



Connected and Automated Vehicle Program Plan

Fall 2017



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Acronyms

AV	Autonomous Vehicle
AASHTO	American Association of State Highway and Transportation Officials
API	Application Programming Interface
ASTM	American Society for Testing and Materials
ATMS	Advanced Transportation Management System
BSM	Basic Safety Message
CAV	Connected and Automated Vehicles
CCB	Change Control Board
CTB	Commonwealth Transportation Board
CV	Connected Vehicle
CV PFS	Connected Vehicle Pooled Fund Study
CVI	Connected Vehicle/Infrastructure
DSRC	Dedicated Short Range Communications
FCC	Federal Communications Commission
HAV	Highly Automated Vehicles
HAR	Highway Advisory Radio
IEEE	Institute of Electrical and Electronics Engineers
ITE	Institute of Transportation Engineers
ITS	Intelligent Transportation Systems
ITSVA	Intelligent Transportation Society of Virginia
IVHS	Intelligent Vehicle-Highway Systems
JPO	Joint Program Office
KSAs	Knowledge Skills and Abilities
MaaS	Mobility as a Service
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
OBE	Onboard Equipment
OEM	Original Equipment Manufacturer
RSE	Roadside Equipment
SAE	Society of Automotive Engineers
SDO	Standards Development Organization
SORAC	Systems Operations Research Advisory Committee
SPaT	Signal Phase and Timing
STSMO	Subcommittee on Transportation Systems Management and Operations
TaaS	Transportation as a Service
TED	Traffic Engineering Division
TIM	Traffic Information Message
TMPD	Transportation and Mobility Planning Division
TOC	Transportation Operations Center
TRB	Transportation Research Board
TSM&O	Transportation Systems Management and Operations
TVD	Transportation Video and Data
TWG	Technical Working Group

USDOT	United States Department of Transportation
UTC	University Transportation Center
UVA	University of Virginia
V2I	Vehicle to Infrastructure
V2I DC	Vehicle to Infrastructure Deployment Coalition
V2V	Vehicle to Vehicle
VCC	Virginia Connected Corridor
VDOT	Virginia Department of Transportation
VII	Vehicle-Infrastructure Integration
VTRC	Virginia Transportation Research Council
VTI	Virginia Tech Transportation Institute

Executive Summary

The development and adoption of Connected and Automated Vehicles (CAV) is moving at a rapid pace. As these vehicles begin to appear on publicly owned roads in significant numbers, those who own and operate the roads need to be prepared for their impacts. These emerging technologies will impact every aspect of the Department, including operations, construction, maintenance and information technology, as well as the potential impacts to the way the department funds its day-to-day operations and looks at partners. Preparing for a future of CAV will require the Virginia Department of Transportation (VDOT) to develop new policies, programs and partnerships, address rapidly changing technologies and the need to deploy and maintain those technologies, manage and analyze new data from a variety of new sources and address the funding needs associated with both the implementation of new roadside and backend technologies and the impacts these new vehicles may have on funding. As a result, VDOT will also need to develop and implement a plan to address the impacts of this paradigm shift in mobility. This document provides a strategic roadmap to guide VDOT in the deployment and sustainment of CAV technologies and solutions.

VDOT's vision for CAV is to **capitalize on the safety and operational benefits** of CAV technologies to meet its goals and objectives. VDOT also has the vision to position Virginia as **the most attractive state** for industry to deploy, test, operate and evolve CAV products and services.

The goals and objectives of VDOT's participation in the CAV program are focused on four key areas:

- Reduce crashes and fatalities on Virginia roadways by improving safety measures.
- Improve mobility to reduce delay, increases system reliability and provides more efficient use of physical infrastructure.
- Reducing infrastructure investments through efficiencies enabled by the conversion of vehicles that are connected and automated
- Enhance traveler information

The deployment of CAV technology and applications will be a phased approach spread out over the next 20 years. The technology in the vehicles will evolve as market penetration increases. The CAV Program Plan provides phased strategies and strategic actions that will prepare the Department for the resulting changes as the technology becomes integrated into standard business practices. The overarching strategy of the program focuses on preparing the organization for the future rather than on prioritizing individual projects or development efforts. This high-level guidance is intended to provide strategic actions to help VDOT achieve its vision of capitalizing on safety and operational benefits and on attracting industry to the Commonwealth of Virginia.

The approach to the plan implementation is two-fold. Foremost, focus on the strengths that make Virginia unique to an early, successful deployment of technology. Secondly, support research, development and implementation using a needs-based approach.

Successful plan implementation will require that VDOT rely on the diverse resources that are unique to Virginia. The key resources and differentiators which will ultimately be leveraged include:

1. VDOT owned and operated roadways with diverse urban, suburban, and rural characteristics, including a large network of High Occupancy Toll (HOT) lanes
2. An “Open-for-business” regulatory environment for innovative transportation solutions
3. Statewide mature, robust, and supported networking and cloud-based data services
4. Trusted world-class research and testing capabilities
5. Local leadership and expertise in cybersecurity, including military partners
6. A strong knowledge-based economy with a large and growing, highly trained workforce to support the technology sector
7. Proximity to Washington, D.C.
8. Four season testing
9. Diverse infrastructure
10. Extensive managed lanes (HOT lanes) network to test and operate
11. Knowledge based economy

To prepare for the future of CAV in Virginia, the DOT has developed an internal series of near-term and mid- to long-term actions that are technical in nature and focus on partnerships and external coordination:

- Organizational Actions:
 - Identify and designate roles and responsibilities for the CAV Program Manager, CAV Deployment Lead positions and other key staff
 - Launch the CAV Program Plan Department wide to internally promote and support the creation of a culture of innovation and proactive integration of CAV technologies into plans, programs and projects
 - Coordinate and convene Executive Steering Committee for the CAV Program
- Technical Actions and Activities:
 - Focus on development and early deployment activities.
 - Demonstrate the capabilities and benefits of CAVs
 - Integrate CAV strategies into the long-term planning and programming processes
 - Develop a data architecture plan and strategy
- External Partnership-Related Actions:
 - Track technology advances that will impact the CAV program
 - Develop an external stakeholder outreach, communication and coordination strategy that is coordinated with the VDOT CAV strategy

As the technologies associated with CAV continue to advance, VDOT will take mid- and long-term actions to ensure continued success with CAV programs and implementations. Due to the rapid changes in the industry, these actions cannot be defined as tightly as the near-term actions. However, VDOT has identified three key actions to support mid-term and long-term planning

efforts, including the development of:

- Develop Mid- and Long-Term Implementation Plans
- Establish Deployment Guidance for Stakeholders
- Develop CAV Standards and Specifications

To accomplish this vision, VDOT needs key resources dedicated to the implementation of the CAV program plan. These key resources include staffing, contracting/partnering and funding for implementation, operations and maintenance. Full-time leadership, contract support, partnerships in both the public and private sectors, an investment plan, and education are critical for program success and the achievement of VDOT goals. The success of both short- and long-term VDOT CAV visions will rely on effective contributions of contract staff, automotive industry and university research under championship of VDOT leadership.

1 Purpose

This document provides a strategic roadmap to guide the Virginia Department of Transportation (VDOT) in the deployment and sustainment of Connected and Automated Vehicle technologies and solutions, which are expected to bring transformative change to the safety and efficiency of surface transportation. State and local transportation agencies will be impacted by these changes and it is imperative that VDOT is fully prepared to leverage Connected and Automated Vehicle technologies in fulfilling its mission.

2 Vision

VDOT's vision for CAVs, is to **capitalize on the safety and operational benefits** of CAV technologies to meet its goals and objectives. VDOT also has the vision to position Virginia as **the most attractive state** for industry to deploy, test, operate and evolve CAV products and services. The key resources unique to Virginia are listed below and the strengths of Virginia are detailed in **Figure 2.1**.

1. VDOT owned and operated roadways with diverse urban, suburban, and rural characteristics, including a large network of High Occupancy Toll (HOT) lanes
2. An "Open-for-business" regulatory environment for innovative transportation solutions
3. Mature, robust, and supported networking and cloud-based data services
4. Trusted world-class research and testing capabilities
5. Local leadership and expertise in cybersecurity, including military partners
6. A strong knowledge-based economy with a large and growing, highly trained workforce to support the technology sector
7. Proximity to Washington, D.C.
8. Four season testing
9. Diverse infrastructure
10. Extensive managed lanes (HOT lanes) network to test and operate
11. Knowledge based economy

VDOT's proximity to Washington, D.C., puts Virginia in the spotlight with respect to both testing and demonstration from the USDOT and other Federal agencies involved in CAV development activities, potentially coordinating with VDOT and using VDOT infrastructure for those tests and demonstration. Likewise, many federally legislators either travel through or live in northern Virginia, giving VDOT the opportunity to showcase its investment and the resulting impacts.

Three other components factor in to the success of the CAV program in Virginia. First, Virginia has four seasons, experiencing heat and humidity, cold and snow and significant weather from hurricanes and other major events. This diversity presents an opportunity for industry to do research and development in Virginia in varied weather conditions. Secondly, Virginia is often referred to as the mid-point of I-95 where travelers using the I-95 corridor traveling from the

northeast United States to the southeast stop as a mid-point along the journey. As a result, deployments in Virginia need to be coordinated with all the surrounding states to insure interoperability – no “one-off” type deployments are permitted. Finally, the geography and economic climate within Virginia will require the deployment to be truly multi-modal, working not just on passenger vehicles, but buses, trucks and freight vehicles, trains and other modes. These three factors, taken in combination with the seven unique factors above will position VDOT to lead in the development and deployment of a state-wide, multi-modal system that can operate in a wide range of environments.

VDOT’s embrace of new and emerging mobility technologies has created a culture of innovation as new technologies are developed, deployed, operated and maintained across the Commonwealth. This culture of innovation will help Virginia take advantage of those technologies to optimize the anticipated benefits of these technologies. Automation alone will not provide the desired system benefits in terms of overall mobility, safety and efficiency; although it is likely to result in crash reductions as market penetration increases. VDOT will take a proactive role in the planning and implementation activities to support the adoption and operations of CAVs. This approach will enable VDOT to support a thriving CAV program that directly benefits travelers and citizens throughout Virginia that reduces the frequency and severity of crashes, reduces congestion and improves situational awareness of its roadway network. Finally, this approach will also permit VDOT to focus on the future needs associated with traffic management and operations and likely reduce the need for traffic control infrastructure.

The Operations Division developed a CAV Program Plan when leadership recognized the need to formalize the Department’s efforts. **Action Item 3.2.2** from VDOT’s FY 16 Business Plan provides the objective to develop a statewide Connected Vehicle Program Plan. As referenced in the FY16 Business Plan, the objective of the CAV Program Plan is to maximize the safety and operational benefits of these emerging technologies, to outline the department’s vision of the future state of CV technologies, the impact of that future state on transportation within the commonwealth and define strategies that VDOT will plan to utilize to take advantage of the technology.

Furthermore, the Program will strive to concurrently reduce infrastructure costs and improve State of Good Repair to repurpose spending from obsolete assets to core needs and innovative approaches. Over time, CAV technology implementations will help to drive VDOT toward reduced overall public-sector transportation infrastructure investment.

The objectives envisioned through this plan are expected be realized at various points in the future as CAV technologies mature and become more widely available. Accordingly, this plan identifies and describes further in Sections 5 and 6:

- Near-Term Development of Foundational Elements
- Mid-Term and Long-Term Strategies
- Program Management Approach

This plan is a living document that will be reviewed and revised periodically to address changes in technology and within VDOT.

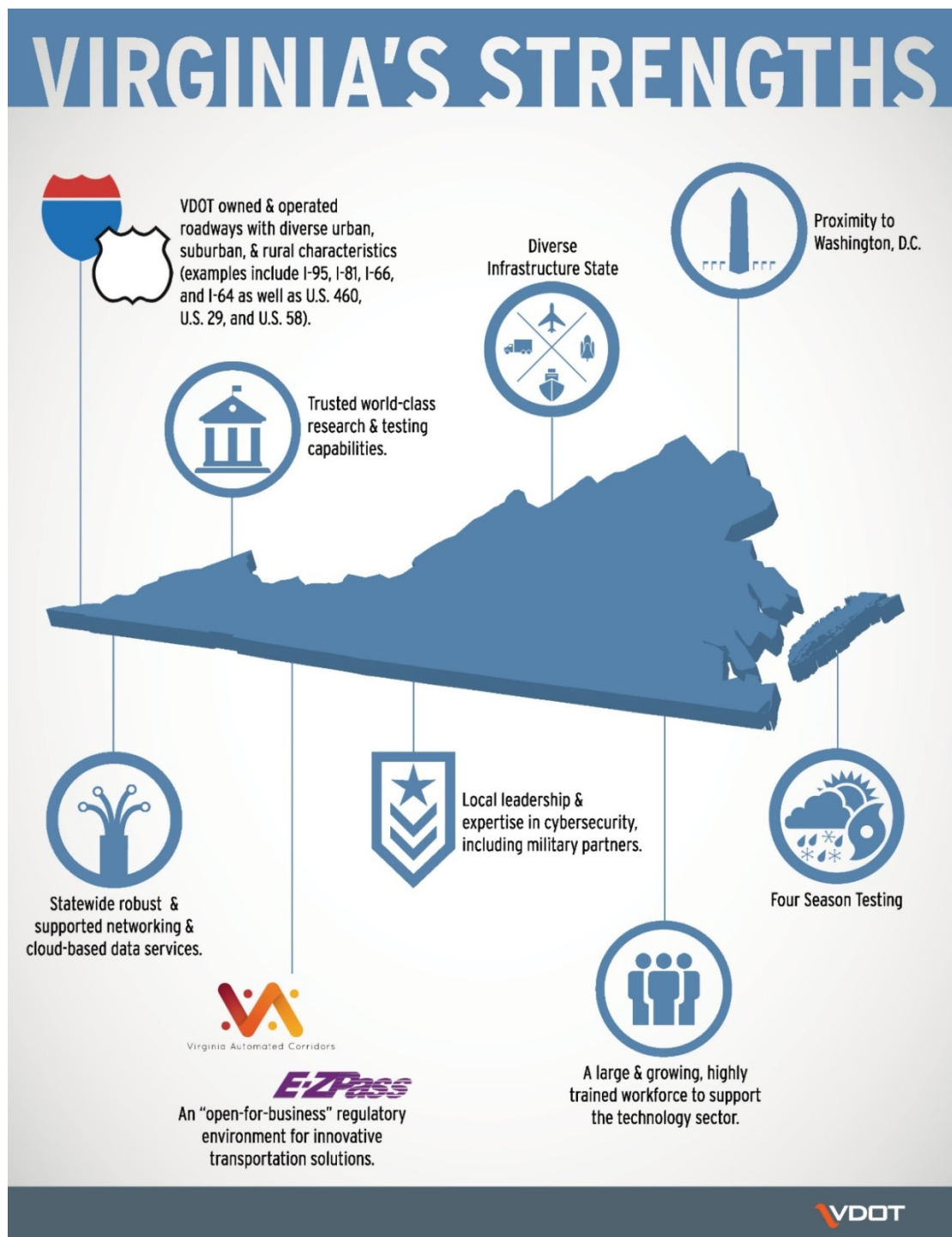


Figure 2.1 –Virginia’s Strengths to Advance CAV

3 Goals and Objectives

Alongside imminent advances in vehicle technology, which are primarily led by the private sector, VDOT's role in delivering the infrastructure needed to allow for efficient surface transportation for the Commonwealth will continue. For example, VDOT will continue to be responsible for work zones needed to maintain a state of good repair of the roadways and for signal operations at intersections. VDOT envisions a future environment where Connected and Automated Vehicle applications provide connectivity between vehicles, roadside infrastructure and wireless devices. This interconnected environment is expected to meet the following objectives:

Increased Safety

CAV safety applications will enable vehicles to have 360-degree awareness of hazards and situations that vehicle operators cannot see. These safety applications have the potential to reduce crashes through advisories and warnings and ultimately removing the driver from the responsibilities associated with vehicle operations. For example, through audible and visual alerts, drivers may be advised about school zones, sharp ramp curves, pedestrians or icy road conditions; and may be warned in more imminent crash situations, such as during merging operations or if the vehicle ahead stops suddenly. These applications will help the Department meet its goals in reducing the frequency and severity of crashes, injuries, and fatalities on roadways within the Commonwealth.

Improved Mobility

Connected and Automated Vehicle mobility applications are intended to provide a connected, data-rich environment based on information transmitted anonymously from thousands of vehicles in real time. This information can help transportation managers monitor and improve transportation system performance – for example, by adjusting traffic signals, enhancing transit operations, or dispatching maintenance crews and emergency services. Mobility may also be improved because of collision avoidance technologies preventing crashes. Additionally roadway capacity could be improved through reduced vehicle headways. This information can also help public agencies and private Mobility as a Service (MaaS) and Transportation as a Service (TaaS) operators manage fleets more efficiently. Existing targets to improve highway performance and mobility are focused around providing congestion-free travel on the interstates every day. Additional targets are currently being developed that seek to measure and improve upon incident duration reduction.

Mobility will also be improved through increased accessibility to transportation when fully autonomous vehicles become operational. The impacts to society will be modeled and measured in more detail as the technology becomes more readily available.

Reduced Infrastructure Investments

Over time, connected vehicle environments are expected to reduce the need for new infrastructure investments. For example, reductions in signage may be realized as information is sent directly into vehicles; roadway cross sections could be reduced or we may see reductions in

guard rail as cars gain latitudinal control features; and reductions to intersection controls may be seen when cars can communicate with each other directly to avoid conflicts.

Enhanced Traveler Information

Providing travelers with real-time information about traffic congestion and other travel conditions helps them make more informed decisions. This information should be provided through prioritized dissemination channels based on cost effectiveness to reach the largest number of people, including vulnerable communities. Informed travelers may decide to avoid congestion by taking alternate routes or public transit, or by rescheduling their trip. The ability for vehicles to communicate with infrastructure can allow drivers to have additional information to help them make better decisions as they travel. For example, it could help a vehicle traverse a signalized corridor at an optimal speed to reduce stops. The use of enhanced traveler information can be measured quantitatively and qualitatively through the number of partners consuming VDOT's data feeds, the reach of their dissemination channels, and through regular outreach to measure their satisfaction partners with the enhanced traveler information.

As the shift continues toward fully-automated vehicles, the traveler information system will become more integrated within the systems of those operating the overall control systems of automated vehicles and MaaS and TaaS providers to support their operations. The needs for detailed, granular operations and infrastructure condition data will become more critical. However, it is also anticipated that new partnerships will evolve with the private sector to potentially collect, process and distribute traveler information.

4 Current Initiatives

As CAV technology evolves, early adopters are identifying best practices from their research efforts and applying them to design and deployment initiatives in live roadway environments. VDOT has been actively engaged in many national and local initiatives over the past ten years. In this time, VDOT has seen a shift in focus from research and theoretical studies to a focus on implementing deployments as the technology has matured. VDOT's involvement in these initiatives allows for the opportunity to take part in and be a strong leader in the national discussion. It also allows VDOT to quickly learn from and adapt to best practices as lessons are learned from on-going deployments across the globe.

4.1 National Initiatives

The national CV program is a direct outcome of the Federal Communications Commission's allocation of 75MHz in the 5.9GHz band dedicated to vehicle safety applications. The USDOT, through FHWA, NHTSA and the ITS JPO, along with other modes, have taken an active lead in the advancement of the technologies and standards needed for a national deployment of this technology. The automotive industry has been aggressively supportive of the program as well, including all the automakers, including the Collision Avoidance Metrics Partnership (CAMP), the Society of Automotive Engineers (SAE), IEEE and others in the development of standards,

applications and testing the standards, hardware and applications that comprise the overall program.

In 2014, NHTSA issued a Notice of Proposed Rulemaking (NPRM) for Motor Vehicle Safety Standard 150 (MVSS 150), announcing that it was their intent, after significant research, development and testing, to mandate the implementation of Vehicle to Vehicle (V2V) technology in all new vehicles sold in the United States. The focus of the NPRM was on the use of the spectrum dedicated by the FCC for the program. In January of 2017, NHTSA issued the draft rule and requested comments from the industry on that draft rule that largely followed the NPRM but was broader in terms of the technology options for V2V communications. It is expected that NHTSA will issue the final rule in 2019 which will mandate implementation in all new vehicles sold in the US by 2023. Research and development will continue by the USDOT, the automakers and the automotive industry as a whole over the coming years as they all prepare for implementation of the V2V rule.

In 2016, NHTSA issued a draft AV policy that lays out NHTSA's vision for how autonomous vehicles will be regulated in the future. This policy was needed because the industry was rapidly developing AV technologies for passenger cars, with some automakers expecting fully autonomous vehicles available for purchase as early as 2021.

There has been currently significant Congressional action focused on Automated Vehicles in 2017 and committed to a 2018 update based on the ongoing Congressional action. NHTSA released an update to their 2016 AV policy in September 2017, "Automated Driving Systems: A Vision for Safety." The 2017 Guidance appear to offers a general softening from a regulatory standpoint reflective of the new administration and no major policy shifts.

4.1.1 USDOT Connected Vehicle Research Program

USDOT funds research that supports the development of CV technology, standards, policies and applications. This ongoing research is developing prototype applications that address real-world safety, mobility, and environmental concerns. These applications are being developed by a community of consultants and research experts and are in varying levels of maturity, ranging from Concept of Operations to deployment in research test beds. USDOT provides CV workshops and webinars to keep public agencies current on emerging technical standards, proposed rule-making and funding opportunities. USDOT also invests in pilot sites to design, deploy, and evaluate CV deployments.

More information about the USDOT Connected Vehicle Research Program is available at https://www.its.dot.gov/research_areas/connected_vehicle.htm.

4.1.2 Connected Vehicle Pooled Fund Study (CV PFS)

CV PFS is a partnership of more than 20 transportation agencies, led by VDOT, which facilitates the development and evaluation of CV applications. Since its establishment in 2009, the program prepares state and local transportation agencies for the deployment of CV technologies.

Most recently, the CV PFS has focused its research efforts on deployments to demonstrate the effectiveness of CV applications. USDOT has recognized the effectiveness of this group and has funded many projects that are of importance to the transportation owners such as a connected vehicle signal system that facilitates efficient movement and prioritization of all modes of transportation.

VDOT is the chair of the CV Pooled Fund Study and coordinates agendas, meetings, and memberships.

More information about the CV PFS is available at <http://www.cts.virginia.edu/cvpfs>.

4.1.3 NCHRP Connected and Automated Vehicle Research Program

The National Cooperative Highway Research Program (NCHRP) conducts studies to address real-world needs within the transportation industry, including the advancement of CAV research. NCHRP is administered by the Transportation Research Board (TRB) and sponsored by AASHTO members. VDOT serves on multiple NCHRP Project panels to help shape and guide the future of research activities. NCHRP has funded research to address policy, planning and deployment impacts of CAVs on transportation systems, specifically addressing key concerns and providing planning tools to enable deployment.

More information about the latest NCHRP research on CAV is available at <http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=3824>.

4.1.4 AASHTO Committee on Transportation System Operations

The Committee on Transportation System Operations focuses on three areas: operations, wireless communication, and highway transport. The committee shall be responsible for all aspects of vehicle operations, communications, and systems management on the highway system, including passenger and commercial vehicle operations. This committee strives to transform the national transportation community to a transportation systems management and operations (TSMO) culture that focuses on effectively managing and operations the surface transportation system in order to reduce crashes, injuries, fatalities and improve network efficiency and system mobility. TSO also guides the National Operations Center of Excellence and the Operations Technical Service Program, in collaboration with ITE and ITS America.

AASHTO recently underwent a restructuring to improve strategic alignment between Board of Directors and Technical Committees. As a result, a new committee structure is in the process of being implemented. VDOT is part of the leadership team for the Committee and has active participants in the various subcommittees.

There will remain a subcommittee focused specifically on CAVs and VDOT has been an active member since the CAV subcommittee was launched. This has allowed VDOT staff to provide valuable input into the production of documents such as the *National Connected Vehicle Field Infrastructure Footprint Analysis*, which lays out deployment strategies for state and local agencies as they build out connected vehicle infrastructure. In fact, the deployment approach in the Footprint Analysis was followed in the development of this document. The AASTHO CAV subcommittee is also responsible for developing and promoting a nationwide challenge for states to deploy Dedicated Short-Range Communication (DSRC) radios that have the capability to broadcast basic message sets to support CV applications, such as those that include signal, phase, and timing (SPaT) information, at a minimum of 20 intersections. The goal of this challenge is to develop equipped corridors throughout the country to show a commitment of roadway owners and operators to deploying CV technologies. The SPaT challenge was adopted by AASHTO in 2016 and launched in 2017.

More information about the AASHTO Committee on Transportation Systems Operations is available at <http://stsmo.transportation.org/Pages/Connected-Vehicles.aspx>.

4.1.5 Vehicle-to-Infrastructure Deployment Coalition (V2I DC)

In 2015, AASHTO, ITE and ITS America established the V2I DC to bring industry experts and stakeholders together to help move the deployment of CAV technology forward in a coordinated fashion, while broadening the conversation to increase stakeholder involvement. Under this deployment coalition, five technical working groups were established that each have a specific focus with a common goal of resolving issues to advance the deployment of V2I technologies. VDOT has participated in the V2I DC as a member of TWG #2 – Deployment Research, TWG #3 – Infrastructure Owner, OEM and Supplier Partnerships, and TWG #4 – Deployment Guidance.

VDOT has participated in several meetings of the V2I DC to coordinate CV Pooled Fund Study research and provide input to coalition activities.

More information about the V2I DC activities is available at <http://transportationops.org/V2I/about>.

4.1.6 Interstate 95 Corridor Coalition (I-95 CC)

In 2016, VDOT assisted the I-95 Corridor Coalition in setting up a Connect and Automated Vehicle Workshop to help provide guidance to states on where technology is headed and what states can do to prepare for CAV. The I-95 CC continues to provide guidance to its membership about the future of CAV and VDOT is an active participant.

4.2 Initiatives within Virginia

In addition to its participation in national CV initiatives, VDOT has been actively researching, planning and deploying connected vehicle technologies in Virginia since 2004. The following on-going initiatives show VDOT's dedication to advancing the technology. This Plan will help to encourage the inclusion of CAV technology and anticipated benefits to be considered for inclusion in efforts throughout the Department. For example, the commonwealth's statewide long-range plan, VTrans2040, and the 2017 Virginia Highway Safety Plan both include CAV topics within their respective plans. The current initiatives have poised VDOT to be a leader in the field by attracting the interest and involvement of auto manufacturers, auto suppliers, developers, and other parties required to move the national program from research into meaningful deployments in Virginia.

VDOT's experience in working with connected and automated environments has found that a successful CAV program will be reliant on four key focus areas:

1. Infrastructure deployments to collect data and disseminate information,
2. Fleet vehicles to receive and transmit data,
3. Data availability and the effective management of that data, and
4. Development of applications to transform the data into useful information.

Additionally, the CAV Program is meant to support VDOT's specific goals and other programs and plans, which include the specific operational goals as shown in **Table 4.1** which was developed as part of VDOT's response to a FHWA procurement in 2015 for Connected Vehicle Pilot sites. This Table also illustrates a **sample** process that should be followed when considering which CV applications are best for a specific deployment.

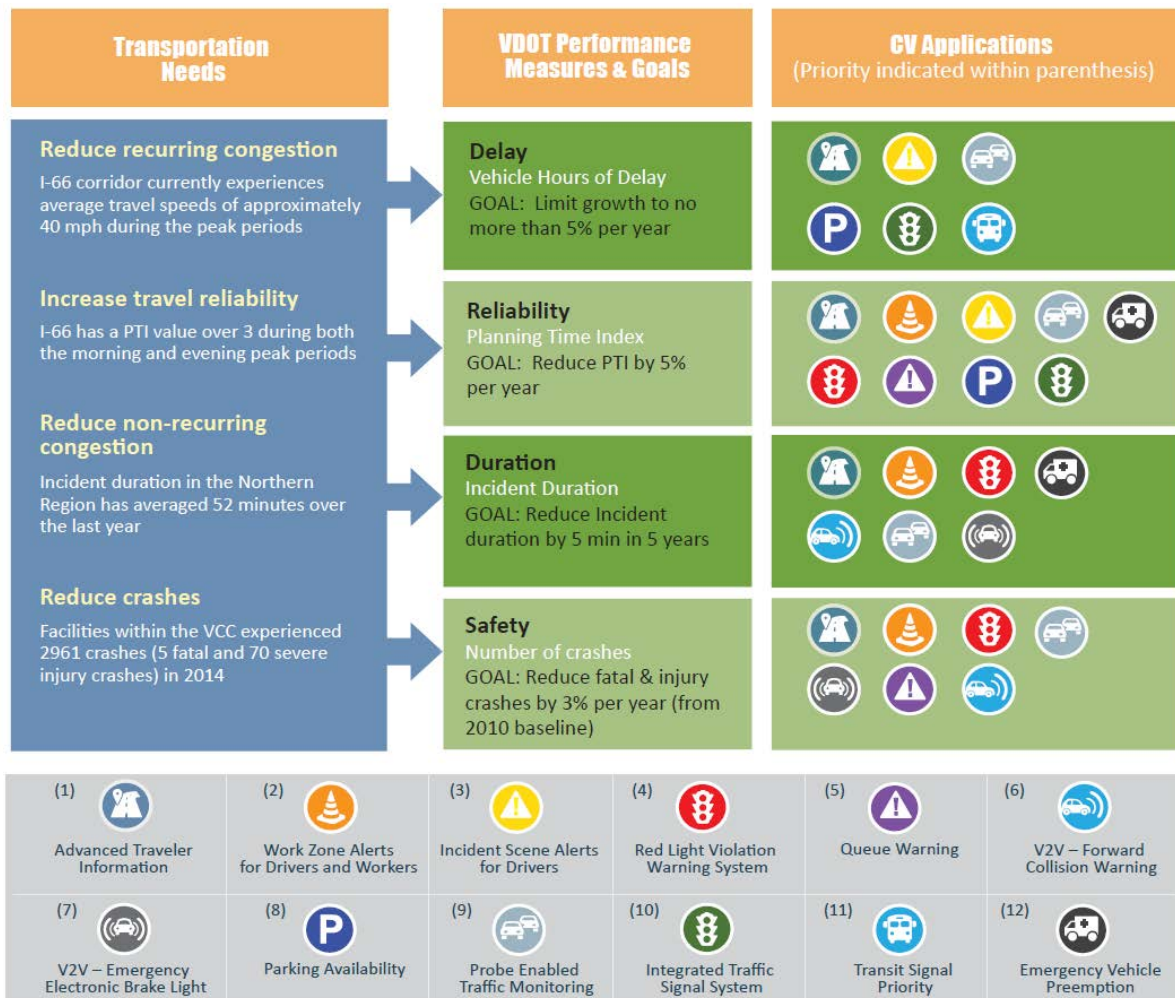


Table 4.1 – Sample Connected Vehicle Applications to Address Transportation Needs

4.2.1 Virginia Transportation Research Council

The Virginia Transportation Research Council (VTRC), VDOT's Research Division, is responsible for conducting and coordinating all research activities for VDOT. To address specific research needs for VDOT's key business areas, VTRC has established research advisory committees that provide a professional forum to identify new research topics, help set research priorities and assist in assembling resources to address research needs.

The Systems Operations Research Advisory Committee (SORAC) identifies and establishes research needs for VDOT's statewide operations program. It also aggressively works to implement recommendations from specific research projects to operate Virginia's transportation system as efficiently and effectively as possible, and ensure safe and secure travel within the Commonwealth. The SORAC has championed several research projects to investigate CV

concepts, technologies and applications in Virginia. Other Research Advisory Committees within the VTRC are also investigating how to leverage CAV technologies.

4.2.2 Virginia Automated Vehicle Strategic Plan

The Commonwealth of Virginia has embraced the potentially transformative nature of AV and taken steps to harness AV in support of Commonwealth-wide transportation system goals. Many strategies will need to be addressed at a Commonwealth level, rather than at a department or office level within Virginia. To address this need, the Commonwealth has developed the Virginia Automated Vehicle Strategic Plan. The Plan was developed by the Office of the Secretary of Transportation for the Commonwealth of Virginia, directed by the Office of Intermodal Planning and Investment.

4.2.3 Virginia Smart Roads

The Virginia Smart Roads, located in adjacent to Virginia Polytechnic University in Blacksburg, VA, are a unique, state-of-the-art, full-scale, closed test-bed research facility managed by the Virginia Tech Transportation Institute (VTTI) and owned and maintained by VDOT. The Smart Roads were originally conceived as a 5.7-mile future road project to provide a more direct connection between Interstate 81 and Blacksburg, but the idea emerged in the late 1990s to construct a portion of the road to serve as a real-life laboratory for public and private research. The Smart Roads continue to play an important role in the overall success of the institute and its research endeavors. Transportation scientists and product developers have spent more than 20,000 hours conducting research on this high-tech highway since its opening.

Two construction projects have been completed to build the Smart Roads' initial 2.2-mile test bed: the initial 1.7-mile, two-lane test bed that opened in March 2000 and a second project completed in May 2001 to build one of Virginia's tallest bridges and provide an additional 200 yards of roadway. The Smart Roads' weather producing capabilities, which include seventy-five weather-making towers, artificial snow production of up to four inches per hour (based on suitable weather conditions), production of differing intensities of rain with varying droplet sizes, and fog production add to the uniqueness of this facility for testing CAV technologies. Expansion of an urban test track has been completed in 2017 and the addition of three miles of rural roadways in the valley below the original test bed is slated for completion in 2018.

The Smart Roads are equipped with the following equipment to support the testing and evaluation of CAV deployments, additional equipment can be easily added as needed:

- Seven roadside equipment (RSE) units that facilitate CV communications
- Two mobile roadside equipment sites
- A CV-compatible signalized intersection controller model

4.2.4 Virginia Connected Corridor (VCC)

In 2012, USDOT awarded funding to the Virginia Tech Transportation Institute (VTTI), UVA and Morgan State University to establish the Connected Vehicle/Infrastructure University Transportation Center (CVI-UTC). The CVI-UTC focused on CV/infrastructure research and deployment to improve safety and mobility. VDOT supported the CVI-UTC by building a CV test bed in Northern Virginia and at the Smart Road at VTTI.

Since the CVI-UTC deployments, VDOT and VTTI have continued their partnership by expanding the test bed in Northern Virginia to become the VCC. The VCC offers a unique opportunity to capitalize on investments made by VDOT to begin evaluating and deploying CV technologies. VDOT targeted one of the most congested corridors in the United States for the test bed and installed CV technologies along portions of I-66, I-495, US 7, US 29 and US 50. The selected corridors provide real-world challenges and opportunities that are well-suited for the deployment of CV technologies.

The Smart Roads are been outfitted with roadside equipment and a VDOT traffic signal with the same controller and configuration as those deployed in Northern Virginia. The VCC was designed so that applications and technology could be developed and tested at the Smart Roads prior to being deployed in live traffic in Northern Virginia.

Within the VCC project area, VDOT has deployed road side equipment, associated networks, and performed a variety of system level tests with vehicles that have been outfitted with CV technologies. Projects have also been initiated to develop CV applications that will benefit regional stakeholders and attract additional application developers and equipment manufacturers to test and demonstrate the capabilities of their products and services.

More information about the VCC initiative is available at www.vtti.vt.edu/facilities/vcc.html.

4.2.4.1 VCC Development Activities

VDOT and VTTI have collaborated over the past two years to add and expand several core components of the VCC so that new technologies and applications can be deployed and evaluated. The VCC will foster an environment that allows research to be conducted on CVs addressing VDOT's transportation challenges. These near-term foundational elements generally follow the four main focus areas described above that are believed to be required for a successful program, which are: infrastructure deployments to collect data and disseminate information; fleet vehicles to receive and transmit data; data availability and the effective management of that data; and development of applications to transform the data into useful information. To accomplish this, the VCC Environment will be enhanced to include:

- Open Cloud Computing Environment
- Signal Phase and Timing Data
- VCC Monitoring Tools

- VCC Traffic Information Message Generator and Server
- Multi-function VCC App
- Improvements to Signs and Markings

One clear gap between the near-term development efforts and the four main focus areas is the number of vehicles that are able to receive and transmit data. Efforts are currently underway with fleet providers, transit operators, and others to address this gap with aftermarket equipment until vehicles become more readily available that can communicate in VDOT's CAV environment.

4.2.4.2 VCC Open Cloud Computing Environment

The VCC Cloud Computing Environment provides a centralized system that supports the management of CV message traffic between research entities interacting on the corridor. The cloud includes connectivity to RSE units installed along the corridor to receive and broadcast messages to passing vehicles. This connectivity may vary by location as VDOT is currently using both leased and agency-owned communications. Basic Safety Messages (BSM) are received from vehicles equipped with DSRC OBEs and Traveler Information Messages (TIM) can be broadcast back to vehicles. In addition, a cellular communications interface has been added that allows bi-directional communications to cellular-only equipped devices and OBEs that are outside the range of DSRC RSE equipment.

All message traffic is received by the system and posted to a series of message queues providing a convenient access point and Application Programming Interface (API) through which applications (e.g., USDOT Data Exchange Server) may access the system. Additional interfaces have been developed that pull traffic, incident, weather, and dynamic message sign data from the VDOT data sharing website and automatically generate TIMs that are posted to the RSE's and the cellular interface for broadcast back to participating vehicles. All message traffic is archived to a persistent data storage and management system. Figure 4.1 illustrates the Cloud Computing Environment.

The CAV Program supports the VDOT Innovation and Technology Implementation Plan's development of a VDOT Operations Data Portal, which is being led by VDOT Operations Division, the Office of Technology Strategic Planning, Traffic Engineering Division, and others. The objectives of developing this data portal are to accelerate the development of CV technologies, encourage engagement of auto manufacturers' device and business development, and to simplify the process to access VDOT's data. CAV Program staff will work with the team to achieve these objectives.

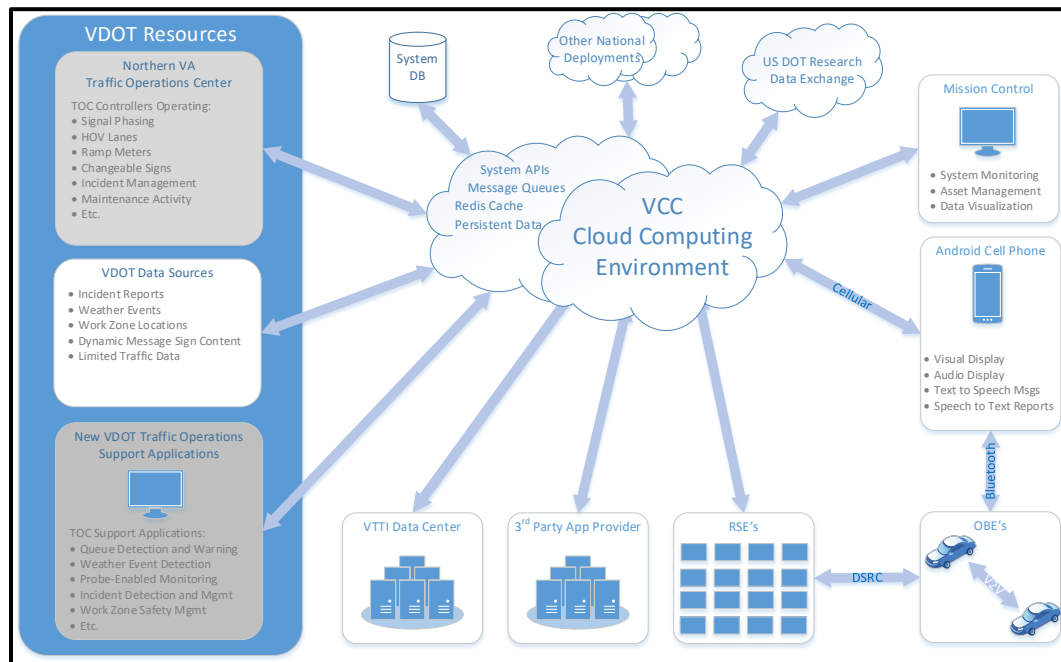


Figure 4.1 – VCC Open Cloud Computing Environment

4.2.4.3 VCC Monitoring Application

The VCC Monitoring Application, shown in Figure 4.2, is a Mission Control Function that provides situational awareness for monitoring corridor activity and events.

The tool includes a map with detailed overlays that monitor and display the following information that are generated or used within the VCC environment:

- RSE location and communication status
- Active Traveler Information Message postings
- CV/RSE DSRC interaction
- Vehicle speeds and brake state
- General traffic speeds (from Google)
- Dynamic Message Sign locations

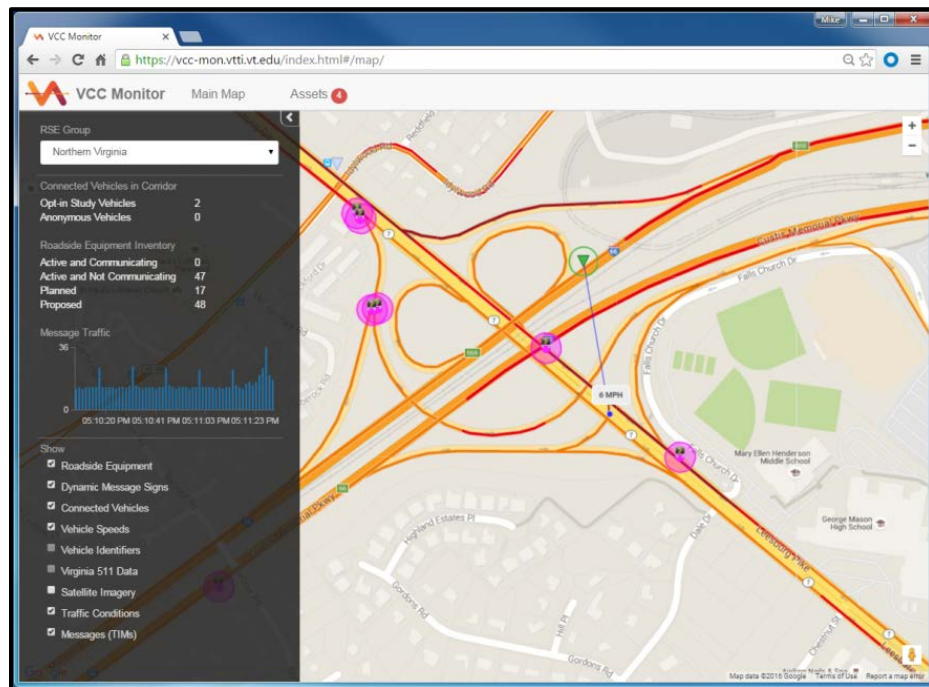


Figure 4.2 – VCC Monitoring Application

4.2.4.4 Traveler Information Message Generator and Manager

The Traveler Information Message Generator interfaces within the Cloud Computing Environment and provides the ability to manually create and post Traveler Information Messages (TIMs). The TIMs are based on the J2735 SAE standard that is designed to enable the broadcast of messages to vehicles based on location and relevant traveler information. The TIM Generator allows the operator to select an area on the map and enter specific information (e.g., short text, long text, category, directionality, start/end time, and RSE deployment set). The generator can create TIMs of any type, duration and purpose. There are more than 80 TIM categories ranging from weather to traffic incident information. The TIM Generator will customize the messages to the preference of the driver. All messages that have been posted are stored for historical purposes.

The TIM Server Manager, shown in Figure 4.3, can receive a TIM posting from any internal or external source. It manages distribution and scheduling of each message for both DSRC and cellular based users. For DSRC users, the Server forwards TIMs to selected RSEs. The RSE receives the TIM and uses a TIM broadcast service to broadcast the message to vehicles within range. For cellular users, the Server aggregates TIMs based on geo-location and message start time. It feeds TIMs to vehicles as they head towards each aggregator location, only sending what is necessary to minimize data flow.

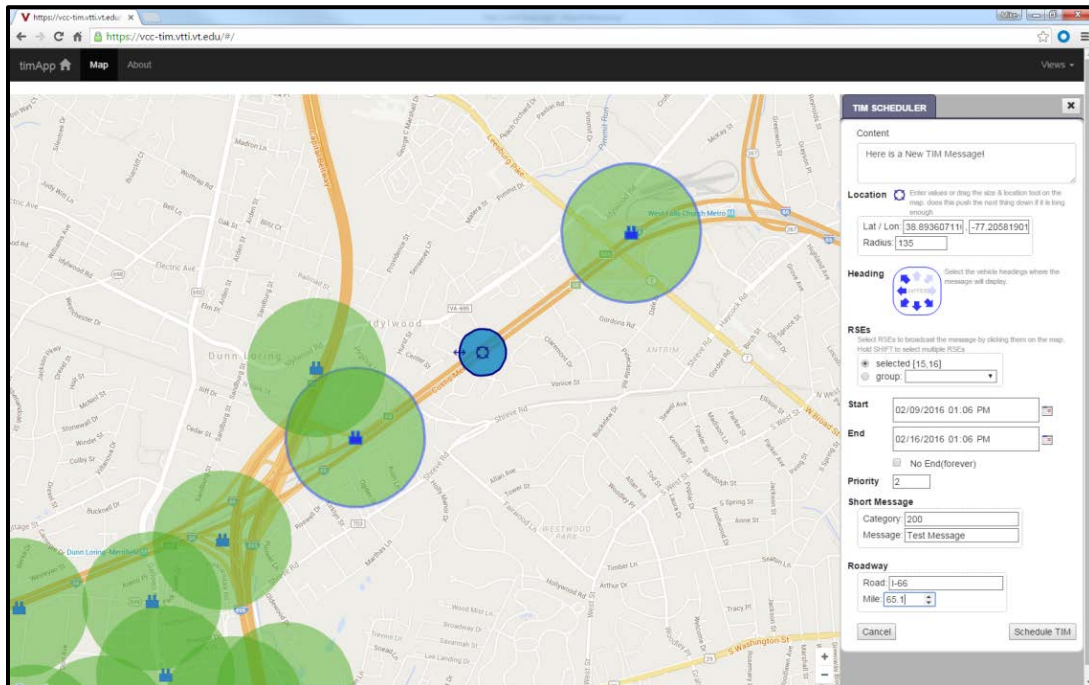


Figure 4.3 – TIM Generator

4.2.4.5 VCC Mobile Application

A mobile application (app) has been developed that can be downloaded on Android smartphones initially and is intended to exercise and test the capabilities of the VCC. The app can use both cellular and DSRC communications. Because it supports users with cellular service only (no access to DSRC), the basic capability works statewide. It is intended that the application will support TIM and custom messaging through a user interface that includes visual and audio indications. Initial functions include:

- Work Zone Details
- Weather Advisories
- Traffic Incidents
- Dynamic Message Sign Content (active messages)
- Driver Reported Issues

The app is designed to limit distractions to the driver and provide relevant real-time data. Once the functionality has been tested and refined, an iPhone app will be developed to accommodate a larger penetration of users. The mobile app will also be expanded to include multiple CV functional applications.

4.2.5 Virginia Automated Corridor

The Virginia Automated Corridors is a partnership between Virginia Tech Transportation Institute (VTTI), VDOT, Transurban, and HERE Technologies. It offers automated-vehicle developers the opportunity to test their technologies on Virginia roads covering more than 70 miles of interstates and arterials in the Northern Virginia region, including Interstates 66, 495, and 95, as well as US Routes 29 and 50 and Route 234. The corridors also include two test-track environments—the Virginia Smart Roads, located on-site at the VTTI in Blacksburg, VA, and the Virginia International Raceway, located in Alton, VA.

The Virginia Automated Corridors integrate multiple resources, including:

- Access to dedicated high-occupancy toll lanes managed by Transurban along I-495 and I-95.
- High-definition mapping capabilities, real-time traffic and incidents, intelligent routing, and location cloud technology supported by HERE, which has worked with major automakers on previous automated-vehicle projects.
- Pavement markings maintained by the VDOT for completeness and retro-reflectivity.
- Accurate localization via high-precision global navigation satellite systems.
- CV capabilities enabled by dedicated short-range communications and cellular technology; access to sophisticated, unobtrusive data acquisition systems.
- And operations at higher speeds along a test track that features complex curves.

More information about the Virginia Automated Corridors initiative is available at <http://www.vtti.vt.edu/facilities/vac>.

4.3 Production Level Components

As VDOT maintains and further develops its existing deployments, there will be a shift in emphasis from research to operations as illustrated in Figure 4.4, VDOT CAV Technology Maturity Model. VDOT will continue to refine its strategy as technologies mature and evolve. As a result, projects will shift from research and development to production level over time.

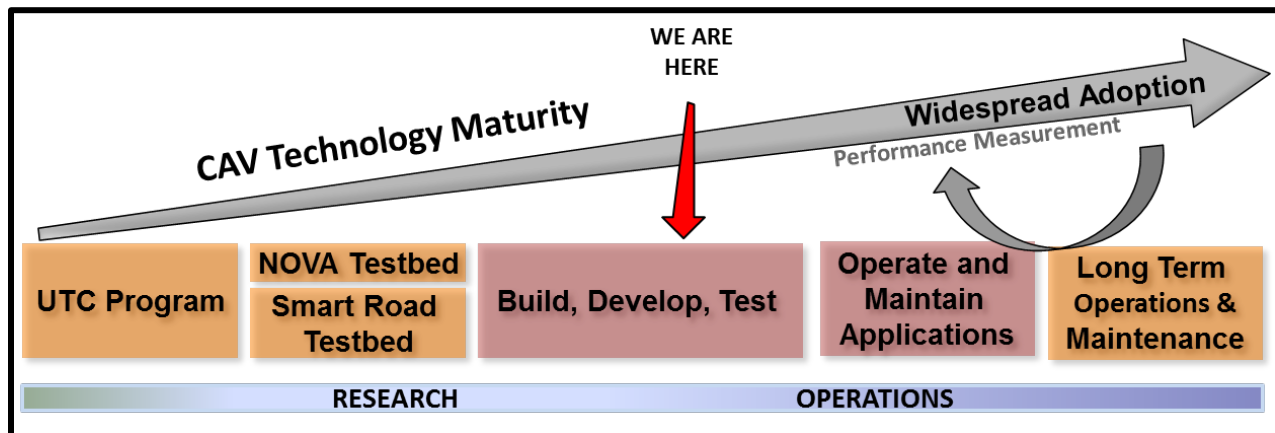


Figure 4.4 –CAV Technology Maturity Model

4.3.1 SmarterRoads.org Data Portal

VDOT's Smarter Roads Data Portal is a new cloud based data portal initiative that provides free, widespread access to a wealth of VDOT information to anyone interested in creating value-added transportation applications and products for end users. SmarterRoads provides direct access to real-time roadway and transportation information – beyond currently available VDOT traffic operations data – in one portal site. In October 2017, 24 distinct data feeds were available through the portal. This portal will support advances in V2V and V2I communications that promise to improve the safety and mobility of users of transportation systems. By publishing this data for public access, VDOT is accelerating CAV technology development in Virginia by sharing transportation data with third-party sector business, application developers and university partners. The site was launched in August 2017 and contains 24 data sets available for CAV application developers, located in Appendix B. The site can be accessed by visiting www.smarterroads.org, as shown in Figure 4.5.

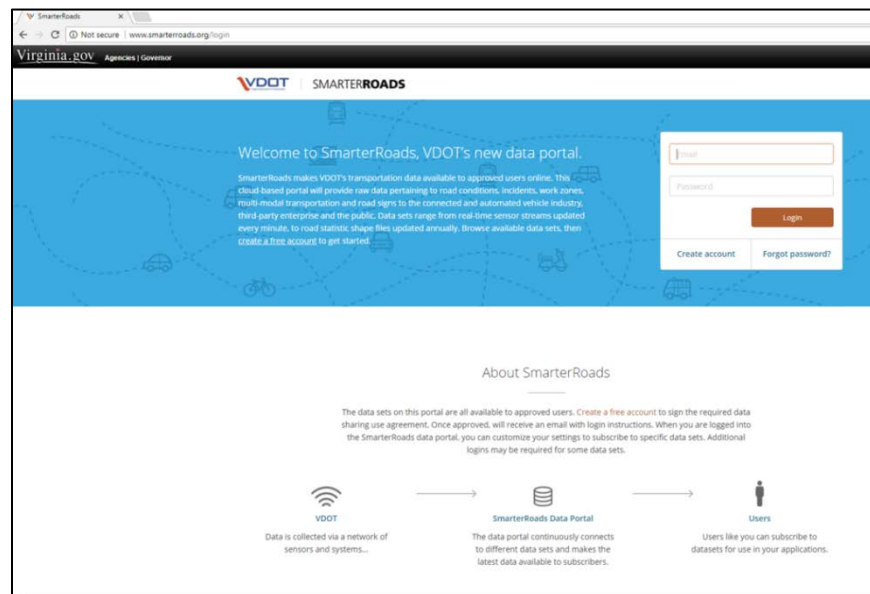
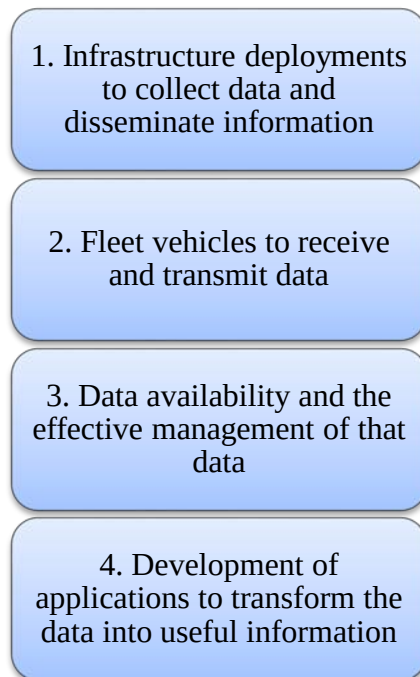


Figure 4.5 – Smarter Roads Data Portal Website

5 VDOT's CAV Deployment Work Program

The deployment of CAV technology and applications will be a phased approach spread out over the next 20 years. The CAV Program Plan will help to guide the Department through the change as the technology becomes integrated into standard business practices. The Plan will clearly illustrate the connection between performance goals and measure the strategies. The deployment strategy will maintain and regularly update this program plan, as well as an implementation plan and other documents as needed. The overarching strategy of the program focuses on highlighting integration and mainstreaming of research projects into scalable projects and/or products that can directly support VDOT business practices. The program should identify projects that support both research initiatives and deployment initiatives.

VDOT's experience in working with connected and automated environments has found that a successful program will be reliant on four key focus areas:



These elements will continue to provide a strong base for the program to leverage the advances in V2V and V2I communications that are anticipated. The framework will also help to identify the gaps that VDOT may be able to manage a need that industry may not be able or able to address, such as work zone information or evacuation routes on state highways.

Strategies selected for deployment must address VDOT goals and priorities, and provide measurable benefits. The application selection process also needs to continually assess commercially available solutions as technologies and services will rapidly evolve.

This “needs and opportunity-based” approach to application selection will be further refined during project planning for specific corridors or application areas to ensure the applications produce measurable benefits.

VDOT will also be exploring ways to use the data collected from connected vehicles to improve performance monitoring, planning, modeling, simulation, safety analysis and operational investment decision making. The two-way communications that CV technologies offer may be able to be leveraged to improve VDOT’s traffic operations data and reduce the funding that is needed for traffic data collection.

The plan is structured in two components – near term actions and mid to long term actions as shown in Figure 4.6. The near-term actions are foundational – they are the basis on which the long-term CAV program in Virginia is implemented and they are focused on the “known” in terms of technology, policies, etc. versus those that are currently in a constant state of change. The mid- to long-term strategies are designed to take into consideration the constant evolution of CAV technologies and policies.

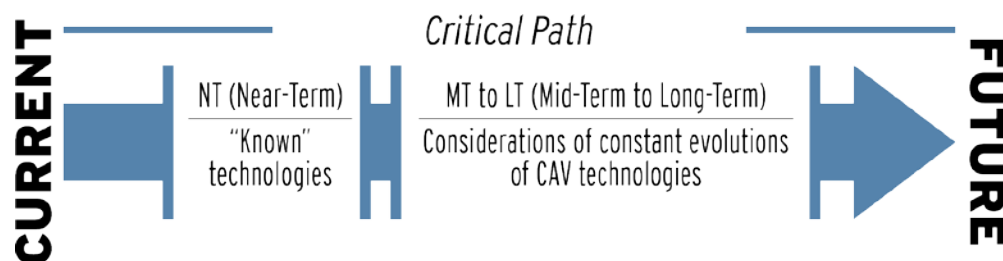


Figure 4.6 – Near Term and Mid to Long Term Actions

5.1 Near-Term Actions

VDOT is already taking a strong leadership role in the CAV industry, both internally with projects like the VCC and externally through partnerships with both the public and private sector. This proactive approach has helped ensure VDOT is in a strong position to support industry and to take advantage of the safety and mobility benefits of these emerging technologies. VDOT will take actions in the near-term that focus internally on VDOT, that are technical in nature and that focus on partnerships and external coordination:

- Organizational Actions:
 - Identify and designate roles and responsibilities for the across the organization, including Chiefs, Division, and Districts
 - Launch the CAV Program Plan Department wide to internally promote and support the creation of a culture of innovation and proactive integration of CAV technologies into plans, programs and projects
 - Coordinate and convene Executive Steering Committee for the CAV Program
- Technical Actions and Activities:

- Focus on development and early deployment activities.
- Demonstrate the capabilities and benefits of CAVs
- Integrate CAV strategies into the long-term planning and programming processes
- Develop a data architecture plan and strategy
- External Partnership-Related Actions:
 - Track technology advances that will impact the CAV program
 - Develop an external stakeholder outreach, communication and coordination strategy that is coordinated with the VDOT CAV strategy

These VDOT-led actions will raise the Department's knowledge and awareness of CAV technologies. It will also allow VDOT to include CAV technologies into construction and maintenance projects as they are designed and advertised. Over time, the CAV Program will develop approved specifications and standards for CAV technologies and integrate more completely into the mainstream planning processes.

VDOT is in the early stages of beginning to include CAV strategies into the long-term planning and programming processes. VDOT has held several stakeholder workshops to encourage local agencies and partners to begin to consider the impacts of connected and automated vehicle technologies. In 2016, VDOT included CAV technologies considerations as potential technology drivers in statewide scenario planning exercises. In these exercises, planners considered various adoption rates as well as how available the technology may vary between urban and rural areas of the Commonwealth.

Data architecture planning that focuses on interoperability between systems will allow for a level of flexibility that VDOT will need to address the needs of its different stakeholders. The main difference in the architecture as we move towards the integration of CAV technologies is a focus on making VDOT data more open and accessible, while keeping the system secure. Another difference that VDOT will likely experience is it will see a movement away from a more traditional data exchange model of simply pushing out data emerge into an architecture that allows for two-way communications. For example, VDOT may investigate incorporating more data from vehicles and devices along with crowdsourced data, instead of relying so heavily on data from equipment in the field.

VDOT will continue demonstrating the capabilities and benefits of CAVs through existing technical activities, especially those called out in Section 4. Many CAV strategies can be low cost while improving specific issues. In addition, many applications do not require new roadside infrastructure, rather they can leverage existing communications where available. Mobility and environmental applications can generally take advantage of commercially available wireless technologies such as cellular, GPS, Bluetooth, and/or Wi-Fi to transmit messages with less stringent latency requirements. Safety critical applications currently still require DSRC as it provides the necessary high availability, low latency communications that current cellular technologies cannot provide.

VDOT will need to continue to evaluate new communications technologies as they become available. A communications plan will be developed as part of the CAV Program to address this need. Outreach and training materials will be needed to facilitate communications within VDOT for all staff to develop a common understanding of efforts that are already underway, as well as what is expected to be implemented in the near term. Communications will also be needed to share information with stakeholders including local agencies and consultants. Local agencies may be pursuing similar efforts through local grants, for Smart Cities, for example. Another clear example can be seen by looking at telecommunications industry leaders as they assert that 5G cellular technology, which could become available as soon as 2020, may meet the latency and availability requirements to make it suitable for some safety critical applications. The CAV Program will work to coordinate and stay engaged with these types of efforts.

5.1.1 Near-Term Development of Foundational Elements

VDOT has established the VCC to address various deployment challenges. Many of these challenges (e.g., stability of standards, cybersecurity protocols, application availability, cost-effective and reliable hardware, etc.) are being actively addressed by USDOT and the industry. However, most applications require significant end-user penetration rates to be effective. Until penetration rates are sufficient to generate perceived benefits, the consumer demand to purchase and install equipment will be limited.

In the meantime, VDOT is continuing to expand the technical components of the CAV Program in the near-term (next 2 years) through a deliberate two-pronged approach. First, VDOT and VTTI will continue to develop foundational elements of the VCC environment. Secondly, VDOT's recent Roadway of the Future document has identified several near-term action items to spur the deployment and operation of CV technologies in Virginia. Many of the identified action items will draw upon the foundational components developed for the VCC. Each of these approaches is discussed in more detail in the following sections.

5.1.2 Improvements to Signs and Markings

VDOT has heard throughout the industry that maintaining roadway signage and markings in a good state of repair is very important. VDOT is committed to maintaining a good state of repair by using an investment approach for system preservation to develop a data-driven strategic plan for the state of good repair of major highway assets. Research on advances to signs and markings are also being explored as potential ways to support CAV systems. VDOT will continue to work with the industry to evaluate different signing and marking strategies and their effectiveness for all roadway users and document the results of this evaluation. This includes the manufacturers of signing and striping elements and the automotive industry. This is one area where VDOT can leverage our strengths, especially the operations of a significant percentage of the roadway infrastructure in Virginia, to partner with industry.

5.2 Mid-Term and Long-Term Actions

VDOT recognizes the need to invest in planning efforts to ensure as the CAV Program grows in Virginia that it does so in a coordinated fashion. VDOT needs to take the lead in planning and providing guidance for other jurisdictions within Virginia. To address this need, VDOT has identified a few key actions to support mid- and long-term planning effort, including the development of:

- Mid-Term and Long-Term Implementation Plan
- Establish Deployment Guidance for Stakeholders
- Standards and Specifications

5.2.1 Mid-Term and Long-Term Implementation Plan

The CAV Program Manager will develop and maintain a Program Implementation Plan in coordination with the CV Executive Steering Committee and other initiatives, such as those identified by the Commonwealth Transportation Board and VDOT's Executive Leadership. The implementation plan will provide details regarding existing projects, and offer direction on additional near- and mid-term objectives.

For example, the CAV Program will work closely with and take direction from the Commonwealth Transportation Board's Subcommittee on Innovation and Technology to meet its goals and objectives to improve safety and mobility, reprioritize investment decisions, and support economic development and job creation in the Commonwealth.

Several action items have been developed to by the Commonwealth Transportation Board that generally relate to accelerating the deployment of CAV technologies and supporting the operation of AV in Virginia. Action items have been developed by the Subcommittee that will be included in the CAV Program's Implementation Plan, such as those shown below:

- Cloud Based Data Portal for Connected and Automated Vehicles
- Promote Virginia CAV Technology Development
- Enhance Intersection Operations While Reducing Traditional Infrastructure
- Identify and Deploy Appropriate CAV Roadway Infrastructure

5.2.2 Establish Deployment Guidance for Stakeholders

VDOT anticipates the need to develop deployment guidance and outreach to external stakeholders. Stakeholders such as local agencies, transit agencies, first responders, and commercial vehicle operators will ultimately become integrated into Virginia's CAV environment. The VDOT guidance will be tailored to apply the applicable elements of the USDOT V2I Deployment Guidance, as well as other guidance and policy documents as they become available. This key set of stakeholders will be critical to the success of the CAV Program.

This should include:

- The steps stakeholders need to take to prepare for CAVs, including what equipment will be necessary in their fleets and at their back office
- Locations where local transportation agencies should deploy DSRC or other technologies
- How stakeholders can provide data into the Open Computing Environment
- How stakeholders can test CV technologies within the VCC

In addition, the Enterprise Pooled Fund Study through their ITS Planning Guidance (Warrants) Review Support task is developing Planning Guides for eight V2I Connected Vehicle applications. Virginia should adopt the applicable guides into its process for identifying new transportation technology strategies.

5.2.3 Develop CAV Standards and Specifications

VDOT develops and maintains standards and specifications that impact all business areas within VDOT. As the CAV technology matures VDOT will need to develop standards and specifications for the technology both on the roadside including both arterials and freeways. This may include identifying standards and specifications for controllers, roadside equipment units and communications protocols needed to support the efficient rollout of CAV technology. VDOT can also capitalize on the early advances of in-vehicle technology. As CAV features are available, VDOT should identify standards and specifications for their fleet vehicles and potentially contractor fleet vehicles as well. This should include aftermarket technology or mobile applications as applicable.

One area that VDOT can establish leadership in this arena is participating in the Standards Development Organizations (SDO) that are working in this area. Organizations such as SAE and IEEE are focused on the vehicle-side of the standards and have not included perspectives from the infrastructure organizations that own and operate the infrastructure on which these vehicles will operate. As part of the mid-term strategy, VDOT will identify the appropriate SDOs for participation and the appropriate people within VDOT to participate. As becoming a full voting member of the SDO's typically takes time, VDOT will start this process in the short term with the expectation of full participation in the mid- to long-term.

6 Program Management Approach

For VDOT to establish and maintain a successful CAV Program, it is imperative the program has the resources it needs to thrive, including staffing, contracting support, and funding. Additionally, strong leadership and good working relationships are needed at all levels, both inside VDOT and among our private sector partners. This section defines the day-to-day roles and responsibilities needed to support a strong program governance structure that will work to enhance and expand the program.

6.1 Key Resources

While there are a number of resources required to establish and maintain a successful CAV Program within VDOT, of particular importance are people, contracting tools and money. This section identifies the high-level staffing, contracting and financial resources required to realize a complete CAV Program at VDOT.

6.1.1 Staffing

In September 2016, the Operations Division created and hired a new CAV Program Manager to serve as VDOT's subject matter expert on advanced vehicle technologies, serve as a champion to promote the program internally and externally, and develop and oversee VDOT's long-term strategy and implementation of advanced vehicle technologies. In October 2017, this responsibility was transferred to the Chief of Innovation.

An initial attempt to identify roles and responsibilities across the organization was identified. Appendix A categorizes the primary stakeholder's involvement with the CAV Program in a RACI Matrix – a common project management tool used to define roles and responsibilities on a team. The RACI Matrix defines the following roles for each task:

- **Responsible:** These people have responsibility for certain tasks. They are the 'creator' of the deliverable.
- **Accountable:** This is the person accountable for the job in hand who will give approval.
- **Consulted:** These people would like to know about the task and we would seek their opinions before a decision or action.
- **Informed:** This group get one-way communication to keep them up-to-date with progress and other messages after a decision or action.

Over time, staff across the Agency will build knowledge, skills and abilities in the connected and automated vehicle domain, especially as new technologies infiltrate the transportation industry. VDOT will work with its university partners to develop training programs. These programs should be customized to address the needs across the agency including those of technicians, planners, field staff and higher-level managers. VDOT should also draw upon training resources

available through the USDOT and relevant industry associations such as ITS America, ITS Virginia (ITSVA), and the Institute of Transportation Engineers (ITE).

In addition to expertise in automotive and roadside technologies, VDOT's CAV Program will require the expertise of VDOT's IT staff and contractors. CAV technologies will produce large volumes of data that will need to be analyzed and turned into useful information. Some of this effort will be accomplished through third party data providers, but VDOT will need to ensure it has qualified staff that can manage and analyze large data sets, field device security and communications networks.

In terms of workforce development to support the program in the future, Virginia is home to one of the nation's most educated populations. In 2015, Virginia ranked well above the national average and 6th among states in the percentage of the population with at least a bachelor's degree. This is due, in large part, to the technology sector that has evolved around the federal government. This also offers a highly trained workforce to support innovation, which is fundamental to advancing CAV deployment in Virginia. VDOT will take advantage of our educated population for recruiting for open positions, promotion to attract new businesses in the area and in the development of outreach and educational materials.

Workforce development also requires the training or re-training of personnel to design, maintain and operate the VDOT system in a CAV environment. VDOT will work with the universities within Virginia and the Community Colleges to help develop appropriate curriculum for engineers and technicians.

Consultant support and additional staff resources will be needed as the Connected and Automated Program continues to develop and grow.

6.1.2 Contracting

CAV technologies and applications need to be seamless across the transportation network regardless of the infrastructure owner. Travelers expect their driving experience to remain consistent through all roads including those operated and maintained by VDOT, localities or private facilities. As the lead CAV agency in Virginia, VDOT should establish multi-agency contracts to facilitate and assist localities, transit agencies, and other operators to deploy CAV technology that is interoperable across the Commonwealth. These contracts should allow for the purchase and installation of roadside technology as well as on-board equipment for fleet vehicles. These contracts should include the necessary consultant and contractor support to facilitate CAV planning and deployment efforts as the complexity of this technology may reach beyond the skill sets of existing state forces.

Over time, other agencies and localities will likely be able to develop and manage their own Connected and Automated Vehicle contract resources and VDOT can shift efforts towards maintaining and disseminating related specifications, standards and applications that other Commonwealth agencies can reference in their contracts.

6.1.3 Funding

VDOT will need to develop an Investment Plan to identify dedicated funding for the initial investment in CAV technologies, as well as the operations and maintenance of this technology, including data management. While there are equipped and non-equipped vehicles on the roadway, VDOT will need to continue to support traditional ITS infrastructure. As the population of equipped vehicles increases, VDOT can begin to decommission non-safety related ITS infrastructure. At that point, operations and maintenance funding can be re-directed to support the CAV Program. This will likely be a phased approach as some infrastructure can be decommissioned earlier than others. For example, Highway Advisory Radio (HAR) systems could be decommissioned as more drivers rely on smart phone or in-vehicle applications to obtain traveler information.

The establishment of solid cost/benefit data on Connected and Automated Vehicle technologies and applications will be critical in the pursuit of sustained funding for the program. The Chief of Innovation in partnership with VTRC should establish cost/benefit data for CAV technologies, infrastructure and applications that are operational in the VCC. The reliability and confidence in this data will improve as more vehicles are equipped, the VCC is expanded and more CAV applications are deployed.

6.2 External Partners

The CAV environment requires involvement from a diverse community of participants as shown in **Table 6.1**, External Stakeholder Roles and Responsibilities. This table is not exhaustive, but it represents the key participants that VDOT will interface with as it establishes and expands its Connected and Automated Vehicle Program.

Despite nearly two decades of research and deployment across the country, a significant amount of uncertainty remains at the national level regarding the details of what a CAV environment will entail. VDOT must take advantage of technology as it becomes available to move the Department closer to meeting its safety, mobility, and environmental objectives. At the same time, VDOT must remain flexible to be able to adjust to changes in the CAV environment as technology, standards, policies, and applications mature. These changes will be influenced by a variety of stakeholders as shown in **Table 6.1**, who may have, at times, conflicting objectives. VDOT's CAV Program, through its CV Executive Steering Committee, will need to periodically reevaluate VDOT's investment decisions and strategies.

In addition to the stakeholders in **Table 6.1**, the success of the program in the Commonwealth of Virginia is dependent on working with many partners internal to the Commonwealth. These partners are necessary to support variety of challenges associated with CAV implementation in Virginia, including regulatory, policy, funding and financial issues, economic development, workforce development and information technology issues (data security, cybersecurity, big data, data sharing, etc.). Through the Executive Steering Committee, VDOT will begin to reach out to these entities within the Commonwealth to develop relationships, using the outreach

materials that are to be developed as part of the near-term objectives. These internal entities include:

- Virginia Secretary of Transportation's Office
 - AV 20XX Working Group
- Virginia Information Technologies Agency
- Virginia Department of Motor Vehicles
- Virginia Department of Rail & Public Transportation
- Virginia State Police
- Commerce Department
 - Labor and Industry
 - Economic Development Partnership
- Governor's Office
 - Unmanned Systems Commission
- Road User Advocates (e.g. Virginia Trucking Association and AAA)

Stakeholder	Primary Role / Responsibility
USDOT	The USDOT's Intelligent Transportation Systems Joint Program Office (ITS JPO) fosters the research, development and deployment of CAV technologies and coordinates CV efforts across multiple agencies. The USDOT also provides funding opportunities for the pilot deployment, testing and evaluation of CAV technologies.
National Highway Traffic Safety Administration (NHTSA)	When warranted, the NHTSA can establish regulations requiring manufacturers to include equipment to support CV safety applications in new vehicles by a future date.
Federal Communications Commission (FCC)	The FCC allocates and manages spectrum in the 5.9 GHz range for Dedicated Short Range Communications (DSRC) to support the CV environment.
State and Local DOTs	DOTs across the U.S. will own and operate roadside infrastructure to establish DSRC-based communications with vehicles. DOTs will also manage and control how data is shared with their systems.
Research Institutions	Public and private research institutions will continue to investigate the effectiveness of CV strategies, technologies and applications.
Standards Development Organizations (SDOs)	Several SDOs are involved in the development and maintenance of CV data and communications standards. These include: • The Institute of Electrical and Electronics Engineers (IEEE) • American Society for Testing and Materials (ASTM) • Society of Automotive Engineers (SAE)
Auto Manufacturers	Auto manufacturers will develop and offer CAV capabilities in new vehicle models and provide an open framework that allows after-market equipment manufacturers to expand CAV capabilities.
Parts Suppliers and After-market Equipment Manufacturers	Tier One-part suppliers and the automotive aftermarket industry develop and deploy commercially-available products for installation in existing vehicles to enable CAV capabilities.
Road User Advocate – AAA	AAA is the largest advocate for road users in the nation, providing traveler aid and assistance and automobile insurance. AAA is an advocate of CAV and is a good representative of the industry.
Cybersecurity Industry	Virginia is the home to a significant number of private companies working in the cybersecurity industry who can help develop policies, procedures and technologies to support VDOT in the implementation of cybersecurity solutions.
Military Partners	The US Military is actively engaged in developing AV solutions to support their ongoing operations in all aspects of their programs, including logistics, on-base operations and wartime operations.
Corridor Coalitions	Virginia is a member of two multi-state corridor coalitions that address transportation management systems and operations (TSM&O) issues as a corridor to help ensure consistency along the corridor (I-81 and I-95). These corridor coalitions are beginning to focus on CAV issues to help ensure coordination on a regional basis.

Table 6.1: External Stakeholder Roles and Responsibilities

6.3 Program Governance

The primary governance structure of the CAV Program is its Executive Steering Committee, described in Section 6.3.1. Technology and systems are a key component of CAV deployments, there is a need to apply strong governance practices to address:

- Internal coordination and information sharing
- Project planning needs
- Changes in technology or industry product offerings
- Outside influences (legislative mandates or industry shifts)
- Desired enhancements

6.3.1 Executive Steering Committee

A CAV Executive Steering Committee was established in January 2017 to guide the program to maximize the benefits of existing and emerging connected and automated vehicle technologies to meet VDOT's goals and objectives. The committee's scope is intentionally limited to focus on connected and automated vehicle topics and decisions that VDOT can apply resources to, including operations improvements, maintenance, infrastructure investments, long range transportation planning, and other related areas.

Due to the scale and complexity across stakeholders, to govern this project, an Executive Steering Committee is proposed with membership including VDOT staff, consultants and researchers engaged in CV-related efforts in Virginia. These groups will ensure operational and strategic goals are being delivered as expected. The Executive Steering Committee is responsible for:

- Developing key partnering and operational relationships between VDOT and expert stakeholders to establish program direction and gain acceptance of changes;
- Setting clear guidance and priorities for the program to ensure a balance between delivering today and driving toward the future state;
- Creating clear accountability for decision-making and delivery so that there is a line of sight between what must be done and who must do it, and a transparent understanding of expectations;
- Monitoring delivery against strategic and operational goals to ensure the program is delivering what it intends to deliver; and
- Providing an escalation process for issues and risks so they can be resolved before affecting delivery.
- Assisting to facilitate and encourage the efficient transfer of knowledge and experience from research to implementation and integration into VDOT's business practices.

The Executive Steering Committee membership is shown in **Table 6.3**, Executive Steering Committee Membership. Advisory members will be included when needed to advise the Committee on various topics, such as technology recommendations.

NAME	REPRESENTING	ROLE
Rob Cary	Commissioners Office	Chair
Virginia Lingham	CAV Program Manager	Staff Coordinator
Robin Grier	Transportation Demand and Mobility Planning	Voting Member
Dean Gustafson	Operations	Voting Member
Ray Khoury	Traffic Engineering	Voting Member
Cathy McGhee	VTRC	Voting Member
Murali Rao	Technology Strategic Planning	Voting Member
Hari Sripathi	Regional Operations	Voting Member
Branco Vlacich	Maintenance	Voting Member
Zac Doerzaph	VTI	Advisor
Ken Earnest	Operations	Advisor
Marshall Herman	Communications	Advisor
Van Nguyen	Traffic Engineering	Advisor

Table 6.3 – Executive Steering Committee Membership

7 Plan Revisions & Approval

The Special Assistant to the Chief of Innovation is responsible for updating the Plan and tracking its changes as it evolves over time. **Table 7.1** summarizes the versions that have been prepared and reviewed. The table also includes high-level remarks regarding the changes that are made or other factors that may help provide insight and continuity regarding the Plan's development.

Date	Version Number	Primary Author	Reviewed By	Approval Date	Notes
10/10/2017	Fall 2017 V0	Operations Division (VL/KE) with Consultant Support from HNTB		10/11/2017	

Table 7.1 – Plan Revision and Approval Tracking

8 References

The following websites and documents were referenced in the development of this plan:

- Connected Vehicle Pooled Fund Study - <http://www.cts.virginia.edu/cvpfs/>
- AASHTO, Subcommittee on Transportation Systems Management and Operations (STSMO) - <http://stsmo.transportation.org>
- USDOT JPO 2015-2019 ITS Strategic Plan
<http://www.its.dot.gov/strategicplan/index.html>
- NCHRP 20-24(98), Connected/Automated Vehicle Research Roadmap for AASHTO
<http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=3752>
- Virginia's 2013 Election: A Geographic Perspective-
<http://blogs.nvcc.edu/ips/2013/07/01/virginias-2013-election-a-geographic-perspective/>
- Virginia Department of Transportation Performance Dashboard
<http://dashboard.virginiadot.org/>

Appendix A: Roles and Responsibilities Matrix

VDOT Connected and Automated Vehicle Program															
RACI Matrix															
Updated: 12/21/2017															
Function	Task	CHIEF		DIVISIONS									DISTRICTS		
		Chief of Innovation	Chief Engineer	Research Council	TMPD	Traffic Engineering	Operations	Maintenance	Governance and Leg. Affairs	Office Tech Strat. Plan.	Communications	Information Tech.	District Administrator	District Planning	Regional Operations
Plan	Strategic Planning for Regional/Corridor CV Deployments	A	C	R	C	C	C	C	C	C	I	I	C	C	C
	Maintain CAV Program Plan	A/R	C	C	C	C	C	C	C	C	I	I	C	C	C
	CV Pooled Fund Study Chair	A/R	I	R	I	I	I	I	I	I	I	I	I	I	I
	CAV Program Coordination	A/R	C	C	C	C	C	C	I	I	I	I	I	C	C
	CAV Research, Development and Testing	A	C	R	I	C	C	C	I	I	I	I	I	I	C
	Maintain VCC/VAC Partnerships	A	C	R	I	C	C	C	I	I	I	I	I	I	I
	Business Development with Private Sector	A/R	C	C	C	C	C	C	I	C	I	I	C	C	C
	Track and Assess State and Federal Legislation and Rulemaking	A	C	C	C	C	C	C	R	I	I	I	C	C	C
	Identify and Pursue CV Funding Opportunities	A	C	C	C	C	C	C	R	I	I	I	C	C	C
	CAV Cyber Security Design/Architecture	A	C	C	I	R	R	C	I	A/R	I	R	C	I	C
	Coordinate with localities and Regional entities including MPO's and PDC's.	A	C	C	R	C	C	C	I	I	I	I	R	C	C
Pilot	Develop Pilot CAV Specifications, Standards, and Projects (Including VCC/VAC)	A	C	R	I	C	C	C	I	C	I	C	C	I	C
	Provide subject matter expertise on CV and supporting communications technologies	A	C	R	I	C	C	C	I	C	I	C	C	I	C
	Implementation of Pilot CAV Projects	A	C	R	I	C	C	C	I	C	I	C	C	I	C
	Operate and Maintain Pilot CAV Projects	C	A	R	I	C	C	C	I	C	I	C	C	I	R
Deliver	<i>Develop Post-Pilot CV Specifications, Standards and Contracts</i>	C	A	C	I	R	R	R	I	C	I	I	C	I	C
	<i>Oversee Post-Pilot CV System Integration Efforts and Provide Technical Expertise</i>	C	A	C	I	C	R	C	I	C	I	R	C	I	C
Operate	<i>Operate Post-Pilot CAV Deployments</i>	C	A	I	I	C	R	C	I	I	I	C	C	I	R
	<i>Monitor and Optimize CAV Systems</i>	C	A	I	I	C	R	C	I	I	I	C	C	I	R
Maintain	Provide and Manage DSRC Licenses (Pilot and Post-Pilot Projects)	C	A	I	I	C	C	R	I	I	I	C	I	I	C
	<i>Oversee Maintenance of Post-Pilot CAV Assets</i>	C	A	I	I	C	R	R	I	I	I	C	A	I	R
	<i>Establish Maintenance Performance Measures</i>	C	A	I	I	R	R	R	I	I	I	C	I	I	R
Support	Serve on National Committees	A/R	C	R	R	R	R	R	I	I	I	I	I	I	I
	Serve on Statewide Committees	A/R	C	R	R	R	R	R	I	I	I	I	C	C	C
	Serve on Regional/Local Committees	I	I	C	C	C	C	C	I	I	I	I	A/R	R	R
	Technical Assistance on New Innovations	A	C	R	C	C	C	C	I	C	I	C	I	C	C
	Vendor/Product Review	A	C	R	R	R	R	R	I	R	I	R	C	C	C

Legend:

R = Responsible, does the work
A = Accountable, approves the work
C = Consulted, input needed (2-way discussion)
I = Informed, Situational Awareness (no input)

Tasks with Bold Font = Current Activities
Tasks with Blue Italic Font = Future Activities

Appendix B: List of Smarter Roads Data Portal Data Feeds

- 24 feeds available in Oct 2017

1. Average Daily Traffic
 - a. Listing of each interstate and primary highway that estimates the average traffic on any given week day
 - b. Updated annually
2. Crashes
 - a. Motor vehicle crash data that compiles all reportable accidents (crashes that involve a fatality, injury or property damage of at least \$1,500).
 - b. Updated annually
3. District Boundaries
 - a. Boundaries of the nine VDOT districts.
 - b. Updated annually
4. Dynamic Message Signs (Active)
 - a. Information on the location and the current (active) messages of all active Dynamic Message Signs (DMS) signs across the state.
 - b. Updated every minute
5. Dynamic Message Signs (All)
 - a. Locations and current messages of all Dynamic Message Signs (DMS) signs across the state, regardless of being active or not.
 - b. Updated every minute
6. Map Data (MAP)
 - a. Intersection information, including the location of lanes and which signal group controls the movement of each lane. Provides opportunities for safety, mobility and environment applications.
 - b. Updated daily
7. Paving Schedules
 - a. Status of all pavement projects across the state. Pavement status is tracked by projects and are color coded to show status.
 - b. Updated annually
8. Quarterly Crash Data
 - a. Quarterly data on crashes
 - b. Updated quarterly
9. Road Construction
 - a. Road construction projects included in the annual Six-Year Improvement Program that outlines the planned spending for proposed transportation projects for construction development or study for the next six years.

- b. Updated annually
- 10. Signal Data: Controller Configuration
 - a. Site/intersection configuration file, including information on location, detectors, and phases
 - b. Updated daily
- 11. Signal Data: Controller Inventory
 - a. Information on all existing signal controllers and initial status, including description, model, site, and controller mode
 - b. Updated daily
- 12. Signal Data: Controller Status
 - a. Real-time status data of signal control devices, including operational status, controller mode, and coordinated state.
 - b. Updated every second
- 13. Signal Data: Detector Data
 - a. Real-time detector measures for all local and system detectors
 - b. Updated every minute
- 14. Signal Data: Green Split
 - a. Real-time green split data for each phase of a controller
 - b. Updated every second
- 15. Signal Phase and Timing (SPaT)
 - a. Traffic signal control information that conveys the current state of each phase in the system. Provides opportunities for safety, mobility and environment applications.
 - b. Updated every second
- 16. Speed Limits
 - a. Speed limit information including varying factors from VDOT's Traffic Engineering Division such as vehicle type, time of day and more.
 - b. Updated annually
- 17. Traffic Sensor Stations
 - a. Data from Traffic Sensor Stations (TSS).
 - b. Updated every minute
- 18. Travel Advisories & Lane Closures
 - a. Weekly lane closures and potential travel advisories based on information from VDOT's 511 tools.
 - b. Updated every minute
- 19. Truck Restrictions
 - a. Specific truck routes and information for truckers for length-based truck routes and restrictions to aid in proper route selection across the state.
 - b. Updated monthly

20. VDOT Traffic Incidents

- a. Information on VDOT traffic incidents
- b. Updated every minute

21. Vehicle Miles Traveled

- a. Daily Vehicles Miles Traveled (VMT) by jurisdiction and vehicle class for public road segments across the state of Virginia.
- b. Updated annually

22. Weather Events (Long)

- a. Information on long-term weather events
- b. Updated every minute

23. Weather Events (Long Defaults)

- a. Information on long-term weather defaults
- b. Updated every minute

24. Weather Events (Short)

- a. Information on short-term weather events
- b. Updated every minute

