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Automated, Autonomous and Connected Vehicle Technology Assessment

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Electric Vehicle Transportation Center

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1. Summary

The U.S. Department of Transportation (USDOT) and almost every state DOT are showing extreme interest in the application of automated and connected vehicles (ACV). This combined application can significantly reduce crashes, energy consumption, pollution and the costs of congestion which in turn will offer a fundamental change to the U.S. transportation network and system. The objective of this technology assessment project is to evaluate the vehicle technologies, actions, laws and policies that are now in place and to assess their future usage. The assessment also evaluates the highest level of automated vehicles called autonomous or self-driving vehicles. In fact, autonomous vehicles are the area that is receiving the most interest from both the general public and government agencies. The project will also evaluate how electric vehicles (EVs) will participate in this future ACV transportation system.

2. Introduction

The technology world for automated, autonomous and connected vehicles (ACV) and their use can be separated into two areas – area one being the technology research and development done by the automotive, university, information technology (IT) innovators and engineers and the second being the actions by federal, state and local governments whose activities in R&D, laws, policies and demonstrations are needed and required to implement the technologies. For purposes of this investigation, these two areas will form our assessment.

Let's begin our discussion with the three definitions for automated, autonomous and connected vehicles.

- Automated vehicle is a vehicle that has some level of convenience or safety-critical control functions that occur without direct driver input. It is noted that in defining automated vehicles there are, in reality, two definitions – automated as defined in the previous sentence and autonomous which is defined as a driverless or self-driving vehicle. Also noted is the fact that almost all of the public and governmental attention is directed at autonomous vehicles.

- Connected vehicles (CV) employ vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication to provide real-time warnings to a human driver to help avoid crashes and increase vehicle efficiency. Additional information can include traffic signal status, traffic congestion and construction warnings, as well as impending severe weather events. CV technologies can also allow non-vehicular systems such as the traffic signal control system to react to real-time information from the vehicle.

With these general definitions, the details for each area follows

3. Automated and Autonomous Vehicles

Fully automated (sometimes called autonomous) or “self-driving” vehicles are defined by the U.S. Department of Transportation's National Highway Traffic Safety Administration (NHTSA) as “those in which operation of the vehicle occurs without direct driver input to control the steering, acceleration, and braking and are designed so that the driver is not expected to constantly monitor the roadway while operating in self-driving mode.” Further, the NHTSA has categorized vehicle automation into five levels; the higher the level the more automated the vehicle is. Listed below are the NHTSA’s five levels of automation: [1]

Level 0 – No-automation -- Driver is in complete and sole control of the primary vehicle controls – brake, steering, throttle, and motive power – at all times. These vehicles can have driver aiding systems such as lane departure warnings, blind spots or forward collision warning.

Level 1 – Function-specific Automation – The driver has overall control and is responsible for safe operation, but can choose to cede limited authority over a primary control. Automation at this level involves one or more specific control functions. Examples include electronic stability control or pre-charged brakes, where the vehicle automatically assists with braking to enable the driver to regain control of the vehicle or stop faster than possible by acting alone.

Level 2 – Combined Function Automation – This level involves automation of at least two primary control functions designed to work in unison to release driver control. An example is adaptive cruise control in combination with lane centering. Driver is disengaged.

Level 3 – Limited Self-Driving Automation – This level of automation allows the driver to cede full control of all safety functions under certain traffic or environmental conditions. Driver is not expected to constantly monitor the road, but must be able to reengage the driving task and is expected to be available for occasional control, but with sufficiently comfortable transition time.

Level 4 – Full Self-driving Automation – Vehicle performs all driving functions and monitors roadway conditions. In this case, the vehicle is designed to perform all safety-critical driving functions and monitor roadway conditions for an entire trip. Such a design anticipates that the driver will provide destination or navigation input, but is not expected to be available for control at any time during the trip. This includes both occupied and unoccupied vehicles. Vehicles with level 4 automation are also referred to as autonomous vehicles.

It is interesting to note that auto manufacturers draw a distinction between autonomous cars and self-driving cars. Autonomous cars will look like the vehicles we drive today with technology systems taking over from the driver under certain circumstances while self-driving cars are a stage further on. However, the self-driving vehicle could lose the steering wheel and the vehicle will do all the driving using a system of sensors, radar and GPS mapping that autonomous vehicles will employ. While personal cars will remain, the future will see a fleet of self-driving shared vehicles filling the streets of towns and cities. [2]

Technologically, almost all research and development in automated vehicles is being done by the automotive engineers and designers associated with the automotive manufacturing and marketplace or in combination with IT designers. Both of these market forces have the desire to sell more vehicles as a result of ACV or to implement the technologies because of the safety features.

Looking at automobiles in their normal driving environment presents a great challenge in technology and policy. Almost all present vehicles have some type of automated function. Examples are: cruise control, anti-locking brakes, lane departure warning, blind spot monitoring, back-up cameras and sensing, automatic collision notification, intelligent or automatic parking assist, night vision with object detection, adaptive cruise control, adoptive headlight and forward collision warning. These driving functions are at levels 0, 1 and 2 dependent upon the function. Levels 3 and 4 are almost entirely in the R&D stage, but some OEMs are close to Level 3. For example, Tesla implemented its auto pilot technology in October 2015. Cadillac and Volvo have also announced Level 3 vehicles in 2016, but they are not currently available. Level 4, full self-driving automation vehicles have been demonstrated by many auto companies and research organizations that include Google, Carnegie Mellon University, Mercedes GM, Nissan, Audi, to name a few.[3,4]

AVs and CVs are technologies that enhance and improved a mode of transportation by being interconnected within the transportation network. These vehicles will require some dedicated infrastructure development but most of the technology will be embedded in the individual vehicle and will traverse existing networks (i.e., cellular, satellite, etc.).

4. Autonomous Vehicles

Driverless or autonomous vehicles will usher in a revolution in both safety and fuel efficiency. Addressing first, the safety aspects, a study from McKinsey & Company, found the potential for a reduction of up to 90 percent in driving fatalities by using self-driving cars is due to the fact that computers are so much better drivers than error-and distraction-prone humans. In the U.S. alone, this would equate to about 30,000 lives saved each year and up to $190 billion in annual savings from healthcare costs associated with accidents. This translates to 10 million lives saved globally each decade. [5]

In the energy area, a recent study found that driverless cars and car-sharing services could save up to 90 percent of the fuel we currently consume, mainly through “right-sizing” the vehicle required for each task. [6] If a person needs a quick ride five miles from town, a single-person self-driving EV would pick that passenger up and take him or her to the desired destination. If a family needs an electric SUV for a beach excursion, that would be provided. By right-sizing each vehicle for each trip, the needless transportation of tons of steel would be dramatically reduced from today’s highly wasteful default driving situation. In addition, driverless cars can be actively driven for far more hours in the day through car-share services like Uber and Lyft, further increasing the efficiency of our entire transportation system. [7]

Autonomous vehicles sense their surroundings with techniques such as radar, LIDAR, GPS, odometry, and computer vision. Advanced control systems interpret sensory information to identify appropriate navigation paths, as well as obstacles and relevant signage. By definition, autonomous vehicles are capable of updating their maps based on sensory input, allowing the vehicles to keep track of their position even when conditions change or when they enter uncharted environments. Autonomous cars have control systems that are capable of analyzing sensory data to distinguish between different cars on the road, which is very useful in planning a route to the desired destination. [4]

Historically, the first modern self-sufficient (and therefore, truly autonomous) cars appeared in the 1980s, with Carnegie Mellon University's Navlab and ALV projects in 1984 and Mercedes-Benz and Bundeswehr University Munich's Eureka Prometheus Project in 1987. Since then, numerous major companies and research organizations have developed working prototype autonomous vehicles.

Our interest here and the primary interest of government agencies are on automobiles, however, many ground transportation vehicles also employ autonomous driving. Examples of autonomous ground vehicles are the monorail at Disney World, passenger shuttles at airports, ship gantries or mining trucks. Other examples of existing automation are aircraft autopilots, underwater vehicles and trains.

With regard to autonomous vehicles, work has been done that focuses on modifying existing cars or robotic cars to become semi-autonomous. This type of approach would use automated highway systems that construct exclusive lanes for operation and be equipped with electrical or magnetic guides on the vehicles. Highway computers would then manage the autos for speeds and avoidance of crashes. This type of approach is only applicable for special cases where special highway systems exist or are under development.

However, as to the advantages of autonomous vehicles, there are problems and obstacles to be overcome. Items such as who is liable for accident damage; IT software reliability, and its subject to compromise; laws and regulations for use; loss of drivers ability to control the auto; drivers being inexperienced if manual driving is required; driving retail jobs, and privacy: ethical problems in an unavoidable crash and the ability of systems to operate in extreme weather conditions - rain and snow. In fact, tests have already been conducted that show autonomous vehicles have the same problems as humans on snow or ice. [8]

How close are we to self-driving cars? The following quotes from Elon Musk of Tesla gives some thoughts on this future. [9]

The big news in the field of self-driving cars comes from Tesla, which unveiled and installed its autopilot technology over the cellular phone network last October 2015. [10] The reaction from Tesla owners seems to be generally positive, even though there have been some issues and a few negative reactions. Tesla made clear that its new feature is still in beta mode and is not a full autopilot. It is not yet known when the full autopilot features will arrive. Even with the current beta autopilot, however, the self-driving Tesla is highly functional. A recent cross-country test in a Model S took just 58 hours to drive the entire distance, and fully 96 percent of the 3,000 miles was driven by a non-human (i.e., the computer autopilot) at an average speed of 51.8 miles per hour. [10]

The Tesla system uses twelve sonar sensors in the front and rear bumpers plus its autopilot which is a combination of adaptive cruise control - this maintains a preset distance from a car in front of you even as its speed changes—and an enhanced version of lane departure prevention Tesla calls Autosteer. Tesla's Autopilot doesn't correct wandering; it simply steers for you. [10].

5. Connected Vehicles

Connected vehicles are vehicles that use any of a number of different communication technologies to wirelessly communicate with the driver, other cars on the road (V2V), roadside infrastructure (V2I), and the "Cloud." CV technology can revolutionize vehicular travel as we know it today. Connected vehicles can improve vehicle safety, improve vehicle efficiency, improve commuting times, greatly reduce crashes, reduce the need for new infrastructure, improve energy efficiency by more efficient driving, reduce travel times, provide lighter, more fuel-efficient vehicles and create more efficient infrastructure that will reduce energy consumption and expand opportunities for vehicle ownership by multiple ownership of self-driving vehicles

With regard to wireless communication, almost all cars after 2010 have in-dash communication systems with screen offering items such as music/audio, navigation, roadside assistance, parking apps, vehicle unlocking and engine control and diagnosing. On EV vehicles, phone apps offer charging station location and distance.

The connected car hardware most commonly used has a proprietary based internet connection and software such as global system for mobile communication modules (GSM) which is integrated into the car's IT system. There are also consumer purchased systems that are plugged into the car's on-board diagnostic port which could allow smart phone apps. Some modern examples of vehicle connectivity are General Motor's OnStar, Ford's Sync, and Chrysler's Uconnect. [11]

Although adding connectivity to vehicles has its benefits, it also has challenges. By adding connectivity, there are issues with security, privacy, data analytics, and aggregation due to the abundance of data associated with vehicles. The increased technical complexity of vehicles makes them more prone to "Bugs" and other system malfunctions can effectively immobilize an ACV.

The U.S. Department of Transportation (DOT) in a joint research effort with the Society of Automotive Engineers (SAE) has already started setting V2V and V2I communication standards, such as using a 5 GHZ frequency for transmission. [12]

Let us now look at laws and regulations as they exist today.

6. Laws and Policies

A most important aspect of ACV technology development is the enactment of laws and policies by the federal, state and local governments. This section looks at laws and policies that have been enacted beginning with the federal actions followed by the states. Note is made that the large majority of enacted laws and policies all refer to autonomous vehicle and do not specifically mention automated or connected vehicles. In addition, the intent of the U.S. laws and policies are to bring safer vehicles to use by the public as fast as possible without hindering technology development.

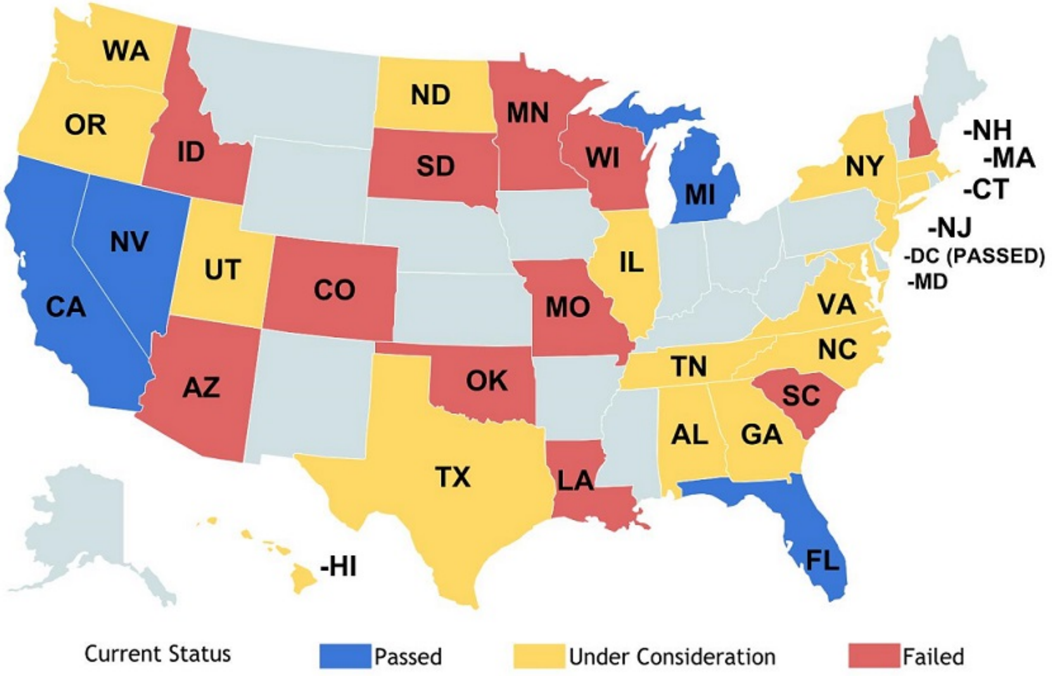
6.1 Federal Actions

The National Highway Traffic Safety Administration's (NHTSA) produced its Preliminary Statement of Policy on Autonomous Vehicles in May 2013. However, in January 2016, U.S. Transportation Secretary Anthony Foxx unveiled a new policy that updates the NHTSA preliminary policy statement and proposes to make a federal dollar commitment of nearly $4 billion over the next 10 years to accelerate the development and adoption of safe vehicle automation. The new policy is designed to facilitate and encourage the development and deployment of technologies with the potential to save lives. Secretary Foxx also stated that within six months, NHTSA will propose guidance to industry on establishing principles of safe operation for fully autonomous vehicles. [13]

Next, on February 4, 2016, NHTSA responded to a request from Google, Inc. to interpret several provisions in the Federal Motor Vehicle Safety Standards as they apply to Google's described design for vehicles Google is developing and testing. The NHTSA stated that Google was the driver of the autonomous vehicle in place of an actual individual. This ruling would allow Google cars to be equipped without a steering wheel. [14]

6.2 State Actions

Nevada, in 2011, was the first state to authorize the operation of autonomous vehicles. Since then, six other states, California, Florida, Michigan, North Dakota, Tennessee and Utah and Washington D.C. have passed legislation related to autonomous vehicles. An eighth and ninth state, Arizona and Virginia have issued orders related to autonomous vehicles. However, there is increasing interest across almost all the states as is shown in the below figure:



These nine state and D.C. actions are summarized as follows. [15]

California legislation defines "autonomous technology," "autonomous vehicle," and "operator"; finds that the state "presently does not prohibit or specifically regulate the operation of autonomous vehicles"; requires rulemaking; permits current operation under certain conditions; imposes additional oversight on the operation of vehicles without a human in the driver's seat; and requires that the "manufacturer of the autonomous technology installed on a vehicle shall provide a written disclosure to the purchaser of an autonomous vehicle that describes what information is collected by the autonomous technology equipped on the vehicle."

In 2012, Florida was the second state to adopt legislation allowing for automated vehicle testing on public roadways. Florida Statue 316.85 addresses the testing of automated vehicles, specifying that “a person who possesses a valid driver license [specific to autonomous vehicles] may operate an autonomous vehicle in autonomous mode.” Such licenses are only valid for testing by authorized persons designated by the manufacturer of autonomous vehicle technologies.

Michigan has defined "automated technology," "automated vehicle," "automated mode," and "upfitter," and expressly permits testing of automated vehicles by certain parties under certain conditions. Michigan has also defined “operator”, addressed liability of the original manufacturer of a vehicle on which a third party has installed an automated system and directed state DOT with the Secretary of State to submit a report on these issues by February 1, 2016.

Nevada has defined "autonomous vehicle" and directed state DMV to adopt rules for license endorsement and for operation, including insurance, safety standards, and testing.

North Dakota has established a legislative management study of automated vehicles.

Tennessee legislation prohibits local governments from prohibiting the use of a vehicle solely on the basis of it being equipped with autonomous technology if the vehicle otherwise complies with applicable safety regulations, defines "autonomous technology" as technology "that has the capability to drive [a] motor vehicle without the active physical control or monitoring by a human operator."

Utah has authorized the department of transportation to conduct a connected vehicle testing program.

Washington D.C. has defined "autonomous vehicle”," required a human driver "prepared to take control of the autonomous vehicle at any moment," restricted conversion to recent vehicles, and addresses liability of the original manufacturer of a converted vehicle. Passed Congressional review (April 2013).

Actions by state Governors include:

Arizona’s Governor Doug Ducey signed an executive order in August 2015 directing various agencies to “undertake any necessary steps to support the testing and operation of self-driving vehicles on public roads within Arizona.” He also ordered the enabling of pilot programs at selected universities and developed rules to be followed by the programs. The order established a Self-Driving Vehicle Oversight Committee within the governor’s office. [16]

Virginia's governor Terry McAuliffe announced in June 2015 a partnership allowing research and development for autonomous vehicles to take place in the state within “Virginia Automated Corridors.”

7. U.S. Department of Transportation (USDOT)

The federal government is in general supporting research, development, testing and development. The USDOT’s Intelligent Transportation System Joint Program Office (ITS JPO) has established an automation program within the overall ITS program. As a first step, the program has developed a 2015-2019 Multimodel Program Plan for Vehicle Automation, a key component of the ITS JPO’s ITS Strategic Plan 2015-2019. [17] The program plan establishes the vision, role, and goals as well as a broad research roadmap for automation research at the USDOT. The USDOT’s role in vehicle automation is to:

- Facilitate development and deployment of automated transportation systems that enhance safety, mobility, and sustainability
- Identify benefit opportunities in automated vehicle technology
- Invest in research areas that further industry investments and support realization of benefit opportunities

- Establish Federal Motor Vehicle Safety Standards and infrastructure guidance [15]

As previously mentioned, U.S. DOT Secretary Foxx, in January 2016 has unveiled a new policy that updates the previous policy statement and proposes a federal dollar commitment of nearly $4 billion over the next 10 years to accelerate the development and adoption of safe vehicle automation. [13] Secretary Foxx also stated that within six months, NHTSA will propose guidance to industry on establishing principles of safe operation for fully autonomous vehicles.

Other US DOT activities include the announced $42 million in awards, in September 2015, to Wave 1 participants in the Connected Vehicle Pilot Deployment Program. The three sites collectively envision a broad spectrum of applications enabled by connected vehicle technologies and driven by site-specific needs. The three Wave 1 sites are [18]:

- Using connected vehicle technologies to improve safe and efficient truck movement along I-80 in southern Wyoming,
- Exploiting vehicle-to-vehicle (V2V) and intersection communications to improve vehicle flow and pedestrian safety in high-priority corridors in New York City,
- Deploying multiple safety and mobility applications on and in proximity to reversible freeway lanes in Tampa, Florida.

The wave pilot deployments begins with an initial concept development phase lasting 12 months followed by a rapid progression to physical, real-world deployment of these concepts in Phases 2 and 3. This current cooperative model is to be followed by a second wave of pilot deployment sites to be identified by USDOT later in the program. [19]

Another major USDOT program is the Smart Cities Challenge proposal request. In December 2015, Secretary Foxx announced the Smart City Challenge, a program to create a fully integrated, first-of-its-kind city that uses data, technology and creativity to shape how people and goods move in the future. The winning city will be awarded up to $40 million in June 2016 from the U.S. DOT (funding subject to future appropriations) to implement bold, data-driven ideas by making transportation safer, easier, and more reliable. 20Additionally, Paul G. Allen, Vulcan Inc., has announced Vulcan's intent to award up to $10 million to the USDOT winner of the Smart City Challenge. [20]

On March 12, 2016, USDOT Secretary Anthony Foxx announced seven city finalists for the Smart City Challenge. The finalists are: Austin, TX; Columbus, OH; Denver, CO; Kansas City, MO; Pittsburgh, PA; Portland, OR; and San Francisco, CA. "The level of excitement and energy the Smart City Challenge has created around the country far exceeded our expectations," said Secretary Foxx. "After an overwhelming response – 78 applications total – we chose to select seven finalists instead of five because of their outstanding potential to transform the future of urban transportation." The USDOT has pledged to help one, "Smart City, "to become the country's first city to fully integrate innovative technologies – self-driving cars, connected vehicles, and smart sensors – into their transportation network. [20]

The Smart City Challenge builds on the U.S. DOT's *Beyond Traffic* draft report issued in February, 2015. [21] *Beyond Traffic* reveals that our nation's aging infrastructure is not equipped to deal with a dramatically growing population in new regions throughout the country and the need for increased mobility options in developing mega regions. The Challenge collaboration represents the belief that creativity and innovation will be absolutely essential to meeting the significant transportation challenges of the future and that lessons learned can be used in other cities to improve networks nationwide and demonstrate a practical path to replacing carbon-based fuel consumption.

8. U. S. Department of Energy

The U. S. Department of Energy has numerous programs directed at electric vehicles. These programs have the goals of cutting battery costs from their current $500/kWh to $124/kWh and increasing energy density from 50 Wh/L to 400 Wh/L, eliminating almost 30% of vehicle weight through light-weight materials, and reducing the cost of electric drive systems from $40/kW to $8/kW/. [22] In the ACV area, the U.S. Department of Energy's Vehicle Technologies Office announced on November 15, 2015 that it had funded a new $2.7 million project with the University of Michigan to study whether vehicles that communicate with each other and their surroundings can help people drive more efficiently. In conducting this project, researchers will work with 500 privately-owned vehicles in the Ann Arbor area to collect information about how they are driven, including energy consumption, speed, and location. The study will examine how drivers interact with different technologies in connected vehicles, especially whether or not those technologies help them drive more efficiently. The study may include both personal and commercial light duty vehicles, with a focus on hybrid electric and plug-in electric vehicles.

9. Florida Department of Transportation (FDOT) AV/CV Program

The Florida Department of Transportation (FDOT) is committed to delivering a transportation system that is fatality free. Automated vehicle technologies have the potential to greatly reduce the number of crashes by aiding drivers in making prompt, safe decisions about driving maneuvers, even preventing many accidents without direct driver input (automatic braking, adaptive cruise control, etc.). Thus, the FDOT program can be summarized as follows:

- Florida is one of only a few states to boast two designated U.S. Department of Transportation Connected Vehicle Test Beds.
- Three research projects are underway to address policy implications, improved mobility for the transportation disadvantaged and aging populations, and AV applications for transit operations.
- Two current pilot projects are testing various automated technologies that could assist driver safety and improve freight efficiency.
- Working Groups comprised of stakeholders are providing recommendations to FDOT and other state agencies on how to best integrate these emerging technologies into existing infrastructure and operations. [23]

The FDOT plan for the deployment of AV/CV technologies on Florida's public roadways has been established through its Florida Automated Vehicles (FAV) initiative. The FAV will create the framework for implementation by engaging stakeholders, developing research and pilot projects, and creating awareness of the technologies and how they support FDOT's vision statement.

A very important component of the FAV initiative is public outreach and education. FDOT understands that professionals and organizations need to be involved from the very beginning in order to proactively prepare Florida for these emerging technologies. Education and awareness of AV/CV technologies, beginning with the planning and engineering community, is essential in order to begin to address the questions and concerns that the general public will generate.

The FAV initiative deploys pilot projects to establish Florida as a leader by leading by example in being an early adopter of the technology. The goals of the FAV pilot projects are:

- Leverage existing infrastructure to maximize benefits
- Develop rich dataset that demonstrates quantitative safety and efficiency gains
- Performance measures
- Comparative analysis before and after AV/CV technologies are deployed.

9.1 FDOT Pilot Projects

Pilot projects provide important data to help FDOT justify proposals or amendments to policy, design and engineering standards. Data that illustrates the use of automated vehicles on public roadways is extremely important because these type of data sets for real-world conditions are scarce. [24]

Project 1—A pilot project collaboration with FDOT District 7 has been implemented to determine if MobilEye technology provides value in preventing avoidable traffic accidents by installing MobilEye's Advanced Driver Assistant System (ADAS) on about 50 vehicles in the Tampa Bay area. Vehicles in this pilot project include FDOT District 7 sedans and light trucks as well as buses, vans, and sedans operated by Hillsborough Area Regional Transit, Tampa Bay Area Regional Transit Agency, Pasco County Public Transportation, and the Pinellas Suncoast Transit Authority.

The MobilEye device includes one forward looking camera and a LED display to provide visual and audible warnings to the vehicle operator of eminent forward collisions, lane departure alerts, and pedestrian/bicycle detection. The MobilEye device does not utilize Global Positioning System (GPS) technology and does not track vehicle movement. A telematics system, provided by GeoTab, is installed on each vehicle to measure the effectiveness of MobilEye's safety enhancements. In order to compare performance measurement, an additional 50 vehicles received no ADAS system and only had the installation of the GeoTab device. If the warnings provided by the MobilEye devices allow FDOT vehicle operators to prevent collisions, the ADAS systems may be recommended for wide-scale adoption by FDOT.

Project 2 –In this pilot project, called "AV/CV/ITS Freight Applications", the goal is to demonstrate that AV technologies can offer increased safety and efficiency for freight operations. This pilot will follow a three-phase approach to measure, deploy and prioritize portions of the perishable-goods delivery supply chain using the perishable flower industry at Miami Airport and the distribution center located in Miami-Dade County. The project's objective is to show travel time reliability can be improved within the region surrounding the MIA by deploying AV technologies on a limited number of drayage operators' fleet vehicles that agree to partner with the project. Each phase of the pilot project is anticipated to take 6-12 months. Efforts are underway to coordinate with public partners, engage private stakeholders, identify and measure repetitive delivery routes, and understand existing transportation system operations.

9.1 FDOT University AV/CV Projects

FDOT is collaborating with state universities to gain a better understanding of any implications associated with planning for and integrating AV/CV technologies into Florida's existing infrastructure. The research projects are [24]:

Florida State University – Enhanced Mobility for Aging Population Using Automated Vehicles - The main objective of this project is to provide information and guidance on how AV/CV technologies could enhance mobility operations for certain segments of the population that include aging and the transportation disadvantaged. The research intent is to identify a possible pilot project, such as para-transit service, and to apply AV technology and determine a plan for implementation.

University of Florida - Policy Implications of Automated Vehicle Technology. - Connected vehicle technology relies on information gathered by vehicles and the transportation infrastructure about real-time operations of the transportation network and the ability to broadcast the information to the vehicle so the driver is able to make informed decisions regarding routing and maneuvering. Research is needed to understand the current policy framework that either enables or prohibits the adoption rate of CV technologies. The research is to provide information and guidance in order to understand what changes may need to be made to existing Florida policy.

Embry-Riddle Aeronautical University – Autonomous Service Vehicle Project --The use of autonomous vehicles for pavement and roadside management services, herein referred to as *autonomous service vehicles*, has the potential to reduce budget and improve the local economy and safety of these operations. Candidate services to be conducted by autonomous service vehicles include inspection of roadways, roadside trimming, and roadside mowing. The objective of this project is to develop sensing requirements and communication specifications for these autonomous service vehicles. Characterizing these requirements will consist of a series of data collections in environments with operating conditions that range from mild to hostile such as rough weather, intense radiofrequency emissions, and high-traffic areas. This research will be conducted using a high fidelity sensor suite and spectral analyzing equipment mounted to a manned vehicle surrogate. Collected data will then be analyzed to characterize sensor performance under these conditions for performing a set of high interest service tasks. The service tasks of interest are: track drying, pavement inspection, and mowing at airports.

Florida State University – Envisioning Florida's Future: Transportation and Land Use in an Automated Vehicle World - The main objective of this project is to provide FDOT and its partners with information and guidance on what the built environment could look like in 2040 and 2060 based on various levels of market penetration of AV/CV technologies. Land use patterns, site development trends, urban design, and human behavior all have a direct impact on the transportation system. This research will rely on transportation professionals to consider multiple scenarios and create consensus on how to begin to prepare for a future in which AV technology has become widely adopted. Specific points of interest include how site design can be adapted to accommodate AV technology, how AV technology will impact the design of intersections, how AV technology will affect parking needs and locations, and how AV technology can be integrated into the design of transit stations.

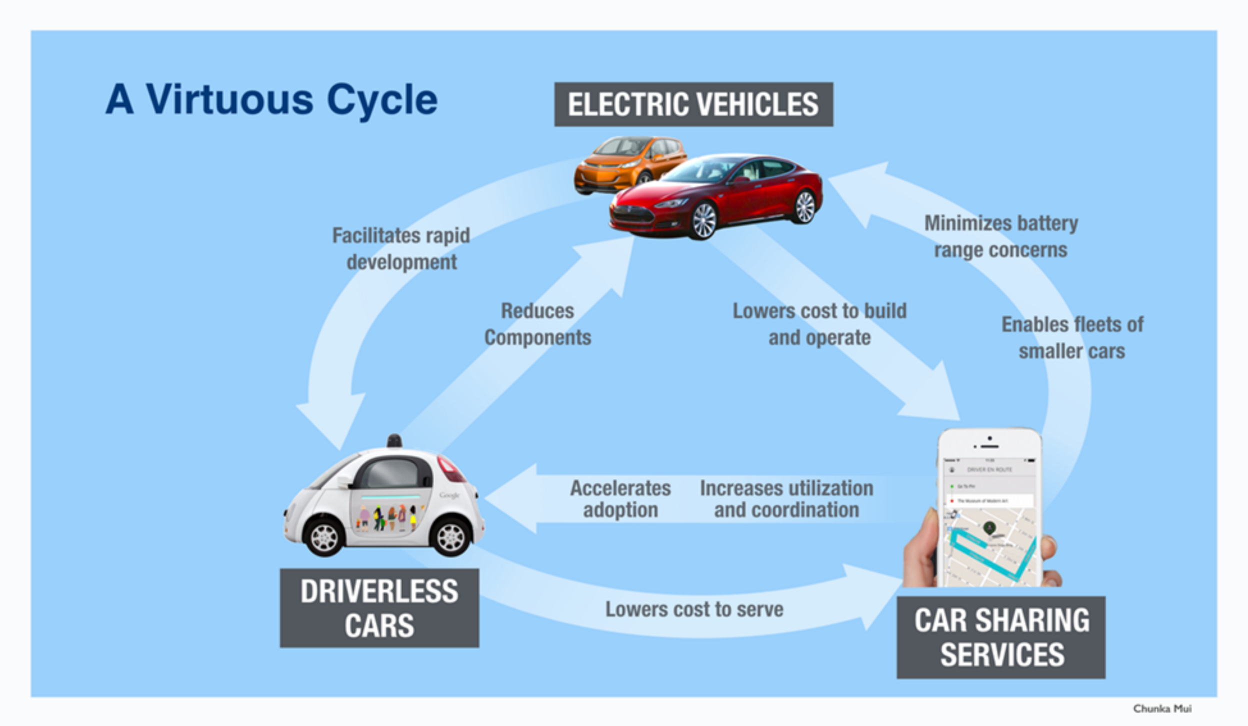
University of Central Florida's Electric Vehicle Transportation Center – An EVTC staff member participates as a member of the Florida Department of Transportation's Automated Vehicles Technology and Infrastructure Working Group. The working group is tasked to identify challenges and opportunities associated with ACV technologies on public roadways, to discuss how the challenges could be mitigated and how to leverage the opportunities. The overarching goal of the working group is to provide FDOT, and other state agencies, with recommendations on how to address potential policy adoption or amendments, engineering and design standard changes, and infrastructure investment priorities.

University of Central Florida – Investigation of Connected Vehicles to Inform Design of Automated Vehicle Systems -- Connected Vehicles facilitate new safety applications such as warnings for wrong way driving and blind spots, however it is still unclear what the best methods are for alerting drivers with this information. The primary objective for this project is to investigate multimodal AV/CV displays for future vehicles to safely and quickly alert drivers of upcoming automation related vehicle warnings. Findings from the effort will result in requirements and recommendations for how to implement CV displays for ease of use and increased safety.

10. Electric Vehicles and ACV

As the transportation sector grapples with ACV and in particular, autonomous vehicles, the research and development of these vehicles have clear and planned paths to utilization. However, the role of how electric vehicles (EVs) fit into the ACV path is not as clear. There is no doubt that in time EVs will play a fundamental role. "Right-Sizing" an electric autonomous vehicle requires much less effort than what is required for a vehicle with an internal combustion engine (ICE). ICE vehicles have hundreds of parts that have to be combined, electric vehicles simply require an adjustment to battery and motor size.

When automatous vehicles become a player in the market place, the driverless cars are most likely to be EVs. Mobility operators such as Uber or Lyte see EVs as the vehicle options since EVs are less costly to maintain and operate. EVs also offer the more acceptable and easier means for rapid development and testing. This virtuous cycle is shown in the below figure. [25]



This report's authors all have extensive experience with electric vehicles obtained through the U. S. Department of Transportation funded Electric Vehicle Transportation Center. Based on this experience, the authors' options are that EVs will play a major future role in ACV because of such technologies as wireless highways, vehicle charging rest stops plus a great variety of telephone apps directed toward charging station locations.

11. Conclusions

This report has presented a technology assessment and evaluation of the technologies, actions and the laws and policies that are in place for automated and connected vehicles. This combination can significantly reduce crashes, energy consumption, pollution and the costs of congestion which in turn will offer a fundamental change to the U.S. transportation network and system. The results show that autonomous vehicles is the area that is receiving the most interest from the general public and the governing agencies. The report has also shown that electric vehicles will be a major participant in the new ACV transportation system.

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