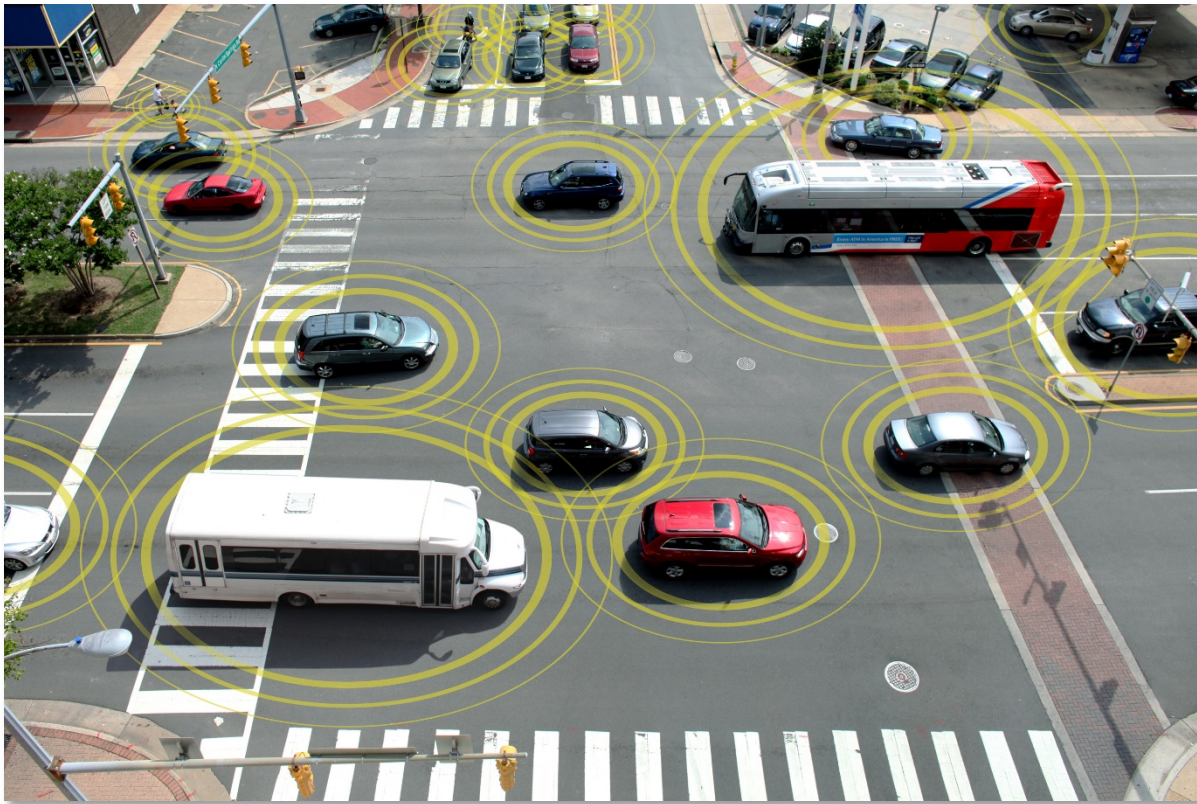# CONNECTED AND AUTONOMOUS VEHICLES (CAVs)

Planning Considerations for the National Capital Region Transportation Planning Board

June 2020

![National Capital Region Transportation Planning Board logo]
National Capital Region
Transportation Planning Board

CONNECTED AND AUTONOMOUS VEHICLES (CAV): PLANNING CONSIDERATIONS FOR THE NATIONAL CAPITAL REGION TRANSPORTATION PLANNING BOARD
Prepared by ICF on behalf of the Metropolitan Washington Council of Governments Department of Transportation Planning
June 2020

ABOUT THE TPB
The National Capital Region Transportation Planning Board (TPB) is the federally designated metropolitan planning organization (MPO) for metropolitan Washington. It is responsible for developing and carrying out a continuing, cooperative, and comprehensive transportation planning process in the metropolitan area. Members of the TPB include representatives of the transportation agencies of the states of Maryland and Virginia and the District of Columbia, 24 local governments, the Washington Metropolitan Area Transit Authority, the Maryland and Virginia General Assemblies, and nonvoting members from the Metropolitan Washington Airports Authority and federal agencies. The TPB is staffed by the Department of Transportation Planning at the Metropolitan Washington Council of Governments (COG).

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The shift from today's automobiles to connected and autonomous vehicles (CAVs) is anticipated to have broad and significant impacts on various facets of mobility and society, such as traffic safety; personal and freight mobility; changing models of vehicle ownership and use; public transit services; and where people choose to live and travel. Given the sheer number of factors that will influence CAV deployment, much uncertainty surrounds how CAVs will function on the highways and local roads and in our communities. However, CAVs are likely to impact regional transportation planning goals, priorities, and activities in significant ways.

This white paper seeks to assist the National Capital Region Transportation Planning Board (TPB), the federally designated metropolitan planning organization (MPO) for metropolitan Washington, in planning for CAVs on the region's transportation system. Specifically, it looks to inform regional conversations on CAVs and TPB's role related to this topic by examining:

- Areas where TPB goals, policies, and activities may substantially interact with CAVs.
- Potential CAV deployment impacts (issues, challenges, opportunities) as they relate to corresponding jurisdictional authorities and roles (primary, secondary, collaborative).
- Opportunities to enhance CAV considerations within TPB's planning products/activities including processes for developing regional CAV principles.

This paper also supports development of the region's planning, policy, and programming priorities related to CAVs and identifies actions TPB may take to further achievement of its goals and minimize the potential for adverse impacts as CAVs are deployed.

CAV Impacts: Relation to Regional Goals and Agency Roles

Research conducted for the white paper identified the following areas of CAV deployment impact, which pertain directly or indirectly to the role of regional long-range transportation planning in the metropolitan Washington region and to the roles of transportation agencies generally:

- **Travel:** includes impacts that directly relate to the mobility of the traveling public, motor carriers, and other road users (access, active/public transportation, goods movement, travel behavior, and safety).
- **Societal:** includes impacts of broad societal concern (equity, employment/economic development, environment, and land use).
- **Organizational:** includes impacts directly related to the activities and responsibilities of infrastructure owner/operators and transportation planning agencies (data coordination, emergency preparedness, funding, infrastructure, operations, reliability, security/privacy, and travel forecasting).

The white paper provides an example linkage between the CAV deployment impact areas/categories identified above and select TPB policy goals and objectives. This helps demonstrate the relevance of

CAVs impacts to nearly every area of the agency's goals and activities. Relative levels of certainty and risk associated with each of the impact areas are also explored.

The white paper identifies the following high-level roles for transportation agencies at various jurisdictional levels as they relate to CAV deployment:

- **Federal role:** vehicle safety, cybersecurity, national standards, grant funding, and research.
- **State role:** policymaking; infrastructure and traffic operations; state-level guidance; and planning, research, development, and testing.
- **MPO role:** transportation plans; travel forecasting and modeling; multimodal transportation.
- **Local role:** curbside management; land use planning and urban design; local transportation project and infrastructure planning, design, operations, and maintenance; interjurisdictional collaboration on infrastructure projects; and local policies.

The white paper also explores issues, challenges, and opportunities related to potential CAV impacts and the corresponding roles (primary, secondary, collaborative) for agencies and private industry.

Opportunities to Enhance the TPB Role in CAVs

TPB leads regional transportation planning and coordination. It convenes member agencies to collaborate on important issues for the region's mobility, accessibility, safety, environment, and quality of life. TPB plans for the region's future, develops consensus on priorities and approaches, and ensures that the MPO's activities meet all federal requirements. Roles for TPB in CAV may include information sharing, engagement, and coordination; regional policy priority development and collaboration; and supporting the integration of CAV considerations into planning and programs. The development of regional CAV principles by TPB could articulate desired outcomes, policy priorities, and investment considerations as they relate to these roles. A process for developing such principles could entail:

- Engagement of members through the TPB committee structure to support the development of regional CAV principles including development of a CAV principles statement of purpose.
- Working with members to collaboratively develop a technical summary that highlights key CAV issues and themes as the basis for establishing regional CAV principles.
- Conducting workshops with TPB members and the board to further discuss and develop draft regional CAV principles.
- TPB staff and board collaboration to refine the regional CAV principle language, develop a draft resolution, and vote on the adoption of the resolution.

Additional CAV enhancement activities could include: undertaking CAV strategic planning; articulating desired CAV outcomes in TPB plans, programs, and initiatives; collaborating with member agencies and organizations; and providing a forum of information exchange in piloting and deploying CAV technologies that advance regional priorities and goals.

While challenges associated with CAVs are significant, TPB and its partners are well prepared to address them.

II. PURPOSE OF WHITE PAPER

Transportation professionals anticipate that connected and autonomous vehicles (CAVs) could have a tremendous impact on the metropolitan Washington region.

Transportation professionals anticipate that connected and autonomous vehicles (CAVs) could have a tremendous impact on the metropolitan Washington region. As was true for the movement from the horse and buggy to the automobile, the shift from the automobiles of today to CAVs may affect various facets of mobility and society, such as personal and freight travel; changing models of vehicle ownership and use; public transit services; and where people choose to live and travel.

This white paper seeks to assist Metropolitan Washington Council of Governments (MWCOG) National Capital Region Transportation Planning Board (TPB), the federally designated metropolitan planning organization (MPO) for metropolitan Washington, in planning for the integration of CAVs on the region's transportation system. This document identifies potential issues and impacts of CAVs as they pertain to the MPO role (e.g., multimodal transportation, safety, and freight) and the planning context for the metropolitan Washington region (i.e., alignment with TPB's goals, policies, and activities). This white paper will support regional conversations on CAVs and inform the development of regional principles that uphold and advance the region's transportation system vision.

III. OVERVIEW OF CAVs

The concepts of connected vehicles and autonomous vehicles are not new, with evolving versions of these technologies under development for decades now. For instance, vehicle-satellite connectivity, cruise control, and antilock brakes were features commonly available in the 1990s. However, the rapid advance and growth in the past decade in different technology fields, such as communications and sensing, and the reduced costs of these technologies, have spurred a drastic push forward in connectivity and automation.

Although terminology varies nationally, this report primarily uses the term "autonomous vehicles."

The University of Virginia Center for Transportation Studies has developed a comprehensive glossary of CAV terms (Glossary), which this report has adopted and which readers may refer to for detailed explanations of CAV technical terminology[1]. As noted in the Glossary, a variety of terms and definitions are currently in use to describe vehicles that partially or fully conduct critical functions of the dynamic driving task (DDT) like steering, acceleration, and braking without direct human driver

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[1] Park, H., Khattak, Z., & Smith, S. (2018, March). Glossary of connected and automated vehicle terms: Version 1.0. Retrieved from: http://www.cts.virginia.edu/wp-content/uploads/2018/03/Glossary-of-CAV-Terms-Ver1.0-03052018-1.pdf

input. These terms include automated vehicles, autonomous vehicles, self-driving vehicles, and driverless vehicles. While there is no broad consensus regarding the use of these terms and definitions, and they are often used interchangeably, experts have increasingly adopted the term "automated vehicles" to refer to vehicles with these capabilities (for example, the widely referenced SAE J3016 "Levels of Driving Automation" standard shown in Figure 1 uses this terminology). For consistency with past TPB documents, however, this report primarily uses the term "autonomous vehicles" to refer to vehicles of these types and "autonomy" to refer to the capabilities that enable these vehicles to partially or fully conduct critical aspects of the DDT without direct human driver input.

The following is a brief overview of each technology:

- **Connected vehicles (CVs):** CVs refers to a range of technologies that allow vehicles to communicate with other connected devices in their environment. Such general communication capabilities are referred to as vehicle-to-everything (V2X). More specific communications include those between vehicles (referred to as vehicle-to-vehicle or V2V communications) and with roadway infrastructure, such as traffic signals and tollbooths (referred to as vehicle-to-infrastructure or V2I communications). These types of communications enable a range of safety and traffic management and operations applications, such as in-vehicle warnings to drivers, transit priority at signalized intersections, and dynamic signal crossings for pedestrians and bicyclists.

- **Autonomous vehicles (AVs):** AVs are enabled by sensors, cameras, radars, and communications technologies that facilitate vehicles to operate without a human driver or with limited human interaction. There are different levels of autonomy, as illustrated in Figure 1. At its lower level (Level 0), the driver is in full control and receives no assistance to perform all driving tasks. As levels progress (Levels 1-4), the vehicles take over partial or all tasks of driving, but only under certain conditions (e.g., sunny days or during light snow/rain). Finally, at its highest level of autonomy (Level 5), the vehicle performs all driving tasks under all conditions.

0	1	2	3	4	5
No Automation	**Driver Assistance**	**Partial Automation**	**Conditional Automation**	**High Automation**	**Full Automation**
Zero autonomy; the driver performs all driving tasks.	Vehicle is controlled by the driver, but some driving assist features may be included in the vehicle design.	Vehicle has combined automated functions, like acceleration and steering, but the driver must remain engaged with the driving task and monitor the environment at all times.	Driver is a necessity, but is not required to monitor the environment. The driver must be ready to take control of the vehicle at all times with notice.	The vehicle is capable of performing all driving functions under certain conditions. The driver may have the option to control the vehicle.	The vehicle is capable of performing all driving functions under all conditions. The driver may have the option to control the vehicle.

Figure 1. SAE J3016 levels of driving automation.

CV and AV technologies were initially developed independently. However, these technologies are increasingly integrated and connectivity has become a complementing, and sometimes enabling,

factor for autonomy. As these technologies continue to coevolve and merge, an integrated version of them has appeared – the CAV – whose deployment presents far-reaching implications for transportation agencies, the traveling public, and society at large.

There are still many unknowns and different scenarios for CAV deployment and adoption. While these scenarios are not the focus of this paper, it is important to consider the potential impacts of CAVs, their relation to metropolitan planning goals, and what roles different public and private sector entities play in CAVs. The remainder of this paper provides some high-level insight into these topics through the discussion of the potential impacts of CAVs on MPOs and other governmental and nongovernmental stakeholder groups. In doing so, this paper highlights those actions within the purview of TPB and other MPOs as well as opportunities for coordination with other CAV stakeholders. Finally, the paper proposes an approach for developing regional principles aligned with the CAVs risks and opportunities identified in subsequent sections of this document.

IV. POTENTIAL IMPACTS OF CAVs ON METROPOLITAN TRANSPORTATION PLANNING GOALS

CAVs are anticipated to have broad and significant impacts on the transportation system and mobility. The nature and timing of these impacts will be influenced by a dynamic interplay of factors. These factors include further advancement of CAV systems and decreased technology production costs as well as the development of complimentary transportation technologies like vehicle electrification and traveler-oriented applications that seamlessly match mobility supply and demand. Additionally, CAV deployment and adoption will be influenced by consumer sentiment and confidence as well as myriad socioeconomic and political forces (e.g., whether there is political inclination for legislation that supports CAVs).

Given the sheer number of factors that will influence CAV deployment, both directly and indirectly, much uncertainty surrounds specific CAV scenarios. Regardless of which path of change unfolds, however, CAVs are likely to play a significant role in terms of regional transportation planning goals (both generally from the perspective of national planning factors, and specific to the TPB's goals in the metropolitan Washington region).

The following section of the white paper introduces a wide range of anticipated CAV deployment impacts – categorized broadly into areas of travel, societal, and organizational concern – and analyzes them through the lens of regional visioning. Additionally, these impacts are evaluated qualitatively with respect to their levels of uncertainty and risk. Later sections build on this framework to identify the roles for public and private sector entities in CAV deployment. In doing so, this white paper seeks to inform the development of the region's planning, policy, and programming priorities and identify which actions TPB can take to positively impact outcomes related to the region's goals as CAVs are deployed.

CAV Impact Areas

Research conducted for this white paper identified the following areas of CAV deployment impact, which pertain directly or indirectly to the role of regional long-range transportation planning in the metropolitan Washington region and to the roles of transportation agencies generally:

- **Travel:** includes impacts that directly relate to the mobility of the traveling public, motor carriers, and other road users (access, active/public transportation, goods movement, travel behavior, and safety).
- **Societal:** includes impacts of broad societal concern (equity, employment/economic development, environment, and land use).
- **Organizational:** includes impacts directly related to the activities and responsibilities of infrastructure owner/operators and transportation planning agencies (data coordination, emergency preparedness, funding, infrastructure, operations, reliability, security/privacy, and travel forecasting).

Many of these CAV deployment impacts have significant implications for TPB's metropolitan transportation goals (both generally from the perspective of national planning factors, and specific to the TPB's goals in for the metropolitan Washington region). Therefore, it is useful to identify which goals and activity areas within TPB's purview may be impacted, including a range of planning, operational, and institutional considerations. It is also useful to consider these impacts relative to their associated levels of uncertainty and risk in order to inform future priorities and the evolution of the region's transportation system goals, objectives, and principles.

Table 1 demonstrates an example linkage between the CAV deployment impact areas/categories identified above and the policy goals and objectives in the *TPB Vision* (1998) – a concise, but influential policy document that lays out eight broad goals to guide the region's transportation investments[1]. Similar alignments between CAV impacts and regional goals and objectives can also be found in COG and TPB documents that build on the *TPB Vision* including the COG *Region Forward Vision*[2] (2010) and the TPB *Regional Transportation Priorities Plan*[3] (2014). These examples help demonstrate the relevance of CAVs impacts to nearly every area of the agency's goals and activities both, directly and indirectly.

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[1] Transportation Planning Board. (1998, October). *TPB vision*. Retrieved form: https://www.mwcog.org/transportation/plans/tpb-vision/

[2] Transportation Planning Board. (2010, January 28). *Region forward vision*. Retrieved from: https://www.mwcog.org/documents/2010/01/28/region-forward-vision/

[3] Transportation Planning Board. (2014, January 15). *Regional transportation priorities plan.* Retrieved from: https://www.mwcog.org/rtpp/

Table 1. Example linkage between CAV deployment impact areas and regional goals/objectives.

Category	CAV Impact Area	Example Linkage to Metropolitan Washington Region Goals/Objectives
TRAVEL	Access	• Fair access/mobility for persons with accessibility needs • Interconnected multimodal transportation system that provides convenient access with reduced automobile reliance • Comprehensive range of choices for regional travelers • Accurate and user-friendly real-time transportation system info available to all regardless of traveler's mode or language
	Active Transportation	• Convenient bicycle and pedestrian access • Reduced auto reliance in the regional core/activity centers
	Public Transportation	• Reduced auto reliance in the regional core/activity centers
	Goods Movement	• The Washington region will be among the most accessible in the nation for international and inter-regional goods movements
	Safety	• Enhanced safety through effective enforcement of traffic/motor carrier laws, and appropriate safety features in facility design
	Travel Behavior	• Reduction of vehicle miles traveled (VMT) and increased non-auto mode share • Convenient bicycle and pedestrian access • Comprehensive range of choices for regional travelers
SOCIETAL	Equity	• Reasonable access/cost for all in the region • Accurate and user-friendly real-time transportation system info available to all regardless of traveler's mode or language • Users of all modes pay an equitable share of costs
	Employment / Economic Development	• Economically strong regional core and activity centers
	Environment	• Meet federal clean air/water and energy conservation mandates • Protect sensitive locations from adverse traffic/development impacts • Reduction of VMT and increased non-auto mode share • Serve as a model for the protection and enhancement of natural, cultural, and historical resources
	Land Use / Urban Form	• Regional coordination of land use and transportation planning • Economically strong regional activity centers with a mix of jobs, housing, services, and recreation in a walkable environment

Category	CAV Impact Area	Example Linkage to Metropolitan Washington Region Goals/Objectives
ORGANIZATIONAL	**Data Coordination**	• Full use of future advancements in transportation technology
	Emergency Preparedness	• Improved management of weather emergencies/major incidents
	Funding	• A fiscally sustainable transportation system • Establish an enhanced funding mechanism for the region's growing mobility and accessibility needs
	Infrastructure	• Adequate management of existing infrastructure assets
	Operations	• Reduction in congestion and congestion-related incidents • Improved reliability/predictability of operating conditions • Full use of future advancements in transportation technology • A user-friendly, seamless system with on-demand, timely travel information to users, and a simplified method of payment
	Reliability	• Improved reliability and predictability of operating conditions
	Security/Privacy	• Full use of future advancements in transportation technology
	Travel Forecasting	• Full use of future advancements in transportation technology

Figure 2 provides a qualitative assessment of the relative levels of risk and uncertainty associated with these impact areas to further inform the region's policy priorities. As the figure demonstrates, some of these impacts have a high degree of certainty. For instance, CAVs should help to support access for persons with limited mobility (e.g., persons with disabilities, the elderly) by enabling vehicle access for those who cannot drive. Conversely, other impacts have a high degree of uncertainty or risk. For instance, CAVs may have very uncertain impacts on land use and travel behavior. On the one hand, CAVs might reduce vehicle ownership as people shift to shared AVs, resulting in fewer vehicle trips; on the other hand, without the burden of driving, people may accept longer trips and take more frequent vehicle trips.

Similarly, some anticipated impacts of CAVs on regional planning goals are direct (e.g., impacts on safety), while others are very indirect (e.g., environmental impacts such as air quality will depend on how CAVs result in changes in travel demand and vehicle miles traveled, as well as associated potential changes in vehicle fuel/technology, such as shifts to electric vehicle fleets). Impacts on transportation funding also reflect a high degree of uncertainty since funding under current transportation funding mechanisms depends heavily on fuel taxes; there may be opportunities for shifting to VMT-based fees or other mechanisms.
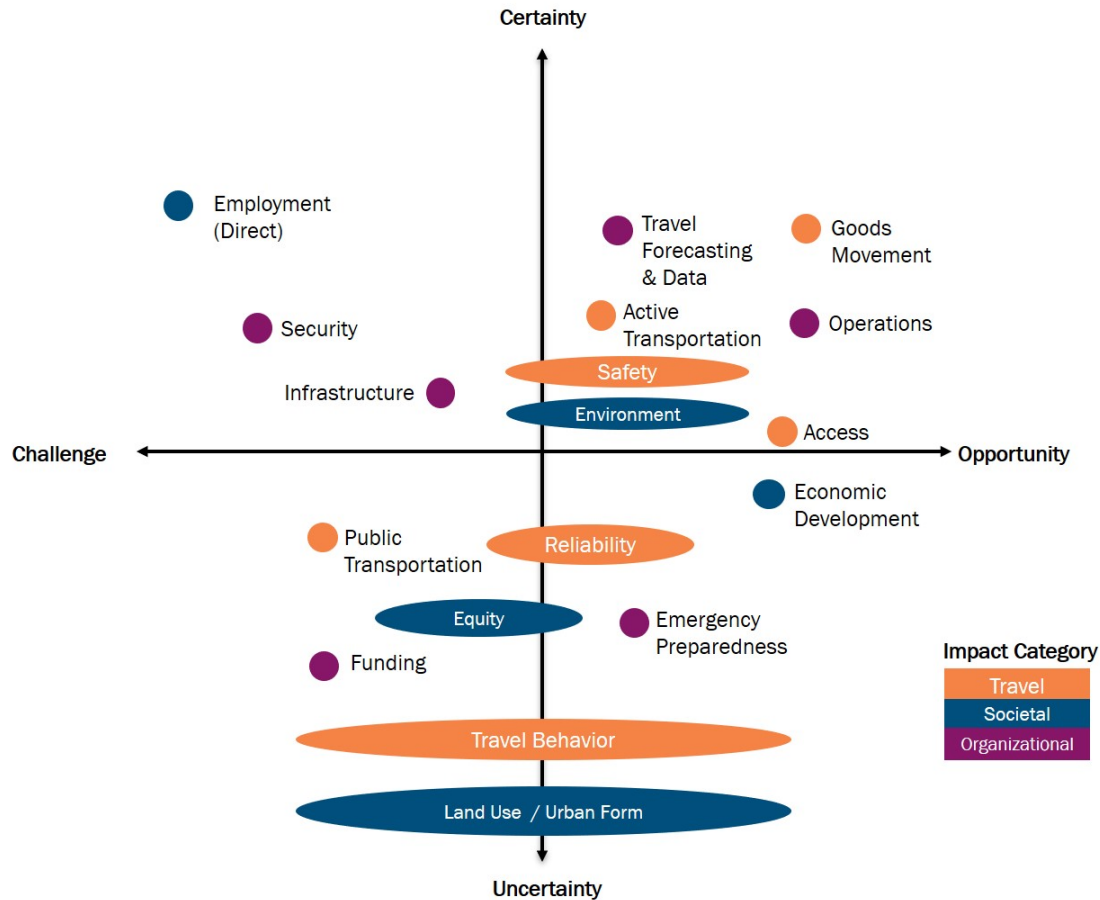
Figure 2. High-level implications of CAV deployment.

The following sections of this document delve further into the challenges and opportunities associated with each of these impact areas and identify corresponding agency roles, including those areas where TPB may play a primary role.

V. POTENTIAL IMPACTS OF CAVs AND CORRESPONDING AGENCY ROLES

Many CAV trends and impacts are driven by global, national, and regional forces such as privately-sponsored technological innovations and broad shifts in socio-economic conditions. Public sector transportation agencies do not have much control over these external forces, but they can adopt an array of policies and transportation investment programs to maximize the opportunities and minimize the risks associated with their potential impacts. In many cases, the agencies with the most direct influence on these policies and investments are the owners and operators of the transportation systems, such as state DOTs, municipalities, and transit service providers. Federal agencies primarily establish requirements and provide guidance to states and localities regarding the use of federal funds to support progress toward system performance targets and broader desired outcomes. This section describes the roles of these governmental stakeholders (federal, state, regional, and local governments/agencies) and private industry as well as the necessary coordination between these groups to support CAV deployment readiness.

Federal Role

The federal government regulates, maintains, and invests in the nation's transportation system and infrastructure. This includes allocation of federal-aid highway and federal transit program funding to states, metropolitan areas, and public transportation agencies through various formula-based and discretionary programs as well as the associated oversight and guidance provided by the U.S. Department of Transportation (USDOT) and its modal administrations. In these capacities, federal agencies play a key role in various aspects of CAVs, including those related to:

- **Vehicle safety:** federal agencies provide vehicle performance guidance for the safe design, development, testing, and deployment of AVs and CVs; they also fund programs that develop and test safe deployment of advanced technology systems such as the Connected Vehicle Safety Pilot and Automated Driving Systems Pilot.

- **Cybersecurity:** federal agencies such as USDOT implement national cybersecurity strategic plans, initiatives, and priorities including those related to vehicle and ITS cybersecurity.

- **National standards:** through initiatives such as the Work Zone Data Exchange (WZDx) and Accessible Transportation Technologies Research Initiative (ATTRI), the USDOT is supporting development, harmonization, and adoption of standards that promote safe, multimodal, and accessible travel including those relevant to CV and AV systems. Additionally, the Federal Highway Administration (FHWA) issues the Manual on Uniform Traffic Control Devices for Streets and Highways[4] (MUTCD), which defines nationwide standards for traffic signs, signals, and road markings. Efforts are underway to identify necessary changes to the MUTCD to support CAV deployment (e.g., ensuring machine readability of traffic signs and pavement markings in varying environmental conditions).

- **Grant funding:** the USDOT provides funding for state and local governments/agencies to develop, test, and deploy CV and AV pilots and demonstrations through initiatives such as the Connected Vehicle Pilot Deployment Program, Integrated Mobility Innovation (IMI) Program, and the Accelerating Innovative Mobility (AIM) Program.

- **Research:** USDOT funds a variety of research programs and activities related to CAVs such as the Federal Transit Administration's (FTA) Strategic Transit Automation Research (STAR) Initiative Demonstration projects and FHWA's Cooperative Driving Automation (CDA) program to enable V2X in AV. Additionally, USDOT has published a variety of research reports and policy/strategy analysis resources and guidance related to CAV deployment including truck platooning, highway infrastructure readiness, human factors, and transportation planning capacity building.

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[4] Federal Highway Administration. (2012, May). *Manual on uniform traffic control devices for streets and highways.* Retrieved from: https://mutcd.fhwa.dot.gov/kno_2009r1r2.htm

State Role

State transportation agencies are tasked with planning, funding, designing, building, maintaining, operating, and improving the National Highway System (NHS) and other highway and multimodal networks under their jurisdiction. They allocate resources from federal-aid programs and maintain compliance with relevant federal statutes and regulations. Additionally, states are tasked with vehicle licensing and registration while state legislatures develop legislation related to transportation funding, financing, and other areas of importance to CAVs. In these regards, states play a key role in various aspects of CAVs and issues potentially associated with CAV deployments, including:

- **Policymaking:** In the absence of federal rules and regulations on AVs and CVs, regulation of these technologies has largely devolved to state governments; many states have also established processes for public and private entities to apply for autonomous vehicle technology demonstration and testing. Notably, both Virginia and the District of Columbia have enacted legislation related to autonomous vehicles, and Maryland has established application protocol for testing.

- **Infrastructure and traffic operations:** State DOTs design, construct, maintain, and operate highway systems and therefore must consider the impacts of CAVs on roadway design (e.g., machine readability of traffic control devices); work zone safety and related communication needs; asset management (e.g., the impact of vehicle platooning on pavements and bridges); and operations (e.g., updates to ITS architecture and the role of CAVs in active traffic management).

- **State guidance:** State-level legislation, directives, procurement policies, or cooperative purchasing (with local governments) may directly or indirectly impact CAVs, especially regarding its infrastructure aspects. States may publish unique state supplements to the national MUTCD that may be of impact to CAVs.

- **Planning, research, development, and testing:** State DOTs conduct statewide multimodal planning and programming. Maryland DOT (MDOT), for example, is leading a CAVs Working Group to assist its modal transportation business units in incorporating CAVs into their programs and has developed a CAV Strategic Action Plan. Virginia DOT (VDOT) has developed the Virginia Connected and Automated Vehicle Program Plan and the Virginia Connected Corridors program, which facilitates development and evaluation of emerging CAV applications through a network of roadside communications devices. Similarly, the District of Columbia DOT (DDOT) has funded an AV scenario planning study that examines the impacts of CAVs across its activities. State DOTs also conduct testing and deployment of advanced technology systems including development of test beds and CV and AV pilot projects. State DOTs may also coordinate and fund similar activities by local and regional governments.

MPO Role

As discussed in more depth in Section V of this report, the influence of MPOs is important though often indirect. MPOs have the responsibility and authority to establish agreement among local, state,

and federal transportation agency partners regarding plans and funding decisions for regionally significant transportation investments, in accordance with federal regulations and requirements. Within this realm, MPOs have a strong influence over several of the aspects of transportation system performance that could be affected by CAV deployment, as documented in Table 1, such as:

- **Transportation Plans:** The MPO develops regional transportation plans, policies, and infrastructure investments to support efficient regional travel and to encourage concentrated development patterns that enable multimodal solutions. The regional plans and required planning, policies, and programs that implement regional plans could be significantly affected by widespread adoption of CAVs and shared mobility services. The most significant of these regional plans is the federally-required quadrennial long-range transportation plan.

- **Travel Forecasting/ Modeling:** The MPO is responsible for data development and modeling to support regional planning and coordination among state and local agencies, which can integrate real-time TSMO data and opportunities for public-private data-sharing as CAV technologies develop.

- **Multimodal Transportation:** TPB gathers information, conducts analysis and supports the development of regional consensus around multimodal priorities, and hosts subcommittees for the following topics, each of which is anticipated to be substantially affected by CAV deployment:

  - **Public Transportation/ Transit Impacts:** TPB develops plans and conducts analysis to support efficient movement in the region including alternatives to driving alone that maximize transit and person movement. TPB monitors technological developments that may benefit transit functions. The MPO encourages regional coordination among public and private sector transit and mobility service providers through its regional public transit subcommittee. The TPB also manages grants that support the deployment of flexible public-private and/or demand-response services.
  - **Bicycle/Pedestrian:** The Bicycle and Pedestrian Subcommittee is responsible for the update and evaluation of TPB's Regional Bicycle and Pedestrian Plan, as well as advising on the pedestrian and bicycle aspects of the Long-Range Transportation Plan (LRTP). The group also advises the region's Street Smart bicycle and pedestrian safety campaign and facilitates information sharing and technology transfer related to state and local programs.
  - **Freight:** The Freight Subcommittee is responsible for integrating current freight issues (including movement of goods by truck, rail, air, water, and pipeline) into TPB's transportation planning process including the region's Transportation Improvement Program (TIP) and the LRTP.
  - **Safety:** The Transportation Safety Subcommittee coordinates with the three State Strategic Highway Safety Plans, advises the maintenance of the Safety Element of the LRTP, and serves as a forum to exchange information on best practices in transportation safety planning.
  - **Transportation Demand Management (TDM):** The Commuter Connections Subcommittee provides overall technical review of the regional TDM Program elements, which focus on reducing single-occupancy vehicle trips and improving regional mobility through implementation of strategies such as ridesharing.

Local Role

As the owners and operators of local roads and transit service, local agencies including municipal and county governments also play a key role in various aspects of CAVs and issues potentially associated with CAV deployments and impacts, including:

- **Curbside management:** growth in urban freight and pick-up/drop-off activities have resulted in increased demand for curb space. These impacts are expected to increase with growing automation, representing an important focus area for municipalities.

- **Land use planning / urban design:** the local jurisdictions with land use authority each develop and maintain a comprehensive plan that includes a land use element; they are also tasked with regulating and permitting on- and off-street parking and designing the streetscape including livability considerations. These urban form factors will play important roles in determining local impacts of CAV deployment.

- **Local transportation project and infrastructure planning, design, operations, and maintenance;:** Where they have this responsibility[5], municipal and county transportation and public works departments plan, design, construct, maintain, and operate local roads and therefore share similar concerns with state DOTs regarding CAV deployment.

- **Interjurisdictional collaboration on infrastructure projects:** Local agencies often collaborate with state, federal, or regional partners (including neighboring local jurisdictions) on projects and planning for infrastructure located within the local jurisdiction, but that the locality may not themselves own or operate.

- **Local policies:** local jurisdictions enact local policies with important implications for CAVs such as regulation of for-hire vehicles.

Addressing CAVs: Issues, Challenges, Opportunities, and Roles

Table 2 provides more detailed considerations as to the CAVs impact areas identified in the previous section, each of which comprise aspects of long-range transportation planning in the metropolitan Washington region, including examination of primary, secondary, and collaborative roles for public sector stakeholders (federal, state, regional, and local governments). The table also addresses the cross-cutting role of private sector stakeholders in CAV development/deployment including industry groups such as original equipment manufacturers (OEM), the automotive industry, information and communications technology (ICT) firms, mobility service providers (MSP), and road builders.

The following section of the white paper builds on the findings of Table 2 to highlight opportunities to enhance the TPB role in CAVs.

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[5] Under Virginia law, a number of Virginia local jurisdictions do not own or operate most public roads within their jurisdictions.

Table 2. CAV Deployment Impacts and Stakeholder Roles.

Impacts			Governmental Roles				Nongovernmental Roles
Issues	Challenges	Opportunities	Federal	State	MPO	Local	Private Sector
Access: Accessibility for persons with mobility impairments/disabilities/youth and elderly	Paratransit provision (wheelchair securement, lack of human operator, etc.); Wayfinding and navigation challenges (free-flowing intersections, elimination of traffic control devices, etc.)	Increased mobility for persons with disabilities and limited travel options; lower cost of paratransit; increased pedestrian safety at intersections	Primary: Regulation and direction re ADA-compliant vehicle design (NHTSA) and intersection design (MUTCD)	Primary: licensing of AV paratransit service operators (private and public); Secondary: enforcement of ADA street & intersection design standards	Collaborative: regional planning including engaging the Access for All Advisory Committee, technical assistance to coordinate public and private transit services and corridor-level signalization/ crosswalk optimization	Primary: coordination of human services transit; implementation of ADA-compliant AV public transit services and intersection design/control systems	Primary: Vehicle design
Active Transportation: Mobility	Fragmentation and disruption of bicycle/pedestrian networks (e.g., increased curbside pick-ups/drop-offs, unsafe crossing with platooned and free-flowing traffic)	Repurpose public right-of-way for active travel	Secondary: technical assistance/guidance on complete street design	Primary: design standards for state-owned roadways	Collaborative: regional bike/pedestrian planning, promotion of complete street policies	Primary: design standards and engineering of locally owned street networks	Secondary
Active Transportation: Safety	Vehicle-pedestrian interactions (e.g., communication of intent and path of travel)	Eliminate human driver error in crashes	Primary: CV/AV design standards	Primary: Safety training/ licensing for CV/AV operators and bicyclists/ pedestrians	Collaborative: studies, data collection on safety issues/ opportunities	Primary: pedestrian & bicyclist safety signage, education, enforcement	Primary: CV/AV design features to enable "communication" with pedestrians and bicyclists
Data Coordination: Data Collection, Sharing, and Standards;	Reluctance of mobility service providers to share travel activity data; high level of effort associated with standard development and harmonization;	Additional data and real-time data may improve planning, operations, and trip-making; standardization	Primary: Collection and management of national databases; standardization protocols; technical assistance to states and MPOs; promote public-private partnerships to share real-time data for planning and TSMO applications	Primary: coordination and negotiation with private sector data vendors and mobility service providers to access real-time data for planning and TSMO purposes	Collaborative: coordination with state and local agencies on data collection, sharing, and management issues; utilize CAVs data for planning purposes	Secondary: Coordinate with regional and state agencies to collect and manage data	Primary: support public-private partnerships to share and develop data

Impacts			Governmental Roles				Nongovernmental Roles
Issues	Challenges	Opportunities	Federal	State	MPO	Local	Private Sector
Employment and Economic Development: Job and Workforce Changes	Loss of driver jobs (taxis, uber, delivery, etc.)	Workforce development; New jobs generated by CAVs	Secondary: provide workforce development program funds to state/local economic development agencies	Secondary: provide workforce development program funds to local economic development agencies and secondary/ higher education institutions	Collaborative: regional planning and partnerships to foster economic and workforce development; support quality transportation options based on anticipated work-based travel demand	Primary: implement workforce development programs through economic development agencies and secondary/ higher education institutions	Primary: partner with public sector entities to train CAV operators, software programmers, and mechanics
Emergency Preparedness: Transportation Emergency Preparedness Planning	Automated driving systems may not function in certain emergency scenarios or be unresponsive to the direction of emergency guidance	Delivery of emergency goods; increased vehicle capacity with shared use; coordinated emergency communication and response	Primary: Partner with private ISPs and CAV manufacturers to ensure continued functionality in emergency conditions; update regulations and funding programs to ensure CAV-capable infrastructure on NHS and other major facilities necessary to mobility during emergencies.	Primary: Allocate federal and state funds to ensure CAV functionality in emergencies; partner with regional planners to support efficient emergency public transport, particularly for households without personally owned vehicles	Collaborative: Support updates of local emergency preparedness plans to ensure coordinated deployment within regional networks; ensure reliable, timely emergency communication through V2X and other ITS channels.	Primary: Update local emergency preparedness plans to ensure coordinated deployment within regional networks.	Primary: Partner with public and private sector partners to ensure CAV system functionality in emergency conditions
Environment: Vehicle energy/fuel technology	Infrastructure and network to support the electrification of mobility	Electrification of mobility	Secondary: Vehicle fuel economy standards; tax incentives for electric vehicle ownership by individuals and businesses	Primary: Investments in state-owned facilities; funding programs to support local infrastructure; tax incentives for electric vehicle ownership by individuals and businesses	Collaborative: supporting regional / local EV readiness planning; incorporate alternative fuel considerations in climate, energy, and environment policies	Primary: EV readiness planning and investments in locally-owned facilities; coordination with electric utility providers; electrification of municipal fleets	Primary: development of EV technology and supportive tech

Impacts			Governmental Roles				Nongovernmental Roles
Issues	Challenges	Opportunities	Federal	State	MPO	Local	Private Sector
Equity: Affordability/ availability/ usability of shared mobility services	Access for vulnerable populations (low income, without credit card, etc.); inequitable distribution of shared mobility services	Improved connection and services to remote/ underserved areas; reduced needs for private vehicles	Primary: Regulation/ direction in coordinating federally funded transit services with privately operated shared mobility services to ensure equitable access and compliance with civil rights regulations; providing funds and technical assistance to support equitable access to farecard payment systems	Secondary: Regulation, incentives to encourage equitable access and public-private coordination of services	Collaborative: regional planning activities including multijurisdictional coordination and development of principles, priorities, and goals to support equitably distributed, coordinated, public-private transit/ shared mobility services and programs; encouraging coordination of local governments with financial institutions and other businesses to broaden access to electronic payment systems;	Primary: Planning, regulation, investments, and public-private coordination to increase equitably distributed access to locally operated public-private transit and shared mobility services	Primary: Leading and supporting coordination with the public sector to develop technology solutions, implementing policies and tools to support equitable access
Freight/Goods Movement: Long-haul autonomy	Regulations to allow platooning; potential for increased impacts on pavements, bridges, etc.; special lane assignments for platoons	Increased fuel efficiency; reduced emissions; enhanced infrastructure capacity and safety	Primary: Regulations, roadway design standards, funding programs, pilots, and coordination with freight providers (mega-regionally, nationally, globally) to deploy CAVs on NHS	Primary: Plan, implement roadway infrastructure investments and coordination with freight providers to deploy CAVs on NHS and regional freight routes	Collaborative: Regional and mega-regional planning, programming, and public-private coordination for infrastructure investments and first/last-mile accessibility to ensure connectivity between CAV NHS facilities and local/regional activity center networks	Secondary: Support regional/ statewide initiatives to encourage CAV deployment on NHS	Primary: Upgrade freight fleets to enable CAV deployment
Freight/Goods Movement: Urban freight	Accommodating increased demand for urban freight movement and curb space	Increased efficiency of last-mile deliveries	Secondary: Encourage regional/ local planning and investments for complete streets that accommodate freight	Primary: Planning, regulation, and infrastructure investments to create complete streets that support freight and multimodal travelers	Collaborative: Regional planning and local technical assistance for complete streets that support freight and multimodal travelers	Primary: Planning, regulation, and infrastructure investments to create complete streets that support freight and multimodal travelers	Primary: Develop innovative vehicle/ system technologies and partner with cities to promote safe, efficient freight movement and delivery in urban environments.

Impacts			Governmental Roles				Nongovernmental Roles
Issues	Challenges	Opportunities	Federal	State	MPO	Local	Private Sector
Funding: Changes to funding streams and mechanisms	Decreases in vehicle-related revenue, gas-related revenue, traffic/parking tickets, public parking revenue, and airport revenue	User-based revenue streams (e.g., VMT tax, tolls); public-private financing of infrastructure and technology resources	Primary: Work with states and cities to develop and deploy new federal revenue sources that are not dependent upon the use of fossil fuels (i.e., alternative to gas taxes); support state and local research, planning, and coordination to develop alternatives to gas taxes, parking fees, etc.	Primary: Develop and deploy alternative revenue streams to fund maintenance/ improvement of NHS and other federal / state networks; coordinate with regional and local partners to develop financing/ revenue streams for locally owned/operated systems	Collaborative: Planning and regional coordination with public and private sector partners to develop new financing mechanisms and revenue streams	Primary: Coordinate with public & private sector partners to deploy new revenue generators and financing mechanisms for local and regional transportation networks/ services	Secondary: coordinate with public sector partners to deploy financing and revenue streams
Infrastructure: Transportation infrastructure design/network changes	Changes in lanes, required signage (horizontal and vertical) condition, use of traffic control devices, communications with legacy systems and associated costs	Traffic flow efficiency improvements	Primary: Update roadway, transit, and vehicle design standards and regulations; coordinate ITS architecture/ standards across states and regions	Primary: Plan, design, deploy upgrade infrastructure and ITS architecture on NHS and state facilities	Collaborative: Coordinate regional plans, policies, programs for infrastructure and ITS architecture upgrades	Primary: Plan, design, deploy upgraded infrastructure and ITS architecture on locally owned/operated facilities and services	Primary: Coordinate vehicle design/ functionality with owners/ operators of public infrastructure and ITS
Land Use: Development patterns	Increased trip lengths and resulting land use inefficiencies/impacts	The increased connection between low-density areas without the need of transit infrastructure	Secondary: Support coordinated land use/ transportation planning for mega-regional corridors, particularly involving the NHS	Secondary: Support coordinated land use/ transportation planning and regional transit for regional and mega-regional corridors, particularly involving the NHS and state-owned infrastructure	Collaborative: Work with COG and its Planning/Housing Directors Committees to coordinate regional transportation-land use plans, policies, and infrastructure investments to support efficient cross-jurisdictional travel and development patterns	Primary: Update local plans, zoning ordinances, growth management policies, and transit/ infrastructure investments to support efficient, coordinated land use-transportation patterns.	Secondary: Provide services/ investments that support local and regional policies/plans for coordinated land use/ transportation strategies.

Impacts			Governmental Roles				Nongovernmental Roles
Issues	Challenges	Opportunities	Federal	State	MPO	Local	Private Sector
Land Use: Parking /urban design	The potential cost of retrofitting infrastructure to accommodate CAVs; parking vehicle circulation and traffic; the need for remote parking facilities	Repurpose unused parking and road space	Secondary: Provide guidance and technical assistance for redesigning local networks.	Primary: Enable flexible design strategies to support the repurposing of street space on urban state-owned facilities.	Collaborative: Provide guidance and technical assistance for redesigning local networks and regional coordination to develop satellite parking centers.	Primary: Update parking and zoning ordinances, street design standards; plan and implemented repurposed street and parking space.	Primary: Private land developers and mobility service providers coordinate with/ support local plans and standards for the design of streets, buildings, and parking areas
Operations: Transportation system management and operations, including transit operations (e.g., transit signal priority); system performance	Data management and processing. How to act on this new level of information? Addressing mixed fleet operations; induced travel due to higher levels of service	Opportunities to improve active traffic demand management, integrated corridor management, etc.	Secondary: Guidance, regulation, design standards for state and local transportation agency TSMO capability and regional coordination	Primary: Plan/ upgrade TSMO capabilities on NHS, state facilities; support regional coordination and local investments in ITS architecture and TSMO capacity	Collaborative: Regional planning, programming, local technical assistance to support improved TSMO elements	Primary: Plan/ upgrade local ITS signal systems, transit vehicle technology, data processing systems	Primary: Participate in public-private partnerships and data sharing/ management to ensure efficient, safe TSMO
Operations: Curbside Management	Increased demand for pick-ups/drop-offs and urban freight delivery; electric vehicle charging stations	Encourage shared-use mobility; improved goods movement efficiency	Secondary: Guidance and technical assistance	Secondary: Guidance and technical assistance	Collaborative: Local technical assistance, regional coordination on multi-jurisdictional urban networks	Primary: Plan and implement street design and regulatory strategies to support efficient, safe traffic flow; design EV charging infrastructure to avoid competition for curb space	Primary: Develop/ deploy innovative freight delivery mechanisms that minimize competition for curb space.
Public transportation: Transit Impacts	Changes in routing, infrastructure, and service; increased competition for ridership	Reduced transit operating costs; increases in service; demand-responsive service	Secondary: Regulation and guidance for coordinating federally-funded transit services with privately operated shared mobility services to enable efficient, flexible, financially viable services	Secondary: Guidance and funding to support flexible public-private and/ or demand-response services	Collaborative: encourage transportation and land use planning to help maximize the effectiveness of transit, and the emphasize of person movement rather than vehicle movement.	Primary: Planning, funding, and delivery of flexible, public-private, and/ or demand response services by municipal and regional transit agencies.	Primary: Partner with local and regional transit agencies to provide seamless, efficient, financially viable services.

Impacts			Governmental Roles				Nongovernmental Roles
Issues	Challenges	Opportunities	Federal	State	MPO	Local	Private Sector
Safety: Changes in driving risk behaviors (Drunk driving, distracted driving, speeding) and driving error	Interactions between human drivers and non-human drivers	Reduced driver error and driving risk behavior; Reduced costs associated with incident management and roadway repair	Secondary: Support for planning and design of street networks to support mixed fleets	Primary: Design standards, TSMO, law enforcement, and driver/operator education and licensing to support safety in mixed-fleet traffic on state-owned roadways	Collaborative: Regional planning and coordination to handle mixed fleet traffic, to establish policy priorities, and to share information on best practices	Primary: Design standards, TSMO, and law enforcement to support safety in mixed-fleet traffic on local networks	Primary: Insurance providers adjust premiums on safety-enhanced CAVs; CAV manufacturers coordinate with agencies to support safe mixed-fleet operations
Safety: CAV functionality in unpredictable situations and environments	Yielding to emergency vehicles, temporary traffic control navigation, choice of trajectory in an unavoidable crash, etc.	Opportunities to implement coordinated incident / emergency response with CAV fleet	Primary: CAV design standards to ensure full functionality in unpredictable environments	Primary: Safety training/licensing for CAV operators	Collaborative: studies, data collection on safety issues/ opportunities	Primary: Upgrade street design features/ signage to ensure CAV functionality in unpredictable environments	Primary: CV/AV design features to enable full functionality in unpredictable environments
Security: Cybersecurity and data privacy	Intrusion/interference with CAV systems; upholding sufficient digital privacy in data collection practices	Enhanced cybersecurity and digital privacy	Primary: Standards harmonization, privacy policies and regulations; Federal cybersecurity protocols	Primary: Planning/ deployment of cybersecurity protocols on NHS and state facilities and ITS networks; Privacy legislation and enforcement	Collaborative: Regional coordination and education with state, federal, local and private sector partners	Secondary: Coordinate with state and federal protocols and guidance	Primary: development and application of cybersecurity protocols to technology and operations; compliance with privacy laws
Travel Behavior: Changes in travel demand, travel patterns, and vehicle ownership preference	Increased VMT (potential zero occupancy trips, longer trips); the increased utility of travel time (ability to work/play during a trip)	Reduced VMT (potential increase in shared use and decreased vehicle ownership)	Secondary: Guidance and technical assistance to support coordinated land use/ transportation planning	Secondary: Guidance and technical assistance to support coordinated land use/ transportation planning	Collaborative: Regional planning and technical assistance to support local incentives, ordinances, and public-private partnerships.	Primary: Create incentives, ordinances, and public-private partnerships to encourage the growth of ridesharing, non-motorized travel, and shorter trips in activity centers	Primary: Growth of shared-use mobility / vehicle sharing options, partnerships with localities, and transit providers to promote efficient travel patterns.
Travel Forecasting: Travel demand modeling	Complexity of non-traditional travel demand models and big data sets; challenges to forecasting assumptions	Additional data may improve forecasting	Secondary: technical assistance to states and MPOs	Primary: Data development and modeling for statewide planning; technical assistance for regional modeling;	Primary: Data development and modeling for regional planning;	Secondary: Coordinate with regional and state agencies to collect and manage data	Secondary

VI. OPPORTUNITIES TO ENHANCE THE TPB ROLE IN CAVs

As the MPO responsible for transportation planning across the metropolitan Washington region, the TPB plays a key role in transportation planning and convening member agencies to collaborate on important issues for the region's mobility, environment, and quality of life. The TPB plans for the region's future, develops consensus on priorities and approaches, and ensures that the MPO's transportation planning activities meet all federal requirements.

Regarding CAVs, roles for TPB may fall into several categories:

1. Information Sharing, Engagement, and Coordination.
2. Regional Policy Development and Collaboration.
3. Integrating CAV Considerations into Planning and Programs.

These categories of activities build on recommendations for MPO activities related to CAVs that came out of work conducted by the Association of Metropolitan Planning Organizations (AMPO) in its *National Framework for Regional Vehicle Connectivity and Automation Planning*[6], combined with understanding of the unique roles, responsibilities, institutional structure, and history of the TPB. Each of these suggested roles are highlighted below.

Information Sharing, Engagement, and Coordination

One of the key roles of the TPB is to convene regional stakeholders to consider important issues for the region. Through its regular TPB meetings, the TPB's technical committees and subcommittees, Citizens Advisory Committee, Access for All Advisory Committee, and other events, the TPB brings together a wide array of policy makers, technical staff, stakeholders, and the public to discuss transportation issues to support economic development, environmental quality, and a high quality of life.

TPB and staff can share information about CAVs in several ways:

- **Increase policymakers' and technical staff's understanding of potential CAV impacts**. The TPB can help to inform and share information regarding the current status of vehicle connectivity and autonomy nationally and within the region. It can also help stakeholders to understand the plausible benefits, opportunities, and challenges, as well as uncertainties regarding CAV deployment and impacts. Providing information and technical resources can be particularly important to inform state and local governments

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[6] Association of Metropolitan Planning Organizations. (2019, January 25). National framework for regional vehicle connectivity and automation planning. Retrieved from: https://www.ampo.org/wp-content/uploads/2019/04/2019-AMPO-Framework-11.pdf

decisions about investments in transit, roadway, and nonmotorized infrastructure and services, land use planning, operations, and technology.

- **Understand public perceptions of CAVs and communicate potential impacts.** The TPB can conduct research to gather information on public perceptions and other factors related to deployment of CAVs. It can also disseminate the findings of studies such as this one through venues including webinars and workshops. These activities can also serve as a forum for engagement of the public on critical CAV issues in order to inform regional CAV policy and strategy development.

- **Provide TPB members and jurisdictions with a better understanding of current CAV activities across the region and advise coordination of activities.** The District, Maryland, and Virginia are each conducting activities related to CAVs. Further, local jurisdictions and the private sector are playing roles in deployment (e.g., autonomous shuttles). These activities may offer opportunities for coordination or lessons learned that can be shared for regional benefit. Consequently, the TPB can serve as a forum to share information on current and planned CAV deployments and associated activities. This information can be shared broadly and in coordination with technical committees in order to raise general awareness of the current status of the region's activities, to benchmark or compare to other regions, and to inform potential future plans and activities at the state, regional, and/or local levels. These activities could build on the TPB's past survey of member agency technical participants, and TPB's 2020 series of webinars on CAVs.

- **Identify and share information on federal and other funding opportunities for CAV deployment and testing.** Over the past several years, there have been a wide number of federal pilots and funding programs that are dedicated to or provide funding support for deployment of CAV applications. Examples include:

  o the Complete Trip: ITS4US Deployment Program,
  o the Federal Transit Administration's (FTA) Strategic Transit Automation Research (STAR) Initiative Demonstration projects,
  o the FTA's Accelerating Innovative Mobility (AIM) Program, and
  o the Federal Highway Administration's (FHWA) Advanced Transportation and Congestion Management Technologies Deployment (ATCMTD) Program.

  By identifying and sharing information about potential federal, as well as private sector and other funding sources for pilots, the TPB can help member agencies to compete for these funds.

Regional Policy Development and Collaboration

Beyond sharing information, the TPB could play a more significant role in advancing regional collaboration to support a common regional direction to CAV deployment and policy. Key actions recommended include:

- **Develop a regional framework for coordination to support CAV deployment in ways that support regional goals, strengthen positive outcomes, and minimize potential adverse impacts.** Just as TPB has played a key role in advancing dialogue about regional housing and land use planning, and by providing a regional transportation policy framework that is intended to guide the region's transportation investments, the TPB could develop a regional policy framework or principles (described further in the section below) that support a common direction for all member agencies. This framework could focus on advancing regional policies and investment priorities that support deployment of CAVs in ways that support regional goals and minimize or mitigate the potential adverse impacts of CAVs. The framework for instance, could result in identifying policy areas of focus in relation to CAVs, such as equitable access, first mile-last mile connections to transit, and strengthening regional activity centers. It could result in identifying potential strategies for concerted regional focus, such as: facilitating the deployment of V2I strategies related to transit signal priority, emergency vehicle preemption, and bicycle/pedestrian focused applications; facilitating the development of infrastructure to support shared electric CAVs; addressing curb space management to advance shared use of CAVs; or enhancing consideration of the role of CAVs in regional land use coordination and activity centers.

  This framework could take the form of a policy document or could be in the form of a strategic plan for CAVs (and potentially other emerging transportation technologies) to identify potential challenges, opportunities, and risks, and develop recommended strategies to support regional goals.

Integrating CAV Considerations into Planning and Programs

The TPB can play an important role in integrating CAV considerations into regional planning and program activities. As the TPB is responsible for ensuring that regional planning complies with federal transportation planning requirements for developing its LRTP and TIP, the TPB can integrate considerations related to CAVs into these documents. As TPB's capabilities evolve to conduct technical analyses and planning related to CAVs, the TPB could potentially support member jurisdictions in integration of CAV considerations into their own technical analyses, enhancements to planning, and other planning and program activities. Examples of these activities include:

- **Conduct scenario planning as part of the long-range planning process to develop and explore possible future regional scenarios for CAV deployment.** Scenario planning is a valuable tool to explore alternative possible futures. The TPB technical staff could consider a scenario planning exercise as part of the next LRTP update, or as a supplementary analysis to explore different possible futures of CAV deployment and impacts. This analysis can build on similar scenario development exercises conducted by the FHWA and some other regions to help inform how transportation system performance may differ from standard forecasts. The different scenarios could be used to inform decision making by highlighting differences in the need and value of transportation investments under different assumptions.

- **Integrate future CAV considerations into travel modeling and analyses.** The TPB could undertake efforts to integrate CAV considerations into its data collection, modeling, and analysis tools. For example, the Regional Travel Survey and State of the Commute Survey

could be expanded or supplemented to gather information on the public's stated preferences regarding using autonomous vehicles, including autonomous transit, as well as potential implications on vehicle ownership and trip making (including number of trips, destinations/trip lengths, and time of trips). Different alternative scenarios for vehicle ownership, travel demand, and land use patterns could be integrated into the TPBs forecasting models and cooperative forecasts, which are used for regional planning and by jurisdictions across the region. Specifically, CAV implications, perhaps drawing on survey information, could be used to adjust assumptions about future changes in travel patterns and vehicle operations. Conducting modeling for different scenarios and providing tools for local governments to conduct such analysis could help in understanding the range of potential implications on transportation system performance, community outcomes, and potential implications on investment needs.

- **Integrate CAV considerations into existing programs.** TPB operates a number of programs such as the Transportation Land-Use Connections (TLC) Program, Commuter Connections Program, and the regional Street Smart Safety Campaign. CAV considerations could be brought into applicable program areas. For instance, the TLC Program could seek targeted opportunities to integrate CAV technologies into the technical assistance. Similarly, opportunities could be identified to engage discussions on applications of CAV technology as part of on-going program activities, such as the Metropolitan Area Transportation Operations Coordination (MATOC) Program. This effort would broadly entail engaging discussions around CAV technology applications and issues within existing program activities, such as safety planning, pedestrian and bicycle planning, freight planning, and equity and accessibility planning discussions.

- **Ensure that CAV applications are integrated into Intelligent Transportation Systems (ITS) architectures including the Regional ITS Architecture**. Under federal law (23 CFR 940), a regional ITS architecture is designed to guide the development of ITS projects and programs within a region, by identifying the roles and responsibilities of participating agencies and stakeholders in the operation and implementation of systems; system functional requirements; interface requirements and information exchanges with planned and existing systems; and a sequence of projects required for implementation. As such, the architecture provides a regional framework for ensuring institutional agreement and technical integration for the implementation of ITS projects or groups of projects. The TPB and member agencies can ensure that ITS architectures are updated to address future for CAVs in the region and ensure that all planned CAV applications are fully integrated into the architectures. This effort would involve coordination to raise awareness of the ITS architectures to ensure they are being used, and that systems engineering principles are shared and utilized in developing state and local applications of CAV technology.

VII.   CAV OUTLOOK

While many unknowns persist, this white paper advances the regional conversation on CAVs and suggests key planning considerations for TPB, such as:

- The potential impacts of CAVs on mobility, society, and institutions.
- The potential impacts of CAVs on the metropolitan Washington region's transportation system principles, goals, and objectives.
- The potential role for TPB in preparing for and responding to these impacts relative to the role of other agencies and private industry.
- The development of CAV principles that can support desired outcomes and minimize risks and adverse impacts related to CAV deployment.

While there are many challenges to addressing the impacts anticipated from CAVs, TPB and its partners are well positioned to address these challenges. TPB has a robust committee structure and supporting staff that are positioned to address and strengthen CAV in metropolitan transportation planning in response to considerations such as these. Existing subcommittees such as the TPB Systems Performance, Operations, and Technology Subcommittee (SPOTS) may increase their focus on CAVs to help address these impacts. Other committees such as the Transportation Safety Subcommittee, Regional Public Transportation Subcommittee, Commuter Connections Subcommittee, and Bicycle and Pedestrian Subcommittee can also contribute to related planning activities on an ongoing basis. Activities TPB could undertake may include:

- Undertaking strategic planning to develop a coordinated approach to CAV and to build technical, institutional, and policy capacity among TPB staff and partner agencies.
- Developing supportive goals, objectives, performance measures, planning/research initiatives, and stakeholder/public education and engagement activities through vehicles such as the regional LRTP, TIP, UPWP, and other TPB-sponsored plans, programs, and initiatives (e.g., TPB's freight and bicycle/pedestrian plans).
- Collaborating with member agencies and organizations.
- Providing a forum of information exchange among public and private sector transportation service providers and facility owner-operators in piloting and deploying CAV technologies that can advance regional priorities and goals.

The findings and recommendations from this white paper can be used to initiate and guide steps such as these that will better prepare the metropolitan Washington region for the arrival of CAVs.

APPENDIX: RESOURCES AND FURTHER READING

This section provides a selection of resources focused on the planning and deployment of CAVs, with an emphasis on relevant initiatives among metropolitan Washington region governments. Further resources include CAV activities and publications by the U.S. Department of Transportation (USDOT) and by a variety of research institutions and non-profits.

Metropolitan Washington Region Governments

REGIONWIDE
National Capital Region Transportation Planning Board (TPB)

- TPB Connected and Autonomous Vehicles (CAV) Webinar #1 - CAV Overview (https://www.mwcog.org/events/2020/5/5/tpb-connected-and-autonomous-vehicles-cav-webinar-1-cav-overview/)

DISTRICT OF COLUMBIA
District Department of Transportation (DDOT):

- DC AV Study (https://lims.dccouncil.us/Legislation/RC23-0172) -- *This report used a scenario-planning approach to develop and analyze the range of potential effects that autonomous vehicles will have on the District and the region in the future.*

Office of the Deputy Mayor for Planning and Economic Development (DMPED)

- Autonomous Vehicles Working Group (https://dmped.dc.gov/page/autonomous)

- DC Autonomous Vehicles Principles Statement (https://dmped.dc.gov/sites/default/files/dc/sites/dmped/publication/attachments/Autonomous%20Vehicles%20Principles%20Statement_0.pdf)

MARYLAND
Maryland Department of Transportation (MDOT)

- MDOT State Highway Administration CAV Program: CAV Vision, Goals, Strategies and Ongoing Initiatives (https://www.arcgis.com/apps/Cascade/index.html?appid=44c92899dc5249038f6c22ba29ac473b)

- Connected and Automated Vehicle (CAV) Strategic Action Plan: A Strategic and Operational Outlook on the Impacts of CAV (https://chart.maryland.gov/downloads/readingroom/StrategicPlanning/MDOT%20SHA%20CAV%20Strategic%20Action%20Plan%20-%20FINAL%20-%20Dec%202017.pdf)

Smart Growth Network / Maryland Department of Planning

- Autonomous Vehicle Implementation: Implications for Transportation Planning [Webinar] (https://smartgrowth.org/autonomous-vehicle-implementation-implications-for-transportation-planning/#)

VIRGINIA
Northern Virginia Transportation Authority (NVTA)

- Transportation Technology Committee (https://thenovaauthority.org/about/committees/transportation-technology-committee-2/)

Virginia Department of Transportation (VDOT)

- Connected and Automated Vehicle Program Plan
  (http://www.virginiadot.org/programs/resources/cav/Release_Final_VDOT_CAV_Program_Plan_Fall_2017.pdf)
- Connected and Automated Vehicle Program Web Page
  (http://www.virginiadot.org/programs/connected_and_automated_vehicles.asp)

U.S. Department of Transportation (USDOT)

ITS Joint Program Office (ITS JPO)
- Complete Trip – ITS4US Deployment Program
  (https://its.dot.gov/its4us/)
- Connected Vehicle Pilot Deployment Program
  (https://www.its.dot.gov/pilots/)
- What Public Officials Need to Know About Connected Vehicles
  (https://www.its.dot.gov/factsheets/jpo_publicofficials.htm)

Federal Motor Carrier Safety Administration (FMCSA)
- Development of Baseline Safety Performance Measures for Highly Automated Commercial
  Vehicles (https://www.fmcsa.dot.gov/research-and-analysis/technology/development-
  baseline-safety-performance-measures-highly-automated)

Federal Highway Administration (FHWA)
- Advanced Transportation and Congestion Management Technologies Deployment Program
  (https://www.fhwa.dot.gov/fastact/factsheets/advtranscongmgmtfs.cfm)
- Cooperative Driving Automation
  (https://highways.dot.gov/research/operations/Cooperative-Driving-Automation)
- Transportation Planning Capacity Building: Connected and Automated Vehicles
  (https://www.planning.dot.gov/planning/topic_CVAV.aspx)

Federal Transit Administration (FTA)
- Accelerating Innovative Mobility (AIM) Program
  (https://cms7.fta.dot.gov/AIM)
- Transit Automation Research (https://www.transit.dot.gov/automation-research)

National Highway Traffic Safety Administration (NHTSA)
- A Framework for Automated Driving System Testable Cases and Scenarios
  (https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/13882-
  automateddrivingsystems_092618_v1a_tag.pdf)
- Estimation of Potential Safety Benefits for Pedestrian Crash Avoidance/Mitigation Systems
  (https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/812400_pcambenefitsreport.
  pdf)

USDOT and the National Science & Technology Council (NSTC)
- Ensuring American Leadership in Automated Vehicle Technologies, Automated Vehicles 4.0
  (https://www.transportation.gov/sites/dot.gov/files/2020-
  02/EnsuringAmericanLeadershipAVTech4.pdf)

Research Institutions and Nonprofits

American Planning Association (APA)
- Policy Principles for Autonomous Vehicles
  (https://www.planning.org/publications/document/9144669/)

Association of Metropolitan Planning Organizations (AMPO)
- National Framework for Regional Vehicle Connectivity and Automation Planning
  (https://www.ampo.org/wp-content/uploads/2019/04/2019-AMPO-Framework-11.pdf) – *This report provides a list of CAV initiatives including MPO, state DOT, and local government effort.*

Bloomberg Philanthropies & The Aspen Institute
- Taming the Autonomous Vehicle a Primer for Cities
  (https://www.bbhub.io/dotorg/sites/2/2017/05/TamingtheAutonomousVehicleSpreadsPDF.pdf) – *This report is the result of learnings gathered from reviewed reports, forecasts, and announcements to produce a compact primer on the future of cities and autonomous vehicles. It is a scan of the future horizon, indicating clear directions of change where there is strong consensus among leading experts.*
- Autonomous Vehicles Accord: Global Cities' Vision for the Future
  (http://dev.hel.fi/paatokset/media/att/f4/f454f0244120762b29d9f9d4ab66041f65aad399.pdf) – *This is a set of principles to guide decision-making around autonomous vehicles by major cities, developed and adopted by the cities of Austin, Buenos Aires, Helsinki, London, Los Angeles, Nashville, Paris, São Paulo, Tel Aviv, and Washington D.C..*

National Association of City Transportation Officials (NACTO)
- Blueprint for Autonomous Urbanism: Second Edition
  (https://nacto.org/publication/bau2/) – *This guide identifies decisions that cities, and government at all levels, must make to reach a people-focused autonomous future that is based on safety, public good, equity, and sustainability with a focus on four key policy areas: transit, freight, pricing, and data.*

National Cooperative Highway Research Program (NCHRP)
- NCHRP Research Report 896: Updating Regional Transportation Planning and Modeling Tools to Address Impacts of Connected and Automated Vehicles
  (http://www.trb.org/Main/Blurbs/178392.aspx)

New York State Association of Metropolitan Planning Organizations (NYSAMPO)
- Establishing a Regional Planning Framework for Connected and Automated Vehicles, version 1, October 2017. Developed by the NYSAMPO Transportation System Management and Operations (TSMO) Working Group – *This report includes a summary of key impacts and issues for consideration in regional planning and decision-making, and provides detailed recommendations and specific activities MPOs can apply toward various elements of long range planning and transportation improvement programs.*

Shared-Use Mobility Center (SUMC)
- Learning Module: Shared Autonomous Vehicles
  (https://learn.sharedusemobilitycenter.org/learning_module/shared-autonomous-vehicles/) – *This learning module focuses on the impacts of AV technology on shared-use and on-demand modes, and it considers them in the context of complex urban environments.*

University of Virginia Center for Transportation Studies
- Glossary of Connected and Automated Vehicle Terms Version 1.0
  (http://www.cts.virginia.edu/wp-content/uploads/2018/03/Glossary-of-CAV-Terms-Ver1.0-03052018-1.pdf)