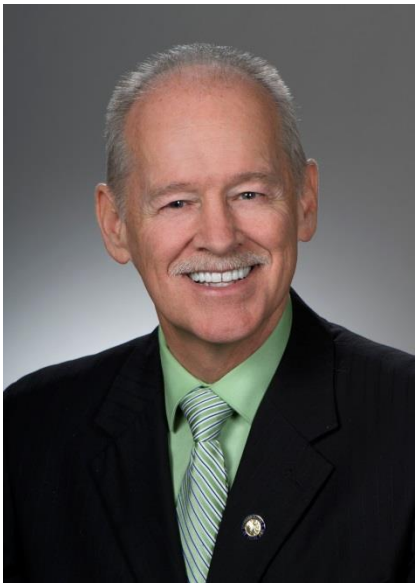
Autonomous & Connected Vehicle Report

Transportation & Public Safety Committee
Chairman's Report

December 2018

OHIO HOUSE OF REPRESENTATIVES



State Representative Doug Green is currently serving his third term at the Ohio House of Representatives and is the current Chairman of the House Transportation and Public Safety Committee. He represents the 66th District, which includes all of Brown County, as well as southeastern Clermont County.

Managing Author:
Eric Leach
Senior Legislative Aide

Contributing Authors:
Travis Ricketts
Legislative Aide

Alyson Houk
Legal Extern to Ohio House Republican Caucus

Table of Contents

Introduction

Automated Driving System (ADS) technology and connected conventional vehicles, commonly referred to as autonomous and connected vehicles, will have the potential to fundamentally change how Ohio, as a society, transports people, goods, and services. This technology will vastly improve safety, significantly reduce transportation times and costs, and change Ohioans traffic patterns. In Ohio, stakeholders across the state are researching, testing, and deploying ADS and connected vehicle technology. This nascent industry has the potential to drive workforce development efforts across the state, opening up new employment opportunities for Ohioans, while also enabling those who currently do not have access to affordable and reliable transportation the ability to live a more independent and productive life.

The implementation of ADS and connected vehicle technology, however, will pose significant questions for Ohio's governments, at all levels. How does the General Assembly maximize this new technology's benefits while mitigating its negative secondary socioeconomic effects? The General Assembly must carefully consider how dramatically this technology may change transportation, infrastructure, and employment. This report has examined these issues and will detail them to provide policymakers at all levels of government a survey of how this technology may impact Ohio and what needs to be done to prepare for its effects, both positive and negative. This report is designed to provide policymakers with a basic understanding of the technology and its potential effects; it is not a technical report in nature, but rather a foundational document to learn about the technology and how it may affect Ohio specifically.

The time horizon for ADS Level 4 (highly automated; no driver needed under **certain** conditions) commercial deployment ranges from 2019-2025 and Level 5 (highly automated; no driver needed under **any** conditions) commercial deployment is forecasted in the 2035-2050 horizon based off of feedback received during the stakeholder engagement process. There are already limited ADS Level 4 deployments in Arizona by Waymo and the company has just launched its commercial ride hailing app dubbed "Waymo One" with its ADS-equipped Level 4 vehicles as of December 2018.[1] Another indicator of how rapidly the technology is progressing is that General Motors has petitioned the federal government to allow the company to remove the steering wheel, pedals, and other driver controls for a modified Chevy Bolt, one of GM's current electric vehicles that has a 240-mile-per-charge range.[2]

Given the lifespan of infrastructure and lag time for government to act, the time for conversations surrounding ADS technology is now. In order for Ohio to realize the benefits of ADS deployment, the General Assembly must ensure the policy and regulatory environment promotes and incentivizes, in a technology-neutral way, the technologies continued testing and deployment. Later in this report, there will be an inventory of exactly what Ohio is doing to establish a policy and regulatory environment conducive to ADS and connected vehicle technology and provide recommendations that will further this goal.

It is important to note why ADS and connected vehicle technology is important for Ohio to be aggressively pursuing. There are predominately three reasons why: safety, economics, and quality-of-life benefits. On the safety front, according to the National Highway Transportation

Safety Administration (NHTSA), 94% of all crashes are caused by human error. The potential safety benefits alone are cause for pursuing this technology and Ohio is already seeing gains from the increased adoption of Advanced Driver Assistance Systems (ADAS) and Active Safety Systems (ASS). These are vehicle systems that automatically intervene to help avoid or mitigate potential collisions; examples include forward-collision warning and smart-braking technologies. The Insurance Institute for Highway Safety (IIHS) is already reporting a 35-50% crash reduction with the aforementioned ADAS and ASS technologies. In Ohio alone, there were 303,282 crashes, 108,800 injuries, 8,763 serious injuries, and sadly, 1,179 fatalities on Ohio roads in 2017.[3] This technology has the potential to reduce those statistics to close to 0. As policymakers, this is a worthwhile endeavor to pursue because with every incremental step toward increased ADAS/ASS and eventually ADS adoption, these numbers will begin to decrease.

The economic benefits of ADS and connected vehicle technology cannot be overstated. This technology is not only a revolutionary change in transportation, not seen since the Model-T and the interstate-highway system, but is also one of three components that is leading the United States toward a third Industrial Revolution. The direct economic benefits of reduced congestion, reduced travel times, reduced fuel consumption, and reduced labor costs will translate to reduced costs to consumers in the form of prices for goods and services. This will be addressed in more detail; however, there is a larger and more important economic picture that must be emphasized.

The world has seen only two true Industrial Revolutions, one in the 19th century and one in the 20th century, but there have been roughly seven major economic paradigm shifts in human history. These revolutions are the product of when three technologies emerge and converge to create what is called, in engineering terms, a general-purpose technology platform, or in more general terms, a new infrastructure, that fundamentally changes the way in which societies manage, power, and move economic activity. First – is the emergence of new communication technologies that allow societies to more efficiently manage their economic activity. Second – new sources of energy emerge to allow societies to more efficiently power their economic activity. And third – new modes of transportation emerge to allow societies to more efficiently move their economic activity. When communication revolutions merge with new forms of energy and new modes of transportation, it does fundamentally change the way societies manage, power, and move their economic activity.[4]

The Industrial Revolutions of the 19th and 20th century are perfect examples to demonstrate this. The British birthed the first Industrial Revolution in the early 19th century. First there was a communications revolution: they invented steam-powered printing, which replaced manual powered printing. Steam-powered printing was a major advancement because it allowed the British to quickly and cheaply mass produce print. In the second half of the 19th century, the British built the first telegraph system across the British Isles. Steam-powered printing and telegraph communication technologies then converged with a completely new source of energy in Britain: coal. They invented the steam engine to extract the coal and subsequently discovered that they could put the steam engine on rails to create trains, which in-turn created a new national transportation and logistics technology. The convergence of these technologies led to

modern, urban life, and fundamentally changed how the British managed, powered, and moved economic activity.[5]

The second Industrial Revolution was birthed in the United States. Centralized electricity and specifically, the telephone, allowed people to communicate across unfathomable distances at the time; later, radio and television emerged as well to amplify the effects of the telephone. These communication technologies converged in the United States with a completely new energy source: cheap oil. Henry Ford then put Americans on the road with the Model T and subsequently, busses and trucks, and later President Eisenhower and Congress launched the development of the national interstate highway system. The second Industrial Revolution fundamentally changed the way the United States managed, powered, and moved economic activity.[6]

The United States is now entering a third Industrial Revolution in the 21st century; it started with a new communications technology 26 years ago called the World Wide Web or what is called today the internet. The United States has digitalized communication and now this communication internet is converging with an emerging, digitalized renewable-energy internet, both of which are converging with a nascent, autonomous transportation internet to create three internets: a communication internet, an energy internet, and an automated transportation-logistics internet. It is one super internet that will fundamentally change how the United States will manage, power, and move its economic activity.[7]

These three internets form a new general-purpose technology platform, or infrastructure, called the "Internet of Things" or "IoT." Companies are embedding sensors in devices so they can monitor real-time activity and then communicate to other devices and machines, communicate with individuals, and communicate with other people. For example, there are sensors now in the agricultural fields that are monitoring the growth of crops, soil salinity, among other things and the sensors are sending out data. There are sensors in factories that are monitoring economic data, sensors in smart homes monitoring energy usage, sensors in connected vehicles that can detect and communicate with the physical world, sensors in warehouses that can operate "lights out" with no human labor, and sensors in roads and infrastructure that are communicating with connected vehicles and traffic management centers. All of these sensors are collecting data, but where does that big data go? It goes to communication, energy, and transportation-logistics internets to manage, power, and move economic activity. This new system is going to be ubiquitous by 2030, connecting everything with everyone.[8]

It is necessary to understand how impactful and important this technology is for the economic future of Ohio. ADS and connected vehicle technology is only one of three components that need to be aggressively pursued in order to allow Ohio's business community to compete with not just neighboring states, but globally. Ohio's gross domestic product (GDP) per capita has remained stagnant while the rest of the country's GDP and global competitors' GDPs continue to increase, which indicates Ohio is regressing and losing competitive economic ground. As innovation and gains in productivity continue to be a major driver of economic growth, Ohio continues to fall behind. Ohio's private sector average annual GDP growth rate from 1991-2016 was 6.7 percent compared with the U.S. average annual GDP growth rate of 8.8 percent, lagging behind more than 2 percent a year over the 26-year period. Ohio's lagging economic growth and

productivity is manifesting itself in slower population growth (and population decline in many places), slower growth in income and wages, increased poverty, and an aging, non-diverse population that does not have the skills required for the new economy.[9]

To reverse the aforementioned negative economic trends, the General Assembly must create the infrastructure ecosystems that will allow business to drive down costs, increase productivity, and most importantly, increase aggregate efficiency. Here is what the Internet of Things platform provides that will allow Ohio businesses to accomplish those goals. Imagine a Small-Medium Enterprise (SME) headquartered in Columbus. This company will be able to access this new Internet of Things platform, that is already emerging, and it can have a transparent picture of all the economic data flowing through the world – if it stays network-neutral. It can go up on the platform and extract its big data on its value chain from the noise of large data sets. Then, it can mine its big data with analytics. It can create its own algorithms and applications that will allow it to dramatically increase its aggregate efficiency, at every point of conversion on its value and supply chains. As it does that, it will dramatically increase its productivity, and dramatically reduce its marginal costs. Some of those marginal costs are going to head toward near zero.[10]

In economic theory, the optimum market is where a company sells at marginal cost. Marginal cost is after fixed costs, once a company pays for whatever the technology is, the marginal cost is what it costs to produce a unit. Now, as society moves to car sharing and ADS deployment, marginal costs are going to begin to plunge toward near zero in transportation and logistics over the next 20-30 years. It is absolutely imperative for Ohio to have the infrastructure ecosystem in place to allow Ohio businesses to benefit from these fundamental economic changes, which will better enable them to compete both domestically and internationally and begin to reverse some of Ohio's long-term negative economic trends. If Ohio fails to do this, the state's long-term negative economic trends will begin to accelerate as it stays plugged into a 20th century infrastructure while other states, Asia, and Europe begin operating on the new 21st century infrastructure[11].

Quality of life benefits brought on by the emergence of ADS technology will impact most Ohioans but will be especially impactful to those who currently suffer from mobility challenges, such as senior citizens, the developmentally disabled, the very young, and those who do not have access to reliable transportation because of costs, such as the working poor. Getting from point A to point B for these populations can be extremely challenging. While public transit and dedicated service routes have provided a partial solution to travel problems experienced by these populations, ADS technology could represent a major step forward for accessibility and independence. This would not only benefit those individuals but also Ohio's economy by potentially decreasing the rate of unemployment and correcting labor market failures caused by the immobility of a portion of the available labor market.

For Ohioans that currently have access to their own personal vehicle, the number one quality-of-life benefit would be from stress relief; that is, the removal of stress from the transportation equation. Beyond just removing the stress of driving, especially in rush hour traffic, ADS technology will free up time for tasks that either increase productivity or leisure. Work-related tasks completed during commutes to and from work will increase Ohioans

economic productivity and personal tasks such as chores, online grocery shopping for example, will increase personal productivity, which then frees up time outside of the vehicle for more leisure time.

The General Assembly and the Governor have three core responsibilities that need to be fulfilled in order for Ohio to remain a leader in this nascent industry. First, Ohio must maintain a conducive and burdensome-free regulatory environment for the development, testing, and deployment of ADS and connected vehicle technology. This includes respecting federal versus state responsibilities, such as deferring to the federal government where necessary on areas like vehicle safety, cyber security, and data privacy standards. Second, Ohio must focus on building the infrastructure ecosystem that will best enable this technology to perform at its peak potential, which means making investments in infrastructure, both basic maintenance and integrating smart technology where applicable. Third, Ohio must prepare the workforce for the changes that are beginning to manifest themselves, which currently include a shortage of high-skill labor but in due time, a displacement of low-skill labor. Investment in retooling workforce training and development systems is critical, not just for ADS and connected vehicle technology but for many other industries as well. Ohio has the potential to lead the United States into this new, data-centric and highly connected world; it is time to get to work.

Executive Summary

Automated Driving System (ADS) technology and connected conventional vehicles, commonly referred to as autonomous and connected vehicles, will have the potential to fundamentally change how Ohio, as a society, transports people, goods, and services. This technology will vastly improve safety, significantly reduce transportation times and costs, and change Ohioans traffic patterns. In Ohio, stakeholders across the state are researching, testing, and deploying ADS and connected vehicle technology. This nascent industry has the potential to drive workforce development efforts across the state, opening up new employment opportunities for Ohioans, while also enabling those who currently do not have access to affordable and reliable transportation the ability to live a more independent and productive life.

The implementation of ADS and connected vehicle technology, however, will pose significant questions for Ohio's governments, at all levels. How does the General Assembly maximize this new technology's benefits while mitigating its negative secondary socioeconomic effects? The General Assembly must carefully consider how dramatically this technology may change transportation, infrastructure, and employment. This report has examined these issues and will detail them to provide policymakers at all levels of government a survey of how this technology may impact Ohio and what needs to be done to prepare for its effects, both positive and negative. This report is designed to provide policymakers with a basic understanding of the technology and its potential effects; it is not a technical report in nature, but rather a foundational document to learn about the technology and how it may affect Ohio specifically.

The time horizon for ADS Level 4 (highly automated; no driver needed under **certain** conditions) commercial deployment ranges from 2019-2025 and Level 5 (highly automated; no driver needed under **any** conditions) commercial deployment is forecasted in the 2035-2050 horizon based off of feedback received during the stakeholder engagement process. There are already limited ADS Level 4 deployments in Arizona by Waymo and the company has just launched its commercial ride hailing app dubbed "Waymo One" with its ADS-equipped Level 4 vehicles as of December 2018.[12] Another indicator of how rapidly the technology is progressing is that General Motors has petitioned the federal government to allow the company to remove the steering wheel, pedals, and other driver controls for a modified Chevy Bolt, one of GM's current electric vehicles that has a 240-mile-per-charge range.[13]

Given the lifespan of infrastructure and lag time for government to act, the time for conversations surrounding ADS technology is now. In order for Ohio to realize the benefits of ADS deployment, the General Assembly must ensure the policy and regulatory environment promotes and incentivizes, in a technology-neutral way, the technologies continued testing and deployment. Later in this report, there will be an inventory of exactly what Ohio is doing to establish a policy and regulatory environment conducive to ADS and connected vehicle technology and provide recommendations that will further this goal.

The General Assembly and the Governor have three core responsibilities that need to be fulfilled in order for Ohio to remain a leader in this nascent industry. First, Ohio must maintain a conducive and burdensome-free regulatory environment for the development, testing, and

deployment of ADS and connected vehicle technology. This includes respecting federal versus state responsibilities, such as deferring to the federal government where necessary on areas like vehicle safety, cyber security, and data privacy standards. Second, Ohio must focus on building the infrastructure ecosystem that will best enable this technology to perform at its peak potential, which means making investments in infrastructure, both basic maintenance and integrating smart technology where applicable. Third, Ohio must prepare the workforce for the changes that are beginning to manifest themselves, which currently include a shortage of high-skill labor but in due time, a displacement of low-skill labor. Investment in retooling workforce training and development systems is critical, not just for ADS and connected vehicle technology but for many other industries as well. Ohio has the potential to lead the United States into this new, data-centric and highly connected world; it is time to get to work.

Process

Beginning in the fall of 2017, the Transportation and Public Safety Committee of the Ohio House of Representatives began this study to examine autonomous and connected vehicle technologies; the technical nomenclature is Automated Driving Systems (ADS's) and connected conventional vehicles. This study has been focused on potential benefits and challenges, how the emerging technology may impact Ohio's economy, manufacturing, public safety, insurance, and infrastructure, as well as a review of current research, testing, federal regulations, and industry activity in Ohio. Most importantly, this study was designed with the purpose to inform the General Assembly and more broadly, government at all levels in Ohio. It is the position of the Ohio House of Representatives that before proposing legislation dealing with such a complex and technical subject, a study should be conducted beforehand. With ADS and connected vehicle technology, the modus operandi is "first do no harm."

Terms and Definitions

ADS and connected vehicle technology have many unique terms and acronyms and it is important for members of the Ohio House of Representatives to have a firm grasp of them. This section is designed to be a resource to learn and refer to in order to become more familiar with the technology and when speaking about it to others. It is important to keep in mind that this is an emerging technology with essentially its own language. Terms have and will continue to change as the technology moves forward and industry coalesces around certain terms and acronyms and discards others.

Below are key definitions and acronyms to understand in order to be able to read and talk about this technology; this is not an exhaustive list. These definitions and acronyms are sourced from SAE International, the primary technical standards organization for this technology:

Advanced Driver Assistance System (ADAS) – Systems designed to help drivers with certain driving tasks (e.g., staying in the lane, parking, avoiding collisions, reducing blind spots, and maintaining a safe headway). ADAS technology is generally designed to improve safety or reduce the workload on the driver. With respect to automation, some ADAS features could be considered SAE Level 1 or Level 2, but many are Level 0 and may provide alerts to the driver with little or no automation.[14]

Active Safety System (ASS) – Active safety systems are vehicle systems that sense and monitor conditions inside and outside the vehicle for the purpose of identifying perceived present and potential dangers to the vehicle, occupants, and/or other road users, and automatically intervene to help avoid or mitigate potential collisions via various methods, including alerts to the driver, vehicle system adjustments, and/or active control of the vehicle subsystems (brakes, throttle, suspension, etc.).[15]

Automated Driving System (ADS) – The hardware and software that are collectively capable of performing the entire DDT on a sustained basis, regardless of whether it is limited to a specific operational design domain (ODD); this term is used specifically to describe a Level 3, 4, or 5 driving automation system.[16]

Conventional Vehicle – A vehicle designed to be operated by a conventional driver during part or all of every trip.[17]

Dynamic Driving Task (DDT) – All of the real-time operational and tactical functions required to operate a vehicle in on-road traffic.[18]

Operational Design Domain (ODD) – Operating conditions under which a given driving automation system or feature thereof is specifically designed to function, including, but not limited to, environmental, geographical, and time-of-day restrictions, and/or the requisite presence or absence of certain traffic or roadway characteristics.[19]

Level 0 – The human driver does all the driving.[20]

Level 1 – An advanced driver assistance system (ADAS) on the vehicle can sometimes assist the human driver with either steering or braking/accelerating, but not both simultaneously.[21]

Level 2 – An advanced driver assistance system (ADAS) on the vehicle can itself actually control both steering and braking/accelerating simultaneously under some circumstances. The human driver must continue to pay full attention ("monitor the driving environment") at all times and perform the rest of the driving task.[22]

Level 3 – An Automated Driving System (ADS) on the vehicle can itself perform all aspects of the driving task under some circumstances. In those circumstances, the human driver must be ready to take back control at any time when the ADS requests the human driver to do so. In all other circumstances, the human driver performs the driving task.[23]

Level 4 – An Automated Driving System (ADS) on the vehicle can itself perform all driving tasks and monitor the driving environment – essentially, do all the driving – in certain circumstances. The human need not pay attention in those circumstances.[24]

Level 5 – An Automated Driving System (ADS) on the vehicle can do all the driving in all circumstances. The human occupants are just passengers and need never be involved in driving.[25]

AV 101

Over the last decade, ADS and connected vehicle technology research has continued to move from academia to vehicle manufacturers. Companies such as Ford, GM, BMW, Volkswagen, and Tesla have been testing their own ADS technologies. One of the most advanced ADS technology projects has been the Google Self-Driving Car project, which was launched in 2009.[26] In late 2015, Tesla released a software update which enabled its Model S vehicle to utilize a vehicle technology feature it called "Autopilot," which is a Level 2 ADAS system.[27] Tesla's Autopilot technology enables the vehicle to autonomously follow the lane it is in, switch lanes on command, park itself, and be summoned remotely, meaning it can park into a garage by itself and can leave the garage and come to the owner. In 2017, GM launched its Super Cruise ADAS feature which is similar to the Tesla Autopilot and is a Level 2 technology.[28] As of 2018, Google's ADS-equipped vehicles have logged eight million miles on public roads, now averaging 25,000 miles per day, and Tesla's Autopilot feature has logged an astounding 1.5 billion miles collectively.[29]

Over the next five years there will be ever-increasing improvements in ADAS and ADS technology. Audi is the first Original Equipment Manufacturer (OEM) to bring to market a Level 3 vehicle with its 2019 Audi A8. The all-new Audi A8 will have a feature called "Audi AI traffic jam pilot" which enables the vehicle to take over the task of driving in certain driving conditions and unlike Level 2, the driver no longer needs to monitor the vehicle while it is driving. They must simply be able to take back the task of driving when the system prompts them to.[30] Unfortunately, due to regulatory and legal obstacles in the United States, Audi will not be operationalizing this technology in the U.S. market, for now.[31] GM has claimed it will be the first high-volume OEM to build Level 4 vehicles in a mass-production assembly plant and that its focus will be on the ride-hailing market first rather than the consumer market. However, GM has not announced when it expects to introduce this vehicle, but in a filing with the federal government in January 2018, it asked permission to do so in a commercial ride-hailing service launching in 2019.[32]

While GM has not announced an introduction date for its planned Level 4 vehicle, 2021 may well be the year of the Level 4 vehicle. Ford has announced that it plans on bringing to the market a Level 4 vehicle by 2021 as has BMW with its iNEXT vehicle.[33] Most other auto manufacturers are in the same early 2020 time horizon for their planned Level 4 products. Time horizons for this technology may speed up as other ancillary technologies are advancing at an exponential rate such as computer power, sensor technology, and machine learning. The below graph illustrates rough-time horizon estimates for ADS deployment and market penetration:

Stage	Decade	Vehicle Sales	Vehicle Fleet	Vehicle Travel
Large price premium	2020s	2-5%	1-2%	1-4%
Moderate price premium	2030s	20-40%	10-20%	10-30%
Minimal price premium	2040s	40-60%	20-40%	30-50%
Standard feature on most new vehicles	2050s	80-100%	40-60%	50-80%
Saturation (everybody who wants it has it)	2060s	?	?	?
Required for all vehicles on road	???	100%	100%	100%

Source: Littman (2018)

34

The pace at which advances in ADS technology are moving when compared to the overall history of the technology and the rate of innovation in ancillary technologies provides the necessary context for the Ohio House of Representatives to begin planning for this technology now, not later.

Federal versus State Responsibilities

As the pace of technological advancement in ADS and connected vehicle technology continues to accelerate, it is important for this report to express clearly what the Ohio House of Representatives should argue are appropriate federal and state responsibilities in the regulation of this technology. This report concurs with the United States Department of Transportation *Automated Vehicles 3.0* advisory report regarding the proper federal and state roles in the regulation of this developing technology.[35] The traditional roles that govern regulatory authority in the transportation sector can and should be used to address automation, as it prevents unneeded confusion and regulatory uncertainty for Ohio businesses. Failure to coalesce around a tried and true, stable framework for regulating this technology will hinder Ohio's ability to compete with other states, Europe, and Asia in the race for commercially deployable ADS technology.

In the transportation sector, the federal government, traditionally, has regulatory authority over the safety performance of vehicles, their equipment, and their participating operation in interstate commerce. Individual states and local governments has regulatory authority over licensing, establishing state and local traffic laws, tort liability, and insurance. It should be the position of the Ohio House of Representatives that a patchwork of state and local laws regarding ADS and connected vehicle technology is not in the public interest. The federal government should focus on what it is best equipped to regulate, which are safety, cybersecurity,

and data privacy standards. Ohio should focus on what it is best equipped to regulate, which is providing for the regulatory framework for this technology to operate in the state, such as licensing, tort liability, and insurance regulations. Furthermore, Ohio must also focus on maintaining and building the infrastructure ecosystem for this technology to operate and flourish in, which means ensuring transportation infrastructure is well maintained, ensuring broadband and communications infrastructure continues to be built, and integrating smart and connected technologies into new and existing infrastructure to enable this technology to communicate and interact with the physical environment.

Ohio Overview

Ohio has a one-stop shop for everything related to ADS and connected vehicle technology, and it is DriveOhio. Its mission is to bring together government, industry, and research partners to enhance Ohio's infrastructure for ADS and connected vehicle technology and for the development of smart mobility innovations. DriveOhio provides industry stakeholders one entity to work with in an emerging field that has many different agencies and offices that potentially lay over each other. DriveOhio is housed within the Ohio Department of Transportation (ODOT) and is a partnership between ODOT, the Department of Public Safety, the Department of Administrative Services, the Ohio Turnpike Infrastructure Commission, the Public Utilities Commissions of Ohio, the Department of Insurance, the Governor's Office of Workforce Transformation, and the Ohio National Guard's Office of the Adjutant General.[36]

Not only does Ohio have a one-stop shop for ADS and connected vehicle technology at the state level, but it also has a pro-research and pro-testing regulatory environment. On May 9, 2018, Governor Kasich signed an executive order that authorized ADS-equipped vehicle testing, subject to certain safety requirements, on any Ohio public road or highway. In order to ensure the safety of the public, the Governor reserves the right to halt testing of any vehicle if there is evidence that the vehicle or technology is not working properly. Further, DriveOhio has been tasked with managing Ohio's Autonomous Vehicle Pilot Program. This program will link Ohio municipalities interested in promoting ADS-equipped vehicle testing with companies looking for places to refine their ADS technology. Both groups will partner with DriveOhio to identify ideal testing opportunities in the state. For municipal partners, by entering into an agreement, municipalities can work with DriveOhio to create an inventory of their roads that offer a variety of testing attributes (e.g., four lanes, hilly, roundabouts, urban or suburban). DriveOhio will then share the inventory with companies looking to test in Ohio. For industry partners, companies wishing to test vehicles that meet the state's requirements can enter into an agreement to participate in the pilot program. DriveOhio will work to identify the unique testing attributes each company needs and will identify locations in Ohio where the company can meet their testing objectives. This pilot program will help engage and connect the public and private sectors to work together cooperatively to better position industry and government for the deployment of this technology.[37]

Policy Challenges for Ohio

ADS and connected vehicle technology is bringing about a myriad of policy challenges that the General Assembly will need to address. By respecting the proper roles for federal and state

government, Ohio will be positioned to effectively tackle policy issues surrounding Infrastructure & Data, Workforce & Labor, and Insurance. It is in these areas that the General Assembly can work to maximize Ohio's attractiveness as a destination for private investment in this technology and become an early adopter, benefiting both economically and socially from the fruits of the technology while also effectively mitigating potential negative secondary socioeconomic effects.

Infrastructure

This report takes the position that the General Assembly should begin addressing short- and long-term infrastructure challenges. While it is not and should not be the General Assembly's role to regulate safety standards or inhibit technological progress related to ADS and connected vehicle technology, it is, however, the General Assembly's role to ensure the infrastructure ecosystem is built and maintained for this technology to deploy in conditions that are as safe as possible and that will maximize returns on investment, both from economic and quality of life perspectives. This responsibility includes ensuring that the state maintains a good state of infrastructure design, operation, and maintenance that will support ADS and connected vehicle deployment. Ohio's roads, highways, and bridges form vital transportation corridors for both interstate and intrastate commerce. The condition, efficiency, and funding of the transportation system is vital to the economic competiveness of the state and its ability to continue to attract private investment, which in turn boosts GDP growth.

ADS and connected vehicle technology play into Ohio's current transportation infrastructure needs. Through stakeholder engagement and evaluating current research, it is clear that the most productive course of action for the General Assembly to take in building the infrastructure ecosystem for this technology is to maintain and repair the current infrastructure while also integrating new technologies into the state's infrastructure lifecycle management process (such as smart pavement, signage, lane markings, and signalization systems, which will better enable ADS and connected vehicle technology to "see" the environment around them), thus increasing system safety and reliability. Due to the large variance in possible outcomes for Ohio's transportation infrastructure, it is vital that the General Assembly focuses on what can benefit both conventional (human) drivers and ADS and connected vehicle technology.

Data

Real-time transportation data is now ubiquitous at a level that was unfathomable just a few decades ago. Private industry has made great progress in learning how to leverage this data, but the public sector has not kept up. Understanding what kinds of data will be created by this technology and understanding how this data can be shared, used, and protected is of utmost importance for the General Assembly. The amount and type of data that could be collected from ADS and connected vehicle technology will be relatively unsettled until those vehicles penetrate the market. As with most things related to ADS-equipped and connected vehicles, this is an evolving area so it is impossible to account for what else could be produced on this topic during this time of great innovation. Generally, what is unlikely to change is that data can and will be collected from the driver, the vehicle, and the infrastructure. Thus, vehicles will become a digital companion that learns habits, adapts to choices, and predicts needs; which means data privacy and security will be an increasingly critical policy area for the General Assembly to monitor.

Due to the still theoretical nature of some potential applications for data in ADS and connected vehicle technology, this report concludes that data privacy standards are best left under the purview of the federal government to create a uniform national standard that will enable Ohioans' data to have the same privacy standards across state lines. However, if the federal government fails to properly and in a timely manner formulate and roll out data privacy standards, then the General Assembly has an obligation to the people of Ohio to begin formulating a regulatory structure for data privacy standards. Currently, data privacy regulations are analogous to the Wild West, where there is relatively little regulatory structure and it is no longer tenable.

Workforce & Labor

The effects on the labor market and the broader economy from ADS and connected vehicle technology will be the first major wave of the next generation of automation – automation that is software based rather than mechanically based. Advanced automation via software and artificial intelligence will affect nearly every industry in Ohio in the coming years. If the General Assembly can create the framework and system responses to address negative effects on the labor market and the broader economy by this first-wave of labor displacement and economic change, then Ohio will be much better positioned to handle more widespread and more severe displacement and economic change, as advanced automation and artificial intelligence exponentially accelerates in the coming years. This report cannot overstate the importance of preparing a framework to manage the displacement of labor and broader economic changes on the horizon; if the General Assembly fails to keep its eye on the ball and allows these issues to go unaddressed, Ohio will be staring down political and social unrest in the coming years.

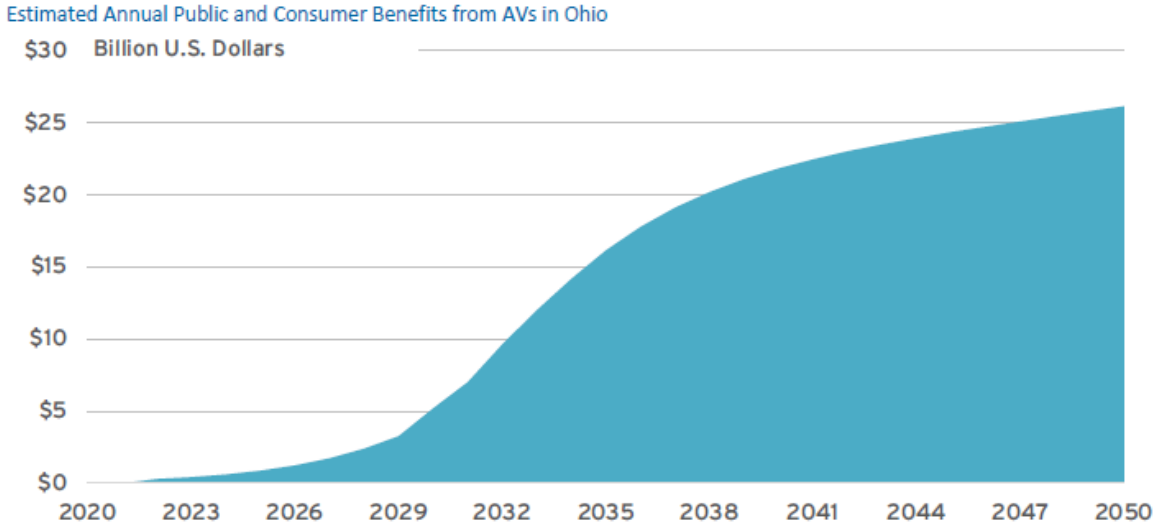
While the threat of labor displacement is real and will materialize in some form or fashion once ADS technology is deployed, its deployment, however, will also lead to gainful employment for some Ohioans who lack access to the job market or who do not have access to reliable transportation to get to and from work. Securing America's Future Energy (SAFE) is a Washington, D.C. based think tank that published a comprehensive study in June of 2018 titled *America's Workforce and the Self-Driving Future* that examined the potential impacts ADS technology might have on the labor market. In this study, the authors took a historical approach to understand the potential impacts that the transition to ADS technology may have on the labor market. The study draws on a range of earlier waves of disruption, such as autopilots in aviation, the industrial revolution, ATMs, globalization, and other innovations. The study conducts a comprehensive review of the historical record that these innovations had on the labor market and is used to infer the potential labor effects that ADS technology portends. The study concludes that ADS technology is likely to result in hundreds of billions of dollars in annual public benefits by 2050, improved transportation options will expand labor market access to both workers and employers, and ADS technology will have a marginal negative effect on employment but will return to full employment soon after, among other conclusions.

While the original study was nationally based, SAFE, upon the request of Chairman Doug Green of the Ohio House of Representatives Transportation & Public Safety Committee, examined Ohio specifically and prepared a secondary memo to inform this report. SAFE's study

found that ADS technology would likely lead to significant productivity gains and economic growth—bringing to mind the rapid economic growth that accompanied the post-Second World War expansion, building of the Interstate Highway System, and suburbanization of the United States. The overall economic and social impacts of deploying ADS technology are very likely to be similarly significant and, overall, highly positive. SAFE's analysis found that ADS technology could lead to $800 billion annually in economic and societal benefits upon full deployment across the United States. Based upon an examination of Ohio's proportion of crash fatalities and vehicle miles traveled in relation to the national total, SAFE estimated that Ohio would see annual benefits of at least $26.1 billion.[38] A more detailed accounting of SAFE's estimates of the public and consumer benefits in Ohio can be seen in the table below.

Additionally, included below the first table is a figure with an estimate of annual benefits in Ohio projected over time:

Public Benefits by 2050 (annual)	**$20.0 Billion**
Congestion	$2.7 Billion
Accident Reduction – Economic Impact	$3.6 Billion
Accident Reduction – Quality of Life Improvements	$11.6 Billion
Reduced Oil Consumption	$2.2 Billion
Consumer Benefits by 2050 (annual)	**$6.1 Billion**
Value of time	$5.7 Billion
Reduction in Cost of Current Taxi Service	$0.4 Billion
Total Annual Benefits (by 2050)	**$26.1 Billion**



Source: SAFE analysis based on David Montgomery, *Public and Private Benefits of Autonomous Vehicles*, June 2018.

When ADS technology takes over driving, those Ohioans in driving occupations will need to retool their skillset to relevant opportunities that this new transportation environment creates

– much akin to the first and second Industrial Revolutions. If Ohio is able to gain insights into the future skills and competencies that will be required, the state will have a head start in building this new emerging workforce. This will help Ohio position itself as the private investment state of choice for this emerging industry and will assist the state in reversing some of its long-term, negative economic trends.

Insurance

The insurance industry will be one of the most heavily impacted industries in the greater $2 trillion dollar automotive market. Insurance provides a much needed function in our transportation system by ensuring motorists and others have financial protection against physical damage, bodily injury, and other liabilities resulting from traffic collisions as well as other events such as theft and weather. Rapid advancements in ADAS/ASS, ADS, and connected vehicle technologies are deploying now or in the short-term. These changes will bring about significant change to the insurance industry, specifically auto insurance. The availability of data and its ability to inform risk and its enabling power for ADS technology deployment is rapidly expanding and will grow exponentially as capabilities continue to advance in sensors, data storage, machine learning, and other related areas. As consumers cede control to ADS-equipped vehicles to make fundamental driving decisions, manufacturers and software developers will become more accountable for accidents and the lines of legal responsibility will begin to blur under certain circumstances. This change in legal responsibility will cause a move toward more product and general liability insurance. Consumers, specifically millennials and younger, desire to multi-task, get places faster, travel safer, share more, and be more environmentally responsible. Those desires along with increased urbanization are already driving rapid changes in consumer views on mobility and vehicle ownership, both of which will contribute to the adoption of ADS technology and the number of vehicles to insure.

The insurance industry has fundamental structural changes on its doorstep and those companies that are able to adapt to the new realities, formulate strategies to quickly capitalize on new market opportunities, and merge with complimentary companies will lead the pack. The questions for the General Assembly with regard to insurance and ADS and connected vehicle technology is, what is its role to ensure that Ohio continues to maintain a stable, robust, and healthy insurance market? How does it ensure that Ohio-based insurance companies have a regulatory environment that will enable them to best compete in an industry that will most likely see consolidations?

Conclusion

ADS and connected vehicle technology will fundamentally change how Ohio, as a society, transports people, goods, and services. This technology promises to usher in an era of safety, increased mobility, and fundamentally change the way in which Ohioans interact with the transportation system. However, with fundamental change in society comes growing pains and the potential for negative secondary socioeconomic effects. Growing pains include building the infrastructure ecosystem for this technology to operate in, such as maintaining current infrastructure while integrating new technology during lifecycle updates. Potential negative secondary socioeconomic effects can manifest itself in the form of labor displacement and

market volatility. These are unavoidable; what the General Assembly must be prepared to do is to address the challenges, and when necessary, to mitigate their effects. There is no stopping the progression of ADS technology; it is coming. However, it is also not prudent to ignore the potential negative socioeconomic effects that it may bring with it. Failure to mitigate negative socioeconomic effects has the potential to create public backlash which may impede the ability for this technology to deploy on an aggressive timeline. The theme of this entire report has been to strike a balance between the need to aggressively pursue the development and deployment of this technology while also creating frameworks and system-wide responses to mitigate any negative socioeconomic effects it may have on the labor market and broader economy.

Below is a complete list of recommendations made throughout this report that the General Assembly should begin pursuing immediately so that Ohio can maintain a competitive edge in this industry, which will incentivize additional private investment to come to the state due to the burdensome-free, mature, and stable regulatory structure:

- **Actionable Items:**
    - Ohio Overview
        - In order to solidify the regulatory environment that has been conducive to Ohio's momentum thus far in ADS and connected vehicle research, testing, and deployment, this report makes the following recommendations for the General Assembly to pursue:
            - The General Assembly should codify DriveOhio as the lead agency for ADS and connected vehicle technology.
            - The General Assembly should codify Governor Kasich's Executive Order allowing state-wide testing of ADS and connected vehicle technology.
            - The General Assembly should establish an Autonomous and Connected Vehicle Task Force that is comprised of a broad range of disciplines and organizations. This Task Force should be a creature of the General Assembly but housed inside DriveOhio. This Task Force should be directed by the General Assembly to provide legislative recommendations on an on-going basis as this technology develops. Inclusive and collaborative planning will pay substantial dividends and as such is in the public interest.
            - The General Assembly should inventory the Ohio Revised Code to identify what areas will need to be amended at some point for this technology – inventory, but do not make legislative changes until there is a need to. Having the Ohio Revised Code inventoried will allow for the General Assembly to be agile and nimble as the technology develops and warrants legislative action.
    - Infrastructure

- The General Assembly should establish a Joint House-Senate Commission on short- and long-term transportation infrastructure funding with recommendations to be expeditiously moved through the committee process in both the House and Senate. This commission should address both short- and long-term funding issues surrounding Ohio's transportation infrastructure and how to best raise and allocate funding to integrate smart technology into the infrastructure lifecycle management system. Further, the proposed Autonomous and Connected Vehicle Task Force should be directed to evaluate and make recommendations to the General Assembly on:

    - New signage, pavement markings, and signalization systems to be integrated into the transportation infrastructure system that will benefit and provide greater value to conventional drivers, ADS-equipped, and connected vehicles than current signage, pavement markings, and signalization systems in use;
    - New transportation infrastructure design guidelines that consider future sensor and communication technology infrastructure installation needs, including access to power, underground conduit for fiber ("Dig Once" policy), locations for device mounting, and other needs;
    - A Roadway Classification System that identifies the infrastructure needed to support various levels of ADS and connected vehicle technology; and
    - Studying and recommending to the General Assembly a "Dig Once" policy that enables broadband infrastructure to be installed in the public right-of-ways where possible during state-funded or supported infrastructure projects that already expose the right-of-way; doing so could reduce the cost of broadband infrastructure buildout by 90%.

- Data

    - The General Assembly should adopt a Joint-Resolution urging Congress to pass uniform federal regulations governing data privacy protections and for those regulations to apply to all users in the Internet ecosystem. These protections should include "opt-in" and "opt-out" protections, allowing Ohioans the ability to decide what and how their data is shared to service providers and third-parties; this requires privacy notices and terms of service to be easy-to-find and written in layman's terms. This resolution should also include language that makes clear that if the federal government fails to properly and in a timely manner pass uniform federal regulations governing data privacy protections, then Ohio reserves the right

to begin formulating its own regulatory structure in the absence of federal action.

- The General Assembly should direct the proposed Autonomous and Connected Vehicle Task Force to recommend, upon collaboration with private industry, public sector agencies, and other stakeholders, a data exchange platform that will enable relevant ADS and connected vehicle technology and related infrastructure data to be anonymized and shared.
    - Such data may include crash data and other related incidents for insurance and public safety purposes
    - Making relevant data available for research and planning models to further academic research and the public good through public sector utilization
    - Making data available to support smart cities and communities

- Workforce and Labor
    - The General Assembly should direct the proposed Autonomous and Connected Vehicle Task Force to begin identifying occupations most at risk of labor displacement from ADS technology, starting from the short- to long-term, and begin identifying what new skill sets and competencies these Ohioans will need to be transitioned back into the workforce as quickly and as smoothly as possible.
        - Further, as part of this directive, this Task Force should bring together the trucking, transit, and taxi/ride-hailing industries together with their respective labor representatives to begin working out a fair, equitable structure to transition their driving workforce into new positions within their organizations or into new occupations. The goal of this is to begin the hard conversations now and avoid political gamesmanship in the coming years, which may delay or impede ADS deployment, neither of which is in the public interest because the General Assembly's failure to properly address labor displacement is a recipe for social and political unrest.

- Insurance
    - The General Assembly should direct the proposed Autonomous and Connected Vehicle Task Force to deliberate and make recommendations on how best to create a regulatory framework for data sharing between auto manufacturers, their supply chains, and the insurance industry. As Ohio moves into a more data-centric world, access to relevant data is paramount. The insurance industry will need access to certain types and amounts of data for two key reasons: first, to develop accurate pricing and

underwriting models, which benefits consumers and second, to make more accurate and fair liability determinations. Bringing stakeholders together through the proposed Autonomous & Connected Vehicle Task Force to negotiate a fair regulatory structure for data sharing between the auto manufacturers and the insurance industry is key to providing a stable regulatory environment for ADS and connected vehicle technology. Without a data-sharing regulatory structure, insurers will be challenged by a lack of data, whether they choose to proceed under a personal liability regime or a products liability regime. Testing data and simulations are a poor substitute for actual data generated by the public using this technology.

- **Positions to take:**
  - Federal versus State Responsibilities
    - The General Assembly should oppose a patchwork of state and local laws regarding ADS and connected vehicle technology as it is not in the public interest. Ohio should defer to the federal government in the regulation of safety, cybersecurity, and data privacy standards.
  - Infrastructure
    - The General Assembly should make basic transportation infrastructure maintenance its first priority in regards to ADS and connected vehicle technology because it is absolutely essential for both conventional drivers and ADS technology; both need well-maintained roads, clear pavement markings, and optimal signage.
    - The General Assembly should make its second priority the integration of smart communication technology into the infrastructure system, such as Dedicated Short Range Communication (DSRC) devices and 5G infrastructure to enable Vehicle-to-Vehicle (V2V), Vehicle-to-Infrastructure (V2I), Vehicle-to-Everything (V2X), and C-V2X (Cellular-Vehicle-to-Everything) communications.
  - Workforce and Labor
    - The General Assembly should commit to a policy that encourages aggressive deployment of ADS technology. Doing so would allow projected annual benefits to begin accumulating in the mid-to-late 2020s and some of those dollars should be directed to upgrading Ohio's ability to mitigate negative socioeconomic costs incurred from the deployment of this technology.
  - Insurance
    - The General Assembly should oppose any attempts to federalize the auto insurance regulatory structure. The reason being that if auto manufacturers

and their supply chains are required to accept greater liability for damages and injuries, they may lobby the federal government to provide greater regulatory oversight of the auto insurance industry to reduce and/or eliminate costs related to complying with the individual and unique regulations of 51 jurisdictions in the United States. Ohio has a top-tier auto insurance market and the General Assembly must guard against any attempt to cede state authority to the federal government on this particular issue.

- The General Assembly should oppose any changes to Ohio's current tort system of assigning liability with regards to this technology, until ADS and connected vehicle technology begins deploying and unforeseen issues arise. During stakeholder engagement there was a rare agreement between the insurance industry and the trial lawyers association regarding this topic; these opposing industries agree that, as of now, Ohio's current tort system will be able to handle this evolving technology.

Process

Beginning in the fall of 2017, the Transportation and Public Safety Committee of the Ohio House of Representatives began this study to examine autonomous and connected vehicle technologies; the technical nomenclature is Automated Driving Systems (ADS's) and connected conventional vehicles. This study has been focused on potential benefits and challenges, how the emerging technology may impact Ohio's economy, manufacturing, public safety, insurance, and infrastructure, as well as a review of current research, testing, federal regulations, and industry activity in Ohio. Most importantly, this study was designed with the purpose to inform the General Assembly and more broadly, government at all levels in Ohio. It is the position of the Ohio House of Representatives that before proposing legislation dealing with such a complex and technical subject, a study should be conducted beforehand. With ADS and connected vehicle technology, the modus operandi is "first do no harm."

From October 2017 to May 2018, the Transportation & Public Safety Committee held hearings on the topic to inform the Committee and public on this new and evolving technology. These hearings included Autonomous Vehicles 101; Manufacturers Briefing; Benefits & Challenges, Economy & Labor; Infrastructure & Industry; Research & Testing; and finally, Insurance. Witnesses that came before the Committee to testify included companies involved in the development, testing, and deployment of this technology, experts in the field, think tanks, as well as government agencies and unions.

Following the committee hearings, stakeholder meetings were held to engage the topics in a more in-depth manner beginning in September 2018 and concluding in October 2018. Twelve stakeholder meetings were held, and the topics covered were: Trucking; Manufacturers, Research, Testing; Regional Transportation and Planning Authorities; Infrastructure; Local Government; Telecoms; Data; Insurance; Tech Companies; Education and Think Tanks; Business Associations; and Unions (unions were reached out to and confirmed but never showed up for their scheduled stakeholder meeting). These meetings were designed to be deep-dive explorations by topic and/or industry. Stakeholders from across Ohio and the United States participated, with a total of over 50 stakeholder organizations providing input and feedback for this report.

There has been broad consensus on many topics, across industries, private and public sector stakeholders, and everyone in between; at the same time, some topics broached during this study have also seen broad disagreements. This report will outline both the areas of consensus and disagreement. Stakeholder engagement, testimony before the committee, and research conducted by academia, consulting firms, and think tanks have informed the report and guided the recommendations provided herein.

AV 101 – History

It is 8:00 A.M. on a cold Monday morning. Betty Buckeye is getting ready to leave for work at the same time as she normally does. Her vehicle knows this as it has access to her calendar, is communicating with her connected home where it sees energy is being consumed and thus, she is no longer asleep. In preparation for her commute to work, the vehicle has begun heating her cabin because it is connected to live weather reports and knows what temperature she prefers for the cabin of the vehicle based on the outside temperature; it knows this because it has learned her preferences over time. As she is grabbing her coffee and files, her vehicle has already begun pulling out of the garage and awaits her outside the front door. As she approaches, the vehicle senses her and automatically opens the door as her hands are full; it knows she is close because it is communicating with her phone, and there no longer is a key or key fob. Once she is in the vehicle, it proactively asks if she is going to work and she replies "I am" and then off she goes. Her vehicle drops her off at the entrance of the building and then proceeds to park itself or alternatively, she has opted to make it a ridesharing vehicle on a network, where while not in use, her vehicle is producing income for her.

For decades, this narrative was in the realm of science fiction, in league with the Jetsons. However, advances in ADS and connected vehicle technology combined with advances in the Internet of Things platform are connecting all of society's different devices together and has made this narrative very close to reality. In fact, the vast majority of the narrative is possible today – vehicles for purchase today are connected and have access to calendars, access to the weather, traffic conditions and so on. Connecting homes to the Internet of Things platform is already possible, through devices like Google Nest, which can communicate with connected vehicles. Tesla vehicles can be summoned from a garage and the doors can be programmed to open when the owner walks up to them, and the Tesla Model 3 does not have a key – the key is the owner's phone. The only part of the narrative that cannot be commercially performed right now is the driving function from Betty Buckeye's home to the office; however, it is only 4-6 years away (if you live in a city) from being commercially available. The technology to do it is here, right now, but it is not ready for commercial deployment yet. However, there is one caveat: for commutes that are mostly heavily congested, then Audi's 2019 A8 sedan is the world's first commercially available Level 3 ADS system that can then make this narrative almost entirely possible.

It is important to understand the history of ADS technology to fully grasp the pace at which its development is now moving. The very first "driverless" vehicles were prototyped in the early 1920s; they indeed lacked a driver but were actually just remotely controlled by a following car using radio technology. So, the idea and goal of "autonomous" vehicles has been around for almost a century. What is considered to be modern autonomous technology did not first appear in vehicles until cruise control was brought to market with the 1958 Chevrolet Imperial, which allowed the driver to maintain speed without the driver using the pedal. This was followed by Anti-Lock Braking Systems (ABS) in 1971. ABS was first introduced in surface vehicles with the Chevrolet Imperial but had been used in aircraft since 1929.[39]

The ABS system monitored wheel speed, analyzed the data to detect skidding, and relayed commands to a hydraulic modulator, in the same automation model that has been used in countless other commercial and industrial applications, including ADS technology. The introduction of cruise control and ABS systems were the first automobile systems that were classified as Level 1 technology in the SAE classification system for ADAS and ADS technology.[40]

During the 1960s and 1970s, the Stanford Cart was developed. This project was initially developed for a space mission to the surface of the moon. However, the Stanford Cart project team led the way in developing the video processing technology that would later be used to provide necessary input to autonomous vehicles. The Stanford Cart was equipped with a rotating camera that the cart would use to process images for ten to fifteen minutes each time it moved roughly three feet. Doing so allowed the cart to navigate slowly around obstacles without human input. By 1979, the Stanford Cart was able to autonomously cross a crowded room of chairs in roughly five hours. The separate avenues of special inputs, function-specific autonomous systems, and video-processing algorithms for autonomous navigation began to converge, which paved the way for contemporary autonomous vehicle development.[41]

In the late 1970s and 1980s began the emergence of contemporary ADS technology. These technologies were in commercially available vehicles that were retrofitted with the sensors, processors, and outputs that were necessary to theoretically navigate themselves through traffic without any external inputs from a human. A professor at Bundesweher University of Munich, Ernst Dickmanns, retrofitted a Mercedes-Benz named Versuchsfahrzeug für autonome Mobilität und Rechnersehen (VaMP) to accomplish this theoretical ability. The vehicle was able to process visual input from the cameras it was equipped with and issue commands to the steering wheel, throttle, and brakes, at speeds up to just shy of 60 mph. This feat was able to be achieved by using newly developed dynamic computer vision technique dubbed “4D Vision,” which helped to counter the issues of time delay due to the much slower computing power of the time.[42]

By the late 1980s, governments around the world began to heavily invest in the development of ADS technology. The Eureka Prometheus Project was the largest ever research and development project in the field of “autonomous” vehicles at the time, with a budget of over $1.1 billion. This project spanned Europe with participation from academia and private industry across Europe.[43] In 1995, the project’s research and development concluded with a 1,200 mile journey from Munich to Copenhagen and back at speeds of up to 80 mph, almost entirely autonomously by Professor Dickmanns VaMP vehicle.[44] In the United States, projects were also underway in the late 1980s to develop this technology. The United States government launched the DARPA Autonomous Land Vehicle (ALV) project which produced land vehicles directed by LIDAR, computer vision, and artificial neural networks.[45] Long-distance ADS technology projects were also launched by American universities such as Carnegie Mellon University.[46]

The DARPA Grand Challenge was launched in 2004 and was designed to incentivize “autonomous” vehicle development by offering $1 million to the team whose “autonomous” vehicle could successfully navigate a designed obstacle course.[47] During the inaugural competition in 2004, no team was successful in completing the challenge; however, in 2005, five vehicles completed the challenge for a prize of $2 million. The first place winner was Stanley,

designed by a team from Stanford University and Volkswagen Group, using technologies gleaned from the Stanford Cart.[48] By 2007, the course had increased in complexity by being an urban setting that required teams to interact with traffic. In that year's challenge, six teams completed the challenge, with Carnegie Mellon's Tartan Racing team winning the grand prize.[49] The 2007 event also experienced accidents, with the MIT and Braunschweig teams colliding and another team colliding with a pillar, which raised public awareness of the mistakes this technology can make.[50]

Over the last decade, ADS and connected vehicle technology research has continued to move from academia to vehicle manufacturers. Companies such as Ford, GM, BMW, Volkswagen, and Tesla have been testing their own ADS technologies. One of the most advanced ADS technology projects has been the Google Self-Driving Car project, which was launched in 2009.[51] In late 2015, Tesla released a software update which enabled its Model S vehicle to utilize a vehicle technology feature it called "Autopilot," which is a Level 2 ADAS system.[52] Tesla's Autopilot technology enables the vehicle to autonomously follow the lane it is in, switch lanes on command, park itself, and be summoned remotely, meaning it can park into a garage by itself and can leave the garage and come to the owner. In 2017, GM launched its Super Cruise ADAS feature which is similar to the Tesla Autopilot and is a Level 2 technology.[53] As of 2018, Google's ADS-equipped vehicles have logged eight million miles on public roads, now averaging 25,000 miles per day, and Tesla's Autopilot feature has logged an astounding 1.5 billion miles collectively.[54]

Over the next five years there will be ever-increasing improvements in ADAS and ADS technology. Audi is the first Original Equipment Manufacturer (OEM) to bring to market a Level 3 vehicle with its 2019 Audi A8. The all-new Audi A8 will have a feature called "Audi AI traffic jam pilot" which enables the vehicle to take over the task of driving in certain driving conditions and unlike Level 2, the driver no longer needs to monitor the vehicle while it is driving. They must simply be able to take back the task of driving when the system prompts them to.[55] Unfortunately, due to regulatory and legal obstacles in the United States, Audi will not be operationalizing this technology in the U.S. market, for now.[56] GM has claimed it will be the first high-volume OEM to build Level 4 vehicles in a mass-production assembly plant and that its focus will be on the ride-hailing market first rather than the consumer market. However, GM has not announced when it expects to introduce this vehicle, but in a filing with the federal government in January 2018, it asked permission to do so in a commercial ride-hailing service launching in 2019.[57]

While GM has not announced an introduction date for its planned Level 4 vehicle, 2021 may well be the year of the Level 4 vehicle. Ford has announced that it plans on bringing to the market a Level 4 vehicle by 2021 as has BMW with its iNEXT vehicle.[58] Most other auto manufacturers are in the same early 2020 time horizon for their planned Level 4 products. Time horizons for this technology may speed up as other ancillary technologies are advancing at an exponential rate such as computer power, sensor technology, and machine learning. The below graph illustrates rough-time horizon estimates for ADS deployment and market penetration:

Stage	Decade	Vehicle Sales	Vehicle Fleet	Vehicle Travel
Large price premium	2020s	2-5%	1-2%	1-4%
Moderate price premium	2030s	20-40%	10-20%	10-30%
Minimal price premium	2040s	40-60%	20-40%	30-50%
Standard feature on most new vehicles	2050s	80-100%	40-60%	50-80%
Saturation (everybody who wants it has it)	2060s	?	?	?
Required for all vehicles on road	???	100%	100%	100%

Source: Littman (2018)

59

The pace at which advances in ADS technology are moving when compared to the overall history of the technology and the rate of innovation in ancillary technologies provides the necessary context for the Ohio House of Representatives to begin planning for this technology now, not later.

Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles

ADS and connected vehicle technology have many unique terms and acronyms and it is important for members of the Ohio House of Representatives to have a firm grasp of them. This section is designed to be a resource to learn and refer to in order to become more familiar with the technology and when speaking about it to others. It is important to keep in mind that this is an emerging technology with essentially its own language. Terms have and will continue to change as the technology moves forward and industry coalesces around certain terms and acronyms and discards others.

Below are key definitions and acronyms to understand in order to be able to read and talk about this technology; this is not an exhaustive list. These definitions and acronyms are sourced from SAE International, the primary technical standards organization for this technology.

Active Safety System (ASS):

Active safety systems are vehicle systems that sense and monitor conditions inside and outside the vehicle for the purpose of identifying perceived present and potential dangers to the vehicle, occupants, and/or other road users, and automatically intervene to help avoid or mitigate potential collisions via various methods, including alerts to the driver, vehicle system adjustments, and/or active control of the vehicle subsystems (brakes, throttle, suspension, etc.).[60]

- **NOTE**: For purposes of the sourcing report, systems that meet the definition of active safety systems are considered to have a design purpose that is primarily focused on improving safety rather than comfort, convenience or general driver assistance. Active safety systems warn or intervene during a high-risk event or maneuver.[61]

Advanced Driver Assistance System (ADAS):

Systems designed to help drivers with certain driving tasks (e.g., staying in the lane, parking, avoiding collisions, reducing blind spots, and maintaining a safe headway). An ADAS is generally designed to improve safety or reduce the workload on the driver. With respect to automation, some ADAS features could be considered SAE Level 1 or Level 2, but many are Level 0 and may provide alerts to the driver with little or no automation.[62]

- **NOTE**: This term is sourced from U.S. Department of Transportation's *Automated Vehicles 3.0* report, not SAE International.

Automated Driving System (ADS):

The hardware and software that are collectively capable of performing the entire DDT on a sustained basis, regardless of whether it is limited to a specific operational design domain (ODD); this term is used specifically to describe a Level 3, 4, or 5 driving automation system.[63]

Conventional Vehicle:

A vehicle designed to be operated by a conventional driver during part or all of every trip.[64]

Driving Automation System or Technology:

The hardware and software that are collectively capable of performing part or all of the DDT on a sustained basis; this term is used generically to describe any system capable of Level 1-5 driving automation.[65]

Dynamic Driving Task (DDT):

All of the real-time operational and tactical functions required to operate a vehicle in on-road traffic, excluding the strategic functions such as trip scheduling and selection of destinations and waypoints.[66]

[Dynamic Driving Tasks (DDT)] Fallback:

The response by the user to either perform the DDT or achieve a minimal risk condition after occurrence of a DDT performance-relevant system failure(s) or upon operational design domain (ODD) exit, or the response by an ADS to achieve minimal risk condition, given the same circumstances.[67]

Minimal Risk Condition:

A condition to which a user or an ADS may bring a vehicle after performing the DDT fallback in order to reduce the risk of a crash when a given trip cannot or should not be completed.[68]

[DDT Performance-Relevant] System Failure:

A malfunction in a driving automation system and/or other vehicle system that prevents the driving automation system from reliably performing the portion of the DDT on a sustained basis, including the complete DDT, that it would otherwise perform.[69]

Object and Event Detection and Response (OEDR):

The subtasks of the DDT that include monitoring the driving environment (detecting, recognizing, and classifying objects and events and preparing to respond as needed) and executing an appropriate response to such objects and events (i.e., as needed to complete the DDT and/or DDT fallback).[70]

Operational Design Domain (ODD):

Operating conditions under which a given driving automation system or feature thereof is specifically designed to function, including, but not limited to, environmental, geographical, and time-of-day restrictions, and/or the requisite presence or absence of certain traffic or roadway characteristics.[71]

Request to Intervene:

> Notification by an ADS to a fallback-ready user indicating that s/he should promptly perform the DDT fallback, which may entail resuming manual operation of the vehicle (i.e., becoming a driver again), or achieving a minimal risk condition if the vehicle is not drivable.[72]

[DDT] Fallback-Ready User:

> The user of a vehicle equipped with an engaged Level 3 ADS feature who is able to operate the vehicle and is receptive to ADS-issued requests to intervene and to evident DDT performance-relevant system failures in the vehicle compelling him or her to perform the DDT fallback.[73]

Taxonomy of Driving Automation

The terms defined above inform part of the taxonomy of driving automation consisting of six discrete and mutually exclusive levels. Central to this taxonomy are the respective roles of the (human) user and the driving automation system in relation to each other. Because changes in the functionality of a driving automation system change the role of the (human) user, they provide a basis for categorizing such system features.[74]

Table 1 summarizes the six levels of driving automation in terms of these five elements. SAE's levels of driving automation are descriptive and informative, rather than normative, and technical rather than legal. Elements indicate minimum rather than maximum capabilities for each level. In this table, "system" refers to the driving automation system or ADS, as appropriate.[75]

Table 1 - Summary of levels of driving automation

Level	Name	Narrative definition	DDT		DDT fallback	ODD
			Sustained lateral and longitudinal vehicle motion control	*OEDR*		
Driver performs part or all of the *DDT*						
0	No Driving Automation	The performance by the *driver* of the entire *DDT*, even when enhanced by *active safety systems*.	*Driver*	*Driver*	*Driver*	n/a
1	Driver Assistance	The *sustained* and *ODD*-specific execution by a *driving automation system* of either the *lateral* or the *longitudinal vehicle motion control* subtask of the DDT (but not both simultaneously) with the expectation that the *driver* performs the remainder of the *DDT*.	*Driver* and *System*	*Driver*	*Driver*	Limited
2	Partial Driving Automation	The *sustained* and *ODD*-specific execution by a *driving automation system* of both the *lateral* and *longitudinal vehicle motion control* subtasks of the *DDT* with the expectation that the *driver* completes the *OEDR* subtask and *supervises* the *driving automation system*.	***System***	*Driver*	*Driver*	Limited
ADS ("*System*") performs the entire *DDT* (while engaged)			*System*	***System***	*Fallback-ready user (becomes the driver during fallback)*	Limited
3	Conditional Driving Automation	The *sustained* and *ODD*-specific performance by an *ADS* of the entire DDT with the expectation that the *DDT fallback-ready user* is *receptive* to *ADS*-issued *requests to intervene*, as well as to *DDT performance-relevant system failures* in other *vehicle* systems, and will respond appropriately.				
4	High Driving Automation	The *sustained* and *ODD*-specific performance by an *ADS* of the entire *DDT* and *DDT fallback* without any expectation that a *user* will respond to a *request to intervene*.	*System*	*System*	***System***	Limited
5	Full Driving Automation	The *sustained* and unconditional (i.e., not *ODD*-specific) performance by an *ADS* of the entire *DDT* and *DDT fallback* without any expectation that a *user* will respond to a *request to intervene*.	*System*	*System*	*System*	**Unlimited**

76

Levels of Driving Automation

The level of driving automation is based on the functionality of the driving automation system, as determined by an allocation of roles in DDT and DDT fallback performance between that system and the (human) user (if any). The lower two levels of driving automation (1-2) refer to cases in which the (human) driver continues to perform part of the DDT while the driving automation system is engaged. The upper three levels of driving automation (3-5) refer to cases in which the Automated Driving System (ADS) performs the entire the DDT on a sustained basis while it is engaged.[77]

Level 0 – No Driving Automation:

The performance by the driver of the entire DDT, even when enhanced by active safety systems.[78]

Level 1 – Driver Assistance:

The sustained and ODD-specific execution by a driving automation system of either the lateral or the longitudinal vehicle motion control subtask of the DDT (but not both simultaneously) with the expectation that the driver performs the remainder of the DDT.[79]

Level 2 – Conditional Driving Automation:

The sustained and ODD-specific execution by a driving automation system of both the lateral and longitudinal vehicle motion control subtasks of the DDT with the expectation that the driver completes the OEDR subtask and supervises the driving automation system.[80]

Level 3 – Conditional Driving Automation:

The sustained and ODD-specific performance by an ADS of the entire DDT with the expectation that the DDT fallback-ready user is receptive to ADS-issued requests to intervene, as well as to DDT performance-relevant system failures in other vehicle systems, and will respond appropriately.[81]

Level 4 – High Driving Automation:

The sustained and ODD-specific performance by an ADS of the entire DDT and DDT fallback, without any expectation that a user will respond to a request to intervene.[82]

Level 5 – Full Driving Automation:

The sustained and unconditional (i.e., not ODD-specific) performance by an ADS of the entire DDT and DDT fallback without any expectation that a user will respond to a request to intervene.[83]

Federal versus State Responsibilities

As the pace of technological advancement in ADS and connected vehicle technology continues to accelerate, it is important for this report to express clearly what the Ohio House of Representatives should argue are appropriate federal and state responsibilities in the regulation of this technology. This report concurs with the United States Department of Transportation Automated Vehicles 3.0 advisory report regarding the proper federal and state roles in the regulation of this developing technology.[84] The traditional roles that govern regulatory authority in the transportation sector can and should be used to address automation, as it prevents unneeded confusion and regulatory uncertainty for Ohio businesses. Failure to coalesce around a tried and true, stable framework for regulating this technology will hinder Ohio's ability to compete with other states, Europe, and Asia in the race for commercially deployable ADS technology.

In the transportation sector, the federal government, traditionally, has regulatory authority over the safety performance of vehicles, their equipment, and their participating operation in interstate commerce. Individual states and local governments have regulatory authority over licensing, establishing state and local traffic laws, tort liability, and insurance. It should be the position of the Ohio House of Representatives that a patchwork of state and local laws regarding ADS and connected vehicle technology is not in the public interest. The federal government should focus on what it is best equipped to regulate, which are safety, cybersecurity, and data privacy standards. Ohio should focus on what it is best equipped to regulate, which is providing for the regulatory framework for this technology to operate in the state, such as licensing, tort liability, and insurance regulations. Furthermore, Ohio must also focus on maintaining and building the infrastructure ecosystem for this technology to operate and flourish in, which means ensuring transportation infrastructure is well maintained, ensuring broadband and communications infrastructure continues to be built, and integrating smart and connected technologies into new and existing infrastructure to enable this technology to communicate and interact with the physical environment.

To better understand why this report has taken the above positions, it is important to have a baseline understanding of how the federal government carries out its current regulatory authority and by which entities. The entity that is most responsible for the federal government's role in regulating ADS and connected vehicle technology falls under the United States Department of Transportation and its subsequent administrations within the Department. According to the Department, its role in transportation automation is to ensure the safety and mobility of the traveling public while fostering economic growth. To fulfill its role in transportation automation, the Department outlines in its *Automated Vehicles 3.0* guidance report that it is pursuing the following activities:

- Establishing performance-oriented, consensus-based, and voluntary standards and guidance for vehicle and infrastructure safety, mobility, and operations.
- Conducting targeted research to support the safe integration of automation.
- Identifying and removing regulatory barriers to the safe integration of automated vehicles.

- Ensuring national consistency for travel in interstate commerce.
- Educating the public on the capabilities and limitations of automated vehicles.[85]

The Department states that as it is pursuing these activities, it is actively engaging and working with stakeholders in the private and public sectors to build consensus and voluntary agreements, where possible, to accomplish the above objectives. Federal regulations regarding this technology will primarily come from the Federal Highway Administration, National Highway Traffic Safety Administration, Federal Motor Carrier Safety Administration, and Federal Transit Administration. Together, these internal administrations of the United States Department of Transportation will provide the federal regulatory framework for ADS and connected vehicle technology.[86]

The Federal Highway Administration (FHWA) is the entity charged with regulatory oversight over the construction, maintenance, and preservation of the United States' highways, bridges, and tunnels. Beyond regulatory oversight, the FHWA provides technical assistance to its counterparts in federal, state, and local agencies to hasten the adoption of innovative policies to improve safety and mobility. As part of its mission, the FHWA administers the Manual on Uniform Traffic Control Devices (MUTCD). The MUTCD establishes national standards for traffic control devices, which are used to regulate or guide traffic on streets, highways, bikeways, or private roads open to public travel. Traffic control devices can include road markings, signage, traffic signals and other devices. Uniformity of standards for these devices are essential to support not only ADS-equipped vehicles but human drivers as well. The FHWA is pursuing an update to the 2009 MUTCD that will take into consideration new technologies that assist ADS-equipped vehicles in interpreting and interacting with the roadway and traffic control devices.[87]

The National Highway Traffic Safety Administration (NHSTA) is the regulatory entity charged with maintaining the safety of the United States' highways. NHSTA carries out its regulatory responsibilities by setting and enforcing safety performance standards for motor vehicles and their equipment and by identifying and requiring the resolution of any safety defects. NHSTA regulates vehicle safety performance standards through its rulemaking process for the Federal Motor Vehicle Safety Standards (FMVSS) regulations. NHSTA has broad authority over safety standards for ADS-equipped vehicles because it is charged with promulgating federal safety standards for new motor vehicles introduced into interstate commerce in the United States. Under federal law, no state or local government may enforce laws or regulations on the safety performance of a motor vehicle or motor vehicle equipment that are different from the federal standard. Thus, under the legal doctrine of preemption, it should be the position of the Ohio House of Representatives that NHSTA has clear legal authority to be the regulating entity for safety standards of ADS-equipped vehicles and their equipment.[88]

Currently, NHSTA's position is that current safety standards do not prevent the development, testing, sale, or use of ADS technology built into vehicles that maintain the traditional cabin and control features of human-operated vehicles. With that in mind, NHSTA has stated that it intends to reconsider its current safety standards as applied to ADS-equipped vehicles and will seek public comment on proposed changes to particular safety standards to accommodate ADS technologies and the possibility of setting exceptions to certain standards that are relevant only when human drivers are present for ADS-equipped vehicles. NHSTA has

also stated that due to the accelerating pace of technological change, especially with regard to ADS development, a new approach is required for the formulation of the Federal Motor Vehicle Safety Standards (FMVSS). This has led to NHSTA concluding that it is necessary to move from lengthy, highly prescriptive and feature-specific or design-specific safety standards to a more flexible, technology-neutral, and performance-oriented framework for promulgating future safety standards. It is clear that the federal entities responsible for regulating non-ADS equipped vehicles are in the process of amending their regulations to take into account this new technology which provides credence for Ohio to let this process play out prior to challenging federal authority on the issue.[89]

The Federal Motor Carrier Safety Administration (FMCSA) is charged with reducing crashes, injuries, and fatalities involving large trucks and busses. The FMCSA accomplishes this mission by regulating the safety of commercial motor carriers operating in interstate commerce, the qualifications and safety of commercial motor vehicle drivers, and the safe operation of commercial trucks and motor coaches. FMCSA has taken the position that the best way to reduce crashes, injuries, and fatalities involving large trucks and busses is by avoiding unnecessary barriers to the development of ADS in commercial vehicles. As automation moves into commercial motor vehicles, FMCSA has stated that it will work with industry, state governments, and other partners to further the safe operation of ADS-equipped commercial vehicles, including law enforcement, inspection officers, and first responders to create new techniques and protocols that address emerging policy questions.[90]

Under federal law, FMCSA consults with NHSTA on matters related to motor carrier safety. NHSTA and FMCSA have different but complementary authorities over the safety of commercial motor vehicles (CMVs) and commercial vehicle equipment. NHSTA has exclusive authority to prescribe federal safety standards for new motor vehicles, including trucks and motor coaches, and oversees actions that manufacturers to take to remedy known safety defects in motor vehicles and motor vehicle equipment. NHSTA and FMCSA collaborate and consult to develop and enforce safety requirements that apply to the operation and maintenance of vehicles by existing commercial motor carriers. Both entities have stated that they will continue to do so in the context of ADS-equipped commercial vehicles. FMCSA already works with Ohio and other Ohio-based stakeholders to develop and enforce safety standards related to the inspection, maintenance, and repair of commercial motor vehicles.[91]

The FMCSA has determined that commercial motor vehicle carriers may deploy ADS-equipped CMVs in interstate commerce, using existing administrative processes. In order for this framework to operate, the FMCSA has amended its regulations to no longer assume that the CMV driver is always a human or that a human is necessarily present onboard a commercial vehicle during its operation. If the motor carrier cannot comply with the Federal Motor Carrier Safety Regulations (FMCSRs) through use of its ADS-equipped CMV, then the carrier may seek an exemption. The carrier would need to demonstrate that the ADS-equipped CMV likely achieves an equivalent level of safety. According to the FMCSA, a motor carrier would not be permitted to operate an ADS-equipped CMV on public highways until it complies with the operational requirements or until the carrier obtains regulatory relief.[92]

To operate an ADS-equipped CMV under existing regulations, the FMCSA has promulgated the following principles it will follow when exercising its oversight. The FMCSA will first ask whether the ADS-equipped CMV placed into operation complies with the requirements for parts and accessories for which there are no FMVSS (i.e., fuel tanks and fuel lines, exhaust systems, and rear underride guards on single unit trucks). A motor carrier may not operate an ADS-equipped CMV – or any CMV – until it complies with the requirements and specifications of 49 CFR Part 393, "Parts and accessories Necessary for Safe Operation." If the ADS technology is installed aftermarket, any equipment that decreases the safety of operation could subject the motor carrier to a civil penalty. In addition, ADS-equipped vehicles that create an "imminent hazard" may be placed out of service and the motor carrier that used the vehicle similarly fined. The FMCSA will then consider whether the motor carrier has complied with the operational requirements of the current FMCSRs. These include, for example, compliance with rules on driving CMVs, including the laws, ordinances, and regulations of the jurisdiction in which the vehicle is operated. However, in the case of vehicles that do not require a human operator, none of the human-specific FMCSRs (drug testing, hours-of-service, commercial driver's licenses (CDLs), physical qualification requirements, etc.) apply.[93]

The above provides the necessary context for the Ohio House of Representatives to allow the federal government time to promulgate a formal regulatory structure for ADS-equipped CMVs. Their interim structure allows for the flexibility necessary for ADS testing and deployment in the commercial vehicle space while also protecting the safety of the motoring public. Ohio does not need to promulgate its own rules regarding CMVs while the FMCSA is also in the process of revising its regulatory structure. Furthermore, the FMCSA has stated that if it determines that state or local legal requirements interfere with the application of FMCSRs, the Department has preemptive authority. Ohio will not benefit by challenging clear federal authority in this regulatory area but would benefit if it is a partner with the FMCSA to create a conducive and advantageous regulatory structure for Ohio; such an area could be federal qualifications for CDLs. The FMCSA has authority, in coordination with the states, to set the federal qualifications required for CDLs. States' role in this process has been to train commercial drivers and issue CDLs but they must follow the FMCSA regulations that set minimum qualifications and limitations on CDLs in order to stay eligible for federal grants. The FMCSA is considering how or whether CDL qualifications should apply to computerized driving systems and Ohio would benefit by being an active, participating partner in those discussions to derive the most benefit for Ohio's industries affected by such rulemaking.[94]

The Federal Transit Administration (FTA) provides financial and technical assistance to local public transit systems and regulates safety measures. Public transit systems includes buses, subways, light rail, commuter rail, monorail, passenger ferry boats, trolleys, inclined railways, and people movers. Over the years, Congress has continued to grant the FTA significant new regulatory authority that has expanded their role as a safety regulatory body. As a result, the FTA developed and published a National Public Transportation Safety Plan (NSP). The NSP functions as FTA's strategic plan and primary guidance document for improving transit safety performance and as a repository of standards, guidance, best practices, tools, technical assistance, among other resources. A major component of the FTA's safety regulatory authority is the new Public Transportation Agency Safety Plan (PTASP) rule. The PTASP rule, which the FTA issued on July 18,

2018, and which will be effective on July 19, 2019, is applicable to transit agencies that operate rail fixed-guideway and/or bus services. Transit agencies must develop, certify, and implement an agency safety plan by July, 20, 2020. The PTASP rule requires transit agencies to incorporate Safety Management System (SMS) policies and procedures as they develop their individual safety plans. The PTASP rule sets scalable and flexible requirements for public transportation agencies by requiring them to establish appropriate safety objectives; to identify safety risks and hazards and to develop plans to mitigate those risks; to develop and implement a process to monitor and measure their safety performance; and to engage in safety promotion through training and communication. As such, these federal oversight requirements are sufficient to warrant the state to defer to the PTASP rule for evaluating the safety impacts of ADS-equipped public transit busses.[95]

Ohio Overview

Ohio has a lot of momentum in its favor in continuing to attract private investment in ADS and connected vehicle technology to the state. Ohio has fixed assets, such as its geographic proximity to major cities across the country and Canada (Ohio is located within a day's drive of 60% of the population) and four-season climate, with both urban and rural settings; these fixed assets give Ohio a boost for testing. Ohio's non-fixed assets, such as its top-tier higher education institutions, high-skill talent base, manufacturing prowess, and expansive transportation and logistics networks provide additional boosts for research, testing, and deployment of this technology. Ohio is a leader in this emerging industry and this section is designed to highlight what we are currently doing to research, test, and deploy ADS and connected vehicle technology.

Ohio has a one-stop shop for everything related to ADS and connected vehicle technology, and it is DriveOhio. Its mission is to bring together government, industry, and research partners to enhance Ohio's infrastructure for ADS and connected vehicle technology and for the development of smart mobility innovations. DriveOhio provides industry stakeholders one entity to work with in an emerging field that has many different agencies and offices that potentially lay over each other. DriveOhio is housed within the Ohio Department of Transportation (ODOT) and is a partnership between ODOT, the Department of Public Safety, the Department of Administrative Services, the Ohio Turnpike Infrastructure Commission, the Public Utilities Commissions of Ohio, the Department of Insurance, the Governor's Office of Workforce Transformation, and the Ohio National Guard's Office of the Adjutant General.[96]

Not only does Ohio have a one-stop shop for ADS and connected vehicle technology at the state level, but it also has a pro-research and pro-testing regulatory environment. On May 9, 2018, Governor Kasich signed an executive order that authorized ADS-equipped vehicle testing, subject to certain safety requirements, on any Ohio public road or highway. In order to ensure the safety of the public, the Governor reserves the right to halt testing of any vehicle if there is evidence that the vehicle or technology is not working properly. Further, DriveOhio has been tasked with managing Ohio's Autonomous Vehicle Pilot Program. This program will link Ohio municipalities interested in promoting ADS-equipped vehicle testing with companies looking for places to refine their ADS technology. Both groups will partner with DriveOhio to identify ideal testing opportunities in the state. For municipal partners, by entering into an agreement, municipalities can work with DriveOhio to create an inventory of their roads that offer a variety of testing attributes (e.g., four lanes, hilly, roundabouts, urban or suburban). DriveOhio will then share the inventory with companies looking to test in Ohio. For industry partners, companies wishing to test vehicles that meet the state's requirements can enter into an agreement to participate in the pilot program. DriveOhio will work to identify the unique testing attributes each company needs and will identify locations in Ohio where the company can meet their testing objectives. This pilot program will help engage and connect the public and private sectors to work together cooperatively to better position industry and government for the deployment of this technology.[97]

Ohio has research facilities dedicated to ADS and connected vehicle technology, as well as demonstration and deployment projects currently underway. Some of these include:

- **The Transportation Research Center (TRC):**
    - The TRC is the largest independent automotive proving ground in North America. This world-renowned testing facility has 4,500 acres of road courses and a 7.5 mile, high-speed oval test track, making the TRC the best place to test and validate nearly any vehicle in a controlled environment.
    - The TRC is managed by The Ohio State University and has more than 800 customers. The facility employs nearly 500 people, including: Research Scientists, Engineers, Project Managers, Designers, Test Drivers, Test Technicians, Vehicle Technicians, among others.
    - The State of Ohio, The Ohio State University, and JobsOhio invested $45 million in the first phase of the Smart Mobility Advanced Research and Test Center (SMART), a state-of-the-art hub at the TRC for automated and autonomous testing. When finished, the 540-acre SMART Center will test new technologies and highly automated vehicles in a closed, safe, secure, and real-world environment.
    - The TRC is home to the National Highway Traffic Safety Administration (NHSTA) Vehicle Research and Test Center, the only federal vehicle test laboratory in the nation. It conducts research and vehicle testing in support of NHTSTA's mission to save lives, prevent injuries, and reduce traffic-related healthcare costs.[98]

- **The Center for Automotive Research (CAR):**
    - Ohio State's Center for Automotive Research (CAR) is a preeminent research center focused on intelligent transportation systems, advanced vehicle safety, and sustainable mobility.[99]

- **The Smart Belt Coalition:**
    - The Smart Belt Coalition is a partnership between government agencies and academic institutions in Ohio, Pennsylvania, and Michigan working together to support the research and testing of ADS and connected vehicle technology. This first-of-its-kind coalition is also working toward the creation of a smart corridor that will eventually stretch from the East Coast to Detroit and Chicago.[100]

- **The Air Force Research Laboratory's Sensors Directorate:**
    - The Air Force Research Laboratory's Sensors Directorate, located at Ohio's Wright-Patterson Air Force Base, leads the discovery and development and integration of sensors for military use.[101]

- **Smart Mobility Projects:**
    - **U.S. Route 33 Smart Mobility Corridor** – The 35-mile stretch of U.S. Route 33 between Dublin and East Liberty (through Marysville) will be one of the longest "autonomous ready" highways in the country. The Ohio Department of Transportation is equipping the four-lane, divided highway with fiber-optic cable

and wireless roadside sensors to allow open-road testing of ADS-equipped vehicles.[102]

- **I-90 Lake Effect Corridor** – Part of I-90 runs through the Lake Erie "snow belt," a geographic region that receives significantly more snow than the rest of Northeast Ohio. The Ohio Department of Transportation is equipping a 60-mile stretch of the interstate with Dedicated Short Range Communication (DSRC) units. It is also going to test wireless technologies designed to send and receive data from those units as from units on public service vehicles. The data, combined with new variable speed limit signs, will help local officials and law enforcement better manage the roadway to reduce crashes and fatalities.[103]
- **I-670 Smart Lane** – The Ohio Department of Transportation is starting construction on the state's first "smart lane," a nine-mile stretch of I-670 between downtown Columbus and the John Glenn Columbus International Airport. The Ohio Department of Transportation is turning the eastbound shoulder into a smart lane that drivers can use during peak congestion. The Smart Lane will also be equipped with high-resolution cameras to monitor conditions from the statewide traffic management center and digital messaging boards to manage traffic speeds and incidents.[104]
- **Ohio Turnpike** – The 241-mile turnpike is long, flat, and straight, making it an ideal open-road site for testing ADS and connected vehicle technology. In fact, the turnpike already has been used to test truck platooning. The turnpike is outfitted end to end with fiber-optic cable. Roadside units will be installed in a 60-mile stretch of the turnpike, and onboard units will be installed in public fleet vehicles, giving the Ohio Turnpike and Infrastructure Commission the ability to better monitor and manage driving and road conditions.[105]
- **Connected Marysville** – Marysville is installing DSRC units in its traffic signals, which will be able to communicate with up to 1,500 public and private vehicles equipped with onboard units. The pilot is designed to test and fine-tune how connected vehicles interact in order to improve safety and congestion and to reduce emissions.[106]
- **Smart Columbus** – The city of Columbus, named the winner of the United States Department of Transportation's first "Smart City Challenge," is creating a first-of-its-kind smart mobility system that will improve safety, mobility, access to opportunity, and sustainability to improve quality of life.[107]

- **Cincinnati/Dayton Workforce Corridor:**

  - The I-75 Workforce Corridor will partner the strengths of mass transit and the technology of ADS-equipped shuttles with the needs of the workforce to quickly get people to and from employment sites. The region's mass transit providers will transport large numbers of riders to and from areas further apart while ADS-equipped shuttles will take those riders to and from employment sites. This project is still under development.[108]

- **Self-Driving Shuttle on Scioto Mile:**

- In partnership with Smart Columbus, the City of Columbus and The Ohio State University, DriveOhio have deployed a low-speed ADS-equipped shuttle service in downtown Columbus. Service destinations include COSI, the Smart Columbus Experience Center, Bicentennial Park, and the new National Veterans Memorial and Museum along Columbus' Scioto Mile. This pilot, the first of a three-phase plan for Columbus, will help develop guidelines that will inform future deployments of ADS technology throughout Ohio and the rest of the country.[109]

- **City Use Cases in Development:**
  - In addition to the cities with projects already detailed here, discussions are actively under way with Athens, Akron, Canton, Cincinnati, Cleveland, Dayton, Dublin, Toledo, and Youngstown. Use cases that highlight each city's unique attributes are under development, ranging from workforce mobility, healthcare and education access, and mobility access for underserved, elderly and disabled populations. Project plans are being developed utilizing potential technology-enabled solutions ranging from ADS-equipped shuttles, ADS and connected vehicle technology testing, connected infrastructure and other smart mobility endeavors.[110]

- **Unmanned Traffic Management Pilot:**
  - DriveOhio is partnering to study the use of unmanned aircraft systems (UAS), sometimes called drones, to monitor traffic and roadway conditions from the air along the 33 Smart Mobility Corridor. Unmanned aircraft will interact with sensors and communication equipment along the corridor to feed data into the state's Traffic Management Center.[111]

In order to solidify the regulatory environment that has been conducive to Ohio's momentum thus far in ADS and connected vehicle research, testing, and deployment, this report makes the following recommendations for the General Assembly to pursue:

- The General Assembly should codify DriveOhio as the lead agency for ADS and connected vehicle technology.
- The General Assembly should codify Governor Kasich's Executive Order allowing state-wide testing of ADS and connected vehicle technology.
- The General Assembly should establish an Autonomous and Connected Vehicle Task Force that is comprised of a broad range of disciplines and organizations. This Task Force should be a creature of the General Assembly but housed inside DriveOhio. This Task Force should be directed by the General Assembly to provide legislative recommendations on an on-going basis as this technology develops. Inclusive and collaborative planning will pay substantial dividends and as such is in the public interest.
- The General Assembly should inventory the Ohio Revised Code to identify what areas will need to be amended at some point for this technology – inventory, but do not make legislative changes until there is a need to. Having the Ohio Revised Code

inventoried will allow for the General Assembly to be agile and nimble as the technology develops and warrants legislative action.

Policy Challenges for Ohio

ADS and connected vehicle technology is bringing about a myriad of policy challenges that the General Assembly will need to address. By respecting the proper roles for federal and state government, Ohio will be positioned to effectively tackle policy issues surrounding Infrastructure & Data, Workforce & Labor, and Insurance. It is in these areas that the General Assembly can work to maximize Ohio's attractiveness as a destination for private investment in this technology and become an early adopter, benefiting both economically and socially from the fruits of the technology while also effectively mitigating potential negative secondary socioeconomic effects.

Infrastructure

Over time, smart highways and roads will enable a fully integrated driving environment for connected vehicles, increasing the safety of ADS-equipped vehicles and creating efficiencies as vehicles move in a coordinated cadence, reducing commute times and energy consumption. Thus, infrastructure is the biggest policy challenge facing the General Assembly regarding ADS and connected vehicle technology. This report takes the position that the General Assembly should begin addressing short- and long-term infrastructure challenges. While it is not and should not be the General Assembly's role to regulate safety standards or inhibit technological progress related to ADS and connected vehicle technology, it is, however, the General Assembly's role to ensure the infrastructure ecosystem is built and maintained for this technology to deploy in conditions that are as safe as possible and that will maximize returns on investment, both from economic and quality of life perspectives. This responsibility includes ensuring that the state maintains a good state of infrastructure design, operation, and maintenance that will support ADS and connected vehicle deployment. Ohio's roads, highways, and bridges form vital transportation corridors for both interstate and intrastate commerce. The condition, efficiency, and funding of the transportation system is vital to the economic competiveness of the state and its ability to continue to attract private investment, which in turn boosts GDP growth. To understand the infrastructure challenges, as it relates to ADS and connected vehicle technologies, it is important to survey what the current infrastructure landscape looks like.

Ohio maintains one of the most extensive and heavily traveled transportation systems in the United States. Ohio ranks second nationally among states in the number of bridges, third in the volume of freight carried on its transportation system, and sixth in both miles of interstate highways and total vehicle miles traveled (VMT).[112] In FY 2018, ODOT had an operating budget of $3.75 billion, of which, $3.22 billion (86%) went toward maintenance of current transportation infrastructure and $474 million (13%) went toward the construction of new infrastructure.[113] Beyond ODOT's operating budget and that of which local governments contribute to infrastructure, the current condition of Ohio's infrastructure has hidden costs for constituents and visitors. Driving on the transportation system costs constituents and visitors a total of $12 billion per year in the form of additional vehicle operating costs (VOC), congestion-related delays, and traffic crashes:[114]

- Driving on Ohio roads that are not maintained to at least minimum specifications costs constituents and visitors a total of $3.5 billion annually in extra VOC. These costs

include accelerated vehicle depreciation, additional repair costs, increased fuel consumption, and tire wear.[115]

- One-third of Ohio's major urban roads and highways have pavement surfaces in poor or mediocre condition, which causes a rough ride that leads to increased VOC.
- The chart below details pavement conditions on major urban roads in the largest urban areas:

Urban Area	Poor	Mediocre	Fair	Good
Cincinnati	25%	25%	14%	36%
Cleveland-Akron	49%	21%	9%	21%
Columbus	24%	24%	14%	38%
Dayton	28%	24%	25%	23%
Toledo	19%	19%	16%	46%

Source: TRIP analysis of Federal Highway Administration data

- Research has indicated serious and fatal traffic crashes in Ohio have associated economic costs pegged at $3.9 billion per year due to lost household and workplace productivity, insurance, and other financial costs.[116]
  - There were 303,282 crashes on Ohio roads in 2017. From those crashes, there were 108,800 non-serious injuries, 8,763 serious injuries, and 1,179 fatalities.[117]
- Traffic congestion in Ohio costs residents and visitors another $4.6 billion each year in the form of lost time and wasted fuel.
  - Ohio's increasing levels of traffic congestion cause significant delays, especially in large urban areas, harming commuting and commerce. The chart below details the number of hours lost to congestion annually for the average driver in Ohio's largest urban areas. It also includes the cost of congestion per motorist, in the form of lost time and wasted fuel:

Urban Area	Cost to Motorists	Hours Lost
Cincinnati	$1,057	44
Cleveland-Akron	$1,001	37
Columbus	$997	44
Dayton	$631	27
Toledo	$983	41

Source: TRIP Estimate Based on Analysis of Texas Transportation Institute and Federal Highway Administration data

- **Funding:**

- Ohio has currently been able to increase highway investments through the use of Ohio Turnpike bond proceeds, but this funding will begin to decrease significantly, beginning in 2019. The state faces both a short-term shortfall in funding for projects to expand highway capacity and a long-term shortfall in funding to maintain the condition and level of services of its roads, highways, bridges, and public transit systems.
- ODOT, in its Access Ohio 2040 report, estimates that the cost of maintaining conditions and level of service on its system of roads, highways, bridges, and public transit systems is approximately $55 billion through 2040. However, only $41 billion is anticipated to be available, leaving a shortfall of $14 billion.[118]
- ODOT construction investment in roads, highways, and bridges increased from approximately $2 billion in 2017 to $2.35 billion in 2018, largely due to Ohio Turnpike bond proceeds, but investment is set to decrease to $1.85 billion in 2019, dropping further to $1.7 billion in 2021.

    - ODOT Annual Investment in Road, Highway, and Bridge Repairs:

Year	Construction Funding Including Turnpike Funding (Millions)
2013	$1,853
2014	$2,421
2015	$2,429
2016	$1,935
2017	$1,992
2018	$2,350
2019	$1,858
2020	$1,821
2021	$1,700
2022	$1,700
2023	$1,700

Source: Ohio Department of Transportation

- Inflation has reduced significantly the funding power of the federal and Ohio motor fuel user fees, which are critical funding sources for Ohio's road, highway, and bridge repairs and improvements. The funding power of the federal 18.4 cents-per-gallon gasoline and 24.4 cents-per-gallon diesel motor fuel user fee, which was last increased in 1993, has had its funding power reduced to 10.7 and 14.2 cents-per-gallon, respectively, due to inflation. The funding power of Ohio's 28 cents-per-gallon user fee, which was last increase in 2005, has had its funding power reduced to 18 cents-per-gallon due to inflation.[119]
- Regarding federal funding, the current federal surface transportation program, which expires in 2020, does not provide adequate funding for Ohio's current

needs and increases in federal funding for transportation has been few and far in-between, with no long-term and sustainable source of funding provided by Congress.

- **Population:**
    - Ohio's population reached approximately 11.6 million residents in 2016, a two-percent increase since 2000, with 8 million licensed drivers in 2016, thus increasing VMT and other stressors on the transportation infrastructure system.[120]
- **Economic:**
    - From 2000 to 2016, Ohio's gross domestic product (GDP), a measure of the state's economic output, increased by 14%, when adjusted for inflation, compared to the national average of 30%.[121]
    - Annually, $1.1 trillion in goods are shipped to and from sites in Ohio, mostly by truck (78%).[122]
    - Approximately 2.4 million full-time jobs in Ohio's key industries like tourism, retail sales, agriculture, and manufacturing are increasingly dependent on the state's transportation infrastructure system.[123]
    - Increasingly, companies are looking at the quality of a region's transportation system when deciding where to relocate or expand. Regions with congested or poorly maintained roads have seen businesses threaten and follow through on plans to relocate elsewhere that have a smoother, more efficient, and more modern transportation system.[124]
        - This is further supported by a 2017 survey of corporate executives by Area Development Magazine that found highway accessibility was the number one site selector factor, followed by labor costs and the availability of skilled labor.[125]
- **Travel:**
    - Vehicle miles traveled (VMT) in Ohio increased by 12% from 2000-2016 (from 105.9 billion VMT in 2000 to 118.6 billion VMT in 2016). The rate of vehicle travel growth has rapidly increased since 2013, increasing 5% between 2014 and 2016 alone. By 2040, VMT in Ohio is projected to increase another 20%.[126]

As these numbers demonstrate, Ohio's transportation infrastructure system needs immediate attention and the current funding structure is not adequate to meet current and future needs. It is critical for the state's roads and highways to be fixed before they reach a point that they require major repairs because those repairs can cost up to around four times more than simply resurfacing roads and highways. Ohio's long-term repair costs will increase dramatically when road and bridge maintenance is deferred.[127] A report on maintaining pavements found that every $1 of deferred maintenance on roads and bridges costs an additional $4 to $5 in needed future repairs.[128] While deferring maintenance increases overall costs, the Federal Highway

Administration estimates that each dollar spent on road, highway, and bridge improvements results in an average benefit of $5.20 in the form of reduced vehicle maintenance costs, reduced delays, reduced fuel consumption, improved safety, reduced road and bridge maintenance costs, and reduced emissions as a result of improved traffic flow.[129]

ADS and connected vehicle technology play into Ohio's current transportation infrastructure needs. Through stakeholder engagement and evaluating current research, it is clear that the most productive course of action for the General Assembly to take in building the infrastructure ecosystem for this technology is to maintain and repair the current infrastructure while also integrating new technologies into the state's infrastructure lifecycle management process (such as smart pavement, signage, lane markings, and signalization systems, which will better enable ADS and connected vehicle technology to "see" the environment around them), thus increasing system safety and reliability.

ADS technology will have a significant impact on Ohio's existing transportation system, including transit; however, the direction and degree of these impacts are still unknown. ADS technology has the potential to both decrease congestion and VMT but also the potential to increase congestion and VMT, depending on how the technology is adopted. If the current ownership model for vehicles remains and access to personal vehicles increases for populations that currently do not have access (such as the elderly, disabled, and those under 16), then the state will see the former scenario play out. However, if the ownership model for vehicles changes to a shared structure, where ADS-equipped vehicles are being utilized for longer periods of time (thus not sitting idle), being shared among many users, minimizing "zero occupancy" travel through effective route management, among other factors, then there is a high probability of the latter scenario playing out.

Due to the large variance in possible outcomes for Ohio's transportation infrastructure, it is vital that the General Assembly focuses on what can benefit both conventional (human) drivers and ADS and connected vehicle technology. Based on stakeholder input from across industries ranging from infrastructure, regional planners, insurance, education, business, and law, this report concludes:

- The General Assembly should make basic transportation infrastructure maintenance its first priority in regards to ADS and connected vehicle technology because it is absolutely essential for both conventional drivers and ADS technology; both need well-maintained roads, clear pavement markings, and optimal signage.
- The General Assembly should make its second priority the integration of smart communication technology into the infrastructure system, such as Dedicated Short Range Communication (DSRC) devices and 5G infrastructure to enable Vehicle-to-Vehicle (V2V), Vehicle-to-Infrastructure (V2I), Vehicle-to-Everything (V2X), and C-V2X (Cellular-Vehicle-to-Everything) communications.

To accomplish these two priorities, the General Assembly should establish a Joint House-Senate Commission on short- and long-term transportation infrastructure funding with recommendations to be expeditiously moved through the committee process in both the House and Senate. This commission should address both short- and long-term funding issues

surrounding Ohio's transportation infrastructure and how to best raise and allocate funding to integrate smart technology into the infrastructure lifecycle management system. Further, the proposed Autonomous and Connected Vehicle Task Force should be directed to evaluate and make recommendations to the General Assembly on:

- New signage, pavement markings, and signalization systems to be integrated into the transportation infrastructure system that will benefit and provide greater value to conventional drivers, ADS-equipped, and connected vehicles than current signage, pavement markings, and signalization systems in use;
- New transportation infrastructure design guidelines that consider future sensor and communication technology infrastructure installation needs, including access to power, underground conduit for fiber ("Dig Once" policy), locations for device mounting, and other needs;
- A Roadway Classification System that identifies the infrastructure needed to support various levels of ADS and connected vehicle technology; and
- Studying and recommending to the General Assembly a "Dig Once" policy that enables broadband infrastructure to be installed in the public right-of-ways where possible during state-funded or supported infrastructure projects that already expose the right-of-way; doing so could reduce the cost of broadband infrastructure buildout by 90%.[130]

These recommendations are derived from testimony before the Ohio House of Representatives Transportation and Public Safety Committee for this study, stakeholder engagement, and various meetings conducted throughout the process. These recommendations also adhere to this report's philosophy of state versus federal responsibilities; the role of the General Assembly is to provide for the infrastructure ecosystem for ADS and connected vehicle technology to operate, and it is the federal government's role to regulate safety, cyber security, and data privacy standards.

Data

Real-time transportation data is now ubiquitous at a level that was unfathomable just a few decades ago. Private industry has made great progress in learning how to leverage this data, but the public sector has not kept up. Understanding what kinds of data will be created by this technology and understanding how this data can be shared, used, and protected is of utmost importance for the General Assembly. The amount and type of data that could be collected from ADS and connected vehicle technology will be relatively unsettled until those vehicles penetrate the market. As with most things related to ADS-equipped and connected vehicles, this is an evolving area so it is impossible to account for what else could be produced on this topic during this time of great innovation. Generally, what is unlikely to change is that data can and will be collected from the driver, the vehicle, and the infrastructure. Thus, vehicles will become a digital companion that learns habits, adapts to choices, and predicts needs; which means data privacy and security will be an increasingly critical policy area for the General Assembly to monitor.

- **Road and Traffic Data**

Most ADS-equipped vehicles will both generate and receive mapping updates at frequent intervals.[131] Experimental ADS-equipped vehicles rely on out-ward facing sensors to collect real-time data about what is happening in the immediate and long-range roadway environment that the vehicle is moving through.[132] ADS-equipped vehicles rely on the sharing of data regarding static and dynamic road and traffic conditions to get around. Dynamic data would include work zones, road closures, signal phase and timing, etc. while static data would include bus stop locations and crosswalk locations.[133] This information could be relayed via the sharing of digital maps; thus, the U.S. Department of Transportation is working with states that already publish work zone data to harmonize feeds and establish standards.[134]

In order to keep mapping and algorithms up to date, there will be a constant flow of information between the supplier and the ADS-equipped vehicle. Though this data sharing will likely trigger privacy concerns, some flow of information will be necessary to maintain the safety of ADS technology.[135]

- **Basic Safety Messages**

This category of data encompasses information broadcast vehicle-to-vehicle and vehicle-to-infrastructure. The core contents of that information include data describing a vehicle's position, e.g. latitude, longitude, and elevation, and motion, i.e. heading, speed, and acceleration. This data is broadcast to surrounding vehicles in order to assess threat potentials.[136]

- **Connected Vehicle Applications**

These applications are service packages from various data sources that support performance monitoring and other uses of previously collected data. An example of one such application would be for weather, which could include a service package for collecting road weather data and detecting environmental hazards in order to alert drivers.[137] Other examples include:

  - Advanced Automated Crash Notification Relay

This is a connected vehicle application that will help to transmit data via other vehicles and roadside hot spots that will help to enhance incident response.[138]

  - Intelligent Traffic Signal System

Data collected vehicle-to-vehicle and vehicle-to-infrastructure may also be combined with data about pedestrian and non-motorized travelers to control traffic signals and maximize traffic flow while maintaining the safety of all individuals traveling through the intersection.[139]

- **Floating Car Data**

Floating car data is generally defined as data from vehicles that are currently being driven. At a minimum, this data would include a vehicle's movement and location while in motion and when stationary, which would include at least a timestamp and the location's coordinates.[140]

Examples of personal information that may be associated with driverless vehicles would be information about vehicle ownership, registration, and vehicle insurance information.[141] Driverless cars will generate real-time location information about its user, as well as records of past travel patterns.[142]

ADS-equipped vehicles will collect a tremendous amount of information regarding a user's movements, which may be information that law enforcement may attempt to obtain without a warrant. This will likely be challenged as impermissible under the Fourth Amendment.[143]

Trucks and buses will likely generate less private data about specific human persons and more data about corporations or any other entities that may own or use driverless vehicles.[144]

- **Light Detection and Ranging (LIDAR)**

An example of how a car may collect data about the cars around it without any type of data sharing occurring between the cars is the LIDAR technology. The LIDAR unit is capable of bouncing laser beams off object surfaces up to 100 meters around the vehicle and builds a 3D picture from that raw data collection. This helps the vehicle to determine the identity and distance of objects that are near in order to view all obstacles in real time.[145]

- **Voluntary Data Exchanges**

The U.S. Department of Transportation advocates for voluntary data exchanges that will help to accelerate the safe integration of ADS-equipped vehicles. These exchanges may include the public and private sector exchanging data regarding infrastructure conditions or exchanges among private sector entities that would enable learning and focus on mitigating risk. This may run into issues with consumer privacy laws.[146]

The important thing to keep in mind when assessing the possibility of voluntary data exchanges is that collection, recording, sharing, storage, auditing, and deconstruction of data that is recorded by a manufacturer must be in accordance with the manufacturer's consumer privacy and security agreements.[147] The National Highway Traffic Safety Administration thus recommends that data shared with third parties be de-identified, which means stripping the data of elements that make the data directly or reasonably linkable to a specific vehicle owner or user.[148]

- **Data Storage**

During the stakeholder meeting related to data it was determined that if there was even just 1% of ADS-equipped vehicle penetration in Ohio, the vehicles would produce 186 petabytes of data per day. It would cost $66.9 million dollars a day to store all of that information. This means that data storage will either be greatly truncated or only stored for a very short period of time in order to avoid those tremendous costs. That in turn means that the sensors need to be capable of handling the decision of what to do with the data it is collecting. It is also important to mention cloud computing because the data could be moved to the cloud rather than local data storage.[149]

Federal Law

The U.S. Department of Transportation has stated that conflicting state and local laws and regulations will create confusion, introduce barriers, and present compliance challenges which may stifle innovation in this area.[150] As technology advances, new data and privacy challenges are presented, so Congress has not attempted to regulate ADS-equipped vehicle data use specifically just yet. There are multiple federal laws in place that may be construed to regulate AV/CV data. Recent decisions of the Supreme Court of the United States may also indicate that there is an expanding privacy right in our personal vehicles and that may extend to driverless vehicles, as elaborated below.

- **Federal Statutes**
    - Drivers Privacy Protection Act

This Act protects an individual's personal information that is contained in the motor vehicle registration and licensing records that are held by the BMV. There are no similar laws created yet for the recordkeeping requirements for personal information associated with ADS-equipped vehicles, but the Act may be construed to protect information that is held by the BMV.[151]

- Electronic Communications Privacy Act

The Act is about three decades old and there is a considerable interest in replacing it with an updated communications privacy statute. A new iteration of this could possibly prohibit unauthorized interception of most electronic communications to and from ADS-equipped vehicles.[152]

- Telecommunications Act of 1996

There is potential that certain components of ADS-equipped vehicle data will be regulated under the Telecommunications Act of 1996 because the Federal Communications Commission (FCC) adopted the Open Internet Order in March of 2015, which classifies mobile and fixed broadband Internet access service as a telecommunications service regulated under Title II of the Communications Act.[153]

- Federal Trade Commission

In 2015, the Commission issued a report in which both ADS-equipped and connected vehicles are discussed as examples of the "Internet of Things," which requires privacy protections.[154] The FTC will likely play a major role in determining the consumer privacy aspects of ADS-equipped vehicles.

- Communications Assistance for Law Enforcement Act (CALEA)

Any ADS-equipped vehicle that has access to public telephone networks or the Internet will be subject to CALEA. CALEA requires telecommunications carriers to assist law enforcement in accessing telecommunications networks.[155] The Stored Communications Act will also facilitate law enforcement access to ADS-equipped vehicle communications.[156] Access to stored data

related to communications will likely only require a subpoena or a "2703(d) order" based on a reasonable belief that the records are relevant and material to a criminal investigation.[157]

- U.S. DOT GPS Restrictions

Federal legislation was passed that restricted the Department of Transportation from using FY 2015 funds to mandate GPS tracking in private passenger vehicles without providing full and appropriate consideration of privacy concerns under the Administrative Procedure Act.[158] This may suggest that Congress will not allow extensive data-sharing practices to take place without a proper consideration of the privacy concerns raised by ADS-equipped vehicles.

There is not one entity alone that regulates all aspects of ADS-equipped vehicles within the federal government, but the U.S. Department of Transportation certainly carries the major responsibilities.[159] Congress has not proposed coordinating all ADS-equipped vehicle regulatory matters within a single federal regulatory program yet, but that may be something that certain interest groups push for.[160]

- White House Consumer Privacy Bill of Rights

The White House released a report in 2012 regarding protecting consumer data privacy while also promoting innovation.[161] The Consumer Privacy Bill of Rights provides a baseline of protections for consumers. The rights include individual control, transparency, respect for context, security, access and accuracy, focused collection, and accountability. The NHTSA was inspired by this to propose guidelines for manufacturers' privacy policies that would include transparency, choice, respect for context, minimization, de-identification, retention, data security, accountability, integrity, and access.[162]

- Other Actions

The SELF Drive Act (H.R. 3388) has not yet been passed by both the United States House of Representatives and the United States Senate, but the version that passed the House required AV manufacturers to develop a privacy plan that would share the practices of the manufacturer with respect to data minimization, de-identification, and retention of information about vehicle owners and occupants.[163] If passed, the bill would require an FTC study of who has access to vehicle owner or occupant data; how that data is collected, used, shared, or stored, and what methods are available to delete data from the vehicle about the owners or occupants prior to the sale, lease, or rental of the vehicle.[164]

- **Federal Agencies**

  - Federal Highway Administration

The Federal Highway Administration (FHWA) published a notice in 2014 requesting information about connected vehicle mobility applications. FHWA was looking to leverage connected vehicle data for use in commercial applications, as well as traffic management and safety programs. The FCC does not specifically regulate connected vehicle communications platforms yet, but introducing this commercial aspect of things may result in the FCC taking action.[165]

- **United States Supreme Court Decisions**

The Supreme Court held in *Katz v. United States*, 389 U.S. 347, 351 (1967) that the Fourth Amendment protects people, not places, and that anything a person seeks to preserve as private, even in areas accessible to the public, may be constitutionally protected. This section explores how the Supreme Court has expanded this constitutional protection and how this may be applied to the data produced by driverless vehicles.

- *Delaware v. Prouse* (1979)

The Supreme Court observed that "an individual operating or traveling in an automobile does not lose all reasonable expectation of privacy simply because the automobile and its use are subject to government regulation." The Court further stated that, "people are not shorn of all Fourth Amendment protection when they step from their homes onto the public sidewalks. Nor are they shorn of those interests when they step from the sidewalks into their automobiles."[166]

- *Indianapolis v. Edmond* (2000)

The Supreme Court held that absent a judicial warrant, stopping every vehicle on a roadway for general law enforcement purposes constitutes an unreasonable seizure for the purposes of the Fourth Amendment.[167]

- *Arizona v. Gant* (2009)

The Supreme Court recognized that the privacy interest of motorists is important and deserving of constitutional protection. Justice Stevens wrote, "[a]lthough we have recognized that a motorist's privacy interest in his vehicle is less substantial than in his home, the former interest is nevertheless important and deserving of constitutional protection."[168]

- *United States v. Jones* (2012)

The Supreme Court held that a search did occur when government agents placed a GPS device on a suspect's automobile and then used that device to track the individual for 28 days. The potential implications of this case on data and privacy law related to ADS-equipped vehicles is limited by the fact that there was not majority rationale for the holding, thus it is unclear what test to apply. Nevertheless, it is clear that GPS surveillance of vehicle movements does trigger Fourth Amendment protections.[169]

An individual typically lacks a reasonable expectation of privacy in information that was voluntarily communicated to a third party, as could be construed to be the case with data produced by an ADS-equipped vehicle. This is known as the third-party doctrine and may be used by law enforcement to acquire information from communications providers or manufacturers regarding ADS-equipped vehicle use. It is possible that this rule could change before ADS-equipped vehicles become more common because some members of the Court have expressed hesitation over the third-party doctrine.[170]

- **National Security and Criminal Law**
    - National Security concerns

There are internally facing sensors that provide internal vehicle operation data. These sensors may provide points of access for hackers to insert malicious code that could misdirect or even take control of an ADS-equipped vehicle. This is a vulnerability that the federal government is working to address because it affects vehicle safety and national security.[171]

Automated controls are the most vulnerable to car hacking. ADS-equipped vehicles analyze data, model it, and make data-driven predictions and decisions, such as actuating vehicle controls, but the computation demands of advanced security systems needed to protect ADS-equipped vehicles from external threats may drain resources and slow analytic functioning in ADS-equipped vehicles. There is no legal regulation currently regarding this use of artificial intelligence in operating a vehicle, but due to the national security and safety concerns this will likely become an area of extensive legal regulation.[172]

i. FISA and PATRIOT Act

Access to ADS-equipped vehicle data for national security reasons will likely be governed by Foreign Intelligence Surveillance Act (FISA) and portions of the Uniting and Strengthening America by Providing Appropriate Tools Required to Intercept and Obstruct Terrorism Act (PATRIOT Act).[173]

- Impact on Criminal Law

Criminal laws related to forbidding particular types of programming or reprogramming of these vehicles (i.e. hacking, programming to go beyond the speed limit, programming to get to your destination as quickly as possible no matter what, etc.) would be difficult to write and enforce, but they may be on the horizon.[174]

Data Law in Ohio

As is a recurring theme in data law, Ohio does not have much established law regarding data use, collection, and privacy because this is a developing area of the law. Ohio does not have any specific laws regarding data and ADS-equipped vehicles. In order to predict where law may be headed on this topic, it is important to understand the circumstances in which the General Assembly has interacted with the handling of data previously and what guidelines those statutory provisions laid out concerning data management.

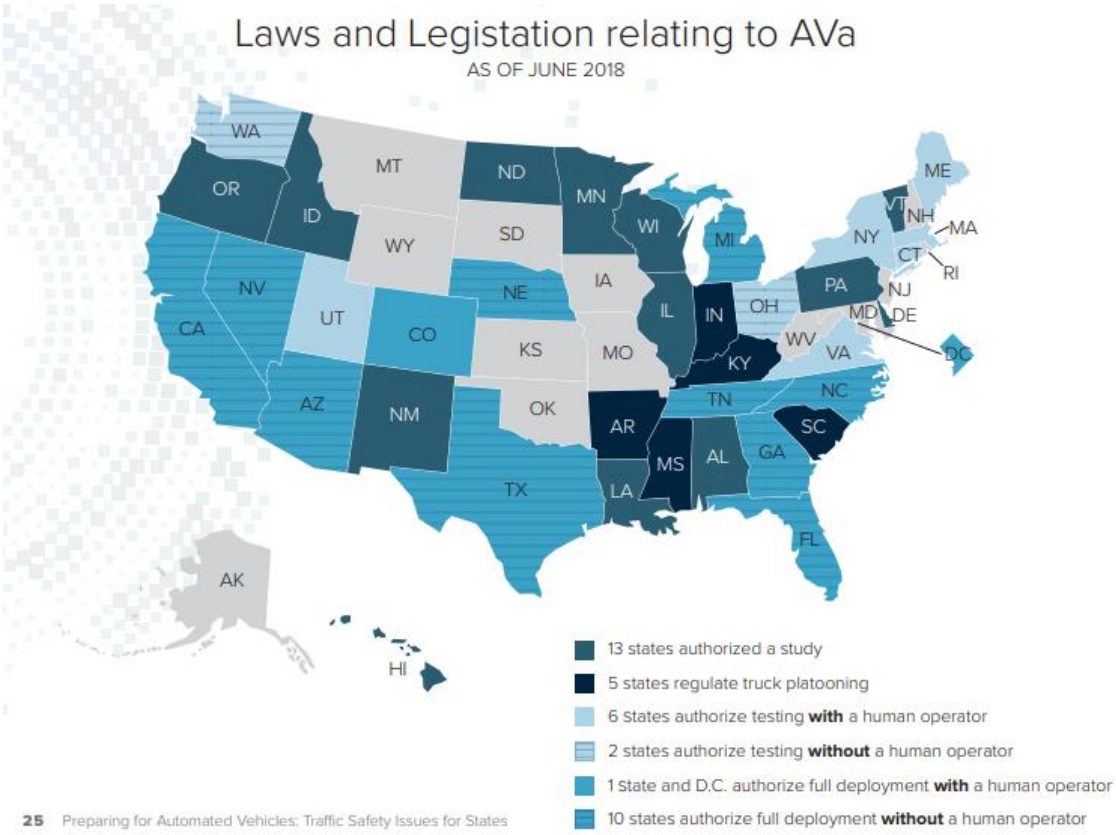
The Department of Administrative Services touched on data and privacy when establishing the Enterprise Data Management and Analytics program. Under R.C. 125.32, the state agency that provides data to the program retains ownership over the data. That means that the Department of Administrative Services would not be required to respond to requests for records or information regarding that provided data, including public records requests, subpoenas, warrants, and investigatory requests. The same confidentiality laws protecting the data under the state agency that provided the data follow the data while it is being used under the program. Any analysis produced by the program that resulted from data from multiple

agencies must compare the confidentiality laws of the source data and apply the most stringent of those obligations to the analysis data. R.C. 125.32(D) requires the Department of Administrative Services to develop a data-sharing protocol and a security plan for the program to determine how the data will be protected. The data-sharing protocol is required to include: 1) how participating state agencies may use the confidential data in accordance with confidentiality laws applicable to the provided data; 2) who has authority to access data gathered under the program; and 3) how participating state agencies shall make, verify, and retain corrections to personal information gathered under the program.

One of the more serious topics regarding data and ADS-equipped vehicles is what to do when there is a data breach. Ohio has a law that may provide a framework for determining how a data breach should be handled. R.C. 1349.19 protects Ohio citizens against unauthorized access to and acquisition of computerized data that would compromise the security or confidentiality of that individual's personal information. The statute requires that any person who owns or licenses computerized data that includes personal information must disclose any breach of the security of their system to any resident whose personal information was, or is reasonably believed to have been, accessed and acquired by an unauthorized person. The term "personal information" covers an individual's name in combination with a social security number, driver's license or state identification number, or an account, credit, or debit card number in combination with any required security code, access code, or password. If the person does not provide written, electronic, telephone, or substitute notice within 45 days, then the Attorney General's Office may conduct an investigation and bring a civil action upon an alleged failure to comply with the requirements of the section. The statute also dictates that any waiver of this requirement would be contrary to public policy and would be void and unenforceable. It is clear that Ohio cares about data privacy, so there is always a possibility that this section could expand to cover data that was shared by an ADS-equipped vehicle if there would ever be a data breach.

State Comparison

Twenty-nine states have enacted legislation specifically related to autonomous and connected vehicles, but it is rare for any of them to touch on data.[175] Even in the reports prepared by other states on this topic, data is never well-covered because it is such a developing area.



Source: Governors Highway Safety Association - Preparing for Automated Vehicles: Traffic Safety Issues For States

Forty-seven states have enacted privacy breach statutes, which are commonly referenced as data breach, security breach, or privacy breach. These statutes typically dictate that if personal information is improperly disclosed by a covered public or private entity, then the individual whose information was disclosed must be notified of the data loss. Congress has not enacted a national privacy breach statute.[176]

Michigan

Michigan has the most operational ADS and connected vehicle projects and has passed the most significant legislation related to those projects in S.B. 995, 996, 997, 998 (2016) and S.B. 169, 663 (2013). The most relevant of those laws would likely be S.B. 998, which provides immunity for automated technology manufacturers when modifications are made without the manufacturer's consent.[177]

Pennsylvania

Pennsylvania produced an ADS and connected vehicle report in 2016 that sought to consolidate most of the data collection within their Department of Transportation. The report by the Pennsylvania Department of Transportation also recognized a value in data sharing with key stakeholders, engagement with governmental and education institutions, and formation of strong partnerships with the cybersecurity community. It also put in writing the policy that its

Department of Transportation should adopt for the data that it collects where Pennsylvania DOT is not able to disclose any confidential information, except to "employees, affiliates, agents, or professional advisors who need to know it and who have agreed in writing to keep it confidential." The Department acknowledged though that some data may be proprietary information and may not be shared.[178]

Pennsylvania passed S.B. 1267 in 2016 which updated their traffic signal laws to include upgrades for "intelligent transportation system applications, such as ADS and connected vehicle-related technology" and even redefined an inoperable or malfunctioning signal to include "a signal that uses inductive loop sensors, or other automated technology, to detect the presence of vehicles that fails to detect a vehicle."[179]

Indiana

Indiana passed a law related to defining vehicle platoons and setting standards for the drivers of such platoons and the vehicles to be used.[180] The law defines vehicle platoons as "a group of motor vehicles that are traveling in a unified manner under electronic coordination at speeds and following distances that are faster and closer than would be reasonable and prudent without electronic coordination."[181]

Illinois

Illinois passed a law in August 2017 that prohibited local governments from enacting ordinances that would prohibit the use of autonomous vehicles on their roadways.[182] The bill also defined what an automated driving system equipped vehicle is. An automated driving system equipped vehicles is "any vehicle equipped with an Automated Driving System of hardware and software that are collectively capable of performing the entire dynamic driving task on a sustained basis, regardless of whether it is limited to a specific operational domain."[183]

Wisconsin

Wisconsin produced an ADS and connected vehicle report very light on data analysis in June 2018. The report expressed that several major automakers have adopted privacy principles to guide data collected by vehicles from occupants, but the report highlighted that no federal or state laws currently exist that directly deal with data privacy of CAVs. The report heavily emphasizes the sharing of information with insurers, but seems to express hesitation over federal regulation of data privacy, "the state may be interested in continuing to monitor these issues."[184]

The only piece of legislation that Wisconsin has passed related to ADS and connected vehicle technology was S.B. 695 (2018) that added the definition of platoon to include "a group of individual motor vehicles traveling in a unified manner at electronically coordinated speeds." It is obvious from the report that Wisconsin does not believe any state has passed legislation related to data and ADS-equipped vehicles.

Kentucky

Kentucky released an ADS and connected vehicle report in 2017 that divided the privacy concerns over the collection and use of data into two categories: (1) the government's ability to

access an individual's location and personal data, and (2) the private, commercial use of that personal data. Commercial use could include targeting users through in-car advertising and route selection designed to travel past certain businesses. The report acknowledges the role that federal and state government could play in addressing individual privacy issues through disclosure or establishing rights to data and its usage, but it seems to not consider the privacy issues to be any different from those related to smartphone usage, which is a technology that has been widely adopted. Much like Wisconsin, the report identifies the role that manufacturers will play in sharing appropriate data without identifying information to improve knowledge and outcomes. The conclusion on privacy concerns within the report seems to be that those concerns over data collection and sharing should be addressed by the federal government along with security concerns about hacking.[185]

Kentucky passed S.B. 116 in March 2018 defining platoons and regulating the operation of such platoons. Kentucky defines platoon as "a group of two individual commercial motor vehicles traveling in a unified manner at electronically coordinated speeds at following distances that are closer than would ordinarily be allowed."[186]

Data Conclusion

Currently, there is a large chasm between the large quantities of data available and the capabilities of private industry and the public sector in being able to analyze and make use of all the data that is being created. This chasm needs to be narrowed so that all users can better understand the effects of data. Data is a fundamental component to research and development, planning, and to advancement of the public good, as well as to corporate profit. Collaboratively and deliberately developed regulations and policies can anonymize needed data from industry (crashes, routes, disengagements, aggregate behavior, relevant data for crash reconstruction, etc.) without harming privacy, trade secrets, or vehicle operations.

Due to the still theoretical nature of some potential applications for data in ADS and connected vehicle technology, this report concludes that data privacy standards are best left under the purview of the federal government to create a uniform national standard that will enable Ohioans' data to have the same privacy standards across state lines. However, if the federal government fails to properly and in a timely manner formulate and roll out data privacy standards, then the General Assembly has an obligation to the people of Ohio to begin formulating a regulatory structure for data privacy standards. Currently, data privacy regulations are analogous to the Wild West, where there is relatively little regulatory structure and it is no longer tenable. In its AV 3.0 report, the U.S. Department of Transportation recommends that states begin to work towards identifying data needs and opportunities to exchange data because state and local agencies and industry can work together to identify data elements that will help ADS-equipped vehicles navigate challenging, unique roadway environments and alter operational behavior in relation to changing traffic laws.[187]

Following the overarching philosophy of this report, this report recommends the following actionable items for the General Assembly to pursue:

- The General Assembly should adopt a Joint-Resolution urging Congress to pass uniform federal regulations governing data privacy protections and for those regulations to apply to all users in the Internet ecosystem. These protections should include “opt-in” and “opt-out” protections, allowing Ohioans the ability to decide what and how their data is shared to service providers and third-parties; this requires privacy notices and terms of service to be easy-to-find and written in layman’s terms. This resolution should also include language that makes clear that if the federal government fails to properly and in a timely manner pass uniform federal regulations governing data privacy protections, then Ohio reserves the right to begin formulating its own regulatory structure in the absence of federal action.
- The General Assembly should direct the proposed Autonomous and Connected Vehicle Task Force to recommend, upon collaboration with private industry, public sector agencies, and other stakeholders, a data exchange platform that will enable relevant ADS and connected vehicle technology and related infrastructure data to be anonymized and shared.
    - Such data may include crash data and other related incidents for insurance and public safety purposes
    - Making relevant data available for research and planning models to further academic research and the public good through public sector utilization
    - Making data available to support smart cities and communities

With data being a controversial, contested, and emerging topic both from a policy and legal perspective, this report’s data recommendations seek to strike an appropriate balance of allowing the natural development of customs, norms, and legal doctrine to take hold prior to legislative action and the immediate need for Ohioans to have data security and privacy protections.

Workforce & Labor

Just as the introduction of the Model T by Henry Ford created new jobs and services and eliminated others, it also can be expected that ADS and connected vehicle technology will create new jobs and eliminate others. The mention of this technology typically elicits two types of visions for the future of work; one utopian and one dystopian. The utopian vision consists of happy commuters riding in ADS-equipped vehicles doing work, eating, watching TV, reading, or otherwise enjoying the benefits of the technology. The dystopian vision consists of truckers, taxi drivers, and other transportation occupations put out of work with no alternative path of employment that brings them wages equal to that of their transportation occupations, while the owners of capital enjoy astronomical rises in profit at the expense of the average worker. In reality, the future will materialize somewhere in between these polar extremes, where elements of both visions coexist. Thus, it is vital that the General Assembly begin thinking through the implications that this technology will have on the labor market, the economy more broadly, and how best to take advantage of the benefits while mitigating the negative secondary socioeconomic effects. The effects on the labor market and the broader economy from ADS and connected vehicle technology will be the first major wave of the next generation of automation – automation that is software based rather than mechanically based. Advanced automation via software and artificial intelligence will affect nearly every industry in Ohio in the coming years. If the General Assembly can create the framework and system responses to address negative effects on the labor market and the broader economy by this first wave of labor displacement and economic change, then Ohio will be much better positioned to handle more widespread and more severe displacement and economic change, as advanced automation and artificial intelligence exponentially accelerates in the coming years. This report cannot overstate the importance of preparing a framework to manage the displacement of labor and broader economic changes on the horizon; if the General Assembly fails to keep its eye on the ball and allows these issues to go unaddressed, Ohio will be staring down political and social unrest in the coming years.

One of the areas most heavily affected by ADS and connected vehicle technology, and automation in general, is workforce. ADS and connected vehicle technology will have a significant impact on employment, both positively, as it creates new employment opportunities, and negatively, as it eliminates or downgrades others. ADS and connected vehicle technology will generate jobs across multiple industries, and will result in entirely new occupations being created. Elderly people will regain a significant amount of mobility as a result of ADS-equipped and connected vehicles, but many will still require assistance getting in and out of the car, thus, creating a new occupation. Another example of a potential new occupation would be grocery store loaders, and proof of concept demonstrations are being tested now. Since ADS-equipped vehicles will be able to communicate with other devices on the IoT infrastructure, a digital shopping list could be created via an app that is then shared with the car and the grocery store. Grocery store personnel would then retrieve and load the shopping list items into the car once it drives itself to the supermarket. Because ADS-equipped and connected vehicles will generate vast amounts of data, it is likely that data-based job openings and IT positions will be created. Based off information from the McKinsey and Company research firm, which estimates that “data from autonomous and connected vehicles will be worth as much as $750 billion by 2030,” a

witness before the Committee, Mr. Jason Swanson, Director of Strategic Foresight at KnowledgeWorks, a Ohio based think tank that specializes in advanced automation and workforce, hypothesized that the storage, categorization, organization, and compilation of this data may eventually become an industry of its own. The creation of new jobs also brings with it the potential risk of rising income inequality. Many of these created jobs will, according to Mr. Swanson, "tend to be low-skill, low-wage jobs, such as the need for someone to load and unload vehicles. While jobs in data science and IT are also likely, these jobs will likely require far fewer people."

This technology will also result in the elimination of some career fields. The Transport Workers Union (TWU) Local 208, which is headquartered in Columbus, represents over 800 Ohioans who are employed by the Central Ohio Transit Authority (COTA). The impact of ADS technology on driving occupations, from public transit and trucking to those who repair and maintain commercial vehicles, represents a major concern for the TWU. According to the Council of Economic Advisors, between 2.2 and 3.1 million jobs, both full- and part-time, could be "substantially altered or eliminated due to autonomous vehicle technology" (Transport Workers Union). This will affect the roughly 17,000 bus drivers employed in Ohio. The median wage for a bus operator is 23% higher than the overall median wage, and the top wage for a COTA operator ($28/hour) is 63% higher than the overall median wage in the state. The elimination of these middle-class jobs will leave many otherwise low-skill workers displaced, in dire need of retraining in order to transition to other industries and secure new employment prospects.

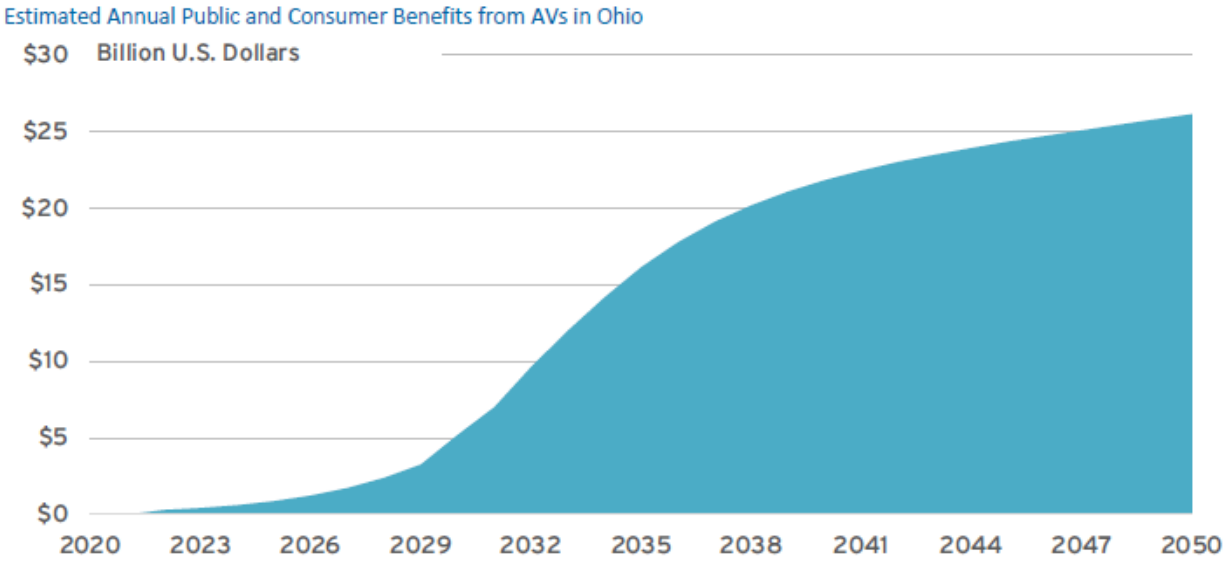
While the threat of labor displacement is real and will materialize in some form or fashion once ADS technology is deployed, its deployment, however, will also lead to gainful employment for some Ohioans who lack access to the job market or who do not have access to reliable transportation to get to and from work. Securing America's Future Energy (SAFE) is a Washington, D.C. based think tank that published a comprehensive study in June of 2018 titled *America's Workforce and the Self-Driving Future* that examined the potential impacts ADS technology might have on the labor market. In this study, the authors took a historical approach to understand the potential impacts that the transition to ADS technology may have on the labor market. The study draws on a range of earlier waves of disruption, such as autopilots in aviation, the industrial revolution, ATMs, globalization, and other innovations. The study conducts a comprehensive review of the historical record that these innovations had on the labor market and is used to infer the potential labor effects that ADS technology portends. The study concludes that ADS technology is likely to result in hundreds of billions of dollars in annual public benefits by 2050, improved transportation options will expand labor market access to both workers and employers, and ADS technology will have a marginal negative effect on employment but will return to full employment soon after, among other conclusions.

While the original study was nationally based, SAFE, upon the request of Chairman Doug Green of the Ohio House of Representatives Transportation & Public Safety Committee, examined Ohio specifically and prepared a secondary memo to inform this report. SAFE's study found that ADS technology would likely lead to significant productivity gains and economic growth—bringing to mind the rapid economic growth that accompanied the post-Second World War expansion, building of the Interstate Highway System, and suburbanization of the United

States. The overall economic and social impacts of deploying ADS technology are very likely to be similarly significant and, overall, highly positive. SAFE's analysis found that ADS technology could lead to $800 billion annually in economic and societal benefits upon full deployment across the United States. Based upon an examination of Ohio's proportion of crash fatalities and vehicle miles traveled in relation to the national total, SAFE estimated that Ohio would see annual benefits of at least $26.1 billion.[188] A more detailed accounting of SAFE's estimates of the public and consumer benefits in Ohio can be seen in the table below.

Additionally, included below the first table is a figure with an estimate of annual benefits in Ohio projected over time:

Public Benefits by 2050 (annual)	**$20.0 Billion**
Congestion	$2.7 Billion
Accident Reduction – Economic Impact	$3.6 Billion
Accident Reduction – Quality of Life Improvements	$11.6 Billion
Reduced Oil Consumption	$2.2 Billion
Consumer Benefits by 2050 (annual)	**$6.1 Billion**
Value of time	$5.7 Billion
Reduction in Cost of Current Taxi Service	$0.4 Billion
Total Annual Benefits (by 2050)	**$26.1 Billion**



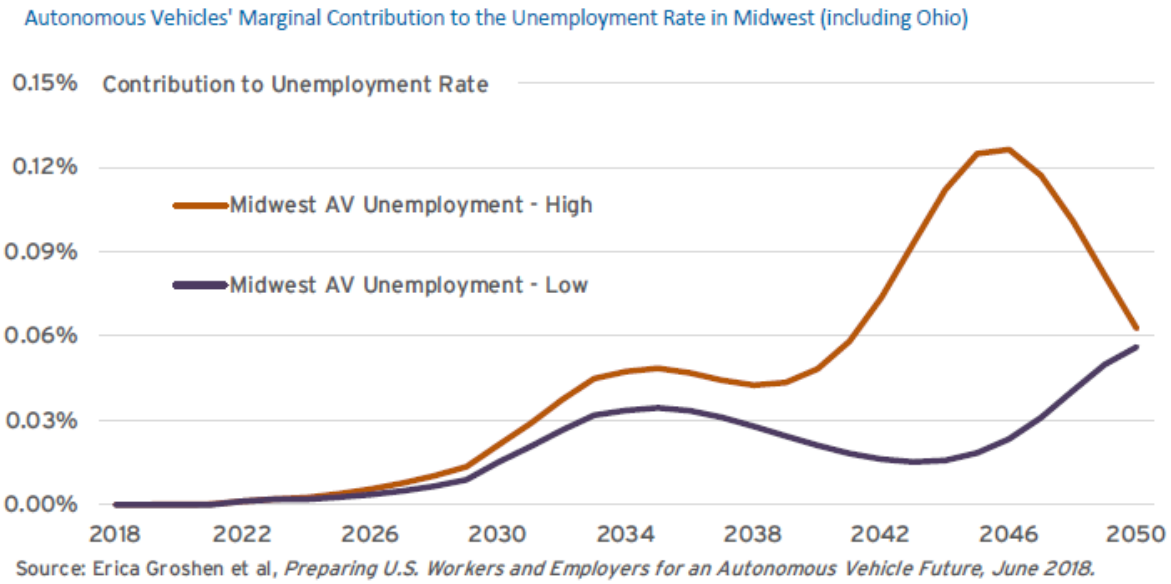
Source: SAFE analysis based on David Montgomery, *Public and Private Benefits of Autonomous Vehicles*, June 2018.

According to SAFE's analysis, the lower cost of travel provided by ADS technology has the potential to enable Ohioans to travel farther, significantly increasing access to job opportunities as well as a broader range of retail goods and services.[189] This in turn expands customer bases for retail establishments, increases the job market for workers, and widens the talent pool for employers, creating productivity gains in the process. To illustrate this, SAFE's study estimated that widespread ADS deployment in the broader Columbus metropolitan area would likely lead to better access to jobs for broad swaths of the population. SAFE modeled the reach of a commute both today and after the widespread deployment of ADS technology in London, a city nearly midway between Dayton and Columbus. For residents of London during peak travel hours, today's commute offers access to 12,000 business establishments employing about 250,000 workers.[190] If the widespread adoption of ADS technology would reduce congestion to off-peak levels, encourage workers to use their commuting time more productively, and add 10 minutes to their commute each way, a total of 38,000 employers and 800,000 jobs would consequently be within a reasonable commute. The improved transportation that ADS technology is expected to bring will give many in low-income communities' access to job opportunities that would previously been unavailable.

Improved Transportation Offers Access to More Work Opportunities in London, OH

SAFE's report identified regional-level impacts of ADS technology to the unemployment rate. ADS technology-related job loss is not expected to be significant for at least 15 years and will be temporary, with peak impacts expected about 30 years in the future. Even at peak, SAFE predicts that the overall increase in unemployment rate due to ADS technology-related displacement in Ohio will be 0.1% or less. The figure below is a projection of the impact of ADS technology on the unemployment rate in the Midwest region, which is the best proxy SAFE

currently has available for the impact on Ohio. Compared to the rest of the country, Ohio has a higher than average concentration of heavy and tractor-trailer drivers (13% above national average) and drivers and chauffeurs (5% above the national average).[191] Therefore, SAFE estimated that the impacts of ADS technology on employment in Ohio will be roughly in line, but slightly higher, than their original study's projections for the nation as a whole.



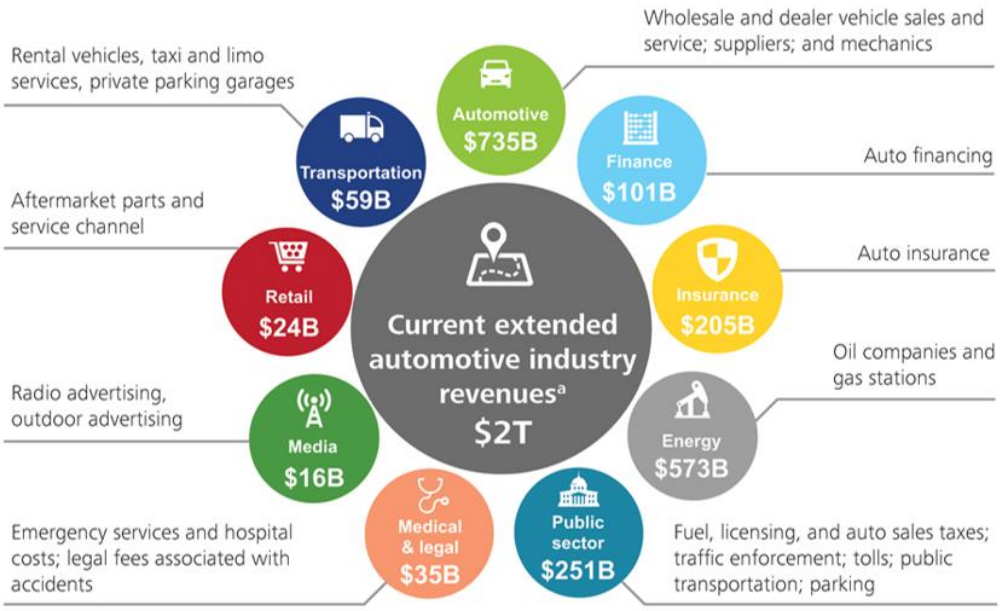
Source: Erica Groshen et al, *Preparing U.S. Workers and Employers for an Autonomous Vehicle Future, June 2018.*

ADS technology has the potential to have effects on the labor market outside of the transportation industry. According to SAFE's analysis, the retail sector has lost 18 times more workers than coal mining since 2001, although new jobs have been created to support e-commerce. SAFE's study looked specifically at what ADS technology availability might do to improve shopper access to the Easton Town Center, a major mall in Columbus, as an illustrative example. It found that the increased willingness of shoppers to travel— even by just two minutes each way—could increase its customer base by 48 percent. The other 13 major shopping centers within Columbus would see their customer base expand by 28-55 percent. In the current challenging environment for the retail sector, ADS technology could provide an additional tool allowing easier and more convenient access to brick-and-mortar businesses.

Source: SAFE analysis based on framework from David Montgomery, *Public and Private Benefits of Autonomous Vehicles*, June 2018.

However, on the flip side, in the $2 trillion greater automotive market, $35 billion consists of medical and legal costs associated with accidents. If accidents are reduced by 90% or more, what happens to labor demand and supply on medical professions (such as trauma surgeons, nurses, EMTs, and others)? Any system-wide changes to how the transportation system operates and its current cause and effects will have trickle-down consequences in the microsystems that surround it, such as the industries in the below graph illustrate:

Extended US Automotive Industry Revenue (2014)



Source: Deloitte analysis based on IBISWorld Industry Reports, IHS, DOT, US Census, EIA, Auto News, TechCrunch. Current revenue represents 2014 figures (or earlier if 2014 data not available) in the United States.
[a]Total revenue is $1.99T.

Source: Deloitte University Press, DUPress.com

This report takes the position, based off testimony before the Committee, stakeholder engagement, and a review of leading academic and consulting studies, that while it is clear that new jobs will be created and some current jobs either downgraded or eliminated, it is not clear what happens to the people who currently occupy jobs at risk for displacement from ADS technology. This report agrees that on the whole, ADS technology will not lead to mass unemployment of transportation workers and their affiliated microsystems; however, it is likely that the wages earned by the demographics that currently make up "drivers" in the transportation industry will be significantly reduced once they are displaced from their driving occupation. Take into account the following driving occupations and the demographics of their Ohio drivers:

- **Truck Driver (Heavy and Tractor-Trailer):**
  - Median Age: 49[192]
  - National Educational Attainment Percentages:[193]
    - High school diploma or equivalent (56%)
    - Less than a high school diploma (19%)
  - Annual Mean Wage: $43,990 ($21.15/hour)[194]
  - Number of Ohioans in this occupation: 74,310[195]
- **Bus Driver (Transit and Intercity):**
  - Median Age: 52[196]
  - National Educational Attainment Percentage: High school diploma or equivalent (84%)[197]
  - Annual Mean Wage: $43,890[198]
  - Number of Ohioans in this occupation: 6,390[199]
- **Taxi Driver & Chauffer:**
  - Median Age: 54[200]
  - National Educational Attainment Percentage: High school diploma or equivalent (79%)[201]
  - Annual Mean Wage: $24,460 ($11.76/hour)[202]
  - Number of Ohioans in this occupation: 7,840[203]
- **Ohio's Workforce:**
  - Median/Average Age: 42[204]
  - Ohio Educational Attainment Percentages:[205]
    - High school diploma or equivalent (34%)
    - Less than a high school diploma (11%)
  - Annual Mean Wage: $46,950[206]
  - Annual Median Wage for High School Graduates & equivalent: $28,203[207]

Reviewing the above demographic profiles, truck drivers, bus drivers, and taxi drivers, as a whole, are older, have lower educational attainment levels, and earn less than Ohio's average worker. What this indicates is that, if these workers are displaced, they are less likely to be able to weather that economic displacement. Further, truck drivers and bus drivers in Ohio make above $40,000 per year because of the skills they have, such as driving a multi-ton bus or tractor trailer that generates significant revenue and needs to be operated safely or it can seriously injure or kill many people. If those skills are no longer required due to ADS technology, there may be on average, a $15,000+ per year loss in wages, based off their educational attainment.

During stakeholder engagement for this report, stakeholders identified potential alternative lateral moves for some displaced drivers. For truck drivers, this lateral move could be managing a platoon of trucks (essentially one truck driver with multiple unmanned ADS-equipped trucks following closely behind) or ADS-equipped trucks would travel unmanned across the interstate system and then park at a hub outside an urban center for a human truck driver to then manually drive through urban environments to its destination and back out to the hub. For bus drivers, instead of driving, they could potentially be on-board providing general assistance, directions, and other customer service functions. While these are all plausible and highly likely scenarios and are supported by research indicating that Ohio will not see large spikes in unemployment; that is not really the fundamental question to be answered. The fundamental question is, will these new employment opportunities due to ADS technology displacement provide equal or greater wages for affected employees?

The United States Department of Labor tracks many different labor statistics and has a plethora of statistical information to evaluate the above scenario provided by stakeholders and to help answer the fundamental question posed above. While there is no equivalent occupation, at the moment, for heavy and tractor trailer drivers that work in conjunction with ADS technology, light truck or delivery services drivers can serve as a proxy because they primarily deliver or pick up merchandise or packages and may load and unload the vehicle. This occupation has been chosen as a proxy because this is not a long-haul occupation and typically has designated routes in a metropolitan area and all the required driving can be done in a standard shift. The below is the demographic information for this proxy:

- **Light Truck or Delivery Services Driver:**
    - Median Age: 49[208]
    - National Educational Attainment Percentages:[209]
        - High school diploma or equivalent (75%)
        - Less than a high school diploma (23%)
    - Annual Mean Wage: $33,500 ($16.10/hour)[210]
    - Number of Ohioans in this occupation: 36,610[211]

Heavy and light truck drivers have roughly the same educational attainment but a $10,000 per year variance in wages. However, heavy truck drivers are handling larger vehicles and require additional licensing, which partially explains the variance in wages. In addition, part of the

variance in wages is the long-haul drives that these heavy truck drivers perform and the current labor shortage of truckers available to trucking companies. It is reasonable to allocate a 50-50 split in the wage variance between the characteristics of the heavy truck drivers driving larger vehicles and additional licensing requirements with the compensation for reduced quality of life, distance traveled, and current labor shortage facing that occupation, it still comes out to a net $5,000 per year reduction in annual wages for this lateral move. If the following wage characteristics are eliminated: quality of life, distance, and labor shortage factors by having laterally transitioned workers moving heavy trucks from hubs outside the urban centers to inside and back out, over standard work shifts, close to home, and with no labor shortage, what makes those drivers worth the additional $5,000 per year?

With that said, noticeable deployment of ADS technology in the trucking industry is most likely not going to occur until the mid-to-late 2020s. With the current demographic profile of the trucking industry in Ohio, a significant number of Ohioans currently in the trucking profession most at risk for labor displacement will be retired or retiring by the time ADS technology penetrates the trucking industry enough to induce labor displacement.[212] Further, with a current labor shortage and the potential for truck platooning to increase the volume of freight per human driver, there is significant opportunity for those truck drivers in the mid-to-late 2020s to have significantly increased wages and quality of life benefits compared to today. If the trucking industry is able to increase the number of young drivers with computer, software, and other technical skills, truck drivers of the future could be software analysts. These analysts could be assisting in the management of data networks supplying the IoT infrastructure with data points along Ohio's transportation and logistics networks and thus have the potential to make significantly more in wages. The truth is, it is still too early to know how quickly this technology will be commercially available or how it will be adopted. However, the General Assembly must begin making preparations to address some truck drivers being displaced due to ADS technology.

Examining the potential lateral movement for bus and transit drivers is much easier. The lateral occupation identified by stakeholders for these drivers already exist. They are called transportation attendants and they provide services to ensure the safety and comfort of passengers aboard ships, buses, trains, or within the station or terminal. These attendants perform duties such as greeting passengers, explaining the use of safety equipment, serving meals or beverages, or answering questions related to travel.[213] Below is the demographic information for this occupation from the Bureau of Labor Statistics:

- **Transport Attendants:**
    - Median Age: Data unavailable
    - National Educational Attainment Percentage: Data unavailable
    - Annual Mean Wage: $27,860 ($13.39/hour)[214]
    - Number of Ohioans in this occupation: 570[215]

As identified above, the wage gap between bus drivers and one of the main identified lateral roles is large, it is $16,000 per year in potential lost wages. Bus drivers are at a more severe disadvantage than truck drivers, primarily because truck drivers will still maintain some skills

necessary that ADS technology will not be able to provide in the near future. Busses are driven on mapped and predictable routes, versus cargo delivery that may or may not change day to day.

For taxi and ride-hailing drivers, the future is much bleaker. There most likely will not be any lateral moves within this industry except to potentially assist newly mobile seniors and those with disabilities who need assistance getting in and out of ADS-equipped vehicles. In the short-term, some human drivers will remain for intricate pick-up locations such as airports and other complex zones. Ride-hailing services will be some of the first companies deploying ADS technology because their business model is at risk without it. Uber and Lyft have been in operation since 2010 and 2012, respectively. Since their launch, neither company has turned a profit (minus one-time divestments) and has secured billions of dollars in venture capital money to enable their rapid growth and expansion across the globe.[216] Investors will not continue to have patience for these companies to continue losing money. In order for them to become profitable, they will need to capture more of the gross revenue being generated from bookings. For example, in the second quarter of 2018, Uber's gross bookings totaled $12 billion but $8.2 billion of that went directly to drivers.[217] The math equation is simple: profitability = eliminating the driver, which will potentially allow Uber to keep the vast majority of the $8.2 billion in gross bookings that have been going out the door quarter after quarter.

While the above picture is bleak, this report is not criticizing the above potential outcomes. This is part of the inevitable transition to ADS technology in Ohio's transportation system. These industries are going to be rational actors in a free-market system and will implement new technology into their business platforms, just as any other industry would. The question that the General Assembly must grapple with, is how will displaced labor be re-trained, up-skilled, and further educated for new potential occupations that will arise or to fill the thousands of jobs currently open in Ohio that employers cannot fill because they lack access to qualified labor?

When ADS technology takes over driving, those Ohioans in driving occupations will need to retool their skillset to relevant opportunities that this new transportation environment creates – much akin to the first and second Industrial Revolutions. If Ohio is able to gain insights into the future skills and competencies that will be required, the state will have a head start in building this new emerging workforce. This will help Ohio position itself as the private investment state of choice for this emerging industry and will assist the state in reversing some of its long-term, negative economic trends. As such, this report makes the following recommendations for the General Assembly to pursue expeditiously and aggressively:

- The General Assembly should direct the proposed Autonomous and Connected Vehicle Task Force to begin identifying occupations most at risk of labor displacement from ADS technology, starting from the short- to long-term, and begin identifying what new skill sets and competencies these Ohioans will need to be transitioned back into the workforce as quickly and as smoothly as possible.
    - Further, as part of this directive, this Task Force should bring together the trucking, transit, and taxi/ride-hailing industries together with their respective labor representatives to begin working out a fair, equitable structure to transition

their driving workforce into new positions within their organizations or into new occupations. The goal of this is to begin the hard conversations now and avoid political gamesmanship in the coming years, which may delay or impede ADS deployment, neither of which is in the public interest because the General Assembly's failure to properly address labor displacement is a recipe for social and political unrest.

- The General Assembly should commit to a policy that encourages aggressive deployment of ADS technology. Doing so would allow projected annual benefits to begin accumulating in the mid-to-late 2020s and some of those dollars should be directed to upgrading Ohio's ability to mitigate negative socioeconomic costs incurred from the deployment of this technology.

Insurance

The insurance industry will be one of the most heavily impacted industries in the greater $2 trillion dollar automotive market. Insurance provides a much needed function in Ohio's transportation system by ensuring motorists and others have financial protection against physical damage, bodily injury, and other liabilities resulting from traffic collisions as well as other events such as theft and weather. Rapid advancements in ADAS/ASS, ADS, and connected vehicle technologies are deploying now or in the short-term. These changes will bring about significant change to the insurance industry, specifically auto insurance. The availability of data and its ability to inform risk and its enabling power for ADS technology deployment is rapidly expanding and will grow exponentially as capabilities continue to advance in sensors, data storage, machine learning, and other related areas. As consumers cede control to ADS-equipped vehicles to make fundamental driving decisions, manufacturers and software developers will become more accountable for accidents and the lines of legal responsibility will begin to blur under certain circumstances. This change in legal responsibility will cause a move toward more product and general liability insurance. Consumers, specifically millennials and younger, desire to multi-task, get places faster, travel safer, share more, and be more environmentally responsible. Those desires along with increased urbanization are already driving rapid changes in consumer views on mobility and vehicle ownership, both of which will contribute to the adoption of ADS technology and the number of vehicles to insure.

In 2016, the auto insurance industry yielded $247 billion in premiums globally (personal and commercial auto combined).[218] The auto insurance industry is currently in a state of imminent transition from the past ways of assessing and pricing risk to new, innovative, and data centric ways of assessing risk. Pressure on premiums is mounting, as evidenced by auto insurance rates being higher than ever, with a national average annual premium of $1,427 (20% higher than in 2011).[219] This may be due to vehicles increasingly becoming saturated with expensive sensors and other equipment which is increasing the severity of vehicle collisions (as well as other factors such as increased distracted driving). However, as more vehicles become equipped with ADAS and soon, ADS technology, the pressure on premiums will invert from upward to downward due to the reduction in frequency of collisions dwarfing the increase in severity of collisions.[220] Another sign of the insurance industry fundamentally transitioning is the volatility in rates across the country. Over the past few years, some states' rates increased more than 60%, and others as little as 1%. In the same time, 10 states saw a net rate decrease, some by as much as 20%. Rate changes from year to year were as high as 9% nationally and up to 45% in certain states.[221] Further, from a macro-level view point, new ADAS technology designed to keep drivers, passengers, and pedestrians safe seems to have little impact on insurance rates, as evidenced in the below chart:

ANNUAL AVERAGE PREMIUMS BY SAFETY TECH FEATURES WITH % IMPACT ON RATES

SAFETY DEVICE	AVG. ANNUAL PREMIUM	% DIFFERENCE	$ SAVINGS
None	$1,427	–	–
Driver Alertness Monitoring	$1,427	0%	$0
Lane Departure Warning Device	$1,427	0%	$0
Night Vision Device	$1,427	0%	$0
Park Assist Device	$1,427	0%	$0
Rear View Camera	$1,427	0%	$0
Blind Spot Warning Device	$1,427	0%	$0
Collision Preparation System	$1,427	0%	$0
Heads-Up Display	$1,427	0%	$0
Electronic Stability Control (ESC)	$1,420	0.50%	$7

Source: Zebra 2018

This could be due to the fact that the accrued safety benefits may be canceled out by the increase in cost to repair those same vehicles when in a collision. Another reason this may be the case is that until ADAS equipment becomes standard, insurers will not have large enough data sets to determine the extent to which various ADAS systems reduce the frequency and severity of collisions. As more data is collected and analyzed on ADAS effects on claims, insurers will also be able to determine whether the accidents that do occur with this equipment lead to a higher percentage of product liability claims, as claimants blame the manufacturer or suppliers for what went wrong rather than their own behavior, which will also be insightful to inform risk pricing for ADS technology as well.[222] Overall, Ohio has a robust and healthy auto insurance market that is evidenced by the state having the 7th lowest average annual premiums of $1,037 versus the national average of $1,427. Further, Ohio has the lowest average annual insurance premiums of the Great Lakes region of $1,037 versus the regional average of $1,375 and even better rates than Michigan, which averages $2,610 in annual premiums.[223]

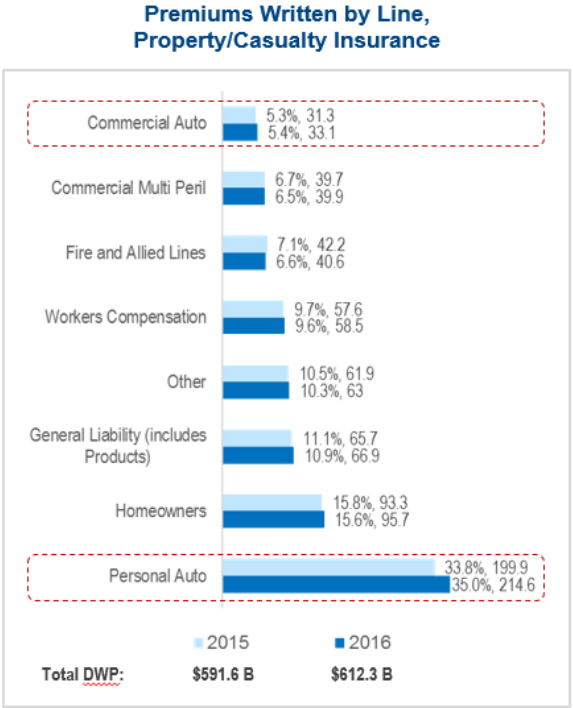
To better understand how ADS, ADAS, and connected vehicle technologies will affect the insurance industry, it is necessary to understand how the industry is currently regulated, how insurance is underwritten, and how current auto premiums are distributed. Then, this report will examine the potential effects these technologies will have on the former, challenges the industry will face, and the opportunities that will come with those challenges.

Insurance is a state-regulated industry with each jurisdiction having its own sets of rules and regulations for auto insurance. Generally speaking, there are two kinds of liability systems. In some states, liability is based on the no-fault concept, where insurers pay the injured party

regardless of fault and in others it is based on the tort system. In Ohio, we utilize the tort system and have a comparative negligence liability system. In 1980, Ohio became the 35th state to enact a comparative negligence law. For the purpose of this law, "negligence" is defined as the failure to exercise the degree of care required of a reasonable and prudent person in any given circumstance resulting in injury or damage to another. Comparative negligence allows for a person to recover damages as reduced by the person's own percentage of negligence. In Ohio, if a party is more than 50 percent at fault, recovery is not allowed. The law applies most often to automobile accidents but also applies in other circumstances.[224]

In regards to underwriting, there are a variety of factors that contribute to the cost of every Ohioan's insurance premium. Currently, these include personal attributes, driving record, and external factors: personal factors include age, gender, marital status, homeowner status, credit score, occupation, level of education, and vehicle make, model, and equipment features; driving record includes traffic violations, accidents, claims, annual mileage, and vehicle use; external factors include geographic regions, weather events, city population, crime rates, and infrastructure soundness.[225] These combined data points are used in actuarial models by insurance companies to determine the level of risk a person poses, which then determines the premium rate that person is assigned based on the predicted risk they expose the insurance company to in the form of claims paid out.

Auto insurance premiums typically fall under property/casualty insurance and under either personal or commercial auto insurance. In 2016, personal and commercial auto insurance made up 35% ($215 billion) and 5.4% ($33 billion), respectively of premium revenue for the property/casualty insurance market. Collectively, these two lines of insurance amount to a total of over 40% of premium revenue, clocking in at $248 billion, as evidenced by the below chart:



Source: NAIC data sourced from S&P Global Market Intelligence, Insurance Information Institute

Based on feedback from stakeholders in the insurance industry and from a review of studies conducted on ADS, ADAS, and connected vehicle technologies potential effects on the insurance industry, this report has identified some common themes that may be on the horizon, both in the short- and long-term for the industry:

- The largest impact these technologies will have is on auto insurance premiums. Each year, more and more vehicles become loaded with sensors and other ADAS technology, more vehicles and infrastructure are being connected, and ADS technology is just on the horizon. The convergence of these inter-related technologies are poised to reduce collisions by 90% or more. On top of the technological effects, the rise of ride-sharing/ride-hailing and decreasing consumer interest in personal vehicle ownership will reduce the total number of vehicles needed to be insured. These two factors alone are indicating a future of precipitous reductions in premiums and volume of business for the auto insurance industry.[226]
    - 2025-2030 has been identified as the common timeframe for the beginning of premiums flat-lining and then beginning to collapse. Supported both by Nationwide Insurance testimony before the House Transportation & Public Safety Committee and studies conducted by others, including Deloitte, which showcases its projections on premiums in the below graph:[227]

Figure 2. Premiums – steady state vs. projections

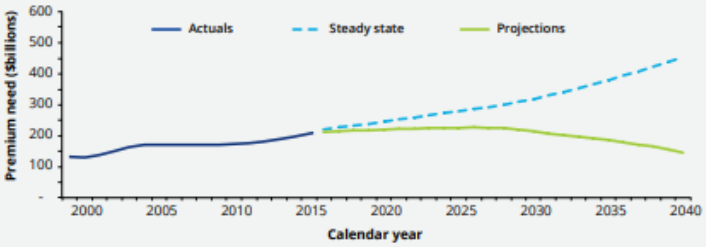
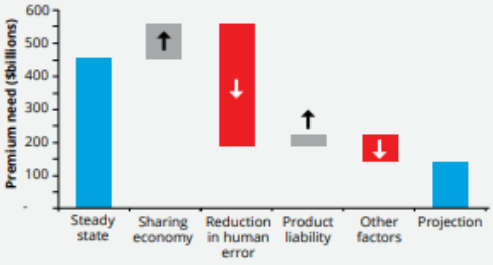


Figure 3. Projected premium breakdown – 2030

Figure 4. Projected premium breakdown – 2040



Steady state: Current mobility environment persists—there are no further advances in driver-assist technologies, autonomous vehicles do not become part of the national fleet, and ridesharing does not continue to expand

Sharing economy: The driver-driven sharing economy could boost premiums as the commercial auto policies for those drivers would tend to be more expensive

Reduction in human error: Addition of autonomous vehicles could reduce premiums of the steady state due to safety benefits

Product liability: Shift from driver liability to product liability could boost premiums

Other factors: Reduced fraud and additional safety benefits from driver-driven and autonomous vehicles could reduce premiums

Source: *Quantifying an uncertain future: insurance in the new mobility ecosystem*, Deloitte Consulting LLP

- Regarding vehicle ownership, Nationwide Insurance in testimony before the House Transportation & Public Safety Committee stated that it projects personal vehicle ownership will fall from 1.9 vehicles per household today to 1.1 by 2050. In addition, Ford has also indicated during stakeholder meetings that it projects personal vehicle ownership will fall with the adoption of ADS technology.
    - Further, research and computer modeling conducted by Accenture in collaboration with the Stevens Institute of Technology indicates that ADS-equipped vehicles will primarily be owned by auto manufacturers such as General Motors, Honda, and Ford, as well as by technology companies such as a Google, and ride-hailing services such as Uber and Lyft.[228] This change in the ownership model is dovetailing with changing consumer desires that indicate a reduction in desire to personally own a vehicle.[229]
- Testimony before the House Transportation & Public Safety Committee, studies conducted by research firms and academics, and feedback received during the stakeholder engagement process have all indicated that auto insurance will shift over time from a negligence (driver/owner responsibility) model to a product and general liability (manufacturer/supply chain responsibility) model, with some degree of negligence, such as lack of maintenance, likely continuing to exist even with ADS-equipped vehicles.
    - Further, in testimony before the Committee, StateFarm, Nationwide Insurance, Property Casualty Insurers Association of America and feedback from the Ohio Insurance Institute and the association representing Ohio's trial lawyers (Ohio Association for Justice) have all indicated that existing state liability and tort laws are sufficient and can evolve to handle ADAS, ADS, and connected vehicle technology. It was repeated in follow-up conversations and meetings that Ohio will benefit by being responsive rather than proactive in tort because the current system is not broken yet and the technology is still evolving.
        - Increased access to data and more data availability will provide greater opportunity to argue comparative fault or contributory negligence, and allow for the apportionment of responsibility for the loss among drivers and manufacturers. Current policies still retain the right to subrogate against other legally liable third parties, including negligent vehicle manufacturers. Under current product liability law, there are several potential causes of action against the manufacturers of autonomous vehicles, including manufacturing defects, design defects, failure to warn, misrepresentation, and breach of warranty. If an autonomous vehicle malfunctions and causes a crash, the list of potentially liable parties includes the vehicle manufacturer, the manufacturer of a component used in the autonomous system, and the software company or engineer who programmed the code used to operate the autonomous system, as well as anyone who serviced the vehicle or the vehicle owners themselves, if modifications were made. Even when manufacturers exercise all possible care to build safe products,

the product may still contain unsafe defects. If that defect causes injury to the user of the product, the manufacturer and all actors in the supply chain, such as wholesalers and retailers, can be held strictly liable for the resulting damages.[230]

- As the auto insurance industry landscape shifts and personal/commercial auto insurance premiums begin a significant and precipitous collapse, new revenue streams will emerge that will allow some, but not all, insurance companies to make up lost revenue from personal/commercial auto insurance premiums. Some of these new product opportunities include:
    - Cybersecurity: As vehicles become more connected and equipped with more advanced sensors, hardware, and software, the need for insuring against cyber vulnerabilities, whether it be from hacking, ransomware etc., will create new product opportunities[231] and has the potential to generate up to around $12 billion in annual premiums.[232] The large amount of and exponentially growing number of Internet of Things (IoT) devices has made large-scale network attacks that exploit their vulnerabilities simpler to execute and there may be vulnerabilities to vehicles from those compromised devices.[233] The potential profit and correlating risk is extremely high in this burgeoning product category for insurance companies.
    - Product Liability: As revenue from personal/commercial lines of auto insurance premiums decline, some of that lost revenue can be moved to product liability lines of revenue. Vehicle related sensors, hardware, and software have the potential for failure through software defects, memory overflow, algorithm defects, and other unforeseen defects, which results in a massive liability for these companies exposed in the vehicle manufacturer and supply chain ecosystem. Insuring these companies and stakeholders could result in $2.5 billion in annual premium revenue.[234]
    - Infrastructure Insurance: Parts of the infrastructure ecosystem, such as cloud server systems, signals, and other safeguards that will be put in place to protect drivers and passengers, could be worth around $500 million in annual premiums. The actual cost to insure this infrastructure ecosystem is likely to be much more than $500 million but most of these systems are managed by governments and thus are self-insured.[235]
    - In the aggregate, the joint study by Accenture and the Stevens Institute of Technology indicates that between these three potential new product categories, there is the potential to generate $81 billion through 2026 ($15 billion per year from 2020 to 2026, with some fluctuations) which can blunt losses in premiums expected through 2050.[236]

The insurance industry has fundamental structural changes on its doorstep and those companies that are able to adapt to the new realities, formulate strategies to quickly capitalize on new market opportunities, and merge with complimentary companies will lead the pack. The questions for the General Assembly with regard to insurance and ADS and connected vehicle

technology is, what is its role to ensure that Ohio continues to maintain a stable, robust, and healthy insurance market? How does it ensure that Ohio-based insurance companies have a regulatory environment that will enable them to best compete in an industry that will most likely see consolidations? This report makes the following recommendations for the General Assembly to pursue expeditiously:

- The General Assembly should oppose any attempts to federalize the auto insurance regulatory structure. The reason being that if auto manufacturers and their supply chains are required to accept greater liability for damages and injuries, they may lobby the federal government to provide greater regulatory oversight of the auto insurance industry to reduce and/or eliminate costs related to complying with the individual and unique regulations of 51 jurisdictions in the United States. Ohio has a top-tier auto insurance market and the General Assembly must guard against any attempt to cede state authority to the federal government on this particular issue.
- The General Assembly should oppose any changes to Ohio's current tort system of assigning liability with regards to this technology, until ADS and connected vehicle technology begins deploying and unforeseen issues arise. During stakeholder engagement there was a rare agreement between the insurance industry and the trial lawyers association regarding this topic; these opposing industries agree that, as of now, Ohio's current tort system will be able to handle this evolving technology.
- The General Assembly should direct the proposed Autonomous and Connected Vehicle Task Force to deliberate and make recommendations on how best to create a regulatory framework for data sharing between auto manufacturers, their supply chains, and the insurance industry. As Ohio moves into a more data-centric world, access to relevant data is paramount. The insurance industry will need access to certain types and amounts of data for two key reasons: first, to develop accurate pricing and underwriting models, which benefits consumers and second, to make more accurate and fair liability determinations. Bringing stakeholders together through the proposed Autonomous & Connected Vehicle Task Force to negotiate a fair regulatory structure for data sharing between the auto manufacturers and the insurance industry is key to providing a stable regulatory environment for ADS and connected vehicle technology. Without a data-sharing regulatory structure, insurers will be challenged by a lack of data, whether they choose to proceed under a personal liability regime or a products liability regime. Testing data and simulations are a poor substitute for actual data generated by the public using this technology.

Conclusion

ADS and connected vehicle technology will fundamentally change how Ohio, as a society, transports people, goods, and services. This technology promises to usher in an era of safety, increased mobility, and fundamentally change the way in which Ohioans interact with the transportation system. However, with fundamental change in society comes growing pains and the potential for negative secondary socioeconomic effects. Growing pains include building the infrastructure ecosystem for this technology to operate in, such as maintaining current infrastructure while integrating new technology during lifecycle updates. Potential negative secondary socioeconomic effects can manifest itself in the form of labor displacement and market volatility. These are unavoidable; what the General Assembly must be prepared to do is to address the challenges, and when necessary, to mitigate their effects. There is no stopping the progression of ADS technology; it is coming. However, it is also not prudent to ignore the potential negative socioeconomic effects that it may bring with it. Failure to mitigate negative socioeconomic effects has the potential to create public backlash which may impede the ability for this technology to deploy on an aggressive timeline. The theme of this entire report has been to strike a balance between the need to aggressively pursue the development and deployment of this technology while also creating frameworks and system-wide responses to mitigate any negative socioeconomic effects it may have on the labor market and broader economy.

Below is a complete list of recommendations made throughout this report that the General Assembly should begin pursuing immediately so that Ohio can maintain a competitive edge in this industry, which will incentivize additional private investment to come to the state due to the burdensome-free, mature, and stable regulatory structure:

- **Actionable Items:**
    - Ohio Overview
        - In order to solidify the regulatory environment that has been conducive to Ohio's momentum thus far in ADS and connected vehicle research, testing, and deployment, this report makes the following recommendations for the General Assembly to pursue:
            - The General Assembly should codify DriveOhio as the lead agency for ADS and connected vehicle technology.
            - The General Assembly should codify Governor Kasich's Executive Order allowing state-wide testing of ADS and connected vehicle technology.
            - The General Assembly should establish an Autonomous and Connected Vehicle Task Force that is comprised of a broad range of disciplines and organizations. This Task Force should be a creature of the General Assembly but housed inside DriveOhio. This Task Force should be directed by the General Assembly to provide legislative recommendations on an on-going basis as this

technology develops. Inclusive and collaborative planning will pay substantial dividends and as such is in the public interest.

- The General Assembly should inventory the Ohio Revised Code to identify what areas of code will need to be amended at some point for this technology – inventory but do not make legislative changes until there is a need to. Having the Ohio Revised Code inventoried will allow for the General Assembly to be agile and nimble as the technology develops and warrants legislative action.

- Infrastructure

  - The General Assembly should establish a Joint House-Senate Commission on short- and long-term transportation infrastructure funding with recommendations to be expeditiously moved through the committee process in both the House and Senate. This commission should address both short- and long-term funding issues surrounding Ohio's transportation infrastructure and how to best raise and allocate funding to integrate smart technology into the infrastructure lifecycle management system. Further, the proposed Autonomous and Connected Vehicle Task Force should be directed to evaluate and make recommendations to the General Assembly on:

    - New signage, pavement markings, and signalization systems to be integrated into the transportation infrastructure system that will benefit and provide greater value to conventional drivers, ADS-equipped, and connected vehicles than current signage, pavement markings, and signalization systems in use.
    - New transportation infrastructure design guidelines that consider future sensor and communication technology infrastructure installation needs, including access to power, underground conduit for fiber ("Dig Once" policy), locations for device mounting, and other needs.
    - A Roadway Classification System that identifies the infrastructure needed to support various levels of ADS and connected vehicle technology.
    - Studying and recommending to the General Assembly a "Dig Once" policy that enables broadband infrastructure to be installed in the public right-of-ways where possible during state-funded or supported infrastructure projects that already expose the right-of-way; doing so could reduce the cost of broadband infrastructure buildout by 90%.

- Data

  - The General Assembly should adopt a Joint-Resolution urging Congress to pass uniform federal regulations governing data privacy protections and for

those regulations to apply to all users in the Internet ecosystem. These protections should include "opt-in" and "opt-out" protections, allowing Ohioans the ability to decide what and how their data is shared to service providers and third-parties; this requires privacy notices and terms of service to be easy-to-find and written in layman's terms. This resolution should also include language that makes clear that if the federal government fails to properly and in a timely manner pass uniform federal regulations governing data privacy protections, then Ohio reserves the right to begin formulating its own regulatory structure in the absence of federal action.

- The General Assembly should direct the proposed Autonomous and Connected Vehicle Task Force to recommend, upon collaboration with private industry, public sector agencies, and other stakeholders, a data exchange platform that will enable relevant ADS and connected vehicle technology and related infrastructure data to be anonymized and shared.
    - Such data may include crash data and other related incidents for insurance and public safety purposes.
    - Making relevant data available for research and planning models to further academic research and the public good through public sector utilization.
    - Making data available to support smart cities and communities.

- Workforce and Labor
    - The General Assembly should direct the proposed Autonomous and Connected Vehicle Task Force to begin identifying occupations most at risk of labor displacement from ADS technology, starting from the short- to long-term, and begin identifying what new skillsets and competencies these Ohioans will need to be transitioned back into the workforce as quickly and as smoothly as possible.
        - Further, as part of this directive, this Task Force should bring together the trucking, transit, and taxi/ride-hailing industries together with their respective labor representatives to begin working out a fair, equitable structure to transition their driving workforce into new positions within their organizations or into new occupations. The goal of this is to begin the hard conversations now and avoid political gamesmanship in the coming years, which may delay or impede ADS deployment, neither of which is in the public interest because the General Assembly's failure to properly address labor displacement is a recipe for social and political unrest.

- Insurance
    - The General Assembly should direct the proposed Autonomous and Connected Vehicle Task Force to deliberate and make recommendations on how best to create a regulatory framework for data sharing between auto manufacturers, their supply chains, and the insurance industry. As Ohio moves into a more data-centric world, access to relevant data is paramount. The insurance industry will need access to certain types and amounts of data for two key reasons: first, to develop accurate pricing and underwriting models, which benefits consumers and second, to make more accurate and fair liability determinations. Bringing stakeholders together through the proposed Autonomous & Connected Vehicle Task Force to negotiate a fair regulatory structure for data sharing between the auto manufacturers and the insurance industry is key to providing a stable regulatory environment for ADS and connected vehicle technology. Without a data sharing regulatory structure, insurers will be challenged by a lack of data, whether they choose to proceed under a personal liability regime or a products liability regime. Testing data and simulations are a poor substitute for actual data generated by the public using this technology.

- **Positions to take:**
    - Federal versus State Responsibilities
        - The General Assembly should oppose a patchwork of state and local laws regarding ADS and connected vehicle technology as it is not in the public interest. Ohio should defer to the federal government in the regulation of safety, cybersecurity, and data privacy standards.
    - Infrastructure
        - The General Assembly should make basic transportation infrastructure maintenance its first priority in regards to ADS and connected vehicle technology because it is absolutely essential for both conventional drivers and ADS technology; both need well-maintained roads, clear pavement markings, and optimal signage.
        - The General Assembly should make its second priority the integration of smart communication technology into the infrastructure system, such as Dedicated Short Range Communication (DSRC) devices and 5G infrastructure to enable Vehicle-to-Vehicle (V2V), Vehicle-to-Infrastructure (V2I), Vehicle-to-Everything (V2X), and C-V2X (Cellular-Vehicle-to-Everything) communications.
    - Workforce and Labor

- The General Assembly should commit to a policy that encourages aggressive deployment of ADS technology. Doing so would allow projected annual benefits to begin accumulating in the mid-to-late 2020s and some of those dollars should be directed to upgrading Ohio's ability to mitigate negative socioeconomic costs incurred from the deployment of this technology.

- Insurance

  - The General Assembly should oppose any attempts to federalize the auto insurance regulatory structure. The reason being that if auto manufacturers and their supply chains are required to accept greater liability for damages and injuries, they may lobby the federal government to provide greater regulatory oversight of the auto insurance industry to reduce and/or eliminate costs related to complying with the individual and unique regulations of 51 jurisdictions in the United States. Ohio has a top-tier auto insurance market and the General Assembly must guard against any attempt to cede state authority to the federal government on this particular issue.
  - The General Assembly should oppose any changes to Ohio's current tort system of assigning liability with regards to this technology, until ADS and connected vehicle technology begins deploying and unforeseen issues arise. During stakeholder engagement there was a rare agreement between the insurance industry and the trial lawyers association regarding this topic; these opposing industries agree that, as of now, Ohio's current tort system will be able to handle this evolving technology.

Appendix

Hearings:

- AV 101
  - October 4, 2017
- Manufacturers Briefing
  - November 1, 2017
- Benefits & Challenges, Economy & Labor
  - December 6, 2017
- Ohio Infrastructure & Industry
  - January 31, 2018
- Insurance
  - April 11, 2018
- Ohio Research & Testing
  - May 23, 2018

Link to Access: http://www.ohiohouse.gov/committee/transportation-and-public-safety

OHIO RAILROAD ASSOCIATION

172 E. State Street
Suite 300
Columbus, Ohio 43215
(614) 224-4010
Fax (614) 228-5637

November 2, 2018

The Honorable Doug Green
Chairman
House Transportation and Public Safety Committee
Ohio Statehouse
Columbus, Ohio 43215

Dear Chairman Green:

Rapid development in the use of technology in freight transportation has led to an exciting and transformative time in our industry. These advancements have opened our respective eye to challenges and opportunities that seemed unimaginable in the not so distant past. In particular, the subject of autonomous vehicle highway operations has implications for public safety that remain unanswered. Of specific concern to the railroad industry is the highway-rail grade crossing. How will autonomous vehicles react to approaching trains and signals? How will motorists sitting in those vehicles react to whatever controlled reactions are programmed? And how does Ohio and the nation move forward with a responsible, thoughtful program?

If autonomous vehicles are truly to operate over all roadways, it is highly likely these vehicles will encounter highway-rail intersections, or more plainly, grade crossings. In Ohio today, there are approximately 5,700 public highway grade crossings, and several thousand private roadway crossings. Since the late 1980s, Ohio has undertaken a comprehensive and multi-faceted approach to reducing crashes and improving safety at these intersections, including the option to eliminate grade crossings altogether via closure and alternative access across the railroad right of way. For the railroad industry, the reduction of at-grade crossings in Ohio is of paramount importance to drastically limit opportunities for collision between trains and automobiles, while also carrying the added benefit of eliminating the potential for the crossing to be blocked in the course of normal railroad operations and service to customers.

From a high of almost 900 crashes per year, Ohio's approach, which has included tens of millions of dollars of investment and maintenance as well as closures, has helped to reduce crashes to about 100 per year. The alarming fact remains that approximately 85% of the crashes that have occurred in Ohio over the last five years have taken place at grade crossings with active warning signals for an

approaching train. These persistent percentages of crashes at grade crossings with the most warning to drivers suggest a propensity by drivers to accept a risk of a crash to avoid being delayed by a train.

Autonomous vehicle operations have been cited by ODOT as improving highway safety, potentially reducing crashes caused by human judgment by 90%. This is a remarkable prediction, and one worth more investigation and study. The railroad industry supports this effort, but we must underscore that some very risky driver behavior is associated with grade crossings, and how the vehicles will react and operate at these locations must be carefully considered.

The freight railroad industry have enjoyed a long-standing grade crossing safety partnership with Ohio state agencies that has been a positive one, resulting in the aforementioned safety achievements benefiting the traveling public. In order for us to maintain the recent success we have achieved in railroad safety in Ohio, it is incumbent upon us to carefully consider the impacts these potential projects may have on our networks. For example, as you may know, in 2017, ODOT and ORDC contacted one of our member organizations requesting their participation in ongoing connected and autonomous vehicle research in Marysville, Ohio.

Specifically, the state sought to work with the railroad on a line segment through Marysville which includes thirteen (13) at-grade crossings, including five (5) private crossings.

Following a review of the state's request, and upon further discussion within the state's freight rail industry, the Ohio Railroad Association offer the following for your consideration as you continue your public policy work on autonomous vehicle research in Ohio:

- Due to the potential for this research to have national and wide ranging implications for the freight rail industry in Ohio, we believe it is essential that the Federal Railroad Administration (FRA) be made aware of this ongoing research in Ohio. The FRA may choose to participate in this research effort at their discretion.

- The FRA issued guidance in Safety Advisory 2010-02 and Technical Bulletin S-12-01 for the nation's freight railroads regarding interconnection between at-grade crossing communication systems and preempted highway signals. It is important that the State of Ohio filly understand the implications of these directives on the state's research, as the terms of this previous guidance creates added complexity and liability for the railroads.

- The freight rail industry does recognize that many of the details associated with this research are experimental in nature and include many unknown variables. However, we think it is critical to establish a basic framework for your research that does not compromise safety or impact service to existing or potential freight rail customers.

While we are not aware of existing relationships between Ohio freight railroads and any autonomous vehicle testing, it is our belief that such testing should move forward. As noted above, involvement by the FRA is a necessity, as any research being done here or elsewhere should be implemented as a national model, not a program unique to Ohio. In a state with five other states and a third of our population on our borders, interoperability of autonomous vehicle systems should be a requirement.

As referenced earlier, existing driver behavior at grade crossings raises concerns. Freight railroad business and train operations to serve that business are forecast to grow. As rail traffic grows, so does the potential for occupied crossings. Trains can occupy a crossing for a variety of reasons, most of them based upon regulatory mandates or public safety concerns.

While it is unlikely that autonomous vehicle technology will improve the flow of traffic at grade crossings, there are other options that should be considered. The best solution to relieving traffic congestion and improve the safety of AV/train interactions at grade crossings is a grade separation. Separations would eliminate both the impact of train operations on traffic flow and AV/train interactions at specific locations. Separations benefit the public in many ways, from relieving congestion due to blocked crossings, improving air quality by reducing idling engines, and reducing time spent sitting in traffic. These are substantial issues, more so in the communities that regularly experience delays due to train operations.

As mentioned, a less expensive consideration is the closure of redundant crossings. Many locations in Ohio have multiple grade crossings in close proximity. This redundancy adds to the cost of maintenance and increases the risk of crashes. Technology holds great promise for safer and more efficient transportation systems. Railroads are more technologically-driven than generally known, and the industry's safety and operational improvements are demonstrating that technology can do even more. But any transportation technologies must be tested to a very high degree of confidence to ensure public safety is enhanced by any application or investment. The benefits must accrue to the source of the technology investment, as well. Only by comprehensive, thoughtful, and inclusive reviews can this goal be attained.

The railroad industry stands ready to participate to ensure both the railroad industry and the public have a high degree of confidence in the implementation of autonomous vehicle technologies in the future.

Sincerely,

Arthur J. Arnold

Executive Director
The Ohio Railroad Association

END NOTES

[1] Hawkins, A. J. (2018, December 5). RIDING IN WAYMO ONE, THE GOOGLE SPINOFF'S FIRST SELF-DRIVING TAXI SERVICE. In The Verge. <https://www.theverge.com/2018/12/5/18126103/waymo-one-self-driving-taxi-service-ride-safety-alphabet-cost-app>

[2] LeBeau, P. (2018, January 12). GM is seeking approval for an autonomous car that has no steering wheel or pedals. In CNBC. <https://www.cnbc.com/2018/01/12/gm-is-seeking-approval-for-an-autonomous-car-that-has-no-steering-wheel-or-pedals.html>

[3] Ohio State Highway Patrol Statistics . (2018). In *Ohio State Highway Patrol*. <https://www.statepatrol.ohio.gov/statistics/statspage3.asp>

[4] Rifkin, J. (2011). *The third industrial revolution: How lateral power is transforming energy, the economy, and the world*. New York: Palgrave Macmillan.

[5] Ibid.

[6] Ibid.

[7] Ibid.

[8] Ibid.

[9] TEConomy Partnerrs, LLC. (2018, July). Ohio BOLD: A Blueprint for Accelerating the Innovation Economy. In Ohio Chamber Foundation. <http://ohiochamberfoundation.com/wp-content/uploads/2018/07/OhioBold-fullreport.pdf>

[10] Rifkin, J. (2014). *The zero marginal cost society: The internet of things, the collaborative commons, and the eclipse of capitalism*. New York: Palgrave Macmillan.

[11] Ibid.

[12] Hawkins, A. J. (2018, December 5). RIDING IN WAYMO ONE, THE GOOGLE SPINOFF'S FIRST SELF-DRIVING TAXI SERVICE. In The Verge. <https://www.theverge.com/2018/12/5/18126103/waymo-one-self-driving-taxi-service-ride-safety-alphabet-cost-app>

[13] LeBeau, P. (2018, January 12). GM is seeking approval for an autonomous car that has no steering wheel or pedals. In CNBC. <https://www.cnbc.com/2018/01/12/gm-is-seeking-approval-for-an-autonomous-car-that-has-no-steering-wheel-or-pedals.html>

[14] United States Department of Transportation. (2018, October 4). Automated Vehicles 3.0 Preparing for the Future of Transportation. In *United States Department of Transportation*. <https://www.transportation.gov/sites/dot.gov/files/docs/policy-initiatives/automated-vehicles/320711/preparing-future-transportation-automated-vehicle-30.pdf>

[15] SAE International . (2018, June). J3016_201806 Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles. In *SAE International*. <https://www.sae.org/standards/content/j3016_201806/>

[16] Ibid.

[17] Ibid.

[18] Ibid.

[19] Ibid.

[20] National Highway Traffic Safety Administration. (n.d.). Automated Vehicles for Safety. In *NHSTA*. <https://www.nhtsa.gov/technology-innovation/automated-vehicles-safety#issue-road-self-driving>

[21] Ibid.

[22] Ibid.

[23] Ibid.

[24] Ibid.

[25] Ibid.

[26] (n.d.). In *Waymo*. <https://www.waymo.com/>

[27] Autopilot Press Kit. (n.d.). In *Tesla*. <https://www.tesla.com/en_CA/presskit/autopilot#autopilot>

[28] Super Cruise. (2017). In *Cadilac*. <https://www.cadillac.com/world-of-cadillac/innovation/super-cruise>

[29] LeBeau, P. (2018, July 20). Waymo's self-driving cars log 1 million miles on public roads in a month. In *CNBC*. <https://www.cnbc.com/2018/07/20/waymos-autonomous-cars-log-1-million-miles-in-a-month.html>; Tesla Autopilot Miles. (n.d.). In *Human-Centered AI - MIT*. Retrieved from https://hcai.mit.edu/tesla-autopilot-miles/>

[30] Audi A8 - Audi AI Traffic Jam Pilot. (n.d.). In *Audi*. <https://www.audi-technology-portal.de/en/electrics-electronics/driver-assistant-systems/audi-a8-audi-ai-traffic-jam-pilot>

[31] Paukert, C. (2018, May 14). Why the 2019 Audi A8 won't get Level 3 partial automation in the US. In *Road Show by CNET*. <https://www.cnet.com/roadshow/news/2019-audi-a8-level-3-traffic-jam-pilot-self-driving-automation-not-for-us/>

[32] Boudette, N. (2018, October 3). Honda Putting $2.75 Billion Into G.M.'s Self-Driving Venture. In *The New York Times*. <https://www.nytimes.com/2018/10/03/business/honda-gm-cruise-autonomous.html>; Boudette, N. (2018, January 12). G.M. Says Its Driverless Car Could Be in Fleets by Next Year. In *The New York Times*. <https://www.nytimes.com/2018/01/12/business/gm-driverless-car.html?module=inline>

[33] Looking Further. (n.d.). In *Ford*. <https://corporate.ford.com/innovation/autonomous-2021.html>; The BMW Vision iNEXT Future Focused . (n.d.). In *BMW Group*. <https://www.bmwgroup.com/BMW-Vision-iNEXT>

[34] Dr. James Hedlund. (2018, August). Preparing for Automated Vehicles: Traffic Safety Issues for States. In *Governor's Highway Association.* <https://www.ghsa.org/sites/default/files/2018-08/Final_AVs2018.pdf>

[35] United States Department of Transportation. (2018, October 4). Automated Vehicles 3.0 Preparing for the Future of Transportation. In *United States Department of Transportation*. <https://www.transportation.gov/sites/dot.gov/files/docs/policy-initiatives/automated-vehicles/320711/preparing-future-transportation-automated-vehicle-30.pdf>

[36] Fact Sheet. (2018). In *DriveOhio*. <http://drive.ohio.gov/assets/DriveOhioMediaKit.pdf>

[37] Autonomous Vehicle Operation in Ohio. (2018). In *DriveOhio*. <http://drive.ohio.gov/news/Gov-Kasich-Signs-Executive-Order-Authorizing-Autonomous-Vehicle-Testing-in-Ohio/Autonomous%20Vehicles%20in%20Ohio.pdf>

[38] SAFE used IIHS state-by-state motor vehicle crash deaths for the state of Ohio, as well as the most recent population estimates from the Census Bureau to isolate these impacts.

[39] U, J. (2016, July 15). The Road to Driverless Cars: 1925-2025. In *Engineering.com*. <https://www.engineering.com/DesignerEdge/DesignerEdgeArticles/ArticleID/12665/The-Road-to-Driverless-Cars-1925--2025.aspx>

[40] Ibid.

[41] Ibid.

[42] Ibid.

[43] Promethus Project. (n.d.). In *Eureka Network*. <http://www.eurekanetwork.org/project/id/45>

[44] Dickmanns, E. D. (2007). *Dynamic Vision for Perception and Control of Motion*. London, United Kingdom: Springer-Verlag London.

[45] DARPA Autonomous Land Vehicle. (1986). In *Archive.org*. <https://archive.org/details/DTIC_ADA167472/page/n3>

[46] No Hands Across America. (n.d.). In *Carnegie Mellon University*. <http://www.cs.cmu.edu/afs/cs/usr/tjochem/www/nhaa/nhaa_home_page.html>

[47] 2004 DARPA Grand Challenge. (2004). In *DARPA Grand Challenge*. <https://archive.darpa.mil/grandchallenge04/index.htm>

[48] 2005 Grand Challenge. (2005). In *DARPA Grand Challenge*. <https://archive.darpa.mil/grandchallenge05/index.html>

[49] DARPA Urban Challenge. (2007). In *DARPA*. <https://archive.darpa.mil/grandchallenge/>

[50] Markoff, J. (2007, November 5). Crashes and Traffic Jams in Military Test of Robotic Vehicles. In *The New York Times*. <https://www.nytimes.com/2007/11/05/technology/05robot.html?_r=2>

[51] (n.d.). In *Waymo*. <https://www.waymo.com/>

[52] Autopilot Press Kit. (n.d.). In *Tesla*. <https://www.tesla.com/en_CA/presskit/autopilot#autopilot>

[53] Super Cruise. (2017). In *Cadilac*. <https://www.cadillac.com/world-of-cadillac/innovation/super-cruise>

[54] LeBeau, P. (2018, July 20). Waymo's self-driving cars log 1 million miles on public roads in a month. In *CNBC*. <https://www.cnbc.com/2018/07/20/waymos-autonomous-cars-log-1-million-miles-in-a-month.html>; Tesla Autopilot Miles. (n.d.). In *Human-Centered AI - MIT*. Retrieved from https://hcai.mit.edu/tesla-autopilot-miles/>

[55] Audi A8 - Audi AI Traffic Jam Pilot. (n.d.). In *Audi*. <https://www.audi-technology-portal.de/en/electrics-electronics/driver-assistant-systems/audi-a8-audi-ai-traffic-jam-pilot>

[56] Paukert, C. (2018, May 14). Why the 2019 Audi A8 won't get Level 3 partial automation in the US. In *Road Show by CNET*. <https://www.cnet.com/roadshow/news/2019-audi-a8-level-3-traffic-jam-pilot-self-driving-automation-not-for-us/>

[57] Boudette, N. (2018, October 3). Honda Putting $2.75 Billion Into G.M.'s Self-Driving Venture. In *The New York Times*. <https://www.nytimes.com/2018/10/03/business/honda-gm-cruise-autonomous.html>; Boudette, N. (2018, January 12). G.M. Says Its Driverless Car Could Be in Fleets by Next Year. In *The New York Times*. <https://www.nytimes.com/2018/01/12/business/gm-driverless-car.html?module=inline>

[58] Looking Further. (n.d.). In *Ford*. <https://corporate.ford.com/innovation/autonomous-2021.html>; The BMW Vision iNEXT Future Focused . (n.d.). In *BMW Group*. <https://www.bmwgroup.com/BMW-Vision-iNEXT>

[59] Dr. James Hedlund. (2018, August). Preparing for Automated Vehicles: Traffic Safety Issues for States. In *Governor's Highway Association.* <https://www.ghsa.org/sites/default/files/2018-08/Final_AVs2018.pdf>

[60] SAE International . (2018, June). J3016_201806 Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles. In *SAE International*.<https://www.sae.org/standards/content/j3016_201806/>

[61] Ibid.

[62] United States Department of Transportation. (2018, October 4). Automated Vehicles 3.0 Preparing for the Future of Transportation. In *United States Department of Transportation*. <https://www.transportation.gov/sites/dot.gov/files/docs/policy-initiatives/automated-vehicles/320711/preparing-future-transportation-automated-vehicle-30.pdf>

[63] SAE International . (2018, June). J3016_201806 Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles. In *SAE International*.<https://www.sae.org/standards/content/j3016_201806/>

[64] Ibid.

[65] Ibid.

[66] Ibid.

[67] Ibid.

[68] Ibid.

[69] Ibid.

[70] Ibid.

[71] Ibid.

[72] Ibid.

[73] Ibid.

[74] Ibid.

[75] Ibid.

[76] Ibid.

[77] Ibid.

[78] Ibid.

[79] Ibid.

[80] Ibid.

[81] Ibid.

[82] Ibid.

[83] Ibid.

[84] United States Department of Transportation. (2018, October 4). Automated Vehicles 3.0 Preparing for the Future of Transportation. In *United States Department of Transportation*. <https://www.transportation.gov/sites/dot.gov/files/docs/policy-initiatives/automated-vehicles/320711/preparing-future-transportation-automated-vehicle-30.pdf>

[85] Ibid.

[86] Ibid.

[87] Ibid.

[88] Ibid.

[89] Ibid.

[90] Ibid.

[91] Ibid.

[92] Ibid.

[93] Ibid.

[94] Ibid.

[95] Ibid.

[96] Fact Sheet. (2018). In *DriveOhio*. <http://drive.ohio.gov/assets/DriveOhioMediaKit.pdf>

[97] Autonomous Vehicle Operation in Ohio. (2018). In *DriveOhio*. <http://drive.ohio.gov/news/Gov-Kasich-Signs-Executive-Order-Authorizing-Autonomous-Vehicle-Testing-in-Ohio/Autonomous%20Vehicles%20in%20Ohio.pdf>

[98] Fact Sheet. (2018). In *DriveOhio*. <http://drive.ohio.gov/assets/DriveOhioMediaKit.pdf>

[99] Ibid.

[100] Ibid.

[101] Ibid.

[102] Ibid.

[103] Ibid.

[104] Ibid.

[105] Ibid.

[106] Ibid.

[107] Ibid.

[108] Ibid.

[109] Ibid.

[110] Ibid.

[111] Ibid.

[112] Modernizing Ohio's Transportation System: Progress and Challenges in Providing Safe, Efficient, and Well-Maintained Roads, Highways, and Bridges. (2018, June). In *TRIP National Transportation Research Group*. <http://www.tripnet.org/docs/OH_Progress_and_Challenges_TRIP_Report_June_2018.pdf>

[113] Division of Finance. (2018, September 1). Financial and Statistical Report. In *Ohio Department of Transportation*. <http://www.dot.state.oh.us/Divisions/Finance/Annual%20Reports/2018%20Annual%20Statement.pdf>

[114] Modernizing Ohio's Transportation System: Progress and Challenges in Providing Safe, Efficient, and Well-Maintained Roads, Highways, and Bridges. (2018, June). In *TRIP National Transportation Research Group*. <http://www.tripnet.org/docs/OH_Progress_and_Challenges_TRIP_Report_June_2018.pdf>

[115] Ibid.

[116] Ibid.

[117] Ohio State Highway Patrol Statistics . (2018). In *Ohio State Highway Patrol*. <https://www.statepatrol.ohio.gov/statistics/statspage3.asp>

[118] Modernizing Ohio's Transportation System: Progress and Challenges in Providing Safe, Efficient, and Well-Maintained Roads, Highways, and Bridges. (2018, June). In *TRIP National Transportation Research Group*. <http://www.tripnet.org/docs/OH_Progress_and_Challenges_TRIP_Report_June_2018.pdf>

[119] Ibid.

[120] Ibid.

[121] Ibid.

[122] Ibid.

[123] Ibid.

[124] Ibid.

[125] Gambale, G. (2017). 31st Annual Survey of Corporate Executives: Confidence in U.S. Economy, Need for Investment in Infrastructure Reflected. In *Area Development* . <http://www.areadevelopment.com/Corporate-Consultants-Survey-Results/Q1-2017/responding-executives-confident-about-Trump-economy-skilled-labor-top-concern.shtml>

[126] Modernizing Ohio's Transportation System: Progress and Challenges in Providing Safe, Efficient, and Well-Maintained Roads, Highways, and Bridges. (2018, June). In *TRIP National Transportation Research Group*. <http://www.tripnet.org/docs/OH_Progress_and_Challenges_TRIP_Report_June_2018.pdf>

[127] Ibid.

[128] Orr, D. P. (2006). *Pavement Maintenance*. Ithaca, NY: Cornell Local Roads Program.

[129] 2008 Status of the Nation's Highways, Bridges, and Transit: Conditions & Performance. (2008). In *Federal Highway Administration* . <https://www.fhwa.dot.gov/policy/2008cpr/>

[130] Rembert, M., Feng, B., & Partridge, M. (2017, April). Connecting the Dots of Ohio's Broadband Policy. In *Ohio State University C. William Swank Program in Rural-Urban Policy*. <https://aede.osu.edu/sites/aede/files/publication_files/Connecting%20the%20Dots%20of%20Ohio%20Broadband_0.pdf>

[131] Glancy, D. J., Peterson, R. W., & Graham, K. F. (2016). A Look at the Legal Environment for Driverless Vehicles. *Legal Research Digest, 69*, 3-80.

[132] Ibid.

[133] United States Department of Transportation. (2018, October 4). Automated Vehicles 3.0 Preparing for the Future of Transportation. In *United States Department of Transportation*. <https://www.transportation.gov/sites/dot.gov/files/docs/policy-initiatives/automated-vehicles/320711/preparing-future-transportation-automated-vehicle-30.pdf>

[134] Ibid.

[135] Glancy, D. J., Peterson, R. W., & Graham, K. F. (2016). A Look at the Legal Environment for Driverless Vehicles. *Legal Research Digest, 69*, 3-80.

[136] Park, H., Khattak, Z., & Smith, B. (2018, March). Glossary of Connected and Automated Vehicle Terms-University of Virginia. <http://www.cts.virginia.edu/wp-content/uploads/2018/03/Glossary-of-CAV-Terms-Ver1.0-03052018-1.pdf>

[137] Ibid.

[138] Ibid.

[139] Ibid.

[140] Ibid.

[141] Glancy, D. J., Peterson, R. W., & Graham, K. F. (2016). A Look at the Legal Environment for Driverless Vehicles. *Legal Research Digest, 69*, 3-80.

[142] Ibid.

[143] Ibid.

[144] Ibid.

[145] Ibid.

[146] United States Department of Transportation. (2018, October 4). Automated Vehicles 3.0 Preparing for the Future of Transportation. In *United States Department of Transportation*. <https://www.transportation.gov/sites/dot.gov/files/docs/policy-initiatives/automated-vehicles/320711/preparing-future-transportation-automated-vehicle-30.pdf>

[147] NHTSA. (2016, September 19). Federal Automated Vehicles Policy. <https://www.transportation.gov/AV/federal-automated-vehicles-policy-september-2016>

[148] Ibid.

[149] Park, H., Khattak, Z., & Smith, B. (2018, March). Glossary of Connected and Automated Vehicle Terms-University of Virginia. <http://www.cts.virginia.edu/wp-content/uploads/2018/03/Glossary-of-CAV-Terms-Ver1.0-03052018-1.pdf>

[150] United States Department of Transportation. (2018, October 4). Automated Vehicles 3.0 Preparing for the Future of Transportation. In *United States Department of Transportation*. <https://www.transportation.gov/sites/dot.gov/files/docs/policy-initiatives/automated-vehicles/320711/preparing-future-transportation-automated-vehicle-30.pdf>

[151] Glancy, D. J., Peterson, R. W., & Graham, K. F. (2016). A Look at the Legal Environment for Driverless Vehicles. *Legal Research Digest, 69*, 3-80.

[152] Ibid.

[153] Ibid.

[154] Ibid.

[155] Ibid.

[156] Ibid.

[157] Ibid.

[158] Ibid.

[159] Ibid.

[160] Ibid.

[161] We Can't Wait: Obama Administration Unveils Blueprint for a "Privacy Bill of Rights" to Protect Consumers Online. (2012, February 23). < https://obamawhitehouse.archives.gov/the-press-office/2012/02/23/we-can-t-wait-obama-administration-unveils-blueprint-privacy-bill-rights>

[162] NHTSA. (2016, September 19). Federal Automated Vehicles Policy. <https://www.transportation.gov/AV/federal-automated-vehicles-policy-september-2016>

[163] National Conference of State Legislatures. (2018, November 07). Autonomous Vehicles. <http://www.ncsl.org/research/transportation/autonomous-vehicles-self-driving-vehicles-enacted-legislation.aspx>

[164] Ibid.

[165] Glancy, D. J., Peterson, R. W., & Graham, K. F. (2016). A Look at the Legal Environment for Driverless Vehicles. *Legal Research Digest, 69*, 3-80.

[166] Ibid.

[167] Ibid.

[168] Ibid.

[169] Ibid.

[170] Ibid.

[171] Ibid.

[172] Ibid.

[173] Ibid.

[174] Ibid.

[175] National Conference of State Legislatures. (2018, November 07). Autonomous Vehicles. <http://www.ncsl.org/research/transportation/autonomous-vehicles-self-driving-vehicles-enacted-legislation.aspx>

[176] Glancy, D. J., Peterson, R. W., & Graham, K. F. (2016). A Look at the Legal Environment for Driverless Vehicles. *Legal Research Digest, 69*, 3-80.

[177] National Conference of State Legislatures. (2018, November 07). Autonomous Vehicles. <http://www.ncsl.org/research/transportation/autonomous-vehicles-self-driving-vehicles-enacted-legislation.aspx>; Michigan Legislature. (2016, December 9). Enrolled Senate Bill 998. <https://www.legislature.mi.gov/documents/2015-2016/publicact/pdf/2016-PA-0335.pdf>

[178] Pennsylvania Autonomous Vehicle Testing Policy: Final Draft Report of the Autonomous Vehicle Policy Task Force. (2016, November 2). <https://www.penndot.gov/ProjectAndPrograms/ResearchandTesting/Documents/AV Testing Policy DRAFT FINAL REPORT.pdf>

[179] The General Assembly of Pennsylvania. (2016, June 27). Senate Bill 1267. <https://www.legis.state.pa.us/CFDOCS/Legis/PN/Public/btCheck.cfm?txtType=PDF&sessYr=2015&sessInd=0&billBody=S&billTyp=B&billNbr=1267&pn=1987>

[180] Indiana General Assembly. (n.d.). House Bill 1290 - Transportation finance. <http://iga.in.gov/legislative/2018/bills/house/1290>

[181] Indiana General Assembly. (n.d.). House Bill 1290 - Transportation finance. <http://iga.in.gov/legislative/2018/bills/house/1290#document-d62ab72a>

[182] Bill Status of HB 791. (n.d.). <http://www.ilga.gov/legislation/BillStatus.asp?DocNum=791&GAID=14&DocTypeID=HB&LegId=101170&SessionID=91&GA=100>

[183] Public Act 100-0352. (n.d.). <http://www.ilga.gov/legislation/publicacts/fulltext.asp?Name=100-0352>

[184] Basten, B., & Vandra, B. (2018, June 29). Report of the Governor's Steering Committee on Autonomous and Connected Vehicle Testing and Deployment. <https://wisconsindot.gov/Documents/about-wisdot/who-we-are/comm-couns/av-final-report-062918.pdf>

[185] Gibson, B. (2017). Analysis of Autonomous Vehicle Policies- Kentucky Transportation Center Research Report. <https://uknowledge.uky.edu/cgi/viewcontent.cgi?article=2577&context=ktc_researchreports>

[186] 18 RS SB 116/GA. (n.d.). <http://www.lrc.ky.gov/RecordDocuments/BillNoCache/18RS/SB116/bill.pdf>

[187] United States Department of Transportation. (2018, October 4). Automated Vehicles 3.0 Preparing for the Future of Transportation. In *United States Department of Transportation*. <https://www.transportation.gov/sites/dot.gov/files/docs/policy-initiatives/automated-vehicles/320711/preparing-future-transportation-automated-vehicle-30.pdf>

[188] SAFE used IIHS state-by-state motor vehicle crash deaths for the state of Ohio, as well as the most recent population estimates from the Census Bureau to isolate these impacts.

[189] Charlie Johnson and Jonathan Walker, Peak Car Ownership: The Market Opportunity of Electric Automated Mobility Services, Rocky Mountain Institute, 2016.

[190] The location of jobs is taken from the United States Census Bureau's 2014 Zip Code Business Patterns, which tabulates the number of employers and workers on payroll for each zip code.

[191] Census Bureau, Occupational Employment and Wages, May 2017 Heavy and Tractor-Trailer Truck Drivers; Census Bureau, Occupational Employment and Wages, May 2017 Taxi Drivers and Chaffeurs

[192] Ohio Legislative Service Commission

[193] United States Bureau of Labor Statistics

[194] Ibid.

[195] Ibid.

[196] Ohio Legislative Service Commission

[197] United States Bureau of Labor Statistics

[198] Ibid.

[199] Ibid.

[200] Ohio Legislative Service Commission

[201] United States Bureau of Labor Statistics

[202] Ibid.

[203] Ibid.

[204] Ohio Legislative Service Commission

[205] Educational Attainment: Ohio by the Numbers. (2017, February). In *Ohio Department of Education*. <https://development.ohio.gov/files/research/P7006.pdf>

[206] United States Bureau of Labor Statistics

[207] Educational Attainment: Ohio by the Numbers. (2017, February). In *Ohio Department of Education*. <https://development.ohio.gov/files/research/P7006.pdf>

[208] Ohio Legislative Service Commission

[209] United State Bureau of Labor Statistics

[211] Ibid.

[212] Automated Vehicles Will Create a Shift in Workforce Demands. (2018, August 7). In *American Center for Mobility*. <https://www.acmwillowrun.org/automated-vehicles-will-create-a-shift-in-workforce-demands/>

[213] United States Bureau of Labor Statistics

[214] Ibid.

[215] Ibid.

[216] Wilhelm, A. (2017). Unpacking Lyft's Projected Financials. In *TechCrunch*. <https://techcrunch.com/2017/11/14/unpacking-lyfts-projected-financials/>; Wilhelm, A. (2018, October 26). Understanding Why Uber Loses Money. In *Crunchbase*. <https://news.crunchbase.com/news/understanding-uber-loses-money/>

[217] Uber's Financials: An Inside Look. (2018). In *The Wall Street Journal*. <https://www.wsj.com/graphics/uber-financials/>

[218] State Insurance Regulation: Key Facts and Market Trends. (2017). In *National Association of Insurance Commissioners*. <https://www.naic.org/state_report_cards/report_card_us.pdf>

[219] The State of Auto Insurance 2018. (2018). In *The Zebra*. <https://www.thezebra.com/state-of-insurance/auto/2018/>

[220] Braun, D. (2018, April 11). Nationwide Autonomous and Connected Vehicles Study Insurance Testimony. In *Testimony before Ohio House of Representatives Transportation and Public Safety Committee*.

[221] The State of Auto Insurance 2018. (2018). In *The Zebra*. <https://www.thezebra.com/state-of-insurance/auto/2018/>

[222] Background on: Self-driving Cars and Insurance. (2018, July 30). In *Insurance Information Institute*. <https://www.iii.org/article/background-on-self-driving-cars-and-insurance>

[223] The State of Auto Insurance 2018. (2018). In *The Zebra*. <https://www.thezebra.com/state-of-insurance/auto/2018/>

[224] Understanding Ohio's Comparative Negligence Law. (n.d.). In *Ohio Department of Insurance*. <http://www.insurance.ohio.gov/Newsroom/Tips/Documents/comparativenegligence.pdf>

[225] The State of Auto Insurance 2018. (2018). In *The Zebra*. <https://www.thezebra.com/state-of-insurance/auto/2018/>

[226] Global Automotive Consumer Study. (2018, February). In *Deloitte*; Braun, D. (2018, April 11). Nationwide Autonomous and Connected Vehicles Study Insurance Testimony. In *Testimony before Ohio House of Representatives Transportation and Public Safety Committee;* Background on: Self-driving Cars and Insurance. (2018, July 30). In *Insurance Information Institute*. <https://www.iii.org/article/background-on-self-driving-cars-and-insurance>; Cusano, J., & Costonis, M. (2017, December 5). Driverless Cars Will Change Auto Insurance. Here's How Insurers Can Adapt. In *Harvard Business Review*. <https://hbr.org/2017/12/driverless-cars-will-change-auto-insurance-heres-how-insurers-can-adapt>

[227] Braun, D. (2018, April 11). Nationwide Autonomous and Connected Vehicles Study Insurance Testimony. In *Testimony before Ohio House of Representatives Transportation and Public Safety Committee*; CloserLook: "To be or not to be" is no longer the question: Insurers confront the "when" and "how" of uneven transition as mobility preferences and capabilities evolve. (2018). In *Deloitte* <https://www2.deloitte.com/us/en/pages/financial-services/articles/autonomous-vehicles-and-insurance-industry.html>; Cusano, J., & Costonis, M. (2017, December 5). Driverless Cars Will Change Auto Insurance. Here's How Insurers Can Adapt. In *Harvard Business Review*. <https://hbr.org/2017/12/driverless-cars-will-change-auto-insurance-heres-how-insurers-can-adapt>

[228] Cusano, J., & Costonis, M. (2017, December 5). Driverless Cars Will Change Auto Insurance. Here's How Insurers Can Adapt. In *Harvard Business Review*. <https://hbr.org/2017/12/driverless-cars-will-change-auto-insurance-heres-how-insurers-can-adapt>; CloserLook: "To be or not to be" is no longer the question: Insurers confront the "when" and "how" of uneven transition as mobility preferences and capabilities evolve. (2018). In *Deloitte* <https://www2.deloitte.com/us/en/pages/financial-services/articles/autonomous-vehicles-and-insurance-industry.html>

[229] CloserLook: "To be or not to be" is no longer the question: Insurers confront the "when" and "how" of uneven transition as mobility preferences and capabilities evolve. (2018). In *Deloitte* <https://www2.deloitte.com/us/en/pages/financial-services/articles/autonomous-vehicles-and-insurance-industry.html>; Global Automotive Consumer Study. (2018, February). In *Deloitte*

[230] [230] Braun, D. (2018, April 11). Nationwide Autonomous and Connected Vehicles Study Insurance Testimony. In *Testimony before Ohio House of Representatives Transportation and Public Safety Committee*

[231] Cusano, J., & Costonis, M. (2017, December 5). Driverless Cars Will Change Auto Insurance. Here's How Insurers Can Adapt. In *Harvard Business Review*. <https://hbr.org/2017/12/driverless-cars-will-change-auto-insurance-heres-how-insurers-can-adapt>; CloserLook: "To be or not to be" is no longer the question: Insurers confront the

"when" and "how" of uneven transition as mobility preferences and capabilities evolve. (2018). In *Deloitte* <https://www2.deloitte.com/us/en/pages/financial-services/articles/autonomous-vehicles-and-insurance-industry.html>; Braun, D. (2018, April 11). Nationwide Autonomous and Connected Vehicles Study Insurance Testimony. In *Testimony before Ohio House of Representatives Transportation and Public Safety Committee*; Gammelgard, R. (2018, April 11). StateFarm Automated Vehicle Technology Testimony. In *Ohio House of Representatives Transportation and Public Safety Committee*; Background on: Self-driving Cars and Insurance. (2018, July 30). In *Insurance Information Institute*. <https://www.iii.org/article/background-on-self-driving-cars-and-insurance>

[232] Cusano, J., & Costonis, M. (2017, December 5). Driverless Cars Will Change Auto Insurance. Here's How Insurers Can Adapt. In *Harvard Business Review*. <https://hbr.org/2017/12/driverless-cars-will-change-auto-insurance-heres-how-insurers-can-adapt>

[233] CloserLook: "To be or not to be" is no longer the question: Insurers confront the "when" and "how" of uneven transition as mobility preferences and capabilities evolve. (2018). In *Deloitte* <https://www2.deloitte.com/us/en/pages/financial-services/articles/autonomous-vehicles-and-insurance-industry.html>

[234] Cusano, J., & Costonis, M. (2017, December 5). Driverless Cars Will Change Auto Insurance. Here's How Insurers Can Adapt. In *Harvard Business Review*. <https://hbr.org/2017/12/driverless-cars-will-change-auto-insurance-heres-how-insurers-can-adapt>; CloserLook: "To be or not to be" is no longer the question: Insurers confront the "when" and "how" of uneven transition as mobility preferences and capabilities evolve. (2018). In *Deloitte* <https://www2.deloitte.com/us/en/pages/financial-services/articles/autonomous-vehicles-and-insurance-industry.html; Background on: Self-driving Cars and Insurance. (2018, July 30). In *Insurance Information Institute*. <https://www.iii.org/article/background-on-self-driving-cars-and-insurance>; Braun, D. (2018, April 11). Nationwide Autonomous and Connected Vehicles Study Insurance Testimony. In *Testimony before Ohio House of Representatives Transportation and Public Safety Committee*; Gammelgard, R. (2018, April 11). StateFarm Automated Vehicle Technology Testimony. In *Ohio House of Representatives Transportation and Public Safety Committee*

[235] Cusano, J., & Costonis, M. (2017, December 5). Driverless Cars Will Change Auto Insurance. Here's How Insurers Can Adapt. In *Harvard Business Review*. <https://hbr.org/2017/12/driverless-cars-will-change-auto-insurance-heres-how-insurers-can-adapt>

[236] Ibid.