Research Paper – Transportation Technologies

1. Introduction

Transportation technologies are rapidly evolving. In response, transportation agencies are preparing strategic plans, expanding partnerships and research, enacting policies, and/or launching pilot projects to better understand and coordinate the impacts and benefits of new technologies.

This paper discusses advanced technologies, and highlights programs and pilots at federal and state government levels and in the private sector that are relevant to West Virginia. The paper also outlines the future direction of technology trends and details how the West Virginia Department of Transportation (WVDOT) is uniquely positioned to leverage lessons learned from peer states and others to chart its own comprehensive response to emerging technologies.

The following list of definitions provide some idea of the core technologies discussed in this paper.

- **Automated Vehicles (AVs):** Vehicles that can navigate the environment around them with varying levels of human input. Driverless or autonomous vehicles represent the highest level of automation where the vehicle can perform all driving tasks without the need of a driver.
- **Connected Vehicles (CVs)**: Vehicles that use communication technology to actively communicate with other vehicles, infrastructure, pedestrians and bicyclists, and the cloud.
- **Transportation Network Companies (TNCs):** Companies that provides riders with ridesharing services via mobile applications (e.g., Uber and Lyft). They provide on-demand trips with integrated payment systems based on a dynamic pricing model.
- **Alternative Energy**: Renewable energy sources that are used and favored in place of fossil fuels. One prominent application is electric vehicles, which seek to address emissions concerns.
- **Big Data**: The availability and collection of large amounts of data that can be used to improve safety, operations, planning, and decision making. As transportation technologies advance, the volume and speed of data continues to increase.
- **Intelligent Transportation Systems (ITS):** The deployment of advanced technologies on transportation networks to increase safety, mobility, and efficiency. Applications can include traffic and weather management systems, traveler information systems, electronic payment and pricing, and other applications specific to transit or commercial vehicles operations.
- **Internet of Things (IoT):** Is the integration of devices with sensors, software, and technology to allow for the exchange of data without requiring a human factor.
- **Smart Connectivity:** Advanced communication (wireless, cellular) that provides a reliable channel for data exchange between IoT devices (e.g., vehicle-to-vehicle [V2V], vehicle-to-infrastructure [V2I] and vehicle-to-everything [V2X]).
- **Hyperloop:** An innovative transportation system to move people and goods through low pressured tubes that enables traveling at hypersonic speed while being energy efficient.

The technologies covered in this paper have the potential to address existing and future transportation challenges including safety, mobility, efficiency, and environmental quality. While each technology will have a unique pace of development and deployment; exploring the current and future trends of these technologies will help provide WVDOT with a vision of what transportation might look like in the future.

It is important to note that the implications of emerging technologies are not restricted to transportation. They also have widespread implications on land use, urban design, equity, and environmental sustainability. Therefore, leveraging emerging technologies could play a critical role in advancing the economic vitality and global competitiveness of West Virginia.

Many state DOTs are currently preparing to navigate the changing technological landscape by engaging with the technology industry; identifying partnership opportunities; investing in technology research, testing and piloting; exploring new and emerging data sources; investing in smart infrastructure; and developing policies and strategic plans. While the amount of effort and type of actions planned and/or taken forward vary between state DOTs, there is general consensus that transportation agencies must take some necessary and relevant steps. Education and preparation for future change is needed, otherwise agencies risk having their goals sidelined by private sector technology developments with no public sector input.

West Virginia is taking some initial steps to link technology and transportation. Current efforts are embedded within ongoing expansion, maintenance, and operations of the multimodal transportation system, including over 38,000 miles of highways operated and maintained by the West Virginia Division of Highways (WVDOH). In addition, the state is developing plans and procedures to extend broadband connectivity. The provision of highway corridors with enhanced connectivity provides the foundation to implement a wide range of transportation technologies.

There are a number of other programs and initiatives involving emerging technologies that are also underway (outlined in this paper). The 2050 LRTP presents the opportunity for WVDOT to address technology effectively and comprehensively as it sets a course for the future though its LRTP. The LRTP will provide the framework to address current challenges and develop a blueprint for future multi-modal transportation investments. Additionally, and since technology is not bounded by a state's border, the LRTP will support in identifying partnership opportunities with external stakeholders to implement plans that could bring about economic prosperity and enhance the quality of life at local and regional levels.

This paper concludes with key considerations to elevate and establish a "technology awareness" within WVDOT. These conclusions are based on an analysis of current and future technology trends, considering the unique challenges of West Virginia in terms of terrain, infrastructure, and preparedness for technology, and under the ongoing uncertainty due to COVID-19 effects on mobility. Opportunities to prepare and position WVDOT for future change include: (1) making organizational changes to streamline and prioritize technology, (2) incorporating technology considerations within key phases of transportation planning, project development, design and operations, and (3) establishing a set of agency goals, objectives and performance measures that embrace technology. These considerations serve as input to the LRTP planning process to set the stage for strategies and implementation actions to ensure that WVDOT leverages short- and long-term opportunities to prepare its transportation system for the future.

2. Where Are We Today?

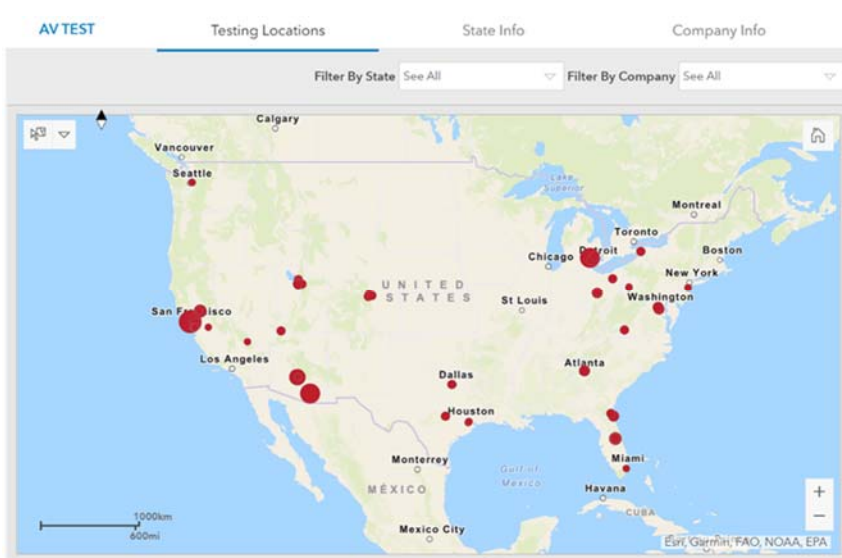
2.1 Overview

The emergence of advanced technologies has prompted federal and state agencies to take actions to promote safe and beneficial technology adoption. The federal government has taken steps to fund and guide implementation, while state agencies have taken steps to prepare strategic plans and evaluate the impacts of technology projects. This section focuses on national and State DOT programs, pilots, and legislation that relate to the current environment in West Virginia.

2.2 Federal Programs

The Fixing America's Surface Transportation Act (FAST Act) was signed in December 2015, providing more than $300 billion to transportation infrastructure projects through 2020. The FAST Act authorized funding for advanced technology programs under the Technology and Innovation Deployment Program ($67.4 million per year), the Advanced Transportation and Congestion Management Technologies Deployment Program ($60 million per year), and the Intelligent Transportation System Program ($100 million per year[1].

Congress has announced plans to develop a federal automated vehicles (AVs) legislation framework while the U.S. Department of Transportation (USDOT) continues to make progress in defining its role and response to AVs throughout the United States. The USDOT's most recent report, "Ensuring American Leadership in Automated Vehicle Technologies: Automated Vehicles 4.0"[2], provides a framework for the agency's investment in emerging AV technologies and their integration through prioritizing safety and security, promoting innovation, and ensuring a consistent regulatory approach.



The National Highway Traffic Safety Administration (NHTSA) recently launched an initiative to support the safe development, testing, integration, and education of driving automation technology. The AV Transparency and Engagement for Safe Testing (TEST) Initiative[3] released a web tool to communicate the testing and development of automated driving systems across the nation. Data is submitted voluntarily by participating local governments and private-sector stakeholders.

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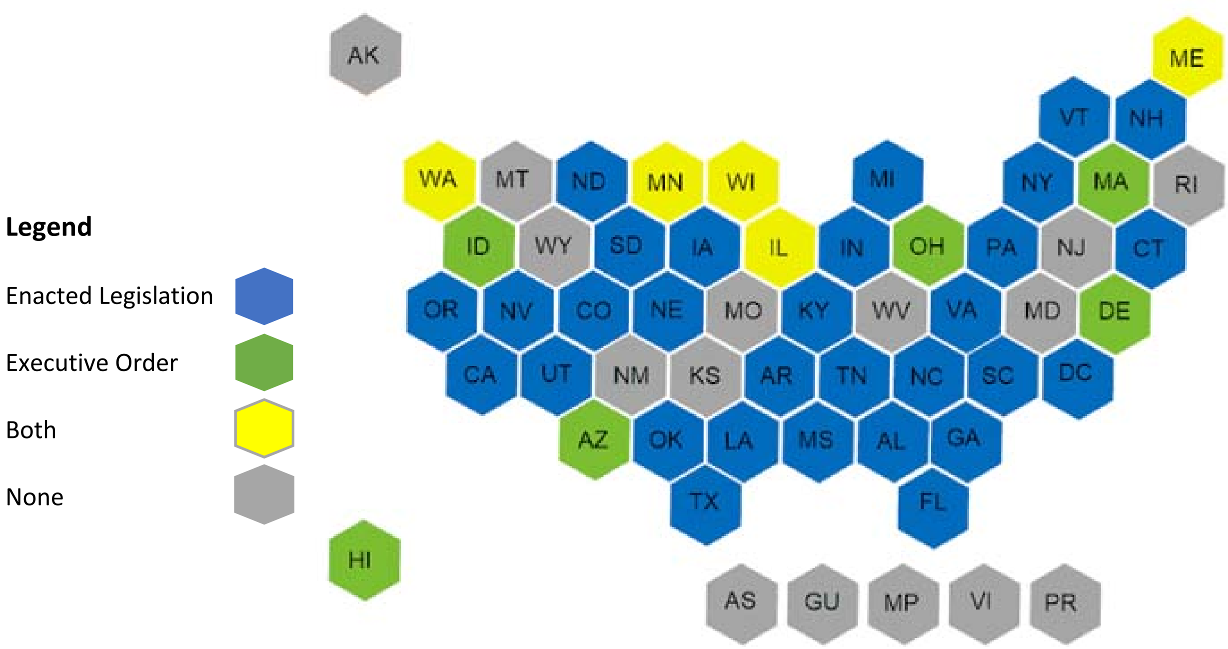
[1] USDOT Federal Highway Administration, Fixing America's Surface Transportation Act or "FAST Act"
[2] USDOT, Ensuring American Leadership in Automated Vehicle Technologies: Automated Vehicles 4.0
[3] NHTSA, Automated Vehicle Transparency and Engagement for Safe Testing Initiative

Federal agencies have taken an active role in improving broadband connectivity, which is crucial to the U.S. economy and will help enable emerging technologies such as AVs. In early 2019, the National Telecommunications and Information Administration (NTIA) announced the creation of the American Broadband Initiative (ABI)[4]. As a partnership with many other governmental agencies, including the U.S. Department of Agriculture (USDA), this effort prioritizes federal funding for broadband. The NTIA has started working on maps to look at the availability of broadband nationwide and understand where the federal government can allocate resources to expand service, especially in rural areas. A web-based interactive map of broadband sites across the U.S. was developed in 2018 allowing users to filter and analyze broadband infrastructure data[5].

State Legislation

Currently, at least 29 states and Washington D.C. have passed legislation related to AVs. The legislation addresses a broad array of AV related topics such as testing and operation permits, driver requirements, insurance and licensing requirements, setting specified routes, following distance for truck platooning, and times and weather conditions for testing and operation. Additionally, 11 states have passed executive orders to respond to AVs and Connected and Automated Vehicles (CAVs), of which some have also enacted AV legislation. 15 states including West Virginia, have not enacted any regulations related to AVs[6], however, lack of specific regulation is not indicative of a lack of progress or relevance. In many of these cases, states are waiting for evolving Federal guidance and/or are actively working with the private sector to develop an optimal regulatory framework.

Figure 1: States with Autonomous Vehicles Enacted Legislation and Executive Order (2020)[6]



[4] NTIA, American Broadband Initiative to Expand Connectivity for all Americans
[5] USDA, Supporting Broadband Tower Facilities in Rural America on Federal Properties Managed at Interior
[6] National Conference of State Legislatures, Autonomous Vehicles Enacted Legislation

In 2017, West Virginia considered but did not enact legislation (House Bill 2910) which would have allowed the operation of AVs by anyone with a valid driver license on public roadways[7]. However, West Virginia House Bill 4447 (2018) enacted a "Dig Once" policy to direct WVDOT to install vacant conduit for future broadband service within new highway construction[8].

Transportation Network Companies (TNCs) – such as Uber and Lyft – continue to disrupt traditional travel. Their dynamic pricing models have impacts on vehicle miles of travel (VMT), congestion, and public transit use. As of June 2017, 48 states and the District of Columbia have passed TNC legislation[9]. Through House Bill 4228 (2016), West Virginia joined the states which regulate TNCs, allowing them to operate in the state under specific vehicle inspections and permit requirements[10].

2.3 Neighboring State Initiatives

Several states that border West Virginia, such as Ohio, Maryland, and Virginia have released statewide plans and/or formalized how to coordinate, manage, and oversee AVs and CAVs related activities.

DriveOhio

DriveOhio
The Future of Smart Mobility

DriveOhio was created in January 2018 by the State of Ohio to oversee coordination and implement interconnected smart roads and smart vehicles. Supported by the Ohio DOT, DriveOhio is a collaboration between government, research, and private industry partners to build Ohio's infrastructure for smart mobility, and to facilitate smart mobility innovations[11].

Maryland DOT: CAV Working Group

Maryland is focused on the mobility and safety benefits related to CAV technologies. The Maryland Transportation Authority (MDTA) Strategic Plan for CAVs[12] published in 2018, and Maryland DOT State Highway Administration (MDOT SHA) CAV Strategic Action Plan[13] published in 2017, have helped Maryland take significant strides in planning for CAVs. The Maryland CAV Working Group, created in 2015, meets regularly to discuss and coordinate the development and deployment of the technology.

Another important initiative is the Maryland Locations to Enable Testing Sites (LETS) for CAVs. Maryland DOT created this only portal to create more opportunities for CAV testing, taking advantage of underutilized spaces in the state. Companies interested in CAV testing can submit an "Expression of Interest" to request use of a specific site. One recent example was the testing of STEER Tech's Automated Valet Parking (AVP) technology at the Dorsey Run MARC station[14]. The program successfully demonstrated the company's technology without any safety issues.

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[7] West Virginia Legislature, House Bill 2910
[8] West Virginia Legislature, House Bill 4447
[9] Texas A&M Transportation Institute, Transportation Network Company (TNC) Legislation
[10] Legiscan, West Virginia House Bill 4228
[11] DriveOhio Website
[12] MDTA Strategic Plan for Connected and Automated Vehicles
[13] MDOT SHA CAV Strategic Action Plan
[14] STEER TECH Website

Virginia Connected and Automated Vehicle Programs

Over the past few years, Virginia has demonstrated that it is "open for business" for AV technologies, through actions by agencies such as the Virginia Department of Transportation (VDOT). Partnerships with university researchers has been a crucial part of the process. The Virginia Automated Corridors (VAC)[15] and Virginia Connected Corridors (VCC)[16] are two examples of programs involving VDOT, the Virginia Tech Transportation Institute (VTTI), and other key statewide agencies to facilitate real-world deployment of CAV technology.

2.4 West Virginia Programs and Activities

Several initiatives are underway in West Virginia that involve emerging technologies; associated with grant opportunities, public university research and private company investment.

Appalachian Regional Commission (ARC) Grants

The ARC focuses on strengthening economic growth throughout the Appalachian Region. The agency outlines five goals in its 2016-2020 strategic plan: Economic Opportunities, Ready Workforce, Critical Infrastructure, Natural and Cultural Assets, and Leadership and Community Capacity[17]. Critical infrastructure focuses on broadband and transportation, opening the possibility for investment in emerging technologies.

VTTI Automated Driving System Demonstration Grant

VirginiaTech Transportation Institute

In 2019, the VTTI was awarded a $7.5 million grant from USDOT to provide guidance for the safe integration of automated driving systems into truck fleets. This program is an important step in accelerating research related to automated systems in the trucking industry, with the potential to improve safety and maximize economic investments. As part of this comprehensive research program, VTTI has assembled a team of automated driving system technology developers, trucking fleets, six state DOTs, and others[18]. The West Virginia Division of Highways (WVDOH) is part of the VTTI team.

West Virginia University (WVU) PRT Modernization Plan

West Virginia University's Personal Rapid Transit (PRT) System began operations in 1979. Originally a demonstration project, it was the first large-scale automated guideway transit system in the nation. Today, about 15,000 university students, employees and visitors ride the system per day[19]. As a unique system, PRT runs on a schedule during busy times and on passenger request during off-peak hours. With system repairs scheduled to be completed in late 2020, WVU has committed to keeping the PRT as a vital part of the state's mobility network.

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[15] VTTI, Virginia Automated Corridors
[16] VTTI, Virginia Connected Corridors
[17] Appalachian Regional Commission, ARC Grants and Contracts
[18] Virginia Tech Daily, $7.5 million study to develop operational plan for mixed truck fleets
[19] West Virginia University, PRT Modernization

Intestate-81 (I-81) Corridor Coalition Freight Traveler Information System

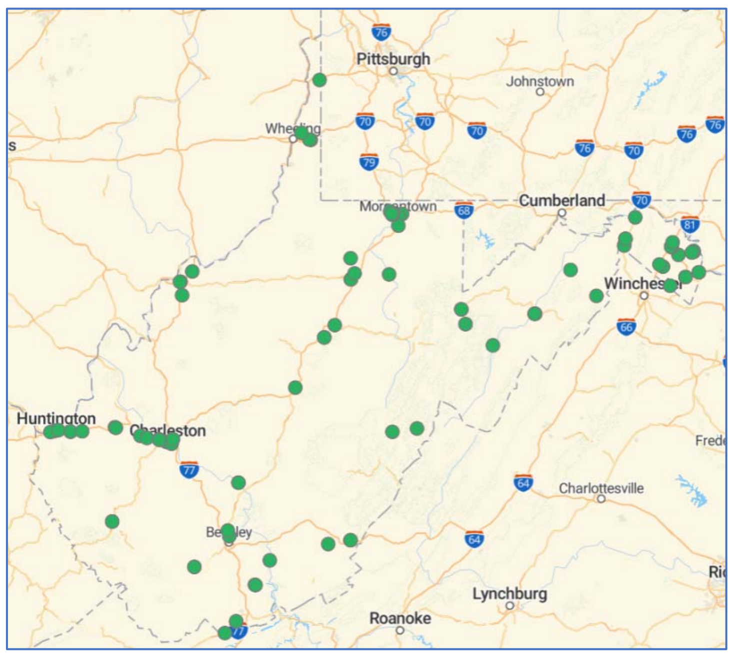
The I-81 Corridor Coalition[20] is a program where WVDOT is collaborating with state DOTs from Tennessee, Virginia, Maryland, Pennsylvania, and New York to enhance the safety and efficiency of freight movement along the I-81 corridor. The I-81 corridor experiences high levels of congestion with around 40% truck traffic and high rates of incidents. The Coalition is adding real-time truck parking information to the existing Traveler Information System that provides travelers with information on travel times, incidents, and weather conditions.

Facebook New River Project

In November of 2019, Facebook broke ground on an extensive broadband development project, called the "New River Project". Through a subsidiary company, Middle Mile Infrastructure, Facebook plans to implement a high-capacity fiber optic cable network from Virginia to Ohio, including a 275-mile route through West Virginia. This project is expected to bring high-speed internet to rural communities, prompting opportunities for more jobs and company investment. With project completion expected in about two years, a reliable network of high-speed communications opens many possibilities for emerging transportation and technology investments throughout the state[21].

Volkswagen Environmental Mitigation Settlement

Volkswagen provided West Virginia $12.1 million for transportation projects that can reduce NOx as part of its settlement. With the funds from the settlement, West Virginia has the potential of shaping the future of EV infrastructure. West Virginia plans to spend approximately five percent of its allocation on eligible projects related to the installation of electric vehicle charging equipment, with an emphasis on locations within, or near, the campuses of West Virginia University and Marshall University[22]. As of October 2020, there are 93 public charging stations with 258 outlets across West Virginia as presented in the map to the right[23].



[20] I-81 Corridor Coalition Website
[21] New River Gorge Regional Development Authority, Facebook Fiber Network Project in West Virginia
[22] West Virginia Beneficiary Mitigation Plan
[23] U.S. Department of Energy, Alternative Fuels Data Center

CAMBRIDGE SYSTEMATICS
Think Forward

West Virginia Hyperloop Development Center

Virgin Hyperloop One is a transportation technology company investing in a new high-speed technology concept called the Hyperloop. The technology is intended to move people and goods at higher speeds for a fraction of the price of air travel. As the company continues to grow and develop its concept of high-speed transport, it is planning on developing testing facilities throughout the U.S., similar to the existing Las Vegas test site[24].

Virgin Hyperloop announced on October 8, 2020 that it will locate its new Hyperloop Certification Center (HCC) on nearly 800 acres of land, spanning Tucker and Grant counties, where it will leverage intellectual capital and resources from West Virginia University, Marshall University, and from across the state. Work on the HCC is expected to begin 2021. WVU's Bureau of Business and Economic Research predicts the total economic impact of the center's ongoing operation on the West Virginia economy to be $48 million annually.[25]

[24] The Verge, Hyperloop One shows off its first superfast test track in the Nevada desert
[25] Gov. Justice announces Virgin Hyperloop to build Hyperloop Certification Center in West Virginia, 10/8/2020

West Virginia Clean State Program

The WV Office of Energy Clean State Program helps facilitate West Virginia's Clean Cities coalition, one of nearly 90 nationwide. Sponsored by the U.S. Department of Energy's (DOE) Vehicle Technologies Program, Clean Cities is a government-industry partnership designed to reduce petroleum consumption in the transportation sector.

WV Clean Cities deploys technologies and practices including idle-reduction equipment, electric-drive vehicles, fuel economy measures, and renewable and alternative fuels, such as natural gas, liquefied petroleum gas (propane), electricity, hydrogen, biofuels, and biogas. Idle-reduction equipment is targeted primarily to buses and heavy-duty trucks. Clean Cities' fuel economy measures include public education on vehicle choice and fuel-efficient driving practices. For example, in 2018, per DOE estimates, alternative fuel vehicle technologies in WV saved over 654,182 gallons of gasoline.[26]

2.5 Summary

Federal initiatives (through programs, grants, and research), activities in neighboring states, and technology pilots in rural states can inform how WVDOT considers its response to emerging technologies. Telecommunication companies and other third-party providers also provide new partnership opportunities that can advance private and public sector objectives.

Given the broad range of efforts and future direction of technology changes, state DOTs are beginning to identify internal resources and organizational arrangements with both public and private partners to better coordinate and communicate with internal and external stakeholders.

[26] West Virginia Clean Cities Coalition. https://cleancities.energy.gov/coalitions/west-virginia

3. Where Are We Going?

3.1 Overview

Emerging technologies have the power to disrupt traditional processes by offering innovative ways to solve transportation challenges. Given the rapid pace and transformative nature of emerging technologies, the future seems quite uncertain. In order to develop forward-thinking frameworks, policies, and action plans, agencies need to consider both the current and future status of technologies. This section discusses anticipated technology trends and future possibilities that would help inform state DOTs planning, programming, and investment decisions.

3.2 Automated Vehicles

The reality of automated vehicles (AVs) is becoming tangible, as more automated driving system features are being introduced in vehicles today and as the industry continues to heavily invest in the development and testing of AVs with the goal of producing self-driving vehicles (i.e., fully autonomous vehicles corresponding to the Society of Automotive Engineers (SAE) Level 5 automation).

While it is debated when exactly AVs that are largely self-driving will be ready for mass deployment, there is consensus on the need to start preparing for AVs and their potential effects on mobility and infrastructure.

There are many different models under which AVs might be rolled out in the future given the current efforts being undertaken in AV development and piloting. Privately-owned AVs is an option considering the existing privately-owned vehicles model, and the progress vehicle manufacturers are achieving in designing highly automated features in their vehicle fleets. However, experts estimate that SAE Level 4 automation (where driving functions is mostly automated, and a driver might be required to take over in certain situations) will cost an additional $10,000 to $50,000 per vehicle[27]. This makes the vehicles substantially more expensive than the price of an equivalent non-automated vehicle. One evolving trend that AV developers and technology companies are pursuing is the deployment of AVs as part of a shared fleet, similar to modern-day car sharing services, referred to as shared automated vehicles (SAV).

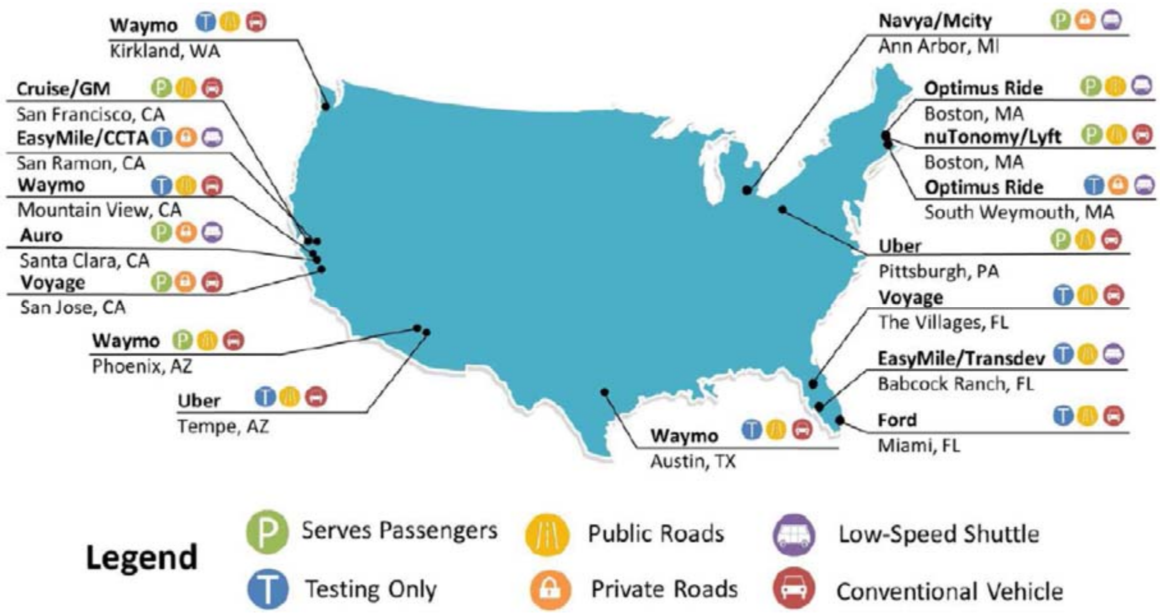
Figure 2 provides an overview of some of the SAV pilots happening across the country as of February 2018. The effort in SAV piloting indicate that the shared AV fleet model may be far more prevalent than personally owned AVs, at least in the initial years of AV deployment, provided that communication infrastructure is available to allow for their operation.

Another observed trend is incorporating AV technology in TNCs private vehicle fleets. Many companies including Uber and Lyft are making large investments in AV testing and piloting with the end goal of providing full commercial ride-hailing/ride-sharing services. Additionally, driverless shuttles, which operate along a pre-defined route at maximum speeds of 25 mph and typically have a capacity of 8-10 people, are being piloted as circulators in city downtowns or in enclosed spaces such as airports, university campuses, etc.

[27] Stocker, A., and Shaheen, S., 2017. Shared Automated Vehicles: Review of Business Models

The future vision for driverless shuttles is operating at higher speed and capacity to replace conventional buses, and potentially provide on-demand door-to-door services. Both AV shuttles and ride-hailing/ride-sharing services are considered opportunities to address transit's first mile/last mile issue, where the provision of transit is too expensive to support short trips.

*Figure 2: Map of A*ctive SAV Pilots (as of February 2018) [22]



There are more than 272 million conventional cars in the United States[28]. Those cars are not going to suddenly become driverless cars. AVs will gradually emerge and there will be decades-long transition period, where conventional cars will share the streets with cars having different levels of autonomy. It is difficult to speculate what the AV penetration rate will be in the future, given that the technology is still developing and there are many obstacles in terms of regulations, supporting infrastructure, costs and user acceptance that are yet to be overcome. However, we can say that the most likely scenario for near future is one of a "mixed fleet" where Level 4 and Level 5 AVs share the roads with vehicles with low to nonexistent automated functions.

3.3 Connected Vehicles and Smart Infrastructure

Connected Vehicle (CV) technology is being developed simultaneously and is often grouped together with AV technology. CVs are vehicles that use communication technologies to exchange data and interact with other vehicles (V2V), smart infrastructure (V2I), and their surroundings including pedestrians, cyclists, mobile devices, and the cloud (V2X)[29]. The key to realize the potential benefits of CVs lies in the communication infrastructure capability. The overall V2X offering, including V2V and V2I, have developed as a result of innovation during the past two decades in communication and location-sensing technology. ITS, more robust telecommunications networks, and GPS-based services have all served as process steps towards the birth and progress in CV technology.

[28] Statista Business Data Platform
[29] The National Academies Press, Bradley et al., 2018; DOT, 2018; Siemens, 2015

The USDOT Intelligent Transportation Systems Joint Program Office (ITS JPO), Federal Highway Administration (FHWA), Federal Transit Administration (FTA), Federal Motor Carrier Safety Administration (FMCSA), and the National Highway Traffic Safety Administration (NHTSA) are collaborating to research and progress the deployment of CV technology nationwide. Over the last 5 years, these USDOT agencies have focused on prototyping and assessing applications that realize the full potential and benefits of the technology.

Researchers have predicted that more than 250 million vehicles globally will be connected this year[30]. Most long-range scenarios on vehicle trends expect the population of CVs to exceed 90 percent by 2050[31].

CV technology futures are uncertain due to multiple challenges. One of the key challenges is that there are still no regulations or standards for vehicular communications. There are ongoing debates on whether Dedicated Short-Range Communication (DSRC) or 5G cellular networks should become the standard. While DSRC assets (on-board units and roadside units) are readily available in the market, 5G is still very much in the development phase with no working prototypes or standards available. However, 5G presents the opportunity for enhanced speed and reduced latency and allows the easy deployment of V2X applications due to smartphones, enabling greater interoperability. It is most likely that the standard of vehicular communications will be a combination of DSRC and 5G in the future.

Another challenge is that the connectivity necessary for providing CV features pose privacy, data security, and physical safety vulnerabilities of CV computer systems. In the long-term, the approach by Congress and the courts of governance of CV will likely guide the development of standards and best practices across the IoT spectrum including CVs[32].

While predictions vary for when AV and CV technologies will be ready for mass deployment, West Virginia like many other states need to start preparing for the future.

West Virginia has a valuable opportunity to test AV and CV technologies given its topographic and rural nature which provides unique road conditions that are marked with quieter roads and less traffic, yet with the complexity needed to develop these technologies to address unique road safety challenges.

Understanding the impacts of AVs and CVs through testing will help WVDOT identify the relevant operating models that would maximize the benefits of these technologies for West Virginia's transportation system, economy, and environment. There also is a great opportunity to coordinate and collaborate across state lines to leverage the benefits of cooperative testing and deployment in terms of cost, effectiveness, diversity of applications and data sharing.

[30] Deloitte, "Who owns the road? The IoT-connected car of today—and tomorrow"
[31] AASHTO, National Connected Vehicle Field Infrastructure Footprint Analysis, June 2014
[32] Baker Hostetler, Legal Developments in Connected Car Arena Provide Glimpse of Privacy and Data Security Regulation in Internet of Things

3.4 Electric Vehicles and Alternative Fuels

Discussions of connected and automated vehicle (CAV) technology is usually coupled with EV technology. It is anticipated that fleets of CAVs will also be electric to maximize environmental benefits. EVs which present an alternative to gasoline and internal combustion engines (ICEs), have been available for decades, but due to several factors - cost, supporting infrastructure, and limited range – their market share has been limited. Today, EVs are only 1% of US vehicle sales. However, the technology is progressing, and battery improvements are providing longer vehicle range, and faster charging capacity. Since the EV battery pack accounts for approximately a quarter of the total vehicle costs[33], improvements are also reducing costs. The US Energy Administration estimates that EVs will comprise 19% of US market share by 2050[34], while other industry estimates have estimated the worldwide share of EV sales by 2040 at over 50%.[35]

The provision of supporting charging infrastructure is critical for successful EV deployment and adoption. Currently, in the U.S., there are approximately 20,000 public and work located EV charging locations[36]. With the EV market in the U.S. expected to continue to rise, the need for public EV charging stations will become more important. It has been estimated currently between 75 to 90% of all EV charging takes place at the user's home, but with higher levels of EV adoption and greater commuting distances, more public EV charging will become necessary.[37] [38]

A recent study was published by DriveOhio in June 2020, entitled *Electric Vehicle Charging Study*[39]*.* The study investigates the need for EV charging along interstate, U.S. highway and State route corridors in Ohio. It focuses on the provision of Direct Current Fast Charging (DCFC) stations that can rapidly deliver significant added vehicle range at locations that are easily accessible by motorists. The study also includes cost estimates and explores funding opportunities to fill in the identified charging infrastructure gaps. The DriveOhio study represents an example of an initiative that West Virginia could undertake to help expand its EV market.

As the adoption of EVs and deployment of supporting infrastructure expands in the future, compressed natural gas (CNG) presents a current low-emission alternative to traditional transportation fuels. Natural gas is a sustainable and cost-effective fuel that increases vehicle efficiency, reducing emissions and brining about environmental benefits. It is recoverable and therefore is readily available. The U.S. is considered one of the primary producers of natural gas due to its abundant domestic supply[40].

[33] The International Council on Clean Transportation, Update on Electric Vehicle Cost in the US through 2030
[34] U.S. Energy Information Administration. Annual Energy Outlook 2019
[35] BloombergNEF Electric Vehicle Outlook. https://about.bnef.com/electric-vehicle-outlook/
[36] Center for Automotive Research, 2018, accessed February 2019
[37] U.S. Department of Energy Office of Scientific and Technical Information, (Heilig et al., 2017)
[38] McKinsey & Company, Charging ahead: Electric-vehicle infrastructure demand, February 2019
[39] DriveOhio Electric Vehicle Charging Study, June 2020
[40] NGVAmerica Website

To support the transition to sustainable vehicle fuels, the FHWA is designating "Alternative Fuel Corridors" where alternative fueling and charging infrastructure and signage are provided along national highway system corridors[41]. The FHWA seeks to expand this national network to promote alternate fuel options and reduce dependency on oil, as well as improve energy security. WV has designated I-70 as an alternative fuel corridor through this program.

3.5 IoT and Big Data

One of the promising early results of IoT technologies (smart sensors/devices) is a significant increase in data availability. As experts anticipate massive increases in the connectivity of vehicle fleet and infrastructure, more data will become available. This is additional to data coming from public agencies, private industry OEMs, smartphones (location-based services data and call data records), app developers, and others.

Transportation agencies are already looking to leverage Big Data to help manage transportation networks, reduce congestion, and improve safety. More and more public agencies are developing open data portals to increase the transparency of government data, which is required by the Freedom of Information Act (FOIA). Virginia's SmartRoads[42] data portal is one example where information on road conditions, incidents, work zones, and multi-modal transportation and asset information is available for the industry to access and use to develop innovative applications.

> The fusion of urban data from increasingly complex networks of sensors allows for new ways to 'sense the city' and enhance transport capability and resilience. Predictive analytics provide a unified approach for extracting useful urban mobility information from networked infrastructure, connected vehicles and smartphones, for real-time estimation of traffic patterns, and deployment of management strategies.
>
> - Dr. Hussein Dia, Swinburne University of Technology

An open-source community is a step in the right direction, but private industry has been and still is particularly hesitant to share data with public agencies or participate in open data portals; lest it get into the hands of their competitors. It is expected that in the near-term, the amount and type of data will continue to increase as newly developed technologies are deployed. In the long run and in order to maximize the opportunities to leverage Big Data to create value and help drive accurate and real-time decision making, the public and private sector shall work collaboratively to address the following two main challenges: (1) data sharing between private industry and public agencies and (2) managing Big Data acquisition, storage, processing, and security.

[41] FHWA Office of Environment, Alternative Fuel Corridors Initiative

[42] VDOT SmartRoads Open Data Portal

3.6 Examples of Technology Applications in the Appalachian Region

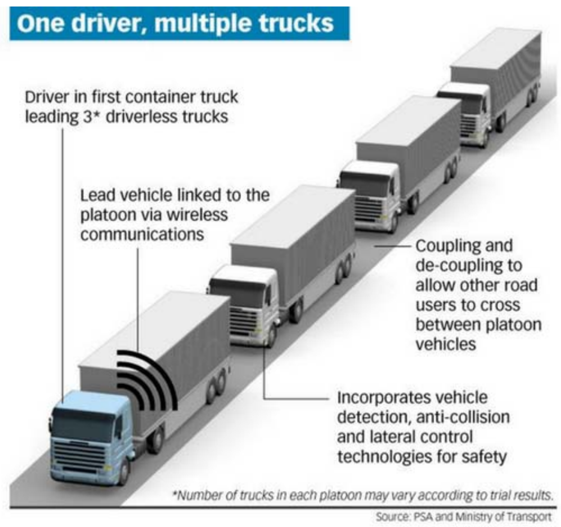
West Virginia has undertaken steps forward in terms of policies, research, and initiatives to help advance technology in the overall Appalachian region. Expanding the highway network as part of the Appalachian Development Highway System (ADHS) and developing the broadband infrastructure along key interstate and State highway routes are considered critical groundwork to support the application of emerging technologies. The provision of highway corridors with enhanced connectivity creates opportunities to implement "smart highway" technologies that would help make rural West Virginia safer, more accessible, and a better place to live and do business; ultimately fostering the region's economic growth.

Technological advances in telecommunications and information technology, coupled with state-of-the art sensing equipment have enhanced the capabilities of deploying ITS. The application of ITS is a great opportunity for WVDOT to manage congestion and incidents improving road safety, and to provide valuable information to road users allowing them to make better informed trip-related decisions. ITS can serve not only passenger vehicles, but also transit and freight movement. ITS applications include traffic and weather management, traveler information systems, real-time parking management, transit management, and others. While ITS programs could be implemented to tackle transportation, challenges faced by a particular state, ITS Coalitions are becoming more common. Such partnerships allow states to share investment costs, data, and best practices, with the end goal of improving the safety and efficiency of shared corridors. This leads to the improvement of the transportation system at a regional level expanding economic development opportunities.

Ohio has made significant advances in recent years to integrate ITS technologies into its transportation landscape including its 32 Appalachian counties. Through the Ohio Governor's Office of Appalachia and in collaboration with the ARC, Ohio is identifying opportunities for future growth and development of the Appalachian region. The Deploying Automated Technology Anywhere (D.A.T.A.) is a demonstration program for testing automated driving systems (ADS) in passenger and freight vehicles, and cooperative automation technology in rural environments[43]. The goal of D.A.T.A. is to collect robust data about AV performance in rural areas and highway environments, specifically in the Appalachian region that provides varying weather conditions and mountainous terrain. Data collected through the program would help evaluate safety and inform rulemaking in the region. West Virginia shares an interest in understanding how vehicle technologies can work within the Appalachian region as well and can learn from the pilot's results.

[43] Ohio DOT, D.A.T.A. in Ohio

Another related opportunity that could help drive the economic development in West Virginia is the use of connected and automated trucks to enable more efficient goods movement statewide and regionally. While mainstream adoption of AV/CV trucks will not be seen in the near future, technological advances such as aerodynamic efficiencies and semi-autonomous features (e.g., automated braking systems) are already under way. A report by McKinsey & Company on the future of commercial transport predicts that by 2025, at least one third of new heavy trucks will be semi-autonomous, eliminating the need for a full-time driver. This will reduce the total cost of ownership of a truck by as much as 35% to 50%[44], freeing up trucking company resources to invest in new trucks, and further speeding up the pace of AV adoption. As consumers become accustomed to receiving deliveries more and more quickly (known as the "Amazon Effect"), this will increase demand for more trucks to be operating non-stop.



In terms of trucks connectivity, truck platooning is one application that could improve safety and traffic conditions, and lower fuel consumption. Truck platooning (see figure[45]) is when several trucks travel in convoy, closely following each other with the aid of communicating driving support systems.

Like other CV applications, truck platooning is enabled by the deployment of IoT devices that allows trucks to exchange data about their location, speed, heading, etc. One barrier to implementation is following-too-closely (FTC) rules in many states mandating 300 feet between vehicles. To date 18 states including Tennessee and North Carolina have fully authorized platooning, and 8 additional states including Kentucky and Indiana have allowed testing or limited deployments[46]. In Virginia, a truck platooning demonstration project was undertaken in collaboration with FHWA, where three trucks traveling in a convoy were tested along I-66[47].

[44] TRUCKS, One-Third of all Long-Haul Trucks to be Semi-Autonomous by 2025
[45] Labroots, Truck Platooning: The Band of Semi-Trailers
[46] Competitive Enterprise Institute, Authorizing Automated Vehicle Platooning, 2018 Edition
[47] FHWA, Research Projects Use CACC to Improve Truck Platooning

3.7 Preparing for Emerging Technologies

Emerging technologies present opportunities to enhance safety, reduce congestion, improve mobility, support the economy, and foster environmental health. The main challenge, however, is that the timing and magnitude of future technological advances are uncertain. Numerous unanswered questions make the future unpredictable — technological hurdles, public acceptance, availability, and cost of technologies.

In the face of this unpredictability, it is essential for WVDOT to prepare for the future in order to successfully navigate current and future challenges and to position the state for continued prosperity.

Like other state DOTs, assessing existing conditions; developing policies and strategic plans (e.g., CAV Plans); investing in research and development to better understand the impacts and benefits of emerging technologies; exploring partnerships with public and private sectors for testing and piloting; and investing in smart infrastructure, are all ways to embrace the birth and continuous development of technologies. In the near-term, however, it is important for WVDOT to make the necessary organizational changes to streamline and prioritize technology, establish a robust set of goals, objectives, priorities and performance measures that embraces technology, and start taking steps to incorporate technology considerations throughout the project development cycle.

3.8 Summary

Understanding how emerging technologies are expected to advance in the future helps inform WVDOT long term vision and priorities for West Virginia's transportation system. Emerging technologies present opportunities to address safety, mobility, and environmental needs, and bring about economic growth. Considering the rapid pace of technology development, state DOTs are starting to plan and take actions to prepare for the future. Similarly, WVDOT needs to be ready to mitigate potential unwanted impacts of emerging technologies while leveraging opportunities.

4. Future Direction / WVDOT Opportunities

4.1 Overview

Emerging technologies will impact transportation in West Virginia in the future, but the rate, scale, and extent of impact are hard to predict. The timing of these impacts is dependent upon several industry factors, and how effectively technology fits within West Virginia's operating environment – notably the mountainous terrain and predominant network of low volume, rural roadways.

As such, the impacts of technology acting on the state may occur unevenly and in phases by regional, local, or corridor-specific location. Interstates and heavily traveled highway corridors provide an attractive ground for technology pilots and programs, and opportunities to coordinate with neighboring states. Broadband installation as part of highway improvements is taking shape as policy in a number of mid-Atlantic states. Additional communications infrastructure that covers more parts of West Virginia can lay the groundwork to enable transportation technologies such as CAV. Coordinated planning and partnerships with third-party providers – who drive high-speed telecommunication - can leverage and achieve both public and private sector objectives.

It is important to note that there are potential implications, many of them representing a negative impact to West Virginia's transportation mobility and economy, for a "do nothing" approach to preparing for emerging technologies.

If West Virginia falls behind neighboring states in regulation and management of new in-vehicle technologies and mobility services, they may face frustrated traveler and business communities. An example of frustrating consequences might include truck platoons being forcing to break up when crossing into the state, or mobility services (like the current or next generation of ride-hailing applications) requiring inefficient border transfers that drive up traveler and operator costs. Certain technologies may not necessarily originate or mature within West Virginia, but at some point, they will be "knocking at the door" and seeking permission to operate (or will simply operate illegally).

Another noteworthy consequence of a "do nothing approach" is a loss of opportunity. Private sector partners seeking testing locations and partnerships look to the public sector for clear and easy processes to understand their opportunities and limitations. They will quickly relocate if the clarity is lacking, preventing agencies from even having a chance to properly assess the opportunity. Additionally, several states, regions, and cities have implemented innovative technology pilots, but then failed to use them to improve broader understanding and capabilities that build a foundation for future efforts. In many cases, very promising technology projects have ended with little fanfare and minimal contributions to overall understanding.

Therefore, it is important for WVDOT to develop, establish, and grow the agency's "technology awareness" to catalyze a wider, more comprehensive, and coordinated response to emerging and disruptive technologies. Strengthening technology awareness can position WVDOT to better navigate risks and exploit opportunities presented by these technologies, and better manage internal resources to achieve agency and broader state goals and outcomes – such as using transportation/technology investments to improve access to education and health care.

Broad and adaptable strategies also address changing external conditions and customer needs, acting on WVDOT's physical infrastructure and support agency responses through new pilots, policies, or processes. As other State DOTs have discovered, effective responses to technology also requires stronger partnerships across state, local and private sector levels. This section outlines a future direction for WVDOT and considerations to organize, prepare, and begin to build a framework to elevate the Agency's role and resiliency to technology.

4.2 Key Considerations for WVDOT

Assessment of Agency Capabilities, Roles and Responsibilities

WVDOT would benefit from an assessment of their capability maturities related to planning for, engaging with, and utilizing advanced technologies. Understanding the existing gaps and weaknesses will support the agency in building up capabilities where needed.[48] A deep look at the roles and responsibilities within WVDOT goes hand-in-hand with this assessment. Emerging technologies do not always fit in traditional DOT siloes and, as a result, can sometimes lead to conflicting messages to partners, disorganized planning, and missed opportunities.

At minimum, WVDOT needs to consider:

- **Partnership Mechanisms and Tools:** Does WVDOT have dedicated staff and resources to support emerging technology and innovative partnership efforts at WVDOT? Who leads the establishment and maintenance of innovative partnerships with private sector, state public agencies, developers, technology/communication companies, universities, local planning partners to strengthen WVDOT's response to emerging technology trends through research, testing and piloting? Are new formal structures needed to drive opportunities for partnership? Do potential partners have a clear path or forum to bring questions and ideas to WVDOT?
- **Funding for Technology Initiatives:** How does WVDOT consider funding requirements for pilots, implementation projects, operations, and maintenance? Does WVDOT have a process in place to explore funding grant opportunities and stay informed about federal grants such as ATCMTD, BUILD, HSIP, INFRA?
- **Legislation to Support Technology and Innovation:** Does current or pending legislation support beneficial technology development and deployment? Who will work with officials to review regulatory, contractual, and proprietary standards and promote flexibility regarding technology projects?[49]
- **Integration of Technology Across Agency Plans:** Are there focused efforts to fit technology into existing plans such as agency business plans, State and regional plans, LRTP, corridor plans, modal-specific plans, and other relevant state agency plans (Commerce, Health/Human Service, Natural Environment)? How does WVDOT promote consideration of technology across agency plans?

[48] FHWA, Capability Maturity Frameworks for TSMO Program Areas
[49] NCSL, Autonomous Vehicles Enacted Legislation

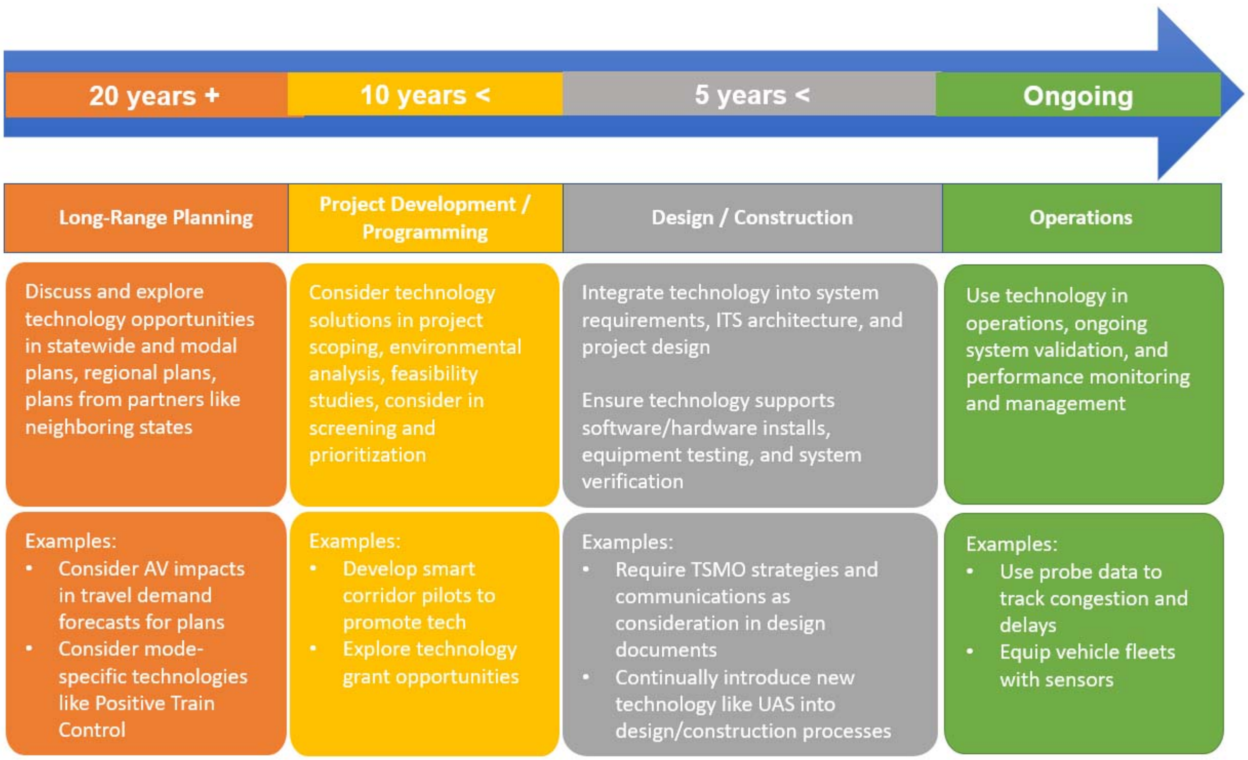
To help integrate technology into WVDOT normal operations, WVDOT could consider the option of a dedicated technology unit or division with a centralized role to manage and coordinate technology-related activities. The division would be focused on coordinating with internal and external stakeholders to help advance technology pilots and initiatives in West Virginia. WVDOT may also consider a process to clearly assign roles and responsibilities across divisions, or to a cross-divisional technology committee.

Establishing Processes to Advance Technology Across Project Life Cycles

WVDOT should prepare for and consider technologies at multiple levels within the agency, and along several points of the project development process. Enhanced processes to incorporate technology could be led by a single champion or through more enhanced coordination, data sharing and communication of technology related decisions. These steps can help WVDOT better leverage transportation investment decisions at the individual project, corridor, or network level.

Figure 3 illustrates key elements for a "WVDOT Framework" to promote and strengthen the linkage between technology and transportation planning, project development, design, construction, and operations phases.

Figure 3: WVDOT Framework for Technology Coordination Across Project Lifecycle



In the **Long-Range Planning** phase, WVDOT can identify potential technologies as well as take steps to create synergy across the variety of plans that shape their actions. Updates to statewide system and mode-specific plans should identify technology opportunities and emphasize those which can benefit multiple objectives and stakeholders. For example, geo-fencing data to support statewide truck parking studies or freight plans can inform safety concerns addressed in the Strategic Highway Safety Plan (SHSP) or rationalize countermeasures in Highway Safety Improvement Programs (HSIPs). The growth of Positive Train Control on more miles of class 1 railroads can reduce fatalities at highway/railroad crossings outlined in SHSP goals. Identifying aviation sites to support takeoff/landing infrastructure for unmanned aircraft systems (UAS or drones) can inform aviation planning and economic development.

In the **Project Development / Programming** phase, WVDOT can use early project scoping to build on long-range plans and achieve multiple statewide transportation and technology related objectives. Here is where WVDOT can advance statewide objectives in specific corridors, for example by incorporating West Virginia's "Dig Once" policy to ensure project by project spare conduit installation forms one or more "spines" of broadband infrastructure opportunity along highway rights of way. Opportunities to connect broadband in project corridors adjacent to traffic signal systems or devices which support West Virginia's Statewide Intelligent Transportation System (ITS) is another consideration, as is identifying cross-connections to the project which service broadband to a WVDOT District Office or future Traffic Management Center. Local planning partner (Regional Planning and Development Councils (RPDCs) and Metropolitan Planning Organizations (MPOs)) involvement in project scoping can also highlight "last mile" connections accessed through adjacent state/local property which in turn may incentivize more telecommunication provider lease agreements.

In the **Design** and **Construction / Inspection** phases, WVDOT has the opportunity to interface with private companies, developers, federal partners, and researchers at West Virginia Universities to leverage smart infrastructure resources and investment. Arrangements to install, test, verify and operate innovative communications and operations ("smart") infrastructure can support a variety of interests, and spur the use of West Virginia's transportation system as a real-world technology proving ground. A broad array of stakeholder involvement – similar to what was done for Ohio's US 33 Smart Mobility Corridor - can leverage operating and resource costs and introduce next-generation data systems. Over time, smart infrastructure uses can support a spectrum of highway and non-highway related applications such as CAV freight tests or UAS deployments.

In the **Operations** phase, WVDOT's existing ITS can serve as a foundation for strengthening the network management ecosystem and integrating new technologies. Retrofits of certain traffic signal systems or other ITS components connected to smart infrastructure could expand capabilities. Small pilot tests of new infrastructure components can identify ways to expand smart infrastructure capabilities such as enhanced traffic management, incident response, and event coordination. Evolving these systems, even through small applications, empowers WVDOT to plan and prepare for stronger network operations and management at a statewide scale. Use of technology in operations also links closely with performance management, an opportunity area discussed below.

Embracing Technology to Support Agency Performance Management

Disruptive technologies may provide new ways to measure key aspects of WVDOT's transportation system and/or offer insight into how traditional measures are adjusted to communicate technology's impact. Disruptive technologies may also require new strategic agency responses, such as a new program, internal resource re-balancing or customized reporting to spotlight how WVDOT is navigating and utilizing change to better oversee its operations. Measures which communicate the cost-benefit implications of applying these technologies will need to develop and evolve over time and include WVDOT's partners like MPOs as they related to two-and four-year federal performance targets.

Data streams and systems are critical to performance management. Existing pavement and bridge management systems should evolve to incorporate new sources of next generation transportation information (data mining, business intelligence, crowdsourcing, or other sources) to facilitate more dynamic data streams of current and predicted asset performance. A more connected vehicle fleet will allow better real-time understanding of recurring and nonrecurring delays. Over time, new data streams – connected with ITS and other smart mobility systems - could supply WVDOT with a broader set of parameters to link and strengthen programmatic investment decisions to defined network goals and outcomes.

4.3 Conclusions

Transportation technologies are rapidly evolving across the U.S. and the world. It is clear that emerging technologies will impact transportation in West Virginia in the future, but the rate, scale, and extent of impact are hard to predict. WVDOT is well-positioned to leverage lessons learned from peer states and others to chart its own comprehensive response to emerging technologies.

Interstates and heavily traveled highway corridors provide an attractive ground for technology pilots and programs, and opportunities to coordinate with neighboring states. Broadband installation as part of highway improvements is taking shape as policy in a number of mid-Atlantic states. Additional communications infrastructure that covers more parts of West Virginia can lay the groundwork to enable transportation technologies such as CAV. Coordinated planning and partnerships with third-party providers – who drive high-speed telecommunication - can leverage and achieve both public and private sector objectives.

WVDOT should recognize the potential implications for a "do nothing" approach to preparing for emerging technologies to avoid falling behind neighboring states in regulation and management of new in-vehicle technologies and mobility services and facing frustrated traveler and business communities. Private sector partners seeking testing locations and partnerships look to the public sector for clear and easy processes to understand their opportunities and limitations and will quickly relocate if the clarity is lacking, preventing agencies from even having a chance to properly assess the opportunity.

It is important for WVDOT to develop, establish, and grow the agency's "technology awareness" to catalyze a wider, more comprehensive, and coordinated response to emerging and disruptive technologies. Strengthening technology awareness can position WVDOT to better navigate risks and exploit opportunities presented by these technologies, and better manage internal resources to achieve agency and broader state goals and outcomes – such as using transportation/technology investments to improve access to education and health care.

There are specific actions WVDOT can undertake. Assessing capabilities and existing roles and responsibilities regarding technology can ensure opportunities are addressed proactively and comprehensively. WVDOT can integrate consideration of technology into all phases of a project life cycle. Finally, performance management is an early opportunity to use technology to address West Virginia's transportation needs. Integrating new data streams will enable a better view of how the system is performing, and ways to further leverage technology and meet WVDOT goals.

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