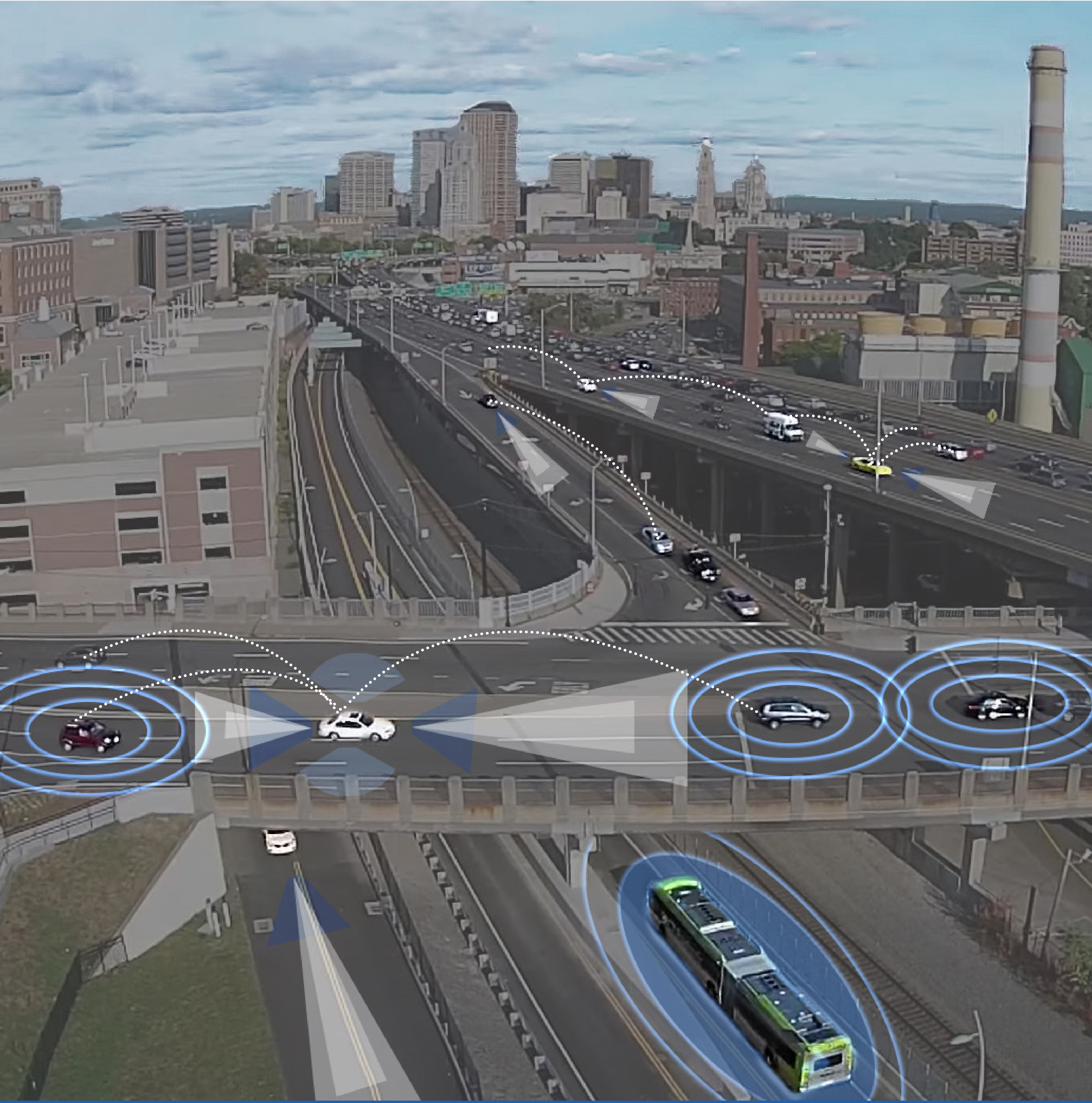

Preparing for Connected and Automated Vehicles
Strategic Plan

February 2021

CONNECTICUT DEPARTMENT OF TRANSPORTATION

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Executive Summary

Connected and Automated Vehicles (CAV) have the potential to radically transform transportation. At full maturity, CAV are anticipated to provide significant safety and mobility improvements that could benefit nearly every aspect and user of the transportation system. While some forms of automation and wireless communication technologies are included in new vehicles sold today, the application of most high automation technologies and high-speed connected vehicle technologies involved in CAV are still being researched, developed and pilot tested throughout the United States and around the world. Due to the emerging nature of these technologies, it is difficult to predict when they will reach a critical mass and begin to provide widespread benefits. This reality creates both an exciting opportunity and an immense challenge for the Connecticut Department of Transportation (CTDOT) and other transportation agencies to properly plan for such a promising and uncertain future.

The CTDOT is a statewide multimodal transportation agency, mobility service provider, and infrastructure owner operator (IOO) in charge of managing the Connecticut highway network and public transportation system. Like other transportation agencies around the country, the CTDOT makes both short-term and long-term transportation service and infrastructure investment decisions based on best available data, industry standards, statutory requirements, as well as agency and stakeholder needs. In preparation for an evolving CAV technological future, the CTDOT will need to develop new highway and public transportation policies, while establishing new programs and partnerships to address the safe deployment and integration of these technologies seamlessly across its multimodal transportation network.

In this CAV future, the CTDOT will be responsible for the maintenance of new CAV-related services and infrastructure, including roadside and backend technologies, while also continuing to meet its traditional state of good repair (SOGR), manage public transportation and potential CAV projects, and its Intelligent Transportation System (ITS) obligations. This is expected to create additional data management and cyber security needs, reflect changing transportation business models and user preferences, and impact CTDOT's already scarce financial resources.

The purpose of this document is to provide the CTDOT's strategic approach to the preparation, deployment and sustainment of CAV technologies and solutions. As part of its longer-term CAV strategy, the CTDOT establishes a vision for the future of CAV that is safe, secure and seamlessly operated across all jurisdictions. As part of this CAV vision, the CTDOT is committed to look for ways in which CAV technologies can become a powerful tool to help meet a variety of the CTDOT's goals to improve safety; enhance mobility, accessibility, and reliability; reduce congestion; support SOGR; provide efficiencies; improve air quality; and support economic growth.

Building off this vision, the CTDOT has developed near-term and long-term strategies that maximize the potential benefits of still evolving CAV technologies:

Near-Term Strategy (2021 – 2025):

The CTDOT will focus its CAV objectives and actions on tangibles and deliverables, centered around the multiple facets of CAV technologies where there has been and continues to be significant advancements by both industry and public sector. This includes a variety of activities such as early policy coordination and development; assessments of workforce and infrastructure readiness; experience deploying pilot projects; and other activities.

Long-Term Strategy (beyond 2025):

The CTDOT will continue to establish a timely feedback loop to adapt and engage with on-going advancements in CAV technologies, policies and readiness in order to prepare for and support larger CAV deployments, to develop more comprehensive CAV policies, and to commit to upgrading the State's infrastructure and workforce for cooperative automation. This long-term strategy will be part of an overall assessment of the CTDOT's own capabilities to implement multimodal CAV supportive infrastructure programs and to facilitate CAV technologies and services at larger scale subject to available funding, standards, market penetration and readiness.

CAV are expected to have multiple benefits, such as improved safety, enhanced mobility and accessibility, potential for less congestion, environmental benefits, and innovative opportunities for both the public sector and private sector to support new jobs and economic growth. CAV also presents risks to those same issues, and faces significant challenges to deployment, including legal and regulatory challenges, security and privacy concerns, adoption of standards, public acceptance, and planning uncertainty. Though not exhaustive, the CTDOT has identified and expanded upon several key issues that may be impacted by CAV and are considered of greatest importance to the CTDOT to continue monitor and evaluate.

In order to maximize opportunities and benefits for both the near-term and long-term strategies, objectives and supportive actions, the success of this plan will require buy-in from the Connecticut General Assembly (State Legislature) to provide the CTDOT with additional key resources. These resources are expected to include additional staffing and funding for CAV research and deployment opportunities, including planning, design, operations and maintenance. These needs would be in addition to the funding and staffing already used for day-to-day activities at the CTDOT.

This CAV Strategic Plan represents a snapshot in time and will be revisited and updated in response to changing technologies; evolving federal, state, and local laws and regulations; and shifts in Connecticut's transportation needs and priorities.

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Overview and Background

Recent industry advancements in wireless communication and driving automation continues to pave the way for new developments in transformative vehicle technologies such as Connected Vehicles (CV) and Automated Vehicles (AV) . Independently, both CV and AV have the potential to bring tremendous impacts to the transportation system. However, it is the combination and the integration of these two types of technologies, forming Connected and Automated Vehicles (CAV), that have the potential to bring the most substantial changes to the future of transportation.

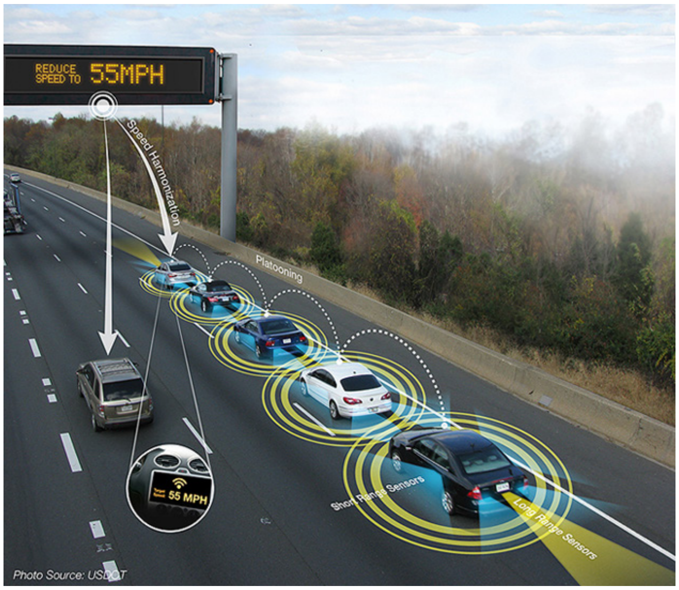
Automated Vehicle (AV): A vehicle that possesses hardware and software collectively capable of performing part of or all the real-time operational and tactical functions required to operate a vehicle in on-road traffic. This includes all driving automation levels as defined by SAE on page 7.

Connected Vehicle (CV): A vehicle that uses standardized communication protocols and technologies to wirelessly communicate with other vehicles, roadside infrastructure, pedestrians, and the cloud.

Inside an Automated Vehicle
Image Courtesy of the U.S. Department of Transportation

Inside a Connected Vehicle
Image Courtesy of the U.S. Department of Transportation

Connected and Automated Vehicle (CAV): A vehicle that is both connected and automated. This vehicle is equipped with various hardware and software that are collectively capable of wirelessly communicating with the world around it (other vehicles, traffic signals, the cloud, etc.) and performing part or all of the real-time operational and tactical functions required to operate in on-road traffic.



Connected Vehicles Platooning
Image Courtesy of the U.S. Department of Transportation

Note: The term "CAV" referenced in this document has a broad range of meanings. On one end CAV implies a potential future transportation network where a significant percentage of the share of vehicles on public roadways communicate with nearly everything around them and can operate with little to no human control. However, the exact timing, impacts and full extent of this scenario are uncertain at this point. On the other end of the range, incremental CAV technological advances are being incorporated into the transportation network today. These technological advances come in the form of automated driver assistance technologies that are included in most new model year vehicles sold today. These technological advances also include the higher-level automated driving systems (ADS) and CV communications that are currently being developed, tested and deployed by automakers, researchers and IOOs in closed course environments and on limited public roadways around the world.

Over the next few decades, if CAV reaches a critical mass on the roadway the range of impacts could be extensive. The proliferation of CAV could cause large-scale changes to road use that may have dramatic implications (some desired, some challenging) for transportation safety, mobility, transit operations, workforce development, personal privacy and security, public investment in infrastructure, among many other broad issues.
Chief among the potential impacts of most importance to the CTDOT is the prospective for CAV to bring dramatic improvements to transportation safety. Currently almost 95% of all roadway crashes in the United States are caused by some form of human error[1], which kill about 40,000 Americans on the roadway each year. In a typical year in Connecticut, over 100,000 crashes, more than 30,000 injuries and more than 250 deaths are the result of human error[2]. If CAV technological capabilities continue to mature and market penetration rates of CAV technologies increase, there could be the potential for significant improvements in transportation safety. This may allow the CTDOT as well as other transportation agencies around the country to better achieve their transportation safety goals and ultimately get much closer to zero deaths on the roadway.

In addition to dramatically improving safety, the potential for CAV to also help reduce congestion and enhance individual mobility options through the development of better coordinated transportation networks, increased vehicle efficiencies and shared mobility services are other key areas of interest for the CTDOT. Typically, in Connecticut, about 80% of commuters drive alone to and from work every day and the average driver sits in traffic for more than 40 hours (more than a full work week) per year. This congestion costs each Connecticut driver about $1,000 in lost time and wasted fuel[3].

In addition to the lack of efficiencies and economic costs brought on by congestion, for many Connecticut families, especially low-income families, the reality or prospect of owning a vehicle and/or having access to quality and reliable transit services are the biggest ladders of opportunity for economic success. With the evolution of new shared mobility options provided by CAV, the traditional transportation mobility and accessibility options of today that are constrained by vehicle ownership models, and an individual's ability to drive or access public transportation may change significantly in a CAV future. If this shared mobility model of CAV comes to fruition, it could provide more transportation options for all users of the transportation system, regardless of an individual's income status, or physical, or mental abilities. This CAV shared mobility model also enables individuals to age in place, particularly in Connecticut, where the average life expectancy is one of the longest in the United States (80+ years),[4] and where the senior population is expected to increase 60% by 2040[5].

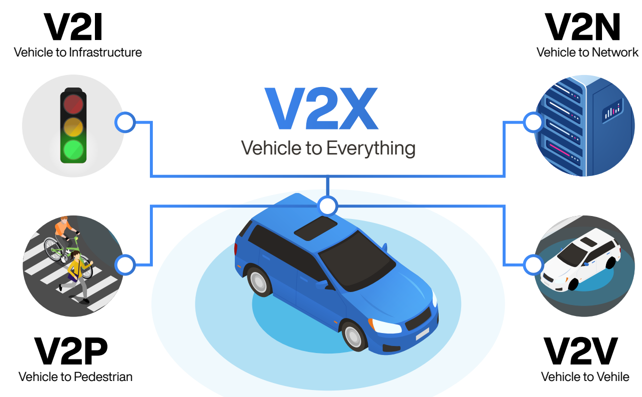
While the prospective safety, mobility and other benefits of CAV are promising, in order for these benefits to

[1] https://www.nhtsa.gov/technology-innovation/automated-vehicles
[2] https://www.ctcrash.u
[3] https://portal.ct.gov/-/media/DOT/documents/dpolicy/2020FastFacts-onlineFINAL.pdf
[4] https://www.ctdatahaven.org/blog/data-connecticut-ranks-high-life-expectancy-cancer-survival-rates
[5] https://ctbythenumbers.news/ctnews/tag/seniors

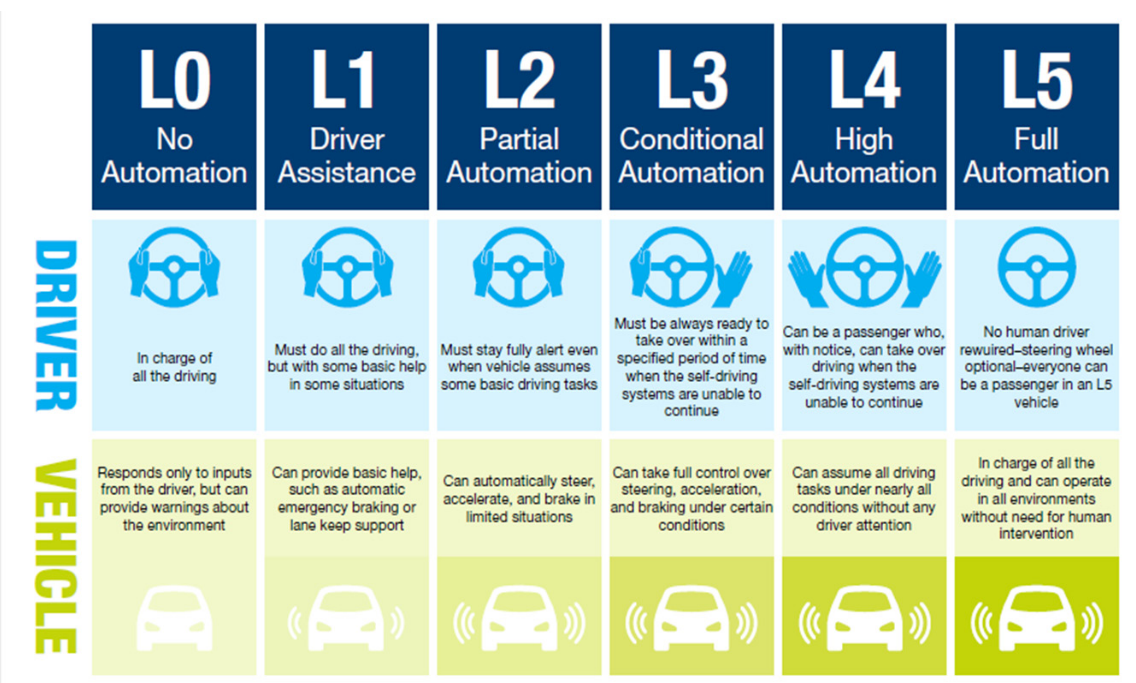
be realized, CAV technologies will need to become widespread. As of today, the viewpoints among many industry experts differ considerably when this may happen. Some of the commonly discussed early actions needed to support or prepare for the advancement and mass proliferation of CAV are extensive and require significant cooperative efforts among a diverse group of public and private sector entities to accomplish. Examples of some of these actions are bulleted below. Over the coming years, the CTDOT will work with others at the local, state, regional and national level to help address some of these issues and participate in efforts to advance the potential for a CAV future that supports the CTDOT's goals.

Actions Needed to Advance CAV

- Increased testing and deployments of CAV technologies and equipment within laboratories, controlled testbeds and especially on public roadways around the country;
- Increased public sector investments and improvements in surface transportation SOGR and cooperative CAV infrastructure to enhance the safety, performance and capabilities of CAV;
- Development of consistent laws, regulations and policies among all levels of government throughout the country that support seamless operation of CAV across all jurisdictions;
- Establishment of additional and effective national industry standards to promote safe, reliable, consistent, and interoperable deployment of CAV technologies that are more future proof and provide both industry and infrastructure owner operators (IOO) with the confidence needed to invest more of their time, resources, equipment and infrastructure into CAV technologies;
- Federal Communications Commission (FCC) preservation of the entire 5.9GHz spectrum[6] (safety band) to limit interference issues and enable and ensure full connectivity options for CAV technologies; and
- Vast improvements in the general public understanding, experience and acceptance of CAV technologies.



Types of Connected Vehicle Communication



SAE Levels of Automation
Graphic Courtesy of SAE

[6] See Appendix A for definition of 5.9GHz spectrum

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Vision, Perspective, and Strategy

Outlined below is CTDOT's vision, perspective and strategy for a CAV future.

Vision

The future of CAV transportation is safe, secure and seamlessly operated across all jurisdictions.

As part of this CAV vision, the CTDOT is committed to look for ways in which CAV technologies can become a powerful tool to help meet a variety of the CTDOT's goals to:

- Improve safety for all transportation users;
- Enhance mobility, accessibility and reliability of the transportation network;
- Reduce and better manage congestion;
- Support SOGR needs and infrastructure upgrades;
- Provide greater efficiencies for highway and transit operations and maintenance;
- Improve air quality, and reduce greenhouse gas emissions; and
- Support economic growth

Perspective

The CTDOT is keenly focused on a service-oriented, infrastructure-based, and multimodal approach towards the advancement of CAV that addresses both current and future (evolving) public transportation and highway transportation needs.

The CTDOT seeks to be a leader in the development, testing and implementation of CAV technologies for public transportation purposes. In the near-term, the CTDOT owns a state-of-the-art CTfastrak bus rapid transit (BRT) facility that it will use to safely test and deploy CAV technologies on full size busses. Over the long-term, the CTDOT intends to continue to evaluate the capabilities and performance of CAV technologies as tools to help address transit challenges facing the state, including the need to continue to provide equitable and cost-efficient transit services. The CTDOT intends to leverage CAV technologies to modernize Connecticut's large fixed route transit services, while also investing in smaller, door-to-door, first/last mile, on-demand, micro transit services.

For highways, the CTDOT is committed to investing in the preparation of leadership, staff and infrastructure by taking an asset management approach to support the future implementation of CAV on Connecticut's roadways. In the near-term, the CTDOT will conduct pilot testing of CAV applications and infrastructure on public road testbeds, including the Berlin Turnpike and CTfastrak. The experience gained from the pilot testing will provide valuable hands-on technical experience and lessons learned. The CTDOT will then apply this experience to improve other projects, to better inform the replacement and maintenance needs of critical roadway assets that support CAV and to provide insight and guidance to national committees as the formation of related CAV standards are being discussed. Such activities will require dedication of internal staff and resources within the CTDOT to support and maintain these efforts. Over the long-term, the CTDOT will continue to evaluate the advancement of CAV technologies and the CTDOT's ability to support them at a larger scale, as applicable.

One of the key improvements that will always be beneficial for both the future of CAV and to human drivers is the need to continually improve and maintain infrastructure in a SOGR. The CTDOT always prioritizes SOGR needs and will continue to do so in preparation for CAV. That said, while the CTDOT attempts to optimize its available resources to improve and maintain as much of the statewide infrastructure in a SOGR as possible, the CTDOT also firmly advocates that the performance of CAV technologies should not become overly dependent on the IOOs. CAV needs to have enough redundancies built in to operate safely in all existing roadways and infrastructure conditions, without becoming overly reliable on an IOO's ability to maintain pristine roads and update their roadside equipment to the latest versions of technology.

Strategy

To maximize the potential benefits of swiftly evolving CAV technologies, while recognizing a growing list of uncertainties, the CTDOT has developed a two-fold, near-term and long-term strategy to best prepare for CAV:

Near-Term Strategy (2021 – 2025): The CTDOT will focus its CAV objectives and actions on tangibles and deliverables, centered around the multiple facets of CAV technologies ,where there has been and continues to be significant advancements by both industry and public sector. This includes a variety of activities, including, early policy coordination and development; assessments of workforce and infrastructure readiness; experience deploying pilot projects; and other activities.

Long-Term Strategy (beyond 2025): The CTDOT will continue to establish a timely feedback loop to adapt to and engage with on-going advancements in CAV technologies, policies and readiness in order to prepare for and support larger CAV deployments, to develop more comprehensive CAV policies, and to commit to upgrading the State's infrastructure and workforce for cooperative automation. This long-term strategy will be part of an overall assessment of the CTDOT's own capabilities to implement multimodal CAV supportive infrastructure programs and to facilitate CAV technologies and services at larger scale subject to available funding, standards, market penetration and readiness.

CTDOT test rides an automated shuttle at the University of Michigan

04

Near-Term Objectives and Actions

Outlined below is detailed information about each of the objectives and actions that the CTDOT will focus on in the near-term (2021 - 2026) to best prepare for a CAV future.

Objective 1 — Strengthen Internal Support for CAV by Establishing a Central Structure to Set Direction and to Coordinate Related Planning, Actions and Needs Across the CTDOT

As other state transportation agencies across the country increase their knowledge base and experience with CAV technologies, many of them are developing internal structures to provide direction and to coordinate activities across their organizations. Similarly, as the CTDOT gets more involved with various CAV initiatives, it is essential that the CTDOT develop an internal structure to set direction and to coordinate related planning, actions and needs across the agency.

SUPPORTIVE ACTIONS:

Establish CAV Standing Committee

The establishment of a new internal CAV standing committee will serve as the central structure to provide guidance and direction to help grow, coordinate and sustain the CTDOT's overall interests and involvement with CAV technologies. Executive oversight will be provided by the Office of the Commissioner. Participating members will be comprised of both upper management and subject matter experts representing key organizational areas across the CTDOT that are likely to be affected by the deployment of CAV technologies. Co-chairs will be selected from the Bureau of Public Transportation and the Bureau of Highway Operations or the Bureau of Engineering and Construction. A secretary will be selected from the Bureau of Policy and Planning. Regular meetings will be scheduled, and sub-committees may be formed as needed to focus on relevant aspects of CAV most critical to the CTDOT.

Figure 1- Connecticut DOT CAV Standing Committee Structure

Establish CAV Lead for CTDOT

A lead CAV position within the Bureau of Policy and Planning will be designated to focus on and coordinate the CTDOT's CAV preparedness and activities. This position will serve as the Secretary on the CAV standing committee and will work directly with the other officers and members of the CAV Standing Committee and each of the affected offices throughout the CTDOT to help organize related CAV planning, actions and needs.

Establish CAV Designees Within Each Bureau

New technologies like CAV need to have a dedicated, multi-disciplinary group within the CTDOT to further innovation. As a result, each Bureau within the CTDOT will designate appropriate personnel, including staff and/or management to be regularly involved with and work on CAV-related activities. For Bureaus that have multiple disciplines that could be impacted by CAV, multiple CAV designees may also need to be identified. For some Bureaus, new positions dedicated to CAV may be needed to sustain this effort, while also being able to balance their workloads and corresponding responsibilities. The CTDOT's Executive Team will work with each Bureau to establish the appropriate personnel required to support CAV.

Objective 2: — Expand the CTDOT's General Workforce Knowledge and Understanding of CAV Technologies by Engaging in CAV Training Opportunities as well as CAV Pooled Fund Studies and Research

CTDOT at CV Pooled Fund Demonstration in Atlanta, GA

Expanding general workforce knowledge and understanding of CAV technologies is a critical early step for the CTDOT to take towards the successful adoption of CAV. Participation in related training opportunities for all areas and levels of the CTDOT will help to foster continuity of operations and begin to educate the workforce about new skillsets and resources that may be required to oversee new forms of transportation under a CAV future. Additionally, participating in CAV pooled fund studies and research enables the CTDOT to learn from others and begin to better understand and address specific CAV challenges and opportunities facing state transportation agencies.

SUPPORTIVE ACTIONS:

Provide CAV Training for the CTDOT's Management and Staff

Due to the potential disruptive nature of CAV technologies, there is a wide range of functional areas across the CTDOT that could be impacted. The CTDOT's CAV standing committee and CAV lead will explore available options to provide relevant instructional training for management and staff that help evaluate the potential CAV technological risks and opportunities for the CTDOT's existing program areas and processes. CAV training may include web-based curriculums, seminars, workshops, lunch and learns, peer exchanges, literature reviews, tours, site trips, conferences and coordination with Connecticut's Local Technical Assistance Program, other state transportation agencies, federal agencies, universities and regional/national associations, etc. These training opportunities will help equip the CTDOT with the effective tools to conduct proper CAV planning and update and/or establish new protocols.

Participate in CAV Pooled Fund Studies and Other Research Opportunities

The CAV standing committee and CAV lead will also work with the CTDOT's Executive Team and the Office of Research as needed to recommend participation in various CAV pooled fund studies and/or other related CAV studies or research efforts critical to the CTDOT's interests and needs. Outlined below are descriptions of the national CAV pooled fund studies that the CTDOT currently financially supports and participates in.

Connected Vehicle Pooled Fund Study

The Connected Vehicle Pooled Fund Study (CV PFS) is a research consortium of local, state, national and international transportation agencies and IOOs led by the Virginia Department of Transportation that plays a leading public sector role in advancing CV systems. To date, more than half of the state transportation agencies around the country are members of the CV PFS, with active and financial participation from Federal Highway Administration (FHWA), Transport Canada, several large engineering and research universities, consultants, vendors and many of the major automakers.

In 2018, the CTDOT joined the CV PFS to collaborate with other states who are more experienced working with CV technologies to improve the CTDOT's knowledge and understanding of CV systems. The CTDOT will continue to participate and contribute additional staff time in functional areas, including, highway management, highway operations and maintenance, highway design, traffic engineering, planning, and transit. Increased participation in the CV PFS will better prepare multiple areas across the CTDOT for pilot testing and deployment of CV infrastructure in Connecticut.

Automated Vehicle Pooled Fund Study

The Automated Vehicle Pooled Fund Study (AV PFS) is an AV research consortium, formed in 2020, comprised of state transportation agencies, led by Drive Ohio (a smart mobility organizational initiative within Ohio DOT). This pooled fund provides a means for state transportation agencies to independently research and address issues that will affect the deployment of AV systems on public roadways. Members of the AV PFS work with FHWA, the American Association of State Highway Transportation Officials (AASHTO), original equipment manufacturers (OEM) and various industry groups to prepare for and research vehicle-roadway interactions, analyze data failures and mitigation methods, help to identify and define standards, and encourage AV interoperability across state borders.

In 2020, the CTDOT joined the AV PFS to expand the CTDOT's general workforce knowledge and understanding of AV technologies, to work collaboratively with other states to address AV challenges and to ultimately better prepare multiple functional units across the CTDOT for pilot testing and deployment of AV systems in Connecticut. As both an IOO and a transit agency, the CTDOT provides a unique, multi-modal perspective to the AV PFS. The CTDOT will contribute staff time to actively participate in the AV PFS, especially in functional areas such as highway management, highway operations and maintenance, highway design, traffic engineering, planning, and transit. Increased participation in the AV PFS will better prepare multiple areas across the CTDOT for pilot testing and deployment of AV systems in Connecticut.

Objective 3 —Advance CAV Pilots and Demonstration Projects in Connecticut to Gain "Hands-On" Experience and Understand Early Benefits

CTDOT at Consumer Reports Test Track

Until sufficient national CAV standards are set, or a clearer consensus around the usage of CAV technologies form, the CTDOT will focus its CAV technology and research investments towards conducting and supporting limited CAV field-testing and small pilot projects in Connecticut. These activities will allow the CTDOT to gain hands-on experience with new technologies and to work and learn from others to solve transportation challenges, as well as evaluate CAV system benefits without making major technology commitments associated with these systems.

Participating in CAV pilots and demonstration projects will also position the CTDOT to provide insight and guidance to national committees as the formation of related standards are being discussed. The demonstration and research efforts will be in systems and functions that are of direct importance and have immediate value to the CTDOT, the state, and the regional and national transportation system.

SUPPORTIVE ACTIONS:

Test and Deploy CAV Transit Technologies on CTfastrak

The CTDOT owns and operates an ideal facility for piloting and deploying CAV transit technologies – the CTfastrak BRT corridor. This facility is a nine-mile, bus-only, fixed guideway in central Connecticut that connects four municipalities, including the state's capital city of Hartford, West Hartford, Newington and New Britain. Success with CAV transit technologies along the CTfastrak BRT corridor has the potential to advance the marketability of near-term CAV transit technologies, while both improving service and creating additional efficiencies. The CTDOT will continue to prioritize CTfastrak and corresponding facilities for testing and deploying CAV transit technologies.

Over the next few years the CTDOT and its assembled team, including the Federal Transit Administration (FTA), Center for Transportation and the Environment (CTE), New Flyer Industries, Robotic Research, Inc., University of Connecticut, and the Capital Region Council of Governments (CRCOG), will be working collaboratively to advance a first in the nation, state-of-the-art, pilot project that tests the performance and operation of full size, automated, and battery electric buses (BEB) in revenue service on the CTfastrak BRT.

This demonstration project will deploy three 40' New Flyer Excelsior Charge BEB equipped with increasing levels of driving automation capable of up to high automation (SAE level 4). Automated driving capabilities demonstrated will include steering, braking, lane keeping, pedestrian and object detection, precision docking at CTfastrak station platforms and platooning of buses all aimed to improve service and safety for workforce and riders.

The automated buses deployed as part of this project will always have a safety attendant behind the wheel to drive and/or take control of operations during testing, as necessary. The buses will be operated and maintained by the Hartford division of CTtransit, which is a brand name for transit services operated by private transit providers under contract with the CTDOT. Extensive testing will take place without passengers at an off-road test facility and on CTfastrak prior to the buses operating in service for passengers. Traffic signals along the CTfastrak fixed guideway will also be updated in order to broadcast connected vehicle to infrastructure (V2I) signal phasing and timing (SPaT) data and MAP data. This broadcasted SPaT data and MAP data will be integrated with the ADS on the buses to further enhance safety through intersections.

The CTDOT is advancing the CTfastrak CAV bus project to:

- Safely test various capabilities of driving automation levels on full size buses
- Enhance safety and efficiency for boarding and alighting passengers at stations with automated precision docking
- Evaluate the potential for platooning in BRT service
- Improve safety and efficiency at CTfastrak intersections by upgrading various traffic signal equipment and installing new V2I roadside equipment
- Demonstrate performance of electric transit fleet
- Accelerate CAV technologies for transit
- Generate and share data to benefit transportation agencies and improve other CAV deployments

Berlin Turnpike in central Connecticut

Test and Deploy CV and Other Traffic Signal Technologies on Berlin Turnpike

The Berlin Turnpike, a major arterial highway in central Connecticut (where the CTDOT's headquarters building is located) provides an ideal live roadway testbed for the CTDOT to begin to evaluate the performance, operation, and effectiveness of V2I and other emerging ITS traffic signal technologies. This state-owned highway has steady high volumes of routine traffic, is a popular destination for shopping with several national and regional retail stores and serves as a main diversionary route for traffic incidents on nearby Interstate 91.

Over the next few years the CTDOT will be completing two traffic projects along a 10-mile segment of the non-expressway portion of U.S. Route 5/15 (Berlin Turnpike) to replace and upgrade 28 signalized intersections near the CTDOT's headquarters. These projects will serve as early adopters for testing and deploying emerging traffic signal technologies, including V2I applications, traffic signal priority, adaptive signal control and automatic traffic signal performance measures (ATSPM). Each of these applications have the potential for improving safety and mobility, enhancing the CTDOT's traffic signal operations and reducing congestion.

Both projects are part of the CTDOT's official entry to the SPaT Challenge[7] , which is a program put together by AASHTO and the National Operations Center of Excellence (NoCOE) to encourage state and local public sector transportation IOOs to cooperate together to achieve deployment of V2I infrastructure with SPaT and MAP broadcasts in at least one corridor or network (approximately 20 signalized intersections) in each state. The SPaT Challenge was set up as an early way for IOOs to encourage and initiate broader V2I deployment as well as demonstrate interest and commitment to the OEMs and private industry towards building a more connected vehicle future.

Both of the projects that the CTDOT will submit as part of the SPaT Challenge will require installation of advanced traffic signal controllers, new non-intrusive traffic detection equipment (cameras, radar, etc.), new backhaul communications (fiber) and include the implementation of adaptive signal control technology and automated traffic signal performance measures software. As part of the traffic signal replacements and upgrades, the CTDOT will install V2I roadside units (RSU) at each intersection and equip various state-owned fleet vehicles with corresponding V2I on-board units (OBU) to test and deploy different V2I applications (e.g. SPaT, signal priority, etc.). Once operational, the CTDOT looks to apply lessons learned from these projects as a template for other traffic signal replacement projects moving forward, where applicable.

Explore Additional Opportunities for CAV Pilot Tests and Limited Deployments in Connecticut

Over the near-term, in addition to pilot testing CAV full size transit on the CTfastrak and pilot testing V2I and other emerging traffic signal technologies along a segment of the Berlin Turnpike, the CTDOT will also consider exploring additional options and ideas for advancing other types of CAV pilot tests and limited deployments in Connecticut as needs arise and as available funding/resources permit. Additional CAV pilots and deployments that the CTDOT may consider would be within systems and functions that are of direct importance and have immediate value to the CTDOT as well as the state, regional and national transportation system. The CTDOT would look for these additional pilots and limited deployments to continue to position the CTDOT to provide insight and guidance to national committees, especially as the formation of related standards are being discussed.

[7] https://transportationops.org/spatchallenge

Objective 4 — Prepare Connecticut's highway and transit infrastructure for CAV by continuing to invest in basic SOGR needs as well as participating in efforts that identify and evaluate effectiveness of multimodal infrastructure improvements for cooperative automation.

CTDOT making SOGR improvements

One of the key improvements that will always be beneficial to both the future of CAV as well as to human drivers is the need to continually improve and maintain infrastructure in a SOGR. The need to improve and maintain the statewide, multimodal transportation system in a SOGR in Connecticut has always been at the core of the CTDOT's mission.

The CTDOT is committed to maintaining SOGR of its infrastructure and actively participates in efforts to advance infrastructure improvements in preparation for cooperative automation. However, the CTDOT, along with multiple state and local transportation agencies, firmly advocates that CAV technologies should not become overly dependent on the IOO's ability to maintain pristine roads and update their roadside equipment to the latest versions of technology in order for CAV to work properly.

The reality is that Connecticut, similar to its state and municipal peers nationwide, has a backlog of aging infrastructure in need of modernization and repair, and constrained resources to make necessary improvements. CAV technologies must improve to be fully functional regardless of roadway and transit infrastructure conditions.

Fortunately, many automated vehicle developers understand the infrastructure challenges and are beginning to design their technologies to operate safely with existing roadway infrastructure. There is also a general understanding between AV developers and IOOs that greater uniformity and quality conditions of roadway infrastructure would be beneficial to both human drivers and automated vehicles. For CV, especially V2I, there is also a shared interest between automakers and IOOs that these technologies must be interoperable and capable of functioning with existing roadway infrastructure (especially traffic signalized infrastructure) without the need for continual or extensive upgrades.

SUPPORTIVE ACTIONS:

Continue to Improve and Maintain the SOGR of Connecticut's Multimodal Transportation System

Over the next five years, the CTDOT plans to invest more than $1.6 billion per year to improve and maintain the SOGR of Connecticut's statewide, multimodal transportation system. Some of the key transportation infrastructure assets that may be vitally important for the future of CAV include pavement, pavement markings, signs, sign supports, traffic signals, highway buildings, ITS communications, bus rolling stock, bus facilities, etc. While some of these assets in Connecticut may presently be in a SOGR, many are not and require significantly more financial investment to achieve SOGR. With Connecticut's distinct four weather seasons, historically under-invested and aging infrastructure, declining transportation revenues and rising construction costs, the ability to upgrade and maintain the State's multimodal infrastructure in a SOGR will always be a challenge.

Participate in Efforts that Identify and Evaluate Effectiveness of Multimodal Infrastructure Improvements for Cooperative Automation

Most of what is to be recommended and/or required in terms of needed highway and transit CAV infrastructure improvements to support cooperative automation is still to be determined. Much of this will likely rely on a combination of advancing CAV technological capabilities; lessons learned from CAV research, pilot projects and other related efforts around the country; and from the collaborative development and implementation of uniform standards by national and international standards organizations. Examples of such standards organizations include the Society of Automotive Engineering International (SAE), Institute of Electrical and Electronics Engineers (IEEE) and the United States Department of Transportation (USDOT).

Over the coming years the CTDOT will work with others to engage in various efforts to assess the State of Connecticut's highway and transit infrastructure readiness for CAV. Such assessments will help the CTDOT to identify cooperative infrastructure improvements needed to support and improve multimodal CAV performance and operations on Interstates, highways, arterials and on downtown city streets while also improving safety and efficiency for drivers today.

The CTDOT will be participating in a variety of multi-modal CAV pilot projects and coordination efforts at the state, regional and national level. The CTDOT's involvement in these types of projects help to provide perspective and build upon lessons learned that will help to better inform CAV infrastructure readiness. Many of these efforts may also help to shape future standards.

As of the writing of this document, the FHWA is pursuing an update to the "Manual on Uniform Traffic Control Devices for Streets and Highways"—the MUTCD—in preparation for the future of CAV and to afford states and local communities with more opportunities to utilize innovation[8]. The MUTCD is the national standard for traffic signs, signals, and pavement markings. In Connecticut, the CTDOT has adopted the MUTCD as the State's standard for such designs. The last edition of the MUTCD was updated in 2012.

According to FHWA, the new MUTCD (and subsequent updates) will be forward-looking in accommodating technologies necessary to support highway connectivity, automation and innovations that improve safety and efficiency and the revised edition will lay the groundwork for supporting the infrastructure of the future[9]. As the FHWA updates the MUTCD, the CTDOT will continue to be engaged with FHWA and with other state and local transportation agencies to ensure that the new roadway standards are implementable and ultimately beneficial to the motoring public as well as to the safety and performance of the state, regional and national transportation systems.

Objective 5 — Expand Internal Efforts to Collaborate on and Advance CAV Preparedness by Incorporating and Considering CAV (as applicable) within the CTDOT's Various Plans, Projects, Programs, Processes, Designs, ITS Architecture, etc.

New TMC at CTDOT Headquarters

In recognition of the potential of CAV to radically transform all aspects of the transportation industry, the CTDOT will expand internal efforts to advance CAV preparedness across all the CTDOT's bureaus and units. The CTDOT will seek out opportunities to normalize the inclusion of CAV considerations in its multimodal planning, policymaking, design, construction, maintenance, provision of transit and highway services and operations activities. This will require that CTDOT staff continue to cultivate a current understanding of CAV technologies and applications, standards, and lessons learned from peer projects.

SUPPORTIVE ACTIONS:

Assess how to best incorporate CAV into planning and modeling activities.

CAV are not mode specific and are expected to impact the transportation system as a whole. The CTDOT will begin to evaluate how best to incorporate CAV, and their implications, into its transportation models and planning documents. Given much of the uncertainty surrounding the timeline for deployment, long-range transportation plans and transportation models may need to look at new scenario-based transportation alternatives. Capital plans, transportation asset management plans, safety plans, and project-specific planning activities will begin to consider CAV and their potential impacts. The statewide ITS Architecture will also need to be evaluated and revised to

[8] https://highways.dot.gov/automation
[9] https://www.fhwa.dot.gov/pressroom/fhwa1823.cfm

reflect the CTDOT's ongoing initial CAV efforts, and prepare for future CAV activities. The CTDOT will also continue to monitor federal guidance and peer agency activities to ascertain best practices in CAV planning and modeling.

Monitor ongoing development and adoption of CAV-relevant standards

Standards, and their widespread adoption, are vital for continued interoperability of the transportation system. The CTDOT will continue to participate in and provide feedback on standards developed by Standards Development Organizations (SDOs), including but not limited to SAE and IEEE. As CAV standards achieve greater maturity and industry acceptance, the CTDOT will seek to include these standards in the Statewide ITS Architecture, regional ITS architectures, and in project design documents.

Encourage every bureau and unit to engage in assessment of potential future CAV impacts on their day-to-day activities.

The wide-ranging impact of CAV on the provision of transportation services will require every bureau and unit within the CTDOT to adjust and adapt over time. The CTDOT will encourage every bureau and unit to assess how future CAV impacts may affect or enhance their ability to provide their basic services. This includes diverse areas such as: planning and policymaking, data collection and dissemination, data analysis, data storage and retention, transportation finance and revenue collection, project construction, public transportation services, mobility-as-a-service programs, transportation system maintenance, highway operations and management, and asset management. Again, the CTDOT will leverage federal guidance and pilot projects, participation in pooled fund studies, participation in industry groups, and communications with peer agencies to incorporate best practices and lessons learned with respect to CAV at the bureau and unit level.

Objective 6 —Expand external efforts to collaborate on and advance CAV preparedness by enhancing and seeking new partnerships and funding opportunities.

Panel discussion at Northeast CAV Summit in CT

The CTDOT will look for opportunities to continue to build upon and form new partnerships with a diverse group of stakeholders including other state transportation agencies, transit authorities, sister state agencies, municipalities, state legislature, colleges and universities, trade associations, non-profits groups, businesses and industries across the state, the Northeast region and the country to broaden collaborative efforts in advancing CAV preparedness. In addition to offering opportunities for information exchange, part of enhancing and forming these new partnerships will also include seeking new funding prospects to help the CTDOT support and advance CAV education, research and deployments in Connecticut.

SUPPORTIVE ACTIONS:

Collaborate with others to establish CAV forums and advance CAV education in Connecticut

In addition to expanding the CTDOT's general workforce knowledge and understanding of CAV technologies, the CTDOT will also work with other stakeholders over the coming years to enhance and establish new forums that broaden the education and preparedness for these technologies. Through these partnerships, the CTDOT will be able to host and/or sponsor CAV summits and events (including virtual ones) as well as facilitate CAV instruction and technical assistance to a wide variety of stakeholders throughout the state, including legislators, municipalities, students, consultants, general public, etc.

Leverage CAV partnerships as opportunities to seek new funding to advance CAV education, research and deployments in Connecticut

As part of the process of enhancing existing partnerships and seeking new ones to advance CAV preparedness, the CTDOT will also look to leverage these partnerships as opportunities to seek new funding sources and progress CAV education, research and deployments in Connecticut. The CTDOT will follow examples from other states who have successfully established and leveraged public and private sector partnerships and funding to provide for on-going opportunities to advance CAV education, research and deployments in their states. Working with others to establish new, on-going funding sources for CAV in Connecticut would be extremely beneficial for the sustainability of efforts to prepare for these technologies.

Objective 7 — Continue to shape CAV laws, regulations and policies by remaining active and staying engaged with related state, regional and national efforts, organizations and stakeholders, including private sector

CTDOT participates in National Dialogue on Highway Automation

The CTDOT will continue to play an active role in shaping state, regional and national policy and process development activities for CAV. This includes active involvement with various efforts, working groups and associations who help educate stakeholder communities and develop the framework for related CAV policies, regulations, laws and processes. Sustaining this commitment going forward requires prioritizing more of the CTDOT's staff and other resources to be involved, especially from the Bureau of Policy and Planning.

SUPPORTIVE ACTIONS:

Described below are the various state, regional and national efforts, groups and organizations that the CTDOT remains actively engaged with to help shape CAV laws, regulations and policy.

Connecticut AV Legislative Task Force

In 2017, the Connecticut AV Legislative Task Force was established by Connecticut's AV law (Public Act 17-69). Per state statute, the AV Legislative Task Force is required to:

- Research and evaluate national AV related standards and guidelines;
- Research and evaluate AV related laws, regulations and policies in other states;
- Recommend how Connecticut should legislate and regulate AV in Connecticut;
- Assess the progress of and make recommendations for pilot testing AV in Connecticut; and to
- Develop reports to the Connecticut General Assembly publishing its findings.

The CTDOT currently serves as a member of the Connecticut AV Legislative Task Force. In addition to the CTDOT, the other members include representation from the Office of Policy and Management (OPM), Department of Motor Vehicles (DMV), Connecticut Insurance Department (CID), the Department of Emergency Services and Public Protection (DESPP), nine individuals appointed by members of the Connecticut General Assembly with varying professional backgrounds and two individuals appointed by the Governor, one with expertise in insurance.

The CTDOT will continue working with the other AV Legislative Task Force members to recommend specific updates to Connecticut's existing AV statutes. The updated framework will provide a higher-level process for safe and efficient pilot testing and operating AV in Connecticut that is more consistent with national best practices.

New England CAV Working Group

The New England CAV working group is a coalition of state transportation agencies collaborating to facilitate the readiness for deployment of CAV in New England and the surrounding region for freight and passenger movement. In addition to the CTDOT, the other members of this working group include the state transportation agencies from Massachusetts, Rhode Island, Vermont, New Hampshire and Maine. The vision for this group is a seamless operation of CAV across New England states and surrounding regions of the United States and Canada. The focus areas for this group include legal and regulatory, technical projects, and education and training.

The New England CAV working group has highlighted multiple issues for a safe CAV future that are unique to this region. New England is a region composed of six small states with active state and local governments, and numerous and diverse urban, suburban and rural communities that have aging infrastructure and four seasons of variable weather conditions. The geographically small states with frequent cross-border travel, crossing multiple jurisdictions, requires a consistent approach to CAV regulation, policy and deployment. The CTDOT is committed to continuing its participation with the New England CAV working group to advance coordination of CAV education, resources and policies throughout the region.

The Eastern Transportation Coalition CAV Working Group

The Eastern Transportation Coalition (TETC) is a partnership of 17 states and Washington DC. TETC is focused on connecting public agencies across modes of travel to increase safety and efficiency and work together to address the pressing challenges facing the eastern corridor. TETC transportation focus areas include systems management and operations, freight and innovation, which includes CAV.

The CTDOT participates in the TETC CAV working group to advance CAV coordination, education and resources with other states up and down the east coast. This collaboration serves as a forum for sharing ideas, processes and approaches, and is an organizing body for collaboration on research projects, implementation of new ideas, and other related efforts that help to shape CAV policy.

Cooperative Automated Transportation Coalition (CAT Coalition)

The Cooperative Automated Transportation Coalition (CAT Coalition) serves as a collaborative focal point for federal, state and local government officials, academia, industry and their related associations to address critical program and technical issues associated with the nationwide deployment of CAV on streets and highways. The CAT Coalition's nation-wide membership includes representation from IOOs, OEMs, technology and service providers, and internet of things (IOT) suppliers. Moving forward, the CTDOT is committed to continuing its participation with the CAT Coalition as a means to advance CAV coordination, education and resources across the country.

American Association of State Highway Transportation Officials (AASHTO)

The CTDOT is an active member of AASHTO, which serves as a liaison between state departments of transportation around the country and the federal government. As an active member of AASHTO, staff across the CTDOT regularly participate in a variety of national committees, sub-committees, working groups and task forces on a range of issues to advance and promote IOO interests and needs in transportation, including CAV infrastructure, technology and policy, etc.

Through AASHTO, the CTDOT has been able to interact with other states, USDOT, other federal agencies, Congress and various industry groups to better understand, prepare for, and advocate IOO positions on a variety of proposed federal CAV laws, regulations, policies and guidelines. Moving forward, the CTDOT will continue to play an active role with AASHTO in promoting IOO interests and needs for CAV infrastructure, technology and policy at the national level.

CAV standards and regulations set at the state and federal level have broad planning and project effects, including the national highway system, arterials and local access roads

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Long-Term Challenges and Opportunities for Continued Evaluation

CAV is expected to have a wide variety of impacts on society, especially as CAV technological capabilities mature, and market penetration levels increase. Outlined below are some of the key CAV challenges and opportunities of greatest importance to the CTDOT. The CTDOT will continue to monitor and evaluate these issues over time.

Safety

Currently almost 95% of all roadway crashes in the United States are caused by some form of human error,[10] which kill about 40,000 Americans on the roadway each year. In a typical year in Connecticut, over 100,000 crashes, more than 30,000 injuries and more than 250 deaths are the result of human error.[11] If CAV technological capabilities continue to mature and market penetration rates of CAV technologies increase, there could be the potential for significant improvements in transportation safety. This may allow the CTDOT as well as other transportation agencies around the country to better achieve their transportation safety goals and ultimately get much closer to zero deaths on the roadway.

Shared Mobility & Accessibility

Traditional transportation mobility and accessibility options have been generally constrained by vehicle ownership models, and an individual's ability to drive or access to public transportation. This may change with the evolution of new mobility options provided by CAV.

Today, several venture capitalists, major tech firms and transportation network companies (TNC) are teaming up and investing billions of dollars in the design and testing of CAV technologies and future CAV fleets, which may revolutionize how people get around in the future, especially in urban areas. Similar to the way that existing TNC operate today, shared mobility CAV fleets would pick up passengers on-demand and take them to their destination without a driver.

Significantly reducing the cost to provide a trip (assuming efficiencies are also achieved in vehicle and technology

[10] https://www.nhtsa.gov/technology-innovation/automated-vehicles
[11] https://www.nhtsa.gov/technology-innovation/automated-vehicles

production), increases the probability that CAV fleet vehicles would be offering automated shared mobility services. If this automated shared mobility model of CAV comes to fruition, it could provide more available, efficient, cost-effective and on-demand transportation options for all users of the transportation system, regardless of an individual's income status, or physical, or mental abilities. This AV shared mobility model also enables individuals aging in place, particularly in Connecticut, where the average life expectancy is one of the longest in the United States (80+ years)[12], and where the senior population is expected to increase by 60% by 2040[13].

Travel and Congestion

Each year, the average driver in Connecticut's urban areas spends more than a full work week (more than 40 hours) stuck in traffic. These traffic jams cost each driver about $1,000 per year in the form of lost time and wasted fuel.[14] The build out for CAV requires connecting vehicle-to-vehicle (V2V) communications and integrating these systems with roadside infrastructure, generating new real-time data about how, when, and where people travel. This real-time information may help foster new mobility applications to keep traffic flowing and make it easier for people to plan and adjust their travel experience. In addition, the CTDOT and other local transportation agencies would also be able to analyze this new available mobility data to prioritize improvements that help make roads less congested, such as optimizing the phasing of traffic signals to eliminate idling and unnecessary stops and starts, etc.

Commercial Delivery Services and CAV

The growth of e-commerce and ever-faster delivery times, has increased the number of delivery trucks on roads and highways and associated congestion and wear and tear. Multiple retailers and freight companies have expressed interest in, are in the process of, or have tested autonomous trucks for deliveries between distribution centers and last-mile deliveries. This presents unique policy and operational challenges for the CTDOT and Connecticut's transportation system. CTDOT will continue to have an open dialogue with industry and monitor to mitigate potential risks associated with autonomous delivery services, while allowing for the safe integration of these vehicles into Connecticut's transportation system.

Environmental Impact

The transportation sector is a significant consumer of fossil fuels and is Connecticut's main source of Greenhouse Gas (GHG) emissions, accounting for nearly 40% of the total.[15] Connecticut has adopted statutory requirements that outline and set ambitious GHG reduction targets but achieving these targets requires the implementation of broad scale measures such as comprehensive electrification of the transportation sector. This may necessitate entire vehicle fleets that are fully battery electric along with robust investments in battery charging infrastructure to support these fleets.

CAV may have the potential to play a vital role in helping Connecticut transition to sustainable low-carbon mobility. Although the evolution of battery electric vehicles (BEV) has developed independent of CAV technologies, oftentimes BEV are serving as the platform of choice for companies producing CAV. This is especially true for automated shared mobility CAV companies that see BEV as a way for their CAV fleets to be more efficiently and cost-effectively managed, enabling more operational predictability and less reliance on fluctuations in motor fuel prices.

Economic Opportunities

The continued research and development of CAV provide the potential for an increased economic opportunity for Connecticut by combining existing capabilities of the state's various industry and knowledge sectors and fostering that environment. Because CAV have a wide cross-disciplinary context, there are corresponding

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[12] https://www.ctdatahaven.org/blog/data-connecticut-ranks-high-life-expectancy-cancer-survival-rates
[13] https://ctbythenumbers.news/ctnews/tag/seniors
[14] https://tripnet.org/wp-content/uploads/2018/08/CT_Transportation_by_the_Numbers_TRIP_Report_May_2017.pdf
[15] https://portal.ct.gov/DEEP/Climate-Change/Transportation

opportunities for Connecticut key industries and significant knowledge communities to benefit from and contribute to CAV research and development. The state's world-class industries – advanced manufacturing, aerospace and defense manufacturing, insurance, financial services, digital media, and green energy sectors, among others – as well as its universities all intersect with the CAV space. This leads to high-potential economic opportunities in the short, medium and especially the long term. By providing an ecosystem that fosters innovation and inter-disciplinary collaboration, and proactively including public and private sector stakeholders in this space, the state can be a proponent for a CAV environment that opens the door to substantial and transformative economic opportunities for Connecticut.

Planning for an Uncertain Future

The exact timeframe and extent for realizing the benefits and challenges of CAV on a system wide scale are largely unknown at this point. This makes it very difficult for the CTDOT and other resource constrained transportation agencies to make bold plans now for such an uncertain future. To mitigate this risk, the CTDOT seeks to balance its limited resources with opportunities for value-added engagement on CAV that focuses on actions for the near-term where there is greater certainty and establishes a timely feedback loop on longer-term developments to adapt as needed.

Public Acceptance

The public has some immense challenges to overcome before CAV operate widespread on public roadways. According to multiple consumer acceptance surveys conducted over the last few years, a majority of the public still say they would feel afraid to ride in a fully automated vehicle. According to a recent AAA survey, 12% of individuals who took the survey would feel safe riding in a car that drives itself, with over 51% of respondents adding that they are interested in laws that make sure CAV are safe. [16]

The public has higher safety expectations and lower error tolerances for vehicles operating without a driver than they do for traditional human-driven vehicles. Even though almost 95% of all crashes and over 40,000 of crash-related deaths in the U.S. today are caused by humans, CAV are still perceived as unsafe. Industry and researchers of AV have driven over millions of miles on public roadways with minimal safety incidents, raises the need for the public and private sector collaboration in changing this perception.

The ability to address these anxieties will require strong partnership between government and industry, specifically as CAVs become available for the public to see and experience. Addressing some of these safety concerns will most likely be achieved via CAV pilot projects that are highly visible with positive community impacts. Providing the public with ways to experience CAVs, potentially via CAV public transit or low-speed shuttles, would clearly demonstrate that non-human driven vehicles are safe and efficient. It is essential for the public to be able to experience the capabilities and limitations of the technology first-hand, so they can develop an informed perspective.

Changing User Preferences and Land Use

CAVs are expected to change the ownership model of vehicles, daily commuting patterns, and land and infrastructure use. Specifically, consumers may opt to subscribe to an AV service provided by a TNC for their daily transportation needs. Additionally, consumers may opt to live farther away from their work, as they would be able to telecommute more and/or work from the AVs as they commute to or from their office. All of these changes will have vast effects on the built environment, including road and infrastructure design, repurposing of streets, vacant parking lots, or wide intersections.

Vehicle Miles Traveled, Congestion and Green House Gas Emissions Considerations

The widespread adoption of CAVs could increase the vehicle miles travelled (VMT) as CAVs complete more point-to-point trips and shared trips. These additional trips could also increase the number of vehicles on roads, congestion in urban centers, while also increasing GHG emitted by CAVs on roads. GHG reductions may take place as electric vehicles and associated charging infrastructure become

[16] https://newsroom.aaa.com/tag/autonomous-vehicles/

more affordable and commonly available. Greater GHG reductions are expected as electric vehicles (or other non-GHG producing vehicle fuels) are adopted for all aspects of the surface transportation system, including TNC AVs, truck and delivery vehicles, transit, or vehicles owned by individuals.

New Costs and Decreasing Revenues

To allow for the safe and efficient operation of CAV, it will be necessary to have infrastructure in a SOGR. This will require the repair and upgrade of existing roadway infrastructure, including pavement surfaces, painted markings, and traffic control devices, etc. It may also be necessary to implement new infrastructure and equipment in order to realize certain connectivity benefits of CAV—this could include installing new roadside devices, variable message signs, wireless networks, fiber backhaul communications and upgraded traffic signal controllers and central software. This, coupled with potentially decreasing personal vehicle ownership and tax revenues from vehicle registrations and fuel taxes, could create a significant budget shortfall for the CTDOT. Though some of the costs for this new and improved infrastructure and equipment may be split between private companies, such as CAV manufacturers, and different levels of government (municipal, state, and federal), other costs such as supplying required power and data connections may fall entirely on government bodies. There will also be costs associated with the administration of CAV test programs and research—again, these are likely to be divided between government, private sector, and institutional bodies. Modeling and studies relating to CAV can help identify the implications of specific policies or cost-sharing alternatives.

Laws & Regulations

There will be a long adjustment period preparing for and adapting to CAV. This adjustment period will likely span multiple decades starting well before the first batch of CAV enter the marketplace and continuing long after CAV become the majority of vehicles on the roadway. During this adjustment period, all levels of government will be tasked to work with the private sector in reviewing, updating and enacting new safe and effective laws and regulations for CAV. The extent and timing of these laws and regulations will be very important. Knowing whether, when and how to legislate and regulate appropriately will be key. It is essential that these laws and regulations strike a balance between advancing CAV technological capabilities, ensuring safety and managing risks.
To avoid a patchwork system, it is also extremely important that the writing of CAV laws and regulations be coordinated and consistently implemented across the United States and that the roles and responsibilities between and within the public sectors and private sectors be made abundantly clear. For example:

- Automakers and device manufacturers need to work with the public sector to dictate the capabilities and availability of CAV technologies and equipment;
- Federal government needs to work with the private sector and the states to oversee and regulate the safe design, construction and performance of CAV technologies and equipment; and
- State and local governments need to work with the federal government and the private sector to oversee the operation of CAV on public roadways, the licensing and training of human drivers, the registering and titling of CAV, the establishment of new insurance limits and liability rules and the reviewing and updating of impacted local traffic laws and regulations.

Standards and Interoperable Platforms

Some of the challenges that several transportation agencies face with CAV are the uncertainties presented by a rapidly evolving industry in which only a few industry-wide standards exist, and in which even fewer industry-wide standards have been broadly adopted or deployed. Vehicle and infrastructure standards often take a long time to develop, and some may become outdated by new technology or innovations when they are finalized, which may especially be true with CAV. However, the development of standards is still crucial to ensure uniform market penetration of CAV and uniform operation of CAV on public roadways. The CTDOT and other IOOs design their transportation infrastructure to meet specifications within standards. Without these specifications, it will be increasingly difficult for the CTDOT and other transportation agencies to boldly invest in new infrastructure required for CAV.

It is essential for industry and government to work together to ensure that the various in-vehicle sensors, roadside equipment, radio, cellular and cloud-based CAV technologies being developed today are interoperable. While it is important to encourage increased competition within and between industries to continually provide better quality technologies, it is also important to ensure that there are common platforms for these technologies to communicate and function outside of their proprietary domain.

Transportation agencies and other stakeholders who will invest in various CAV technologies want to ensure these technologies can be used however they need them, including interoperation with other technologies. CAV technologies built on interoperable platforms will increase the likelihood for more robust construction of transportation infrastructure that is compatible with CAV, thus further increasing the momentum for greater market penetration and uniform operation of CAV on public roads.

DSRC and 5.9 GHz Uncertainty

Most CVs currently operate using a protected band on the 5.9 GHz radio spectrum. Though USDOT originally envisioned DSRC to be “the” enabling communications protocol for CVs, in recent years USDOT has altered its policy to take more of a technology neutral approach, putting more emphasis on industry competition to choose the most effective transportation mobility solutions. In late 2019, the Federal Communications Commission (FCC) proposed to split the 5.9 GHz band for use by intelligent transportation systems (ITS) and WIFI, despite its current use for transportation purposes across the U.S. The FCC argues that splitting the frequency maintains its use for ITS and opens up the remaining frequency for unlicensed use, primarily in the form of additional Wi-Fi frequency. Additionally, the FCC reasoned that the safety critical communications DSRC provides could be provided by C-V2X and future 5G.

5.9 GHz and its designation as the safety band are vital to the interoperability and safe operation of CAVs. Most CV deployments over the past ten years have used the 5.9 GHz safety band as their primary means of communication, with auto OEMs developing DSRC / 5.9 GHz products. Multiple state and local transportation agencies have already invested in 5.9 GHz-related infrastructure upgrades, including DSRC-capable traffic signals and roadside units. The lack of 5.9 GHz’s designation by the Federal government has created significant uncertainty and hampered state, local and industry efforts to further deploy and test CVs and related infrastructure and slowing the development of a safe CAV future.

Information Sharing

With much of the CAV developments around the world happening within small or proprietary circles, broad public access to meaningful information, especially about evolving CAV technological capabilities and constraints is limited. As a result, there is a high risk for public and private investment in CAV to not be utilized efficiently and for duplicative efforts to be commonplace. These inefficiencies may result in some research efforts running out of funding before they can produce valuable results, or they could also become a barrier preventing some other pilots and demonstrations from taking place at all. To address these inefficiencies, as the research, development and deployment of CAV continues over the coming decades, it is essential for the public and private sector entities conducting these activities to broadly share lessons learned and best practices so that all stakeholders can continuously provide and receive value-added information towards the advancement of CAV.

Preparing Workforce

CAV has the potential to displace large portions of Connecticut’s workforce and remake sectors of the economy. Addressing displaced workers and sectors that are negatively affected by CAV will require substantial collaboration between industry, government and the public to tackle together. According to the Connecticut Department of Labor, as of 2020, over 49,000 people[13] in Connecticut are employed in transportation or warehousing occupations. This sector will likely be the most affected by the arrival of CAV, since buses, taxis, trucks, and delivery vehicles may no longer require a driver. However, the operations and maintenance of CAV, and other highly skilled technology positions may increase demand, requiring skillsets in both automotive industry and information technology sector.

Many transportation agencies, including the CTDOT and other IOOs lack the financial resources and expertise in areas such as machine learning, systems engineering, computer science, wireless communications, and data management that are most likely required to oversee new forms of transportation under a CAV future. Large portions of the CTDOT’s workforce are also expected to retire over the coming years. It is not only essential that outgoing positions be filled, but that the CTDOT also staff up and prepare the workforce with skills that meet both current and future (evolving) needs. Limited resources, partnerships with the private sector, universities and other transportation agencies may play a large role to fulfill this need.

CAV Transit

In the future, CAV technologies will likely provide increased mobility options for public transportation users. While fixed route bus and rail services are likely to remain the norm in highly populated urban areas, CAV may offer a better transportation solution for suburban and rural communities. Also, CAV may help to finally solve the last mile problem for public transportation and the need for CAV to be integrated at transit hubs should be a priority going forward.

Safety, Accessibility and Affordability of CAV

Industry must build safe, accessible, and affordable vehicles for all users, regardless of physical or mental abilities. Currently, much of the AV and CV technologies tested today are tremendously expensive and designed to operate in only limited environments, creating serious limitations for users or their operation in challenging weather/road conditions. As CAV technology progresses, the production cost of these vehicles must come down. It is essential that these vehicles be accessible to all users and are able to operate in all environments and conditions, especially on complicated roadways, in mixed fleets and be able to safeguard against human errors and misuse of the technology.

Security and Privacy

The relative infancy of CAV technologies means that a number of questions still remain regarding the algorithms, computer systems and networks that will operate and connect these vehicles. Much like existing computers, smartphones, and tablets, significant concerns have been raised over numerous data, system privacy and security issues. What data will be collected? How will the data collected be used, stored, or shared? Who owns this data? Are CAV susceptible to malware and computer virus codes? What are the risks for secure networks or systems to be hacked? The answers to these questions will be critical, as a single vulnerability or error could prove fatal and/or run the risk of ruin, jeopardizing the safety and security of entire fleets and networks. Developing proper security-credential management systems for the safety of CAV networks, ensuring proper access and use of data and protecting personal safety and privacy against malicious activities are all huge CAV challenges for both industry and government to tackle together in the coming decades.

Ethics

It is also important to consider which groups will be responsible for determining the ethical “rules” that will govern the decisions of CAV on the road. Finding a consensus amongst industry and government on the ethical decision-making of CAV will be an immense challenge for society to solve. This includes establishing consistent and acceptable rights and wrongs for CAV to abide by when their operational scenarios present no good outcome, where both individuals lives and damages are at risk.

CAV technologies present unique challenges and opportunities to Connecticut’s multimodal transportation system

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Conclusion

The CTDOT's approach towards CAV is broad and multifaceted, focusing on developing technical, demonstrative, and research-oriented entry into an emerging and dynamic field in the transportation systems. As a multi-modal agency in one of the country's most technologically robust test-bed regions, Connecticut is positioned to be at the forefront of deploying CAV technology, and monitoring its progress towards the many benefits referred to throughout this document. As a living document, the CTDOT can adjust its approach and adapt to the emerging CAV trends and technologies as they evolve.

The CTDOT is committed to routinely updating this CAV Plan, staying current with recent developments and ensuring better preparedness for a CAV future. The alignment of the agency's mission and potential CAV benefits including safety, air quality, mobility, and congestion management further reinforces the need to remain engaged with CAV activities. Subsequent updates to the CAV Plan will allow the CTDOT to be responsive to new and changing conditions, keeping the CTDOT's preparations relevant to the rapidly changing landscape of CAV technologies.

The CTDOT purposefully focused on short term key objectives and actions in the development of this plan, given the uncertainties regarding CAV technologies and ever-changing regulatory landscape. Actions of the plan focused on developing both internal CTDOT resources (i.e. staff capabilities) and external actions. These actions include both high-impact and highly visible projects and programs, like the pursuit of CAV research funds for CAV deployment on CTfastrak, preparing infrastructure for a "connected" future (i.e. SPaT Challenge), and additional actions (i.e. New England CAV Working Group, CAT Coalition) have been committed to, furthering consensus regarding the region's CAV approach.

As CAV technologies mature and the regulatory landscape further solidifies, the CTDOT has committed to routinely updating the plan and its project and program approaches to a CAV future. This may manifest in the development of additional chapters or subsections within this document to include aspects of CAV that are mode or topic specific, like CAV and Transit, or CAV operations on the Berlin Turnpike. The CTDOT is likely to develop longer-term oriented CAV objectives and actions in future updates.

07 Appendix A: Acronyms List

AAA	American Automobile Association
AASHTO	American Association of State Highway and Transportation Officials
ADAS	Advanced driver-assistance systems
ADS	Automated Driving System
ATSPM	Automated Traffic Signal Performance Measures
AV PFS	Automated Vehicle Pooled Fund Study
BEV	Battery Electric Vehicles
BRT	Bus Rapid Transit
CAT	Cooperative Automated Transportation Coalition
CAV	Connected and Automated Vehicle
CID	Connecticut Insurance Department
CRCOG	Capitol Region Council of Governments
CTDOT	Connecticut Department of Transportation
CTE	Center for Transportation and the Environment
CV PFS	Connected Vehicle Pooled Fund Study
C-V2X	Cellular Vehicle-to-Everything Communications
DESPP	Department of Emergency Services and Public Protection
DMV	Department of Motor Vehicles
DOT	Department of Transportation
DSRC	Dedicated Short Range Communications
FCC	Federal Communications Commission
FHWA	Federal Highway Administration
FTA	Federal Transit Administration
GHG	Greenhouse Gas
IEEE	Institute of Electrical and Electronics Engineers
IOO	Infrastructure Owner Operator
IOT	Internet of Things
ITS	Intelligent Transportation Systems
LSAV	Low-Speed Automated Vehicles
MUTCD	Manual on Uniform Traffic Control Devices
NHTSA	National Highway Traffic Safety Administration
OBU	On-Board Unit
OEM	Original Equipment Manufacturer
OPM	Office of Policy and Management
RSU	Roadside Unit
SAE	Society of Automotive Engineers International
SOGR	State of Good Repair
TETC	The Eastern Transportation Coalition
TNC	Transportation Network Company
USDOT	United States Department of Transportation
V2I	Vehicle-to-Infrastructure Communications
V2N	Vehicle-to-Network Communications
V2P	Vehicle-to-Pedestrian Communications
V2V	Vehicle-to-Vehicle Communications
V2X	Vehicle-to-Device Communications
VMT	Vehicle Miles Traveled

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