevelop urban cores and other inner city areas, primarily by disconnecting land use from parking.[58] Connected vehicles could drop off passengers at a downtown location and then navigate to parking facilities that are underground, on the downtown edge, or urban periphery, thus reducing the need for parking in the downtown core. As noted above, land freed from parking could be invested into more productive uses and would encourage a greater development density than is currently found in many urban areas. Building on the changing ownership models discussed above, connected vehicles operating on a subscription service basis could drop off their passenger at their downtown location and then pick up another passenger at that location for subsequent trip;

[55] *Driving Towards Driverless*. Page 28. *Envisioning Florida's Future.* Pages 16-18.
[56] *Envisioning Florida's Future: Transportation and Land Use in an Automated Vehicle World*. Page 21.
[57] Land use and development patterns are largely based on local policy (municipal comprehensive plans, zoning and subdivision regulations, design standards and guidelines, etc.). However, as any planner who has worked in the municipal development review process can attest, national economic trends exert a powerful influence on development proposals; the adaption of CAV-supportive services and infrastructure may be driven in large part by the real estate's community desire to make their developments accessible.
[58] *How Driverless Cars Can Reshape Our Cities*. Pages 1-2.

parking ultimately becomes irrelevant because the connected vehicle spends its day constantly transporting passengers around the city and does not require a parking space.[59]

MPOs, especially national and state associations like the Association of Metropolitan Planning Organizations and the New York State Association of Metropolitan Planning Organizations, should fund and participate in investigations of the impacts of CAV technologies on land use and urban design. While such activities would be largely speculative at this point and would focus on scenario planning exercises, even an action as simple as convening a roundtable of experts from a range of different fields to present their views and concerns regarding CAV use and capabilities and discuss the potential impacts of these technologies of their community would be beneficial because of the cross-pollination opportunities such a gathering would offer. In addition, such roundtables would offer community leaders a venue to articulate their vision of how CAV technologies enable broader community goals related to safety, land use, economic development, and other topics of concern.

While MPOs are typically not involved in the land use planning and development processes that are administered by local governments (cities, towns, and villages) in New York State, MPOs will have to consider the impacts of CAV technologies on the built environment because of the broader influence that land use trends have on MPO policies. For example, long range plans that recommend guiding new development into urban and village centers will have to consider the role of CAV technologies in these areas and their role in promoting infill development, rehabilitation of existing buildings and facilities, and supporting wayfinding and navigation services in these locations.

Additional commentary on the impacts of CAV technology on Long Range Plans is provided in Section 7, below.

[59] *The Promise and Perils of Autonomous Vehicle Technology*. Page 27.

7. Integrating CAV-related Considerations into MPO Planning Activities

The previous sections of this white paper provided a general overview of the planning implications of CAVs. This section offers set of recommendations on what MPOs can begin doing today to prepare for Connected and Autonomous Vehicles.

7.1. Long Range Planning

When developing their long-range transportation plans, MPOs should address the following considerations for general planning, infrastructure, and service-related recommendations:

7.1.1. General Transportation Planning Recommendations:

- Identify and articulate desired future goals with regards to the safety, efficiency, and reliability of a region or community's transportation system. Once those goals have been defined, demonstrate how CAV technologies can contribute to achieving them.[60]
    - Consider grounding these goals on the ten planning factors in the Fixing America's Surface Transportation (FAST) Act; i.e., identify how CAV technologies will enable the realization of these factors:[61]
        1. Support the economic vitality of the metropolitan area, especially by enabling global competitiveness, productivity, and efficiency;
        2. Increase the safety of the transportation system for motorized and non-motorized users;
        3. Increase the security of the transportation system for motorized and non-motorized users;
        4. Increase accessibility and mobility for people and freight;
        5. Protect and enhance the environment, promote energy conservation, improve the quality of life, and promote consistency between transportation improvements and state and local planned growth and economic development patterns;
        6. Enhance the integration and connectivity of the transportation system, across and between modes, for people and freight;
        7. Promote efficient system management and operations;
        8. Emphasize the preservation of the existing transportation system;
        9. Improve the resiliency and reliability of the transportation system and reduce or mitigate stormwater impacts of surface transportation;
        10. Enhance travel and tourism.

[60] Given the local government structure of home-rule states like New York, a challenge facing regional planning organizations is establishing coordinated goals among municipalities within their jurisdiction that may have different and potentially conflicting community development goals; i.e., inner-ring suburbs and villages may be interested in fostering walkability and pedestrian access while outer-ring suburbs may be more interested in improving vehicular mobility and access.

[61] The FAST Act, signed into law by President Obama on December 4, 2015, is the current legislation authorizing federal funding for transportation investments for Federal Fiscal Years 2016 through 2020. It also provides the structure for MPO planning activities, which are outlined by the ten metropolitan "Planning Factors" listed above. See https://www.fhwa.dot.gov/fastact/ for more information.

- In coordination with member agencies (counties, cities, towns, and villages) that oversee land use planning and development review processes, consider how CAV technologies will influence future land use and civic design by supporting studies (as a funding source, a partnering agency, etc.) on the relationship between land use development trends and patterns and CAV technology. Scenario planning and risk assessment exercises are a useful means of testing various alternatives, such as the impacts of CAV on travel patterns, vehicle ownership, congestion management, and incident response.
- Identify planning for CAV deployments as a regional transportation policy issue alongside safety enhancements, signal synchronization, goods movement, economic development, and incident response (among others) for MPOs to build consensus on a systematic approach through their planning region.

7.1.2. Infrastructure-Related Recommendations:

- Integrate CAV-supportive field instrumentation into ITS planning and deployment projects such as active traffic management systems and communications networks.
- Install CAV-supportive field instrumentation as part of corrective/preventive road and bridge maintenance projects.
- Consider the potential for adaptive reuse in support of CAV services when designing ITS field instrumentation.
- Include the deployment of CAV-supportive technology as a strategy for improving safety, efficiency, and reliability for all modes of transportation (automobiles, transit, pedestrians, bicycles, etc.).
  - Specify the adoption of CAV-supportive technologies as a strategy for traffic congestion management and reduction.
- Expand the concept of “Complete Streets” to include CAV-supportive technologies and infrastructure elements.
  - If the MPO has included strategies and associated recommendations for implementing Complete Streets practices in its Long Range Plan (and/or other planning products), MPO staff should review and revise those products to ensure that CAV-supportive technologies and infrastructure are identified as one element of a complete street and will be integrated into road and street design.
  - If the MPO has a standalone Complete Streets policy, manual, or guide, MPO staff should revise it to include provisions for CAV-supportive technology. For example, language explicitly stating that future street designs will account for the specific needs of CAV establishes the policy foundation for integrating CAVs into Complete Streets in a way that achieves broader community development goals.
- Expand the concept of “Universal Design” to include CAV-supportive technologies and infrastructure elements.
  - Universal Design is the concept that products and built environments (including transportation facilities and services) should be designed for use by all people without the need for adaptation or specialized design. Planners should identify the ways in which CAVs can support efforts to expand personal mobility and access; e.g., by providing mobility options for the elderly and disabled, enhancing wayfinding capabilities, enabling expanded home delivery services.
  - If the MPO has a standalone Universal Design policy or guide, it should be updated to include provisions for CAV-supportive technologies and infrastructure.

- Expand the concept of "Access Management" to include CAV-supportive technologies and infrastructure elements.
  - Consider differences in access needs between human drivers and CAVs.
  - Update Access Management design guides and reference materials to acknowledge the impacts of CAV and suggest ways in which they can be accommodated; e.g., replacement of parking with drop-off/pick-up zones.
- In coordination with state and local departments of transportation, consider what changes will be required to the function, design, and placement of traffic signals, signage, striping, lighting, and other roadway elements to make them applicable to CAVs.
- Acknowledge the concept of "Infostructure;" that is, digital transportation infrastructure, not only for enabling Connected Vehicles but also for supporting multi-modal systems and programs like real-time travel-time displays on both roadside DMS and in-vehicle screens.
- Include a policy statement that CAV-supportive technology be deployed in accordance with the Regional Intelligent Transportation System Architecture (RITSA).
  - Coordinate with member agencies to ensure that a region's RITSA incorporates the CAV-supportive service packages included in Version 8 of the National ITS Architecture (ARC-IT). Federal funds used for ITS deployments, including CAV-supportive technologies, must be expended in conformance with an up-to-date RITSA.

7.1.3. Service-Related Recommendations:

- Monitor developments in the CAV field and maintain situational awareness of advances and potential applications of this technology to metropolitan transportation systems.
  - MPO staff are encouraged to participate in CAV-related conferences, workshops, and technical training programs.
  - Working with regional stakeholders, MPOs should periodically convene roundtables to discuss the anticipated impacts of CAV technologies on their communities and what stakeholders should do to prepare.
- Identify CAV technologies as a potential means of realizing safety-related goals such as reducing or eliminating traffic fatalities and injuries across all modes (i.e., Vision Zero initiatives) and enhancing incident-scene safety for victims, first-responders, and the traveling public.
  - Consider the impacts of CAV technology on Traffic Incident Management (TIM) policies and procedures, specifically with regards to reducing the number of crashes and mitigating the severity of crashes.
  - Identify resources (equipment, training, etc.) that first responders will require when responding to incidents involved CAV.
  - Investigate the use of CAV-generated data to monitor real-time traffic conditions and identify situations with a higher probability lead to incidents (i.e., sudden starts and stops on expressways; traffic backup from an expressway off-ramp onto the mainline). Coordinate with ITS field instrumentation (i.e., remote-controlled traffic signals) to mitigate those conditions.
- Acknowledge the influence of CAV on evolving social and economic trends such as ridesharing and ride-hailing services, and undertake scenario planning efforts to better understand how these trends will impact land use and demand for transportation services. For example, conduct scenario planning efforts for urban, inner-ring suburban, outer-ring suburban, and rural areas, as well as for unique areas (i.e., an abandoned mall site proposed for redevelopment, a harbor/waterfront area, etc.)

- Clarify that the concept of "mobility" focuses on providing transportation system users with the appropriate options for their transportation needs in lieu of a "one-size-fits-all" approach.
- Include mobility-oriented recommendations for enhancing trip planning and en-route navigation functions.
- Consider how CAV will impact navigation and wayfinding capabilities, and identify what public services (i.e., data from roadside sensors) are needed to support those capabilities.
- Develop strategies and programs for ensuring the availability of ride-sharing services to all segments of the population. A basic version of these services, which could potentially be a major boon to the disadvantaged in terms of providing access to employment and educational opportunities, should be available on an equitable basis.
- Assess the impacts of CAV technologies on transit services:
    - Continue the implementation of technical systems and services that enhance the safety and efficiency of transit fleets, such as automated vehicle location systems, intermodal trip planning functions, inter- and multimodal fare payment systems, and real-time service alerts.
    - Consider how alternate models of transit service provision may be implemented. In the future, bus fleets may be supplemented by on-demand services covering "last-mile" gaps; the distinctions between traditional transit fleets and taxis may eventually disappear.
- Acknowledge the importance of data privacy concerns and include cybersecurity-related initiatives as appropriate.[62]
- Consider what (if any) weather-related data CAV will need to function and how this data will be supplied; i.e., expansion of traditional Road Weather Information System
- Identify the optimum data sets and format that this data will take.
    - Articulate what MPOs and their member agencies want to accomplish with data sets generated by CAV (monitor traffic congestion, validate travel demand models, etc.)
    - Develop a policy and associated implementation strategy for how MPOs and member agencies access data generated by CAV.
    - Identify the security and privacy parameters that MPOs and member agencies need to follow to obtain and use data (i.e., data must not be used to identify specific motorists; protection of trade secrets; limited release of freight data that might be of interest to competitors).
    - Maintain transportation network coverage with roadside sensors. Mobile devices such as vehicle probes may provide excellent network-wide data on speeds, congestion, etc., but may not provide much useful data on traffic operations at specific locations such as intersections and interchanges.
- Identify future agency staffing needs and activities related to CAV. Consider how MPO staffing functions may change with the widespread adoption of these new technologies, and what additional staff capacities need to be provided.

[62] See the U.S. Department of Homeland Security's *Future Environment Net Assessment: Autonomous Vehicles* for an overview of cybersecurity concerns and considerations related to autonomous vehicles.

7.2. Congestion Management Process (CMP)

- Use data generated by CAV to identify and monitor congested locations. This data can also be used to validate travel demand model analyses (see Section 7.4 below).
- Strengthen the emphasis on travel time reliability as a key concept and expectation of congestion management initiatives.
- CAV may not eliminate congestion, but they could shift travel patterns and times. This could lead to changes in the causes, location, timing, and duration of congestion.
    - Monitor travel pattern changes; including shifts in routine commuter patterns, freight shipment and delivery services, special event-related disruptions, incident-related disruptions.
    - Consider the impacts on congestion of shifts in goods movement patterns, such as autonomous delivery vehicles are able to make their deliveries at night (see below, Section 7.3).
- Consider the abilities of CAV technologies to enable programs aimed at maximizing road usage at times when there traditionally has been less demand (e.g., nighttime).

7.3. Goods Movement/Freight Planning

- Investigate the use of data generated by CAV freight vehicles to better understand the ongoing evolution of goods movement patterns and the impacts of this evolution on transportation infrastructure use and demand. Anticipated changes include[63]:
    - Goods Distribution: The traditional retail model of central distribution warehouses pared with truck fleets that deliver products to stores where they are purchased by the consumer is shifting to a more decentralized distribution network that minimize stores and deliver products from warehouses directly to consumer's homes. This shift is expected to continue and speed up during the next several decades, with a greater variety of goods being obtained through online ordering.
    - Truck Platooning: While autonomous truck platoons can operate on existing roads, connected vehicle technology may have unique benefits; e.g., traffic signal timing patterns that modify signal phasing in response to approaching truck platoons, thus improving overall safety and efficiency by ensuring that the entire platoon can pass through an intersection.
    - Roaming Stores: Businesses could equip fleets of autonomous delivery vehicles to roam within designated areas and be summoned to consumers' homes to drop off products.
    - Enhanced Just-in-Time delivery services: Greater travel time reliability will enable manufacturers and others to expand their use of just-in-time services.
    - Increased emphasis on overnight delivery services: Autonomous delivery vehicles could be deployed during the evening to make overnight deliveries, reducing the need for

[63] An emerging technology with the potential to further disrupt goods movement is 3-D printing, an additive manufacturing process that transforms three-dimensional digital design files into a solid objects. These objects are fabricated by "slicing" the digital file into multiple layers that are laid down in successive tiers using plastics, metals, alloys, or some other material and fused together. As 3-D printing capabilities mature over the next several decades, they may have a profound impact on goods movement. For example, a customer could order a product online and then have it manufactured on a home 3-D printer or at a neighborhood 3-D print shop where he can pick it up, thus eliminating the need for the product to be shipped. 3-D printing also has implications for supply chain shipments by facilitating greater on-site production of components.

them to be on the road during the day or at peak travel times and making more use of roads during the overnight hours when demand is typically lower than during the day.

7.4. Travel Demand Modeling

- There is a need to update MPO travel demand models to account for the impacts of CAV technologies on future travel patterns. A number of MPOs and private firms have begun investigating scenario planning functions aimed at addressing the uncertainties around how CAV will influence safety, congestion, mobility, and other factors.
  - The Puget Sound Regional Council developed four modeling scenarios that consider how autonomous vehicles may impact road capacity, increase the value of travel time, reduce parking costs, and increase operations costs.[64]
- In the future, as data generated by Connected Vehicles becomes available, this data should be used to calibrate and validate travel demand models. This data is anticipated to fill in the gaps left by current sources, such as Census Bureau data (e.g., the American Community Survey); household travel surveys; and transit, commercial/freight, and other specialized surveys.[65]
  - Data generated by Connected Vehicles is not expected to *replace* the modeling function at MPOs because the planning process will always require projections of future use and demand for transportation infrastructure and services. However, data generated by these vehicles on transportation system performance should be used for informing trend analyses, such as projections of capacity levels, delay, and driver behavior.

7.5. Transportation Improvement Program (TIP)

- Given the state of CAV technology, it is too early to program Connected and Automated Vehicle-supportive projects into TIPs.[66] However, as this technology matures, consideration will have to be given as to how it is addressed in TIP project selection criteria, as well as what funding source(s) can be used to implement it.
  - Depending on the requirements that Connected Vehicles have for two-way communications with roadside instrumentation, future infrastructure projects programmed into the TIP may include elements that are necessary for Connected Vehicle support. This will require the revision of TIP selection criteria to ensure that Connected Vehicle-supportive elements are captured and included in project scoring matrices.
  - Depending on their alignment with long-range plan priorities, infrastructure projects that include appropriate CAV-supportive technologies should receive extra points/higher scores than ones that do not, especially when these technologies are proposed as part of a broader ITS deployment plan.

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[64] *Using an Activity Based Model to Explore Possible Impacts of Automated Vehicles*. Pages 5-7.
[65] *Use of Data from Connected and Automated Vehicles for Travel Demand Modeling*. Pages 9-12.
[66] Depending on their funding source, one exception may be pilot CAV deployment projects.

8. Questions for Discussion

The following questions are provided as a means of generating discussions about the impact of CAV technology among MPOs and their member agencies, as well as other community stakeholders. While the answers to these questions may not be clear (depending on who you ask!), it is worthwhile to begin discussing them so that agency personnel maintain awareness of developments in the CAV field and are able to begin integrating CAV-related considerations into work products.

1. How do Connected and Automated Vehicles contribute to advancing a community's overarching goals regarding transportation system safety, mobility, and accessibility?
2. How can public policy be used to guide Connected and Automated Vehicles towards realizing a community's safety, mobility, and accessibility benefits while avoiding deleterious impacts, such as unequal access to these benefits?
3. What do the public agencies charged with planning, building, operating, and maintaining the transportation system have to do to prepare their infrastructure for Connected and Automated Vehicles? (i.e., if engineers are designing a bridge with a design-life of 75 years, what elements should they consider to make that bridge adaptable to Connected and Automated Vehicles?)
4. How will Connected and Automated Vehicles precipitate social, economic, and cultural changes that influence MPO planning programs and service delivery?
5. Will Connected and Automated Vehicles reinforce or redirect existing land use and development patterns and trends?
6. How will Connected and Automated Vehicles influence civic design, and how will municipal policies and practices related to Complete Streets, Universal Design, and Access Management be revised to accommodate them?
7. What other stakeholders (government agencies, universities, private entities, etc.) need to be brought into the regional transportation planning process to help identify and plan for the impacts of Connected and Automated Vehicles?
8. How will public and private entities coordinate Connected and Automated Vehicles and the supporting services required to maximize their contribution?
9. How will the safety-related impacts of Connected and Automated Vehicles influence Traffic Incident Management (TIM) practices?
10. What will be the impacts of Connected and Automated Vehicles on freight/goods movement in a community?
11. How will Connected and Automated Vehicles contribute to realizing a community's environmental protection and enhancement goals?
12. How will Connected and Automated Vehicles interface with alternate energy sources, such as electrically-powered vehicles, to introduce new capabilities and functions to public and private fleets, private vehicles, and TNCs?

9. Sources

The following is a list of the source materials consulted for this white paper. Not all these sources are cited in the white paper. This is not a complete listing of worthwhile resources to review when considering the impacts of CAV technology on the transportation system, but it is a good start.[67]

- N/A. *A Primer on the Connected Vehicle Environment*. November 2015.
- N/A. *Autonomous Vehicles: A Policy Preparation Guide*. National League of Cities. 2017.
- N/A. *Tourists Can't Lose Road in Radio Guided Automobile*. Popular Mechanix. May 1932.
- Ackerman, Kevin. *Self-Driving Cars Were Just Around the Corner-in 1960*. IEEE Spectrum. August 2016.
- Atkinson, Robert D., Daniel Castro, Stephen Ezell, Alan McQuinn, and Joshua New. *A Policymaker's Guide to Digital Infrastructure*. Information Technology & Innovation Foundation. May 2016.
- Bierstedt, Jane; Aaron Gooze, Chris Gray, Josh Peterman, Leon Raykin, Jerry Walters. *Effects of Next-Generation Vehicles on Travel Demand and Highway Capacity*. FP Think. January 2014.
- Bishop, Richard. *Whatever Happened to Automated Highway Systems?* Traffic Technology International. August-September 2001.
- Blincoe, L.J., Miller, T.R., Zaloshnja, E., and Lawrence, B.A. *The Economic and Societal Impact of Motor Vehicle Crashes, 2010 (Revised)*. DOT HS 812 013. U.S. Department of Transportation, National Highway Traffic Safety Administration. May 2015.
- Brugeman, Valerie; Eric Dennis; Adela Spulber. *Public Perception of Automated Vehicle Technologies*. Michigan Department of Transportation. May 2016.
- Carney, Susan and Nicole Casal Moore. *Driverless Shuttle Service Coming to U-M's North Campus*. University of Michigan News. June 21, 2017.
- Cuddy, Matthew, Alexander Epstein, Cynthia Maloney, Ryan Westrom, Joshua Hassol, Anita Kim, David Damm-Luhr, Caitlin Bettisworth. *The Smart/Connected City and Its Implications for Connected Transportation*. John A. Volpe National Transportation Systems Center, October 2014.
- Chapin, Tim, Lindsay Stevens, Jeremy Crute, Jordan Crandall, Anne Rokyta, Alexandria Washington. *Envisioning Florida's Future: Transportation and Land Use in an Automated Vehicle World*. Florida Department of Transportation, April 2016.
- Childress, Suzanne, Brice Nichols, Billy Charlton, Stefan Coe. *Using an Activity Based Model to Explore Possible Impacts of Automated Vehicles*. Puget Sound Regional Council, 2014.
- DeKales, Jon. *Smart Cities Readiness Guide*. Transportation. Smart Cities Council. 2015.

[67] Those interested in following developments in the Connected and Automated Vehicle technology sphere should also consider subscribing to email newsletters such as ITS America's *SmartBrief*, Driverless Transportation's *Mile Marker*, and Dr. Alain Kornhauser's *Smart Driving Cars*.

- DuPuis, Nicole; Cooper Martin; and Brooks Rainwater. *City of the Future: Technology and Mobility*. National League of Cities, 2015.
- Fagnant, David and Kara Kockelman. *Preparing a Nation for Autonomous Vehicles: Opportunities, Barriers, and Policy Recommendations*. Eno Center for Transportation. October 2013.
- Forrest, Alex and Mustafa Konca. *Autonomous Cars and Society*. Worcester Polytechnic Institute. May 2007.
- Gill, Vajay; Barrie Kirk, Paul Godsmark, and Brian Flemming. *Automated Vehicles: The Coming of the Next Disruptive Technology*. The Conference Board of Canada. 2015.
- Green, Herndon. *Radio Controlled Automobile*. Radio News. November 1925.
- Grush, Bern, John Niles, and Edgar Baum. *Ontario Must Prepare for Vehicle Automation: Automated Vehicles can influence urban form, congestion, and infrastructure delivery*. Residential and Civil Construction Alliance of Ontario (RCCAO). October 2016.
- Goulding, Lynne and Marcus Morrell. *Future of Highways*. Arup. 2014.
- Hawkins, Andrew J. *Meet ALVINN, the self-driving car from 1989*. The Verge. November 27, 2016.
- Hill, Christopher. *Module 13: Connected Vehicles*. ITS ePrimer. U.S. Department of Transportation. Washington, D.C.
- Hopkins, Susan. *Getting Ahead of Autonomous Vehicles: Five Predictions for A&E Professionals*. Bergmann Associates. 2015.
- Hopkins, Susan. *The Time to Plan is Now: 4 Ways Autonomous Vehicles Can Empower Communities*. Bergmann Associates. 2015.
- Hutchinson, Ed; Carl Crane, Lily Elefteriadou, Miguel Lugo, Stephen Spana, Srinivasan Sivaramakrishnan, Yafeng Yin. *Surveying Florida's MPO Readiness to Incorporate Innovative Technologies into Long Range Transportation Plans*. Florida Department of Transportation. August 2016.
- Humes, Edward. *Door to Door: The Magnificent, Maddening, Mysterious World of Transportation*. Harper Collins. 2016.
- Issac, Lauren. *Driving Towards Driverless: A Guide for Government Agencies*. WSP/Parsons Brinckerhoff. 2016.
- Kilbon, Kenyon. *Tomorrow's Thruway Is Here Today!*. Electronic Age. Autumn 1960.
- McKenzie, Brian. *Who Drives to Work? Commuting by Automobile in the United States: 2013*. U.S. Census Bureau. August 2015.
- Mereu, Alex. *A Driverless Future: It's not Just About the Cars*. IBI Group. January 2017.
- Muoio, Danielle. The Company *that Invested Post-It Notes is Hiding Invisible Messages in Signs to Help Self-Driving Cars See the World*. Business Insider. August 13, 2017.
- Peleg, Oren. *Self-Driving Cars Debuted on California's Highways 20 Years ago*. LAist. August 7, 2017.

- Pomerleau, Dean A. *ALVINN, an autonomous land vehicle in a neural network*. Carnegie Mellon University. 1989.

- Roeth, Michael. *CR England Peloton Technology Platooning Test November 2013*. North American Council for Freight Efficiency. December 2013.

- Siegel, Robert and Art Silverman. *Pittsburgh Offers Lessons for Self-Driving Cars*. WBUR. April 3, 2017.

- Sims R., R. Schaeffer, F. Creutzig, X. Cruz-Núñez, M. D'Agosto, D. Dimitriu, M. J. Figueroa Meza, L. Fulton, S. Kobayashi, O. Lah, A. McKinnon, P. Newman, M. Ouyang, J. J. Schauer, D. Sperling, and G. Tiwari, 2014: *Transport*. In: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

- Singh, S. U.S. Department of Transportation. National Highway Traffic Safety Administration. *Critical Reasons for Crashes Investigated in the National Motor Vehicle Crash Causation Survey*. DOT HS 812 115. Washington, D.C. February 2015.

- Sissons, Patrick. *How Driverless Cars Could Reshape Our Cities*. Curbed. February 25, 2016.

- Suplee, Curt. *Social Science Studies the Most Hazardous Thing on the Road: You*. From Research to Reward. National Academy of Sciences. Washington, D.C. 2016.

- U.S. Department of Homeland Security. Office of Cyber and Infrastructure Analysis. *Future Environment Net Assessment: Autonomous Vehicles*. Washington, D.C. June 2017.

- U.S. Department of Transportation. Federal Highway Administration. *Arterial Management: Traffic Control*. Washington, D.C. 2014.

- U.S. Department of Transportation. National Highway Traffic Safety Administration. *Federal Automated Vehicles Policy: Accelerating the Next Revolution in Roadway Safety*. Washington, D.C. September 2016.

- U.S. Department of Transportation. National Highway Traffic Safety Administration. *2015 Motor Vehicle Crashes: Overview*. DOT HS 812 318. Washington, D.C. August 2016.

- Vanderbilt, Tom. *Let the Robot Drive: The Autonomous Car of the Future is Here*. Wired Magazine. 2012.

- Vanderbilt, Tom. *Autonomous Cars Through the Ages*. Wired Magazine. 2012.

- Vinsel, Lee. *The Man Who Invented Intelligent Traffic Control a Century Too Early*. IEEE Spectrum. July 2016.

- Walker, K. Scott, Quing Hong, Leta Huntsinger, Scott Shogan, Richard Wallace. *Use of Data from Connected and Automated Vehicles for Travel Demand Modeling*. Michigan Department of Transportation. October 2015.

- West, Darrell M. *Moving forward: Self-driving vehicles in China, Europe, Japan, Korea, and the United States*. Brookings Institution – Center for Technology Innovation. September 2016.

- Wise, David; Judy Gulliams-Tapia; Melissa Bodeau; Leia Dickerson; David Hooper; Terence Lam; Maren McAvoy; Josh Ormond; Madhav Panwar; Matthew Rosenberg; Chad Williams; Elizabeth Wood. *Intelligent Transportation Systems: Vehicle-to-Vehicle Technologies Expected to Offer Safety Benefits, but a Variety of Deployment Challenges Exist*. United States Government Accountability Office. November 2013.

- Zmud, Johanna; Ipek Sener, Jason Wagner. *Revolutionizing Our Roadways: Consumer Acceptance and Travel Behavior Impacts of Automated Vehicles*. Texas A&M Transportation Institute. April 2016.

10. Acronyms

- AERIS – Applications for the Environment: Real-Time Information Synthesis
- AMPO – Association of Metropolitan Planning Organizations
- AV – Automated Vehicle *or* Autonomous Vehicle
- CMP – Congestion Management Process
- CAV – Connected and Automated Vehicle
- CV – Connected Vehicle. May also refer to “commercial vehicle” in some situations.
- DAC – Driver Acceptance Clinic
- EV – Electric Vehicle
- HAV – Highly Automated Vehicle
- ICE – Internal Combustion Engine
- ITS – Intelligent Transportation Systems
- LRTP – Long Range Transportation Plan. May also be referred to as Long Range Plan (LRP) or Metropolitan Transportation Plan (MTP)
- NHTSA – National Highway Traffic Safety Administration
- NYSAMPO – New York State Association of Metropolitan Planning Organizations
- RITSA – Regional Intelligent Transportation System Architecture
- TIM – Traffic Incident Management
- TIP – Transportation Improvement Program
- TNC – Transportation Network Company
- USDOT – United States Department of Transportation
- VMT – Vehicle Miles Traveled

Appendix A: New York State MPO Long Range Planning for Connected and Automated Vehicles: Current Status (Summer 2017)

This appendix summaries the current treatment of connected, automated, and autonomous vehicles in each of New York State's fourteen MPO long range transportation plans. These plans are typically available as PDF documents on MPO agency websites, and this appendix was compiled by reviewing the plans to identify what, if any, commentary and associated recommendations on these technologies were included in them.[1]

It should be noted that while long range plans establish the policy foundation for MPO planning and programming activities, they may not include a detailed discussion of all transportation planning-related initiatives underway in an MPO region. Many long range plans include broad, high-level policy statements and recommendations regarding enhancements to transportation system safety, mobility, efficiency, and reliability that could be interpreted to support the deployment of connected and automated vehicle-supportive technologies without specifically mentioning them. These technologies are broadly applicable to recommendations aimed at improving all modes of transportation under an MPO jurisdiction, including automobiles, transit (buses, light rail, heavy rail, etc.), trucks (both long-haul and local freight), bicycle, and pedestrian. In addition, many MPOs have thematic planning products (freight plans, bicycle/pedestrian plans, transportation system management and operations/intelligent transportation systems strategic plans) that may include commentary and recommendations on these technologies as well.

1. Adirondack-Glens Falls Transportation Council (AGFTC) – Glens Falls

   Long Range Plan: *2035 Ahead*
   Adopted: November 2013

   - There is no discussion of Connected or Automated Vehicles in this long range plan. According to agency staff, future versions of the plan are anticipated to include a discussion of these technologies.

2. Binghamton Metropolitan Transportation Study (BMTS) – Binghamton

   Long Range Plan: *Looking Forward 2040*
   Adopted: September 2015

   - This plan includes a brief mention of the need for BMTS to plan for emerging technologies, including autonomous vehicles as well as automated transit networks. There is a recognition that these technologies will facilitate greater choice regarding transportation options. (*See Page 44*)

[1] The one exception was the long range plan for the Watertown-Jefferson County Transportation County, which was under development at the time this white paper was prepared. Future versions of this white paper will include applicable information from that plan.

3. Capital District Transportation Committee (CDTC) – Albany

Long Range Plan: *New Visions 2040*
Adopted: September 2015; Amended March 2016

- The CDTC long range plan identifies automated vehicles and self-driving cars as one of a number of technological advancements that are expected to impact the transportation system during the plan's timeframe.
- The plan identifies eight potential impacts of automated vehicles:
    1. Potential for near zero crash fatalities, near zero crash injuries: Virtually all crashes can be avoided by removing driver error.
    2. Significant increase in highway capacity: Narrower lanes, higher speeds, and closer spacing between vehicles could increase highway capacities; improved efficiency at intersections could also increase arterial capacities. Essentially eliminating crashes would also reduce congestion, helping to increase capacity.
    3. Potential for light vehicles: Electronically "crash-proofing" vehicles creates an opportunity to make them lighter, thus making them less expensive and more fuel efficient.
    4. Seniors could drive longer, people with disabilities could drive: Fully automated vehicles would improve mobility for those who can't drive due to age or health issues.
    5. Potential Impacts on Transit: The impacts of automated vehicles on transit is unknown; they could rival transit or they could augment it with, for example, automated shuttles that drop off riders at mainline transit stations.
    6. Potential Impacts on Smart Growth: Automated vehicles could encourage increased sprawl and longer commute trips by reducing the stress associated with driving. However, these vehicles may also make urban centers more attractive and accessible, thus enhancing the appeal of urban living.
    7. Totally Automated Trucks: Truck automation may eliminate the need for drivers to manually operate trucks on interstates, thus allowing them to rest and increasing the number of hours the truck can be in operation, which ultimately reduces costs.
    8. Potential Disbenefits of Totally Automated Vehicles: Traveler privacy, equitable access to the benefits of automated vehicle technology, and the transition period from manually operated vehicles to totally automated vehicles are all areas of concern.
- The plan acknowledges that it is currently not possible to accurately assess the impacts of totally automated vehicles and identifies three general policies to consider:
    1. Potential for totally automated vehicles to impact highway and bridge design: Consider how the increased capacity resulting from automated vehicles in future highway and bridge designs will influence future highway and bridge designs. The Plan recommends that the New York State Department of Transportation should consider if changes to the current design approach are needed to reflect potential changes in future demand as well as potential changes in the congestion threshold that triggers a need for increased capacity.
    2. Smart Growth: Continue to support smart growth policies even though the impacts of automated vehicles are unknown. Use automated vehicle technologies to reinforce Smart Growth concepts such as the redevelopment of urban centers and compact, mixed-use development.

3. Anticipate technology with flexibility and smart near-term investments: Proceed with short and near-term investments in safety and mobility; maintain flexibility to incorporate new technologies as they arrive. (*See Pages 49-51*)

4. Genesee Transportation Council (GTC) – Rochester

Long Range Plan: *Long Range Transportation Plan for the Genesee-Finger Lakes Region 2040*
Adopted: June 2016; Amended June 2017

- GTC's long range plan identifies Connected and Automated Vehicles as an "emerging technology" that is anticipated to impact the transportation system within the timeframe of the plan. The plan identifies Connected Vehicles as vehicles that rely on wireless communications to link with roadside infrastructure and other vehicles, and Automated Vehicles as vehicles with safety features that operate independently of driver control. The plan identifies both potential benefits (increased safety, mobility, and capacity; reduced emissions) as well as potential downsides (potentially high deployment and adaption costs, data security and privacy issues, and induced demand), and links the success or failure of these technologies to public acceptance of them.
- The plan includes a brief discussion of Connected and Automated Vehicles in its section on Transportation Systems Management and Operations/Intelligent Transportation Systems. It links these technologies to broader operations-related strategies aimed at enhancing transportation system safety, mobility, reliability, and efficiency. (*See Pages 40; 85*)

5. Greater Buffalo-Niagara Regional Transportation Council (GBNRTC) – Buffalo

Long Range Plan: *2040 Metropolitan Transportation Plan Update*
Adopted: May 2014

- There is no discussion of Connected or Automated Vehicles in this long range plan. Future versions of the plan are anticipated to include a discussion of these technologies.

6. Elmira-Chemung Transportation Council (ECTC) – Elmira

Long Range Plan: *Elmira Chemung Transportation Plan 2035*
Adopted: December 2014

- The ECTC long range plan identifies a series of "Opportunities and Challenges," including transportation and communications technology, that agencies involved in transportation planning and program implementation are expected to address. The plan mentions automated vehicles and explains that wireless technology will enable improved vehicle safety and real-time traffic and road information that drivers can use to make informed decisions. (*See Page 2*)

- The plan mentions the USDOT's connected vehicle research programs and briefly describes their anticipated safety benefits, such as automated safety alerts. (*See Page 108*).

7. Herkimer-Oneida Counties Transportation Study (HOCTS) – Utica

Long Range Plan: *LRTP Update 2035*
Adopted: December 2014

- There is no discussion of Connected or Automated Vehicles in this long range plan.

8. Ithaca-Tompkins County Transportation Council (ITCTC) – Ithaca

Long Range Plan: *2035 Long Range Transportation Plan Update*
Adopted: December 2014

- The ITCTC long range plan mentions "automated transportation networks" as an example of a new technology that is emerging along with other ITS-related concepts, but does not define this term or discuss any specific technical applications or benefits of such networks. (*See Pages 4.41-4.42*)
- The plan mentions a need for establishing a sustainable "automated rideshare" program for Tompkins County. This program is mentioned in context of an existing computerized ride-matching service, but it is not clear if the reference to automation refers to the type of vehicles (i.e., "automated vehicles) that the rideshare program would depend on or the ride-matching/dispatching elements of this program. (*See Page 5.5*)

9. Orange County Transportation Council (OCTC) – Orange County

Long Range Plan: *Long Range Transportation Plan 2015-2040*
Adopted: November 2015

- There is no discussion of Connected or Automated Vehicles in this long range plan. According to agency staff, future versions of the plan are anticipated to include a discussion of these technologies.

10. Poughkeepsie – Dutchess County Transportation Council (PDCTC) – Poughkeepsie

Long Range Plan: *Moving Dutchess 2*
Adopted: March 2016

- There is no discussion of Connected or Automated Vehicles in this long range plan. According to agency staff, future versions of the plan are anticipated to include a discussion of these technologies.

11. New York Metropolitan Transportation Council (NYMTC) – New York City

Long Range Plan: *Regional Transportation Plan 2045*
Adopted: June 2017

- The NYMTC long range plan identifies a number of "Critical Drivers of Change," including emerging technologies; social, economic, and demographic shifts; changes in land use patterns; and the increasing frequency of extreme weather events, that are expected to impact the future transportation system. One of these drivers, "Operational and Safety Technologies," covers a range of technological applications including connected and autonomous vehicles. The plan identifies the safety benefits of connected vehicle technologies and discusses the broader implications of self-driving vehicles; including crash reduction, productivity improvements, and mobility enhancements. (*See Pages 2-32 – 2-32*)
- Connected Vehicles (CV) Pilot Program: In September 2016, New York City was awarded one of three CV Pilot programs sponsored by the United States Department of Transportation.[2] The plan discusses this pilot program, which is aligned with the city's Vision Zero initiative and is designed to improve traveler, including pedestrian, safety through the deployment of prototype connected vehicle technologies. The pilot program will equip about 250 intersections with instrumentation to collect Basic Safety Message (BSM) data from up to 10,000 vehicles that will be used to provide driver alerts. (*See Page 2-32*)
- Internet of Things (IoT): The plan identifies both Vehicle to Vehicle (V2V) and Vehicle to Infrastructure (V2I) as potentially transformative applications of the IoT (the network of interconnected devices embedding in physical objects or things) to the metropolitan transportation system. (*See Page 5-13*)

12. Syracuse Metropolitan Transportation Council (SMTC) – Syracuse

Long Range Plan: *2050 Long Range Transportation Plan*
Adopted: September 2015

- The SMTC long range plan includes a single reference to autonomous vehicles; it identifies them as a "disruptive technology" that may change some aspects of travel and land use patterns, but is not anticipated to fundamentally change establish urban-suburban commute patterns. (*See Page 101*)

[2] The other two CV pilots were awarded to the Wyoming State Department of Transportation and the Tampa-Hillsborough Expressway Authority.

13. Ulster County Transportation Council (UCTC) – Ulster County

Long Range Plan: *Year 2040 Long Range Transportation Plan*
Adopted: September 2015

- Goal 5 of the UCTC plan identifies planning for "efficient and reliable travel for all modes by investing in strategies that mitigate both recurring and non-recurring congestion." The plan identifies connected and autonomous vehicle technologies as a means of achieving this goal. Objective 5.4, "Transportation Technology," identifies two actions: (a) "Facilitate deployment of Connected Vehicle program technology as it is rolled out by USDOT and vehicle manufacturers" and (b) "Monitor progress of penetration of autonomous vehicles in the general auto fleet and develop appropriate plans and policies." The associated performance measure is to "Monitor deployment of connected vehicle technology and ITS infrastructure – annually." (*See Pages 23-24*)
- The plan recognizes connected and autonomous vehicles as a "game changer" that will be adopted at some point during the plan's timeframe. The plan discusses autonomous vehicles, including commercial trucks, and identifies some of the potential impacts these technologies will have on travel conditions such as enhancing mobility for those currently unable to drive and enabling off-hours goods delivery. (*See Pages 84-85*)

14. Watertown-Jefferson County Transportation Council (WJCTC) – Watertown

Long Range Plan: Under Development
Adopted: Not Applicable

- The WJCTS long range transportation plan is currently under development.