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DANA O. VIOLA
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STATE OF HAWAII
DEPARTMENT OF THE ATTORNEY GENERAL
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December 2, 2019

The Honorable Ronald D. Kouchi
President of the Senate
and Members of the Senate
Thirtieth State Legislature
State Capitol, Room 409
Honolulu, Hawaii 96813

The Honorable Scott K. Saiki
Speaker and Members of the
House of Representatives
Thirtieth State Legislature
State Capitol, Room 431
Honolulu, Hawaii 96813

Dear President Kouchi and Speaker Saiki:

For your information and consideration, I am transmitting one (1) copy for each of you of the Department of the Attorney General's Preliminary Report on the Hawaii Autonomous Vehicles Legal Preparation Task Force. In accordance with Section 93-16, HRS, I am also informing you that the report may be viewed electronically at http://ag.hawaii.gov/publications/reports/reports-to-the legislature/.

If you have any questions or concerns, please feel free to call me at 586-1282.

Sincerely,

Clare E. Connors
Attorney General

c: David Y. Ige, Governor
Josh Green, Lieutenant Governor
Legislative Reference Bureau (Attn.: Karen Mau)
Leslie Kondo, State Auditor
Neal H. Miyahira, Director of Finance, Department of Budget and Finance
Stacey A. Aldrich, State Librarian, Hawaii State Public Library System
David Lassner, PhD., President, University of Hawaii

Enclosure

STATE OF HAWAII

DEPARTMENT OF THE ATTORNEY GENERAL

PRELIMINARY REPORT OF THE HAWAII AUTONOMOUS VEHICLES LEGAL PREPARATION TASK FORCE

Submitted to
The Thirtieth State Legislature
Regular Session of 2020

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INTRODUCTION

On April 30, 2019, the Hawaii State Legislature adopted House Concurrent Resolution No. 220 ("HCR 220") Requesting the Attorney General to Convene an Autonomous Vehicle Legal Preparation Task Force ("Task Force").

Recognizing that the automotive industry was working towards deploying autonomous vehicles and that autonomous vehicles had the potential to benefit the State of Hawaii, the Legislature requested the Task Force to: (1) examine existing laws across United States jurisdictions relating to legal and insurance regulation of autonomous vehicles; and (2) make recommendations relating to legal and insurance regulation of autonomous vehicles in Hawaii.

The Legislature also asked the Task Force to submit a preliminary report to the Legislature of its findings and recommendations by December 1, 2019, and a final report by December 1, 2020.

In order to better understand the issues surrounding autonomous vehicles, the Chair of the Task Force, William J. Wynhoff ("Chair"), assisted by Deputy Attorney General Julia Verbrugge, invited members of the community to participate in the Task Force, including but not limited to Representative Henry J.C. Aquino, Chair of the House Committee on Transportation; Representative Chris Lee, Chair of the House Committee on Judiciary; Hawaii Insurance Commissioner Colin Hayashida; Deputy Director of the Hawaii Department of Transportation, Highways Division Ed Sniffen; the Alliance of Automobile Manufacturers; representatives from the insurance industry; Hawaii Auto Dealers Association; Ulupono Initiative; Blue Planet Foundation; 350 Hawaii; and professors from the University of Hawaii who provided input regarding the technical as well as social ramifications of autonomous vehicles.

The Task Force formed subcommittees focusing on the following areas pertaining to autonomous vehicles: (1) Legal and Regulatory (2) Technical; (3) Insurance; (4) Environmental; and (5) Social Science. The findings of the subcommittees formed the basis for this preliminary report.

The Legal subcommittee members consisted of Tiffany Yajima and Gary Slovin from SanHi Government Strategies[1] and Bill Kaneko from Dentons U.S. LLP. Professor David Ma, from the College of Engineering University of Hawaii was the Technical subcommittee member while Jeffrey Shonka, President and Chief Executive Officer of First Insurance Company of Hawaii was the Insurance subcommittee member. The Environmental subcommittee was comprised of the following members: Lauren Reichelt from Blue

[1] The Alliance of Automobile Manufacturers ("Alliance") is represented in Hawaii by SanHi Government Strategies. The Alliance is a trade association of twelve car and light truck manufacturers including the BMW Group, Fiat Chrysler Automobiles, Ford Motor Company, General Motors Company, Jaguar Land Rover, Mazda, Mercedes-Benz USA, Mitsubishi Motors, Porsche, Toyota, Volkswagen Group of North America, and Volvo Car USA.

Planet Foundation, Greg Gaug, and Kathleen Rooney from Ulupono Initiative, Brodie Lockard from 350Hawaii, and Sun-Ki Chai, Professor of Sociology at the University of Hawaii. For the Social Science subcommittee, Professor Chai was the sole member. We would like to thank these hard-working individuals for the countless hours they dedicated to this preliminary report.

The following is a report containing chapters written by stakeholders interested in autonomous vehicle deployment, which we hope will serve as a promising start to explore the future for autonomous vehicles in Hawaii. The document should be thought of as an anthology of perspectives on the implications and key considerations of autonomous vehicles, rather than a set of definitive recommendation. The chapters tackle the following perspectives:

- Key legal and regulatory issues – this section summarizes the high level legal and policy considerations and includes a summary of the same in other states.
- Technical summary – this section explores the underlying technology considerations and current state of the practice.
- Insurance – this section explores the implications of these changes on the insurance regime and industry.
- Environmental and energy use – this section outlines the key considerations that could ensure that autonomous vehicles improve our transportation system efficiency, ensures greater transportation access to those who may not be well-served, and support, rather than hinder, our state's clean energy goals.
- Social science – This section discusses AVs and the potential transformations to human experiences, differences in experience due to inequalities in access, changes to the labor market, and redesign of transport systems.

It is important to note that this is not a consensus report, but rather a presentation of the issues as Hawaii moves forward. Not all members agree with all chapters.

Furthermore, this report reviews each topic individually to provide different perspectives and considerations regarding possible policies and regulation around AV deployment. At this point in the process, the stakeholders have not ventured into assessing the different tradeoffs or weighing the various considerations against each other. We believe that such prioritization of tradeoffs is premature at this time and up to policymakers depending on their interests and priorities around regulating AVs.

It is also critical to realize that not all the issues and considerations need to be addressed immediately for Hawaii to take the first step into the autonomous vehicle future. Pilot projects are necessary to assess what is needed for a full regulatory regime and that phasing still needs to be explored more effectively.

1. LEGAL & REGULATORY

I. Introduction

Law and public policy provide the framework by which individuals, organizations, and activities exist to maintain an orderly society. With the development of autonomous vehicles, the State of Hawaii, including the various counties, will ultimately need to address and adopt laws, ordinances, rules, policies, and procedures to govern and regulate a wide range of issues, activities, and behaviors directly and indirectly associated with self-driving vehicles. The legal issues impacting autonomous vehicles ("AV" or "AVs") are wide-ranging, and include the regulation of activities, the appropriation of public resources, and the determination of responsibilities and liabilities of car owners, manufacturers, pedestrians, and any and all parties associated with AVs.

The purpose of this section is to provide a broad overview of key legal and policy issues that will need to be addressed at the State and county levels to enable the testing of and ultimate adoption of AVs as a permitted activity in Hawaii.

II. Legal and Policy Considerations

There are opportunities for both federal and state regulatory oversight of autonomous vehicles that support an open pathway for testing and deployment. At present, the federal government regulates vehicle design, construction, and performance, while it is within each state's purview to regulate traffic laws and regulations, motor vehicle insurance and liability, passenger safety, and local infrastructure and road conditions.

Under this framework, today, virtually all vehicle manufacturers and a number of technology companies are engaged in the development of AV technology. As explained in more detail in the Technical Summary in chapter 2, there are 5 levels of automated driving. In levels 0–2, a human driver is solely responsible for monitoring the road and environment around the car. For levels 3–5 this monitoring task is done by the automated driving system.

Although more than half of all U.S. states have addressed autonomous vehicle deployment either through regulatory action or by executive order, vehicle manufacturers are engaged in extensive piloting of level 3, 4, and 5 autonomous vehicles in only a handful of test markets with favorable market conditions. As Hawaii continues to make progress toward autonomous vehicle acceptance, the state government should consider all options that can fully support companies seeking to enter the Hawaii market.

Key considerations that would create favorable regulatory conditions for autonomous vehicle testing and deployment include state licensing requirements, liability and insurance considerations, traffic laws, and enforcement, and potential registration barriers. In addition, factors such as consumer trends, land use, infrastructure needs, cybersecurity, data privacy, social acceptance, environmental impacts, and others raise important questions that need to be considered.

Traffic and Infrastructure

Upgrades to street and highway infrastructure for AVs and non-AVs alike are costly but necessary. Lane markings are a top priority, for example, and should be clear and consistent and protected from prior, erroneous markings. Consistency across traffic signals and signs, crosswalks, and speed bumps also are important factors to consider. In addition, consistent implementation of standards and recommendations from the U.S. Department of Transportation's Manual of Uniform Traffic Control Devices is essential to the safe operation of self-driving vehicles.

Technology and Cybersecurity

To fully deploy, implement, and maintain AVs in Hawaii will require robust telecommunications infrastructure and capacity. High speed and reliable connectivity that is free from interference is essential to operate AVs. Short of that, AVs will not be operational and potentially will cause harm and disruption to consumers, pedestrians, and businesses. AVs will require sophisticated technological support, including high-speed data nodes, links, cables, and broadband connectivity. To support and encourage such technology infrastructure, State and county governments can mandate, incent, charge and/or allocate public resources to ensure technological capability to operate AVs. Investment in such public infrastructure is essential.

Autonomous vehicles require tremendous amounts of data that helps in the development of an AV's driving system. Nationally, automakers are monitoring new developments and technologies and continue to review the Automotive Consumer Privacy Protection Principles to protect personal information collected through in-car technologies.

In addition, cybersecurity concerns must be addressed. At the national level, automobile manufacturers are working in partnership through the Auto Information Sharing and Analysis Center (ISAC) to establish minimum requirements on autonomous vehicle security engineering processes.

Nationally, ISAC members are sharing information about physical and cyber threats, vulnerability, and incidents in order to create a common and internationally agreed upon standard for automotive cybersecurity engineering. The ISAC goal is to create specific minimum requirements for security engineering processes and to define criteria for assessment. This should continue to be addressed at the federal level. *See also the Technical Summary in chapter 2 which explores technology and cybersecurity issues in more detail.*

Motor Vehicle Safety

Motor vehicle safety is primarily regulated by the Federal government, which provides strict safety standards and regulations for manufacturers of motor vehicles and equipment. The Federal Motor Vehicle Safety Standards (FMVSS) and Federal Motor Carrier Safety Regulations (FMCSRs) provide technical and quality standards on virtually all aspects of a motor vehicle, including seat-belts, windshields, brakes, tires, and hood latches; as well as protecting against accidental rollaway, impact protection for the driver, and occupant crash protection.

With the technical overlay of additional electronic components and equipment of AVs, the Federal government will be required to adopt laws and promulgate additional rules. In May 2019, the National Highway Traffic Safety Administration (NHTSA) and the Federal Motor Carrier Safety Administration (FMCSA) announced they will publish in the Federal Register advance notices of proposed rulemaking (ANPRMs) seeking public comment on possible amendments to two sets of federal regulations that impact autonomous vehicles: the FMVSS and the FMCSRs. Both agencies' calls for public comment are aimed at determining whether the rules and regulations currently in place could hamper the effective rollout of autonomous vehicles.[1]

Insurance

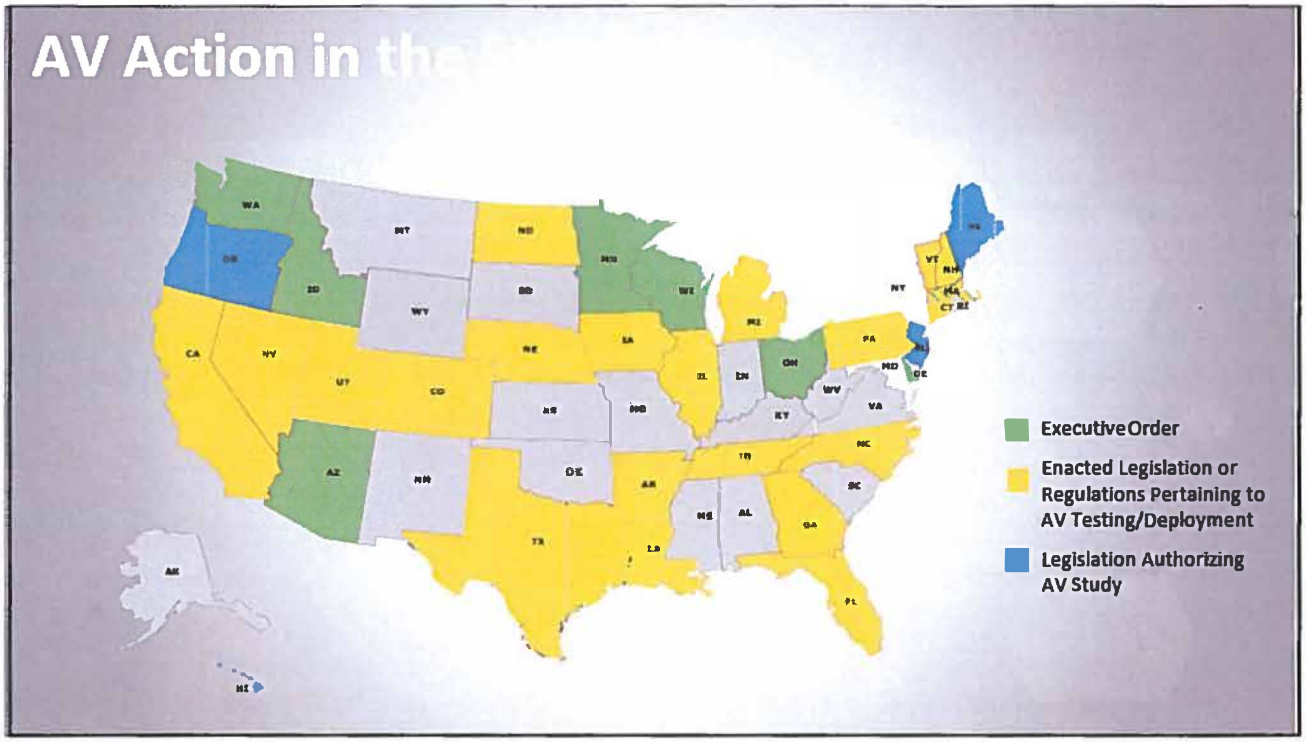
Because the insurance industry is primarily regulated by each state, Hawaii will be required to adopt a series of legal and regulatory measures relating to the entrance of AVs into the marketplace. For example, there may be a shift of liability from the driver to the autonomous vehicle operator and the vehicle manufacturer. Additionally, software designers, technology and telecommunication providers also bear potential risk and liability since AVs will rely on the uninterrupted service required to run driverless vehicles. The degree of driver control, depending upon the level of autonomy, could also be a factor in determining liability, depending on the driver's ability to intervene if the autonomous system ran into difficulty.

It is anticipated that three new business lines of insurance, all of which would need to be regulated, may develop: 1) cybersecurity – protection against remote vehicle theft, unauthorized entry, ransomware and hijacking of vehicle controls; 2) product liability for sensors and software algorithms; and 3) insurance for public infrastructure, including cloud server systems that manage traffic and road networks.

The impact of AVs on the insurance industry is explored in further detail in chapter 3 of this report.

III. State by State Regulatory Overview[2]

Currently, at least 22 states have adopted legislation pertaining to the operation of autonomous vehicles, while at least 10 states, including Hawaii, have issued executive orders related to AVs. This section provides a summary overview of state legislative action or action by executive order to address autonomous vehicles in state jurisdictions.



Source: The Alliance of Automobile Manufacturers

Hawaii

In 2017, Hawaii Governor David Ige signed Executive Order No. 17-07 that opened Hawaii's doors to the testing and deployment of driverless vehicle technology. The executive order established an autonomous vehicle contact in the Office of the Governor to support companies seeking to test self-driving vehicle technology in Hawaii, and encouraged Hawaii's departmental agencies to work with companies seeking to do self-driving vehicle testing and development.

As previously discussed, in 2019, the Hawaii state legislature adopted HCR 220, which further recognized Hawaii as an ideal location for autonomous vehicle testing and use. HCR 220 has resulted in this preliminary report.

Alabama

Alabama does not specifically regulate autonomous passenger vehicles, but the state has passed legislation concerning autonomous truck platooning. Looking forward, Alabama lawmakers are paying greater attention to the subject of widespread autonomous transit.

In 2017, the state Senate created a Legislative Committee on Self-Driving Vehicles to study the issue and in March 2019, legislation was introduced to explicitly permit autonomous vehicles to operate in the state.

Arizona

Arizona has one of the most permissive AV frameworks in the country. Pursuant to a series of executive orders, automakers need only notify the Arizona Department of Transportation before testing, as long as their vehicles comply with state and federal laws governing motor vehicles. As a result, Arizona is seen as a hotbed of AV innovation and has attracted the attention of manufacturers and developers who are testing extensively in the state.

Arkansas

Arkansas lawmakers passed legislation in 2019 that allows AV companies to operate up to three vehicles in the state under an approved pilot program. Already, Walmart, a proponent of the legislation, has announced plans to test self-driving delivery trucks. The state also passed legislation in 2017 that allows driver assistive truck platooning (DATP).

California

California strictly regulates autonomous vehicles and has enacted several laws that establish procedures for the testing and deployment of driverless cars. Operators must meet specific requirements and go through a DMV-administered application process to obtain a permit for testing. Recently, the state expanded its program to allow testing without the need for backup drivers.

Colorado

Colorado has an open regulatory scheme, passed in 2017, that only requires driverless vehicles to comply with existing state and federal law. The Colorado Department of Transportation is even partnering with manufacturers and technology companies to deploy Cellular Vehicle-to-Everything (C-V2X) technology along Interstate 70.

Connecticut

Of the states that have passed autonomous vehicle laws, Connecticut has one of the strictest regulatory structures. Operators must go through a multistage approval process, and testing is only allowed in four municipalities that are designated by the Department of Transportation.

Florida

Under recently enacted legislation, Florida amended its existing AV regulations so that driverless vehicles may now freely operate in the state provided that they comply with existing state and federal laws and carry liability insurance of $1 million.

Georgia

Georgia allows the operation of both autonomous vehicles and trucks under legislation passed in 2017. Driverless vehicles are free to operate in the state as long as they are fully insured and registered with the Department of Motor Vehicles. At present, no robo-taxi services are operating in the state; however, several autonomous shuttle projects are in their infancy.

Illinois

While Illinois has no legislation directly regulating autonomous vehicles, an executive order allows their operation in the state. Under that order, all testing must be approved by the state Department of Transportation prior to deployment, and vehicles can only be operated with an employee of the manufacturer behind the wheel. Legislation proposed in 2019 would allow testing and operation of completely driverless cars.

Indiana

Indiana currently has no laws or regulations concerning autonomous vehicles; however truck platooning is allowed under 2017 legislation. There was an effort this past legislative session to create an autonomous task force with the power to approve operation of fully driverless vehicles in the state, but it failed to receive a vote in the state legislature.

Iowa

Legislation passed this year allows for the operation of fully autonomous vehicles that meet basic insurance requirements. Currently, the University of Iowa is testing driverless cars along a one-mile stretch of rural road near Cedar Rapids.

Louisiana

Louisiana law allows for the operation of both autonomous vehicles and autonomous truck platoons. Legislation passed this year permits driverless vehicles to operate in the state as long as liability insurance of $2 million is in place and is certified by the state Department of Transportation.

Maine

Maine does not currently have any laws or regulations allowing for autonomous vehicles. However, 2018 legislation authorized creation of a Commission on Autonomous Vehicles to coordinate efforts among state agencies and stakeholders to develop a process for testing automated driving systems on a public way. The law requires that the Commission issue an initial written report on its progress by January 15, 2020, and a final report containing findings and recommendations, including suggested legislation, by January 15, 2022.

Maryland

While Maryland does not have any laws explicitly governing autonomous vehicles, the state Department of Transportation has adopted regulations for their operation, including an approval process requiring operator self-certification and insurance coverage of $5 million.

Massachusetts

A 2017 executive order outlined extensive requirements for the operation of autonomous vehicles in the state, including setting maximum speeds and confining the vehicles to specific geo-fenced areas. Some tech companies are already piloting vehicles in Boston, and 15 more municipalities have signed agreements with the state to begin testing.

Michigan

Legislation passed in 2016 allows for testing of driverless vehicles provided that the vehicle is operated by an employee of the manufacturer or a university researcher. Vehicles must operate within predetermined geographic areas and be equipped with crash notification technology.

Minnesota

Minnesota has no laws or regulations specifically addressing autonomous vehicles. According to the state's Department of Transportation, any automated vehicles operating in the state must adhere to "current statute and laws." However in 2018, an executive order creating a Governor's Advisory Council on Connected and Automated Vehicles was established to study the pros and cons and recommend a path forward.

Nebraska

In April 2018, Nebraska lawmakers cleared the way for companies to test self-driving vehicles if the vehicle is capable of operating in compliance with traffic and motor vehicle safety laws. The AV may or may not contain a human driver, but if a human driver is present, he or she must be a licensed driver and covered by insurance. The law also authorizes the operation of an on-demand AV network for the transport of persons or goods, including for-hire transportation or public transportation.

Nevada

Nevada was the first state to pass AV legislation in 2012 and has been at the forefront of driverless vehicle innovation. Recently, the Nevada legislature amended its AV laws to simplify and clarify legal authority over AVs and to permit the testing and full commercial public deployment of self-driving vehicles in the state and to authorize driver-assistive platooning technology.

New Hampshire

A bill that passed the state legislature last year would have created an AV permitting process in New Hampshire but was ultimately vetoed by the governor. Despite the veto, the governor has not entirely foreclosed the possibility of allowing autonomous vehicles on New Hampshire roads, stating that he would consider signing a future bill with greater safety protections.

New York

New York has highly restrictive regulations on AV testing. Under legislation approved in 2017, any testing must be approved by the commissioner of the Department of Motor Vehicles and supervised by the New York State Police. While more relaxed requirements were proposed in the last legislative session, they failed to pass.

North Carolina

Autonomous vehicles in North Carolina face few restrictions. A 2017 law permits their operation as long as they are covered by insurance and meet existing state and federal laws.

North Dakota

North Dakota legislation passed this year allows both driverless vehicle operation and truck platooning. However, no manufacturers appear to be testing in the state as yet.

Ohio

A 2018 executive order positioned Ohio as a leader in the driverless vehicle space. To attract AV researchers, developers and manufacturers, the EO created DriveOhio, a new division of the state Department of Transportation that allows any company to test AVs in the state as long as they register with DriveOhio and have a backup driver behind the wheel.

Oregon

While the state has no current legislation concerning autonomous vehicles, a 2016 law did create an AV task force, which issued its recommendations this year. The Oregon state legislature recently considered legislation that would codify many of the task force recommendations into law, including registration and insurance requirements.

Pennsylvania

Pennsylvania law does not explicitly regulate autonomous vehicle testing, but the state Department of Transportation has created a voluntary registration process. The city of Pittsburgh does have a friendly regulatory climate and offers local government incentives, and therefore has become a hotbed of AV testing.

Tennessee

Legislation passed in 2017 allows certified autonomous vehicles to operate in the state, provided they contain automatic crash recording and notification technology. While no large-scale testing is occurring in the state, a consortium made up of government agencies, universities, and companies with ties to the state, hopes to encourage collaboration and innovation in the AV area.

Texas

Texas's AV-friendly regulatory environment has made the state a magnet for autonomous vehicle testing. State law allows for any autonomous vehicle to operate so long as each is equipped with a collision recording system and the operator has the required insurance policy. Some AV companies have made Houston a primary testing site, partnering with grocery chains and restaurants to make deliveries directly to consumers.

Utah

Driverless vehicles are now expressly permitted on Utah roads under legislation approved this year. While any properly insured autonomous vehicles are allowed to operate, autonomous networks must be registered with the state. This past April, the Utah Transit Authority, in partnership with the state Department of Transportation, began limited testing of an autonomous shuttle in Salt Lake City.

Virginia

Despite having no laws or regulations specifically pertaining to autonomous vehicles, the state has taken an active role in encouraging testing and deployment. Seventy miles of Virginia highways have been designated "automated corridors" and outfitted with high-definition mapping and data acquisition systems to support automated-vehicle testing. Virginia is a prime example of the fact that autonomous vehicles can operate in any state, regardless of whether the state has a regulatory framework, as long as the operator adheres to state and federal law.

Washington, DC

In 2012 the District of Columbia became one of the first jurisdictions to pass legislation regarding the testing of autonomous vehicles. All vehicles tested in the city must have backup drivers and be capable of following the city's traffic laws. An Autonomous Vehicle Working Group, established by Mayor Muriel Bowser in February 2018, has been in discussions with multiple automakers in its search for a partner to pilot an autonomous vehicle program.

Wisconsin

The Wisconsin legislature has not passed any AV laws or regulations; however, a 2017 executive order proposes a regulatory structure for driverless vehicles. An oversight committee has made recommendations, including requiring municipal oversight, an application process and backup drivers. While these have yet to be enacted, the committee also noted that it believes current state law "does not prohibit the operation of autonomous vehicles."

IV. Regulatory Guidance

If the State of Hawaii seeks to move forward with AVs, there are numerous State planning, policy, funding, legal, and regulatory actions that need to occur.

As a matter of statewide policy, the Hawaii State Plan codified under Hawaii Revised Statutes chapter 226 is the over-arching document that provides the vision and planning framework for Hawaii's future. Section 226-10(b)(16) includes a preliminary policy framework for AVs, calling for the "research and development of nonfossil fuel and energy efficient modes of transportation."

In addition, the Hawaii Statewide Transportation Plan should also be updated to include AVs, and include a coherent and methodical approach to plan for and fund public infrastructure and highway improvements needed to operate AVs. Broadband capacity, roadway improvements such as adequate striping of lanes, and cybersecurity measures to ensure uninterrupted technology service are essential to operate AVs. State funds, including potential incentives to attract AVs to Hawaii, would be necessary.

<u>Legislative Considerations</u>

As Hawaii's state policymakers consider AV legislation, the following are key considerations that would establish a basic regulatory framework for autonomous vehicle testing and deployment in Hawaii:

- Create a level playing field for all types of vehicles including electric AVs and

AVs powered by internal combustion engines.

- Freely authorize the deployment of all AV applications related to the transportation of goods and people, including ride-sharing.
- Authorize safe testing and deployment of autonomous vehicles including AVs with level 3, 4 and 5 automation.
- Each level of government has an important role in AV governance. States need flexibility to govern licensing, registration, insurance and law enforcement. Preemption of local level regulations will avoid a patchwork of differing legislation across county lines.
- Require autonomous vehicles to adhere to all state and federal laws when applicable and require that all automated driving system-equipped vehicles comply with state insurance requirements before operating on public roads.

It will be important to bring stakeholders together, including legislators, state transportation officials, automobile manufacturers, insurers, technology companies, the University and academic think-tanks, as well as other interested parties who participated in the Autonomous Vehicle Task Force, to discuss these important issues for our State.

Applicable Sections of Hawaii Revised Statutes

The regulation of AVs, motor vehicles, commercial enterprises, common carriers and rideshare activities will likely require changes in Hawaii law. As previously mentioned, insurance and liability matters may shift from the driver to the AV manufacturer and operator, including technology and broadband providers that are part of AV operations. Changes in Hawaii's insurance law may also be required.

The following is a summary of State laws that would impact the introduction, operation, and regulation of AVs, including the potential likelihood of new chapters and sections within the Hawaii Revised Statutes.

Title	Description	Chapter	Description	Section	Relevancy
10	Public Safety and Internal Security	128B	Cybersecurity	128B-1	Cybersecurity and cyber resiliency
13	Planning and Economic Development	206N	Wireless Broadband and Communications Network	206N-1	Infrastructure and policy provisions for broadband
13	Planning and Economic Development	226	Hawaii State Planning Act	226-1 to 101	Establishment of State's planning priorities
13	Taxation	249	County Vehicular	249-1 to 31	Imposes tax for motor vehicles
14	Taxation	251	Rental Motor Vehicle, Tour Vehicle, and Car-Sharing Vehicle Surcharge tax	251-1	Imposes tax for various commercial vehicles
15	Transportation and Utilities	264	Highways	264-1 to 121	Various provisions for public highways and trails
15	Transportation and Utilities	265A	County Highways and Sidewalks	265A-1	County authority of Roadways
15	Transportation and Utilities	269	Public Utilities Commission	269-1	Regulation of utilities, motor carriers
15	Transportation and Utilities	271	Motor Carrier Law	271-1	Regulates commercial transportation activities
15	Transportation and Utilities	279A	Statewide Transportation Planning	279A-1	Establishes Statewide transportation plan
15	Transportation and Utilities	279D	Metropolitan Planning Organizations	279D-1	Regulates metropolitan planning organizations
15	Transportation and Utilities	279G	Ridesharing	279G-1	Regulates ridesharing arrangements
17	Motor and Other Vehicles	286	Highway Safety	286-1 to 301	Provisions to ensure Highway safety
17	Motor and Other Vehicles	288	Common Carriers, Compulsory Insurance	288-1	Regulates common carriers of passengers
17	Motor and Other Vehicles	291	Traffic Violations	291	Regulates traffic and driver behavior
17	Motor and Other Vehicles	291C	Traffic Code	291C-1 to 221	Regulates traffic and driver behavior
17	Motor and Other Vehicles	291D	Adjudication of Traffic Infractions	291D-1	Traffic violation procedures
24	Insurance	431	Motor Vehicle Insurance	431:10C-101 to 701	Insurance and provisions for motor vehicles

25	Professions and Occupations	437	Motor Vehicle Industry Licensing Act	437-1-51	Regulation and licensure of motor vehicle industry
25	Professions and Occupations	437B	Regulation of Motor Vehicle Repairs	437B-1	Regulates motor vehicle repair dealers and mechanics
25	Professions and Occupations	437D	Motor Vehicle Rental Industry	437D-1	Regulate leasing of rental motor vehicles
26	Trade Regulation and Practice	481I	Motor Vehicle Express Warranty Enforcement	481I-1	State lemon law
26	Trade Regulation and Practice	481J	Used Motor Vehicle Sales and Warranties	481J-1	Regulates sale of used motor vehicles
26	Trade Regulation and Practice	481R	Vehicle Protection Product Warrantors	481R-1	Vehicle protection products
26	Trade Regulation and Practice	487	Consumer Protection	487-1	General provision for consumer protection
36	Civil Remedies and Defenses and Special Proceedings	657	Limitation of Actions	657-1	Tort liability

V. Conclusion

As Hawaii explores AVs as a transportation option, the Hawaii State Legislature and the various County governments will need to enact legislation to account for the new and expanded roles, responsibilities, and activities that will transpire. The Federal government also has legal jurisdiction over significant aspects of AVs, particularly related to vehicle manufacturing and safety. At the state and local level, the variety of issues are broad and complex, and the type and level of regulation can also impact the degree to which AVs are tested and ultimately adopted in Hawaii.

While AV technology continues to advance as the result of extensive research, development, testing and deployment, it is vital to create an open regulatory environment for all forms of innovation. Limiting the testing and ultimate deployment of autonomous vehicles to electric-only platforms while also limiting AVs to shared platforms only would seriously affect interest in Hawaii as a market for autonomous vehicle technology.

Endnotes

1. Source: Dentons, New Federal Autonomous Vehicles Rules on the Horizon (May 28, 2019).

2. TECHNICAL SUMMARY

1. Introduction

Connected and autonomous vehicles (AVs) fall under the umbrella of intelligent transportation systems that have a great potential to change our daily life. AVs can refer to a variety of vehicle technologies that are capable of reducing traffic accidents, enhancing quality-of-life, and improving the efficiency of transportation systems. Additionally, AVs can generate useful data from these connected vehicles, which including both vehicle-centric and infrastructure-oriented data. The developments of AVs work both on the level of the vehicle and transportation system. Many types of vehicle connectivity and automation are feasible and coordinated in many ways. AVs AVs have the potential to extend what is possible with driving automation and vehicle connectivity alone. Connectivity has the potential to dramatically improve environment awareness and safety of autonomous vehicles. Automation can make full use of connectivity, especially fast vehicle-to-vehicle communication. [1] The success of AVs depends both on the on-board instrumentation and surrounding environment including road infrastructure and other road users. Thus, five areas lie at the heart of AVs research: inter-AV communications, security and privacy, intersection navigation control, collision avoidance, and pedestrian detection. [2]

AVs rely on public infrastructure and impose external costs, so require more public planning and investment than most other technologies. In order to allow the technology to reach its full potential, government officials, planners, and economic developers need to prepare for infrastructure investments, autonomous vehicle regulations, and AV-induced safety issues. Sound and consistent policy at the state, regional, and local government levels will nudge AVs towards outcomes that would benefit society. Many states and communities are moving forward with efforts to encourage the developments of AVs in their jurisdictions and to prepare for the future, such as Michigan, California, Florida, and Texas.

To identify the best path forward for AVs, it is important to explore and assess public perceptions. The U.S. Department of Transportation conducted a series of driver acceptance clinics (DACs) to obtain feedback on connected vehicle technology and safety applications. The Center for Automotive Research (CAR) researchers designed a web-based survey to gather quantitative data on perceptions of the U.S. population of AVs. The results of the survey are generally encouraging. However, public perceptions of AVs are dynamic, complex, and hold deep transportation policy implications. [3]

The development of AVs is taking place across multiple disciplines, as well as in academia and public sector. For now, the transformative technology is still being developed, tested and evaluated. In order to critically evaluate the significance and technical soundness of AVs, this report conducts a comprehensive summary. It covers five areas related to AVs: major technical components, current developments in different states, critical evaluations of benefits and limitation, perceptions of the U.S. population of AVs, and roles the state government should play in AVs deployment.

2. Connected and Autonomous Vehicles

2.2.1 System Components

Connected and autonomous vehicles (AVs) can be defined as vehicles that are capable of automated driving and connectivity with other vehicles or road users, the road infrastructure, and the cloud (Guanetti et al., 2018). The successful deployment of AVs in an intelligent transportation system depends on vehicle connectivity system, vehicle automation system, transportation infrastructure, and communication infrastructure.

Vehicle Connectivity System

Vehicle connectivity enables the exchange of digital communication between a vehicle and the surrounding environment. Connectivity has emerged in the past decades to improve safety, mobility, and vehicle cooperation. As considered within the U.S. DOT Connected Vehicle Research Program, vehicle connectivity focuses on vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I) and vehicle-to-everything (V2X) system communication. Dedicated Short Range Communication (DSRC) and cellular communication (4G and 5G) support the development of vehicle connectivity. DSRC is a wireless communication technology, which was designed to ensure timely and low-latency communication. DSRS has been used by U.S. DOT and several private companies to develop standards and products. The applications of DSRC include safety warnings, intersection assistance and safety, traffic conditions, payment of tolls and parking assistance. Cellular communication enables access to cloud-based data and services. With the development of 5G technology, cellular communication may also compete with DSRC for V2V and V2I communications.

Vehicle Automation System

The Society of Automobile Engineers (SAE) international [4] defined five levels of automated driving. A summary describing the levels is provided below in Figure 1. In levels 0–2 human driver was solely responsible for monitoring the road and environment around the car. For levels 3–5 this monitoring task is done by the automated driving system. An automated vehicle is “driverless” or “autonomous” only when the vehicle (i) controls both steering and acceleration/deceleration, (ii) does not expect the human driver to monitor the driving environment, and (iii) does not rely on the human driver as the fallback for the driving task. [5] Currently, many automakers and technology developers are working to bring automated vehicles to market for use on public roads in real-world conditions, such as Tesla Motors, Google, and Apple.

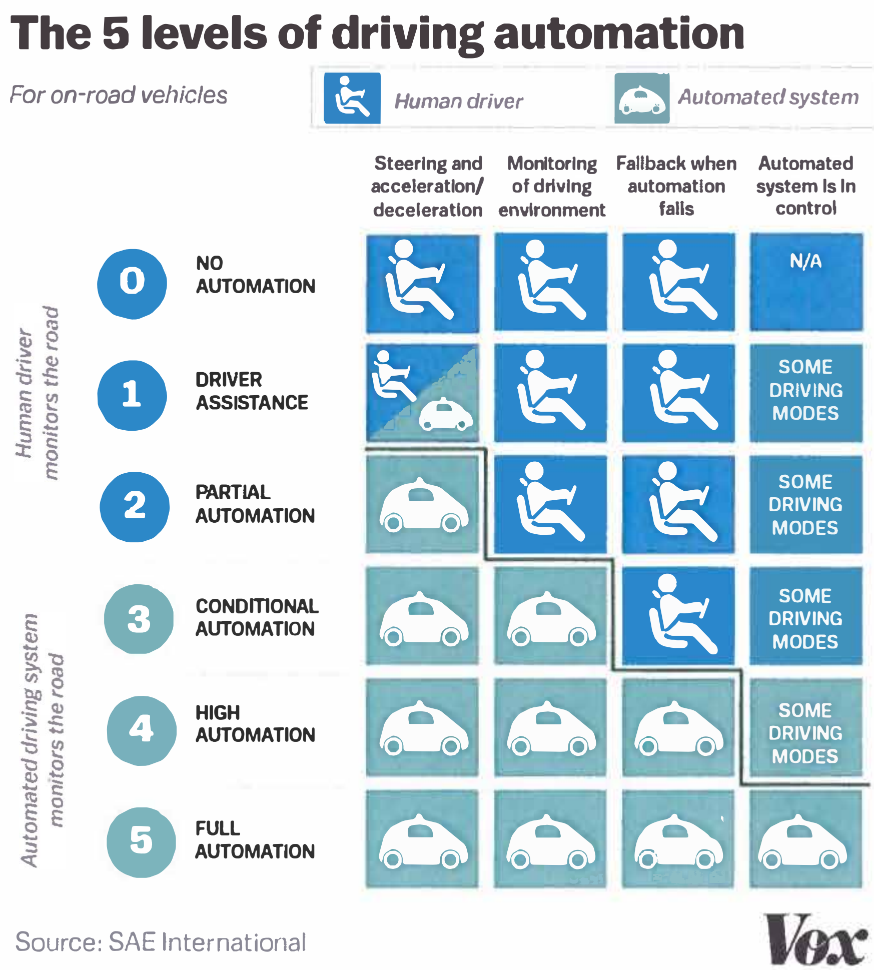


Figure 1. SAE J3016 Levels of Driving Automation (Source: SAE International)

Automated systems operate on a general three-phase design: monitoring, agency, and action (Figure 2). Additionally, automated systems can be considered as intelligent when feedback loops are incorporated.

- Monitoring: Automated vehicles must be capable to accepting raw information about the environment. This includes data from sensors, input from the operator, and data received from wireless connectivity.

- Agency: A system agency is comprised of a series of algorithms that process data from the monitoring process and decide how to act on that data.

- Action: The action component is responsible for controlling and moving the system.

- Feedback loop: The feedback loop allows the system to modify its performance in response to previously actions.

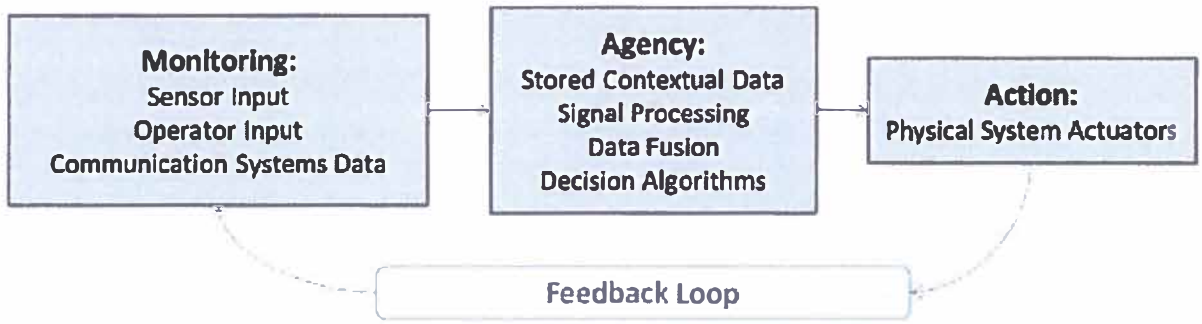


Figure 2. Automated system (Source: Center for Automotive Research).

Automotive sensors allow an automated vehicle to sense the environment. The main sensors equipped on automated vehicles include GPS/Inertial Measurement Unit (IMU), camera, Light Detection and Ranging (LiDAR), ultrasonic sensor, radio detecting and ranging (radar), and audio sensor. Figure 3 displays the functions of four main onboard sensors.

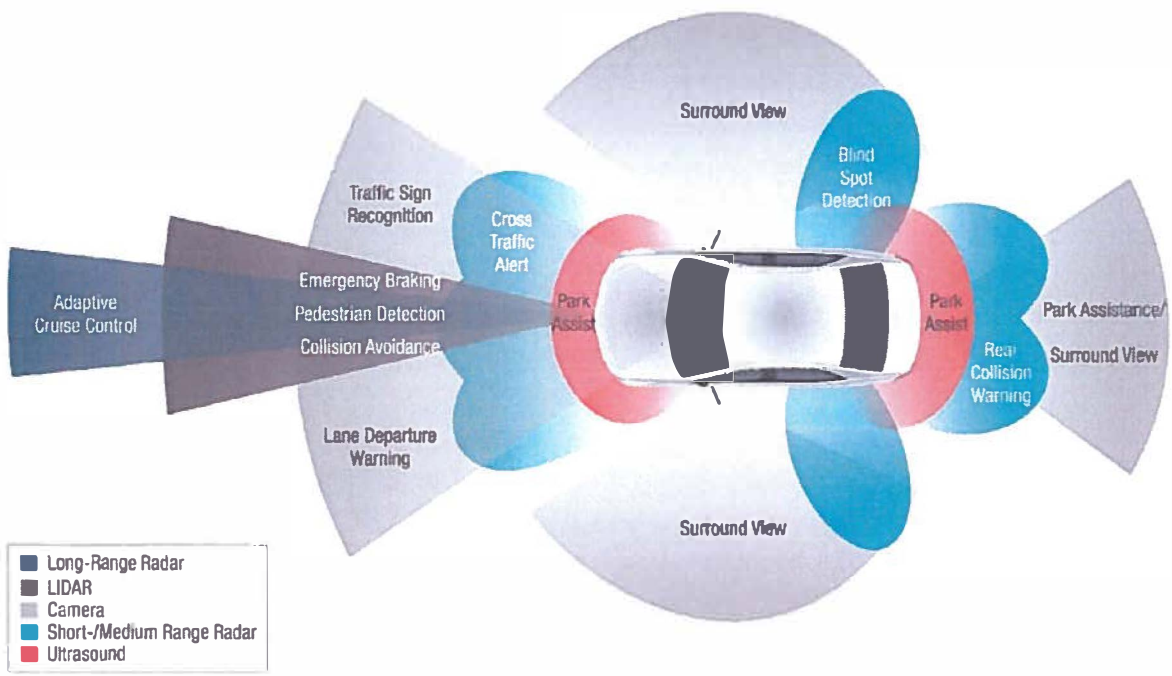


Figure 3. The combination of four main onboard sensors for automated vehicles (Source: Texas Instruments).

- GPS uses real time geographical data received from several GPS satellites to calculate longitude, latitude, speed and course to help navigate automated vehicles. IMU is a device that directly measures a vehicle's three linear acceleration components and three rotational rate components. IMU is a key dynamic sensor to steer the vehicle dynamically, maintaining better than 30-cm accuracy for short periods when other sensors go offline.

- Camera is designed to sense color and shape of objects, which are especially important of detecting traffic lights and the flashing lights of emergency vehicles.

- LiDAR measures distance between the sensor and a target surface by determining the elapsed time between the emission of a short duration laser pulse and the arrival of the reflection of that pulse (the return signal) at the sensor's receiver. Differences in laser return times and wavelengths can then be used to make digital 3-D representations of the target. LiDar is great at capturing information in various types of ambient light (whether night or day), whereas cameras may have difficulty in handling certain occasions caused by shadows or poor lighting conditions.

- Ultrasonic sensor emits sound waves and use reflected waves to measure the distance. These sensors are mostly used for close range applications (i.e., 10 to 20 feet) such as parking assistance.

- Radar transmits microwave radiations and collects reflected waves to measure the speeds and directions of surrounding objects. Due to attributes of microwave, radars are able to operate without limitations of weather conditions (e.g., rain, snow, fog, darkness). Radar is the most preferred AV sensor as it is inexpensive and can perform multiple tasks from short-range to medium and long range applications.

- Audio sensor is designed to discern the direction of sirens. It can detect police and emergency vehicle sirens up to hundreds of feet away.

Transportation Infrastructure

- Changes to existing transportation infrastructure may be required by the transition from human-driven to AVs. This issue will need to be further explored and includes but is not limited to roadway markings, signage, signalization, lane width, and access management as noted below.

- Access Management: The transition from human-driven to autonomous vehicles may require the change from parking to drop-off and pick-up areas. These drop-off and pick-up point will not only appear in airports and train station but also office buildings, commercial areas, apartments buildings and so on.

Communication Infrastructure

Dedicated short range communications (DSRC) allows AVs to communicate with each other and the infrastructure. DSRC uses 75MHz bandwidth near the 5.9GHz spectrum, which is controlled and allocated by the Federal Communications Commission (FCC). In terms of communication range, DSRC covers a maximum of 500 feet in all weather conditions. [8] DSRC system is broken down into two categories of hardware: road infrastructures and user-related equipment. (Figure 4).

Road infrastructures:

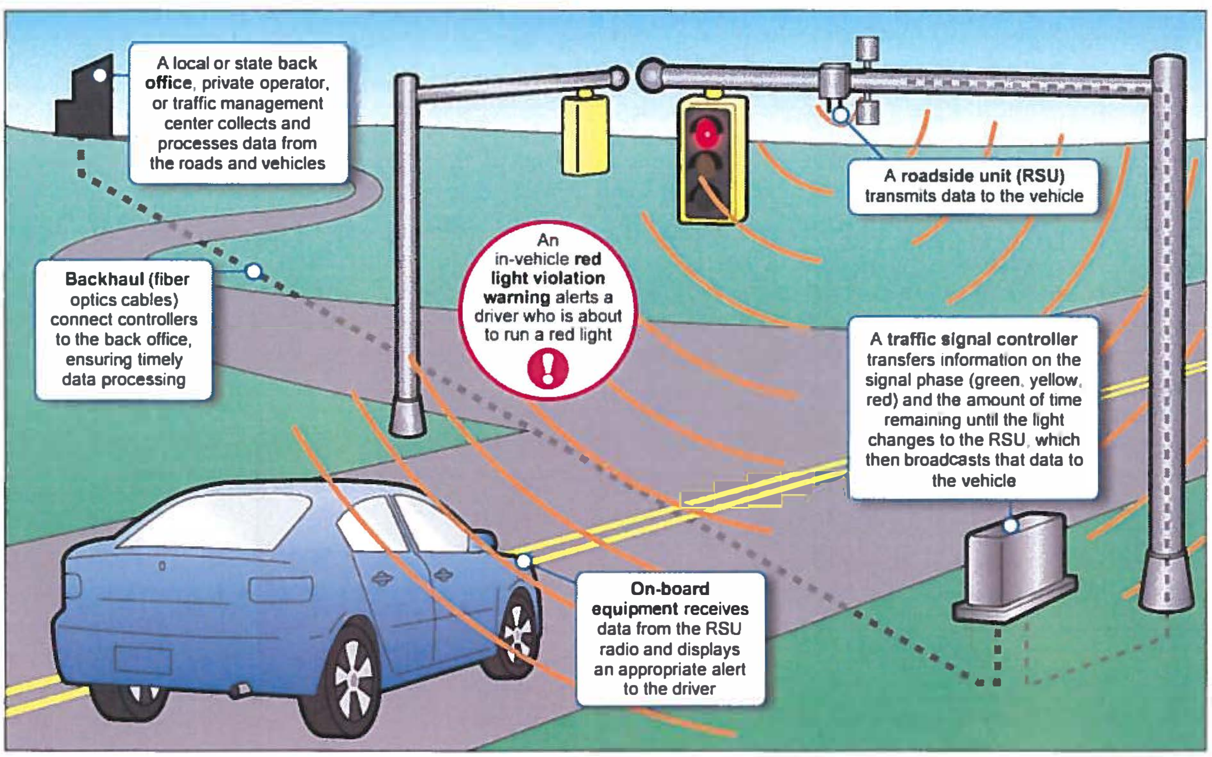
- Roadside units (RSUs) that transmit and receive data from nearby vehicles. The RSUs contain a processor, data storage, and communication capabilities.

- Traffic signal controllers that generate the Signal Phase and Timing (SPaT) message (green, yellow, red, and the amount of time left until the next phase) and transmit that signal to the RSUs.

- Traffic management center that collects and processes aggregated data from infrastructure and vehicles.

User-related equipments:

- Onboard equipments located in the vehicles communicate with the RSUs and process data.



Source: GAO analysis of Department of Transportation documents | GAO-15-775

Figure 4. DSRC architecture (Source: United States Government Accountability Office Report to Congressional Requester, 2015)

Cloud infrastructure can be accessed by cellular communication (4G and 5G), which supplies static and dynamic road information, historical databases, and remote computational power for AVs.

- Static road information includes road grade, road curvature, speed limits, locations of gas and charging station, intersection average delays.

- Dynamic road information includes traffic speed, traffic congestion, road work, weather conditions.

- Historical data includes traffic congestion on highways, and signal phase and timing data. Historical data help route planning by exploring deeper insight on traffic patterns.

- Remote computations including routing and long-term trajectory alleviate the onboard computational requirements.

2.2.2 Main Research Topics

The success of AVs depends both on the on-board instrumentation and surrounding environment including road infrastructure and other road users. Thus five areas that lie in the heart of AVs research: inter-AV communications, security and privacy, intersection navigation control, collision avoidance, and pedestrian detection.

Inter-AV Communications

Vehicle connectivity system of AVs heavily relies on DSRC. A dense urban environment provides many challenges for vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I) and vehicle-to-everything (V2X) system communication. It becomes harder for DSRC to be as effective as they are expected due to multiple propagation paths and many occlusions (e.g., blind spots, buildings). Therefore, the Center for Automotive Research from Ohio State University developed a traffic micro-simulator called the Vehicle and Traffic Simulator (VaTSim) to evaluate overall performance of DSRC in V2V communication. [9] Besides, a high number of AVs in a region would cause control channel congestion. A medication of linear message rate integrated control (LIMERIC) [10] and the application of Shapely-value for an adaptive transmit power cooperative congestion control (AC3) [11] were explored to assist in congestion control of the DSRC network.

Cellular communication is an alternative to DSRC to support V2X communication. However, 3GPP LET, a 4G cellular based V2X (C-V2X) communication, is incapable of provide high throughput and low latency for advanced applications. Numerical results show that when 50 vehicles are present, the probability of 3GPP LTE is actually worse than that of DSRC, which is at 83% and already below the requirements in typical safety application. [2] With the development of 5G technology, the 5G C-V2X is promising for the future. Compared with DSRC and 3GPP LTE, 5G C-V2X offers much higher throughput and reliability (99.999%), longer range (443 m line of sight and 107 m none line of sight), and much lower latency (10 ms end-to-end and 1 ms over-the-air). [12] In addition, 5G C-V2X provides direct messaging services among AVs, allowing short-range communication when cellular towers are unavailable. [2]

Security and Privacy of AVs

AVs are susceptible to two forms of attack, passive and active. Passive attacks read information that is being transferred between an autonomous vehicle and another communication points (e.g., RSUs or autonomous vehicles). A AV will broadcast a message containing verified velocity, location, a pseudonym of the car, and other information to alert other vehicles nearby for safety purposes. Verified data is transferred to an RSU through a virtual machine (VM). As long as the VM is unrevised through the exchanges from one RSU to another or among different locations, the attacker is allowed to collect location data continually. This threat could be modified to the second type of attack if the VM identity and the vehicle pseudonym used are not changed at the same time. [2] The two types of attack are referred as linkage mapping attack. A linkage mapping attack prevention was developed to remove the traceable memory of the target vehicle, which employs synchronous pseudonym and VM identifier changes. [13]

Active attacks may consist of spoofing incorrect data, resending a previous message to obtain validated system keys, message modification of relevant data, or denying of service that prevents data transfer on an affected server where data transference is vital. Han et al. developed a detection and mitigation method for spoofing by using carrier frequency information and code delays. [14] Moore et al. worked on a solution for the regular-frequency signal injection attacks. [15] Satam et al. developed an auto information development framework (AIDF) to prevent security attacks. [16]

Traffic Intersection Navigation

Plenty of traffic intersection control mechanisms have been developed for AVs in recent years. Zohdy et al. controls AVs trajectories using cooperative adaptive cruise control (CACC) system to avoid collisions and minimize delays at an isolated intersection. [17] Lee and Park developed a centralized cooperative vehicle intersection control (CVIC) algorithm for AVs only scenarios at an isolated intersection without turning movements. [18] Colombo et al. built a control mechanism with guaranteed hull principles, which use clusters or platoons to bisect an intersection. [19] Malikopoulos et al. offered a control solution that intends to optimize an intersection by minimizing the energy efficiency of AVs and maximizing the throughput. [20] Liu et al. proposed a mechanism that increases throughput without the need of an intersection manager. [21]

Collision Avoidance

One of the key aspects to the success of AVs is the ability to avoid collisions. Current forms of autonomous collision avoidance increase the overall effectiveness of vehicle accident prevention. Kusano et al. examined the potential effectiveness of the following three precollision system (PCS) algorithms: 1) forward collision warning only; 2) forward collision warning and precrash brake assist; and 3) forward collision warning, precrash brake assist, and autonomous precrash brake. [22] Jiménez et al. presented a collision avoidance system based on Sick LRS 1000 laser scanner. The control system uses a single-layer infrastructure combined with time-to-collision (TTC) algorithms to determine which two actions could be taken in case of danger (braking or steering). [23] Kaempchen et al. proposed a new approach for the calculation of the trigger time of an emergency brake and applied it to different scenarios including rear-end collisions, collisions at intersections, and collisions with oncoming vehicle. [24] Nilsson et al. derived closed-form expressions to estimate the performance of automotive collision avoidance (CA) in worst-case scenarios caused by early or unnecessary interventions or longitudinal/lateral measurement errors. [25]

Vehicle connectivity provides aid from other vehicles to avoid an accident. If vehicles can communicate with one another, they can serve as a cooperative system to reduce single car accidents or multiple car collisions. Desjardins and Chaib-Draa applied modern machine-learning techniques to develop an autonomous vehicle controller with the combination of V2V communication and adaptive cruise control (ACC). [26] Integration of vehicle's trajectory and counter-sway is promising for collision avoidance to truly be successful in autonomous vehicles. Funke et al. proposed a new control structure that integrates path tracking, vehicle stabilization, and collision avoidance. [27]

Pedestrian Detection

Currently, the primary sensors of autonomous emergency braking (AEB) system being utilized to detect pedestrians are cameras and radar. Cameras and short-range radars typically have the capabilities to identify pedestrians up to 60m away, while long-range radars can go up to 180m. Park et al. presented pedestrian target selection using a funnel map for a pedestrian AEB system. Test results showed that the proposed pedestrian AEB system can avoid or mitigate an accident when the vehicle travels at speeds up to 40 km/h. [28]

With the developments of computer vision and deep learning technology, AVs can benefit from them to advance pedestrian detection. Dominguez-Sanchez et al. applied convolutional neural network (CNN) to achieve a reliable detection of pedestrians moving in a particular direction. [29]. Li et al. proposed a novel density enhancement method to improve the quality of a sparse LiDAR 3-D point cloud in pedestrian detection. The enhancement uses radial basis function (RBF)-based interpolation and resampling algorithm to generate a new point cloud that meets a density requirement and geometric shape. [30]

3. Potential Benefits and Limitations of AVs

AVs technologies have the potential to change transportation and our daily life. These technologies could improve road safety, change traffic patterns and congestion, and reduce energy use. Additionally, AVs can generate useful data from these connected vehicles, which including both vehicle-centric and infrastructure-oriented data. However, the implementation of AVs is still facing several kinds of barriers including vehicle costs, legislation and regulation, and unusual risk related to security and privacy.

2.3.1 Potential Benefits

Improve Road Safety

AVs have the potential to dramatically reduce crashes. The statistic from U.S. DOT and National Highway Traffic Safety Administration (NHTSA) for transportation accidents in the United State in 2017 showed that 37133 people lost their lives from motor vehicle crashes. Of all serious motor vehicle crashes, 94% involve driver-related factors, such as impaired driving, distraction, and speeding or illegal maneuvers. [31] Self-driving vehicles would not be affected by these factors, suggesting at least 40% fatal crash-rate reduction (assuming automated malfunctions are minimal and everything else remains constant). [32]

CAVs can be superior to AVs that are not connected. Firstly, connectivity is a better sensor. DSRC range (1000 feet) is much longer than onboard sensor. Knowing driving conditions from 1,000 feet ahead enables preview or model predictive control for safer, smoother, and more efficient driving. It is also possible to learn what is around a corner and what is behind a bus using communication, both are scenarios challenging for onboard sensors to detect. Second, connectivity reduced uncertainty of emergency scenarios. Emergency vehicles can communicate with other AVs to enable safer driving across intersections. [5]

Reduce Congestion

AVs are smarter and safer, but AVs generate an even safer and more efficient traffic with connectivity. AVs can achieve collaboration among multiple vehicles, and can communicate intent and state. Many congestion-saving improvements depend not only on automated driving capabilities, but also on cooperative abilities through V2V and V2I communication. AVs are expected to use existing lanes and intersections more efficiently through shorter gaps between vehicles, coordinated platoons, and more efficient route choices. The adoption of AVs could smooth traffic flows by seeking to minimized acceleration and braking in freeway traffic with adaptive cruise control (ACC) measures and traffic monitoring systems. This increased fuel economy and increased congested traffic speeds by 23–39% and 8–13%, respectively, for all vehicles in the freeway travel stream, depending on V2V communication and how traffic-smoothing algorithms are implemented. [32]

Improve Mobility and Productivity

According to the Bureau of Transportation Statistics report Travel Patterns of American Adults with Disabilities, an estimated 25.5 million Americans have disabilities that make traveling outside the home difficult. An estimated 3.6 million with disabilities do not leave their homes. AVs AVs present enormous potential for enhancing independent and spontaneous travel capabilities for travelers who are too young to drive, elderly or disabled. With the increasing use of AVs, their passengers will have the opportunity to work within vehicles.

Reduce Energy consumption and Emissions

The National Renewable Energy Laboratory developed eight scenarios to test energy consumption of light-duty AVs. In the most positive scenario, automated vehicles could help reduce energy consumption of light-duty vehicles by 83 percent. In the most negative scenario, they could increase energy use by as much as 217 percent. Fortunately, the role of communities and public agencies is to develop and implement policies that would make the positive scenarios more likely. [7]

Parking Saving

The increase use of AVs will impact on parking in terms of use, location, and design. Connectivity will enable more efficient use of existing parking spots. Vehicles will directly locate nearby empty parking spots and choose the one based on distance. Without the need for human drivers to park the vehicle, parking spaces could be smaller because AVs are able to park closer together than human drivers do. Shared AVs will spend more time transporting passengers or traveling to pick them up. ·They will spend less time parked, which will lower demand for parking, especially in commercial and office areas. Thus, municipal parking construction or expansion could become unnecessary and some parking areas could be transformed into pick-up and drop-off locations.

Generate Useful Data

Automated vehicles have the potential to generate vast amounts of data that can support a variety of transportation agency needs and applications, which includes both vehicle-centric and infrastructure-oriented data.

Advanced sensors, processors, enhanced driver interfaces, and other on-board units (OBU) are able to record and deliver the vehicle-centric data through wireless networks. The data include basic vehicle measures, vehicle safety data, environmental probe data, vehicle diagnostics data, and vehicle emissions data.

The infrastructure subsystem, including specific DSRC-capable roadside equipment (RSE) and more traditional ITS equipment distributed on and along the roadways, is able to provide and exchange data elements related to roadway characteristics, road conditions, intersection status, and field equipment status. [33]

2.3.2 Limitations and Risks

Safety Risks

Automated driving technology has been expected to help reduce road fatalities. However, two deaths involved Uber and Tesla vehicles using driverless systems in Arizona and California in March 2018. The AVs safety issue is a concern to the general public, government agencies, as well as the AVs manufacturers. Both the National Highway Traffic Safety Administration (NHTSA) and the National Transportation Safety Board (NTSB) investigated fatal crashes onsite and published either preliminary or final reports. It can be concluded from these reports that probable causes of these fatal crashes span from human driver's inattention to driving environment complexity, ignorance of the take-over request from the vehicle, and distraction from some secondary tasks. [34]

In order to understand the mechanism of AVs crashes, Wang and Li comprehensively investigated AV crashes' causes based on the most recent records from the California AVs crash database published in October 2018. The results concluded that severe injuries can happen if the vehicle is on automated driving mode and is the major responsible party for the crash. The highway is identified as the location where severe injuries are likely to happen due to high travel speed. Collision types of AVs-related crashes are dependent upon the driving mode, location, and whether crashes are associated with yielding to pedestrians/cyclists. [34]

Reports by eight companies operating autonomous test vehicles in 2017 indicate that disengagements exceeded one per 5,600 miles. [35] Common problems included failing to recognize a 'no right turn on red signal' cars that planned to merge into traffic with insufficient space, failing to brake enough at a stop, difficulty detecting vehicles approaching in opposite lanes, problems maintaining GPS location signals, software crashes, inability to recognize construction cones, confusion over unexpected behavior by other drivers, plus other hardware and software problems. [36]

Vehicle and Infrastructure Costs

The cost of AV platforms is one barrier to large-scale market adoption. The prices for the top 27 selling vehicles in America range from $16,000 to $27,000. [37] LiDAR systems on top of AVs cost $30,000 to $85,000 each and additional costs will accrue from other sensors, software, engineering, and added power and computing requirements. [38]

New infrastructure investments could be necessary to maximize the benefits of AVs. Federal, state, and local public agencies are working with the automotive industry and research community to develop, test, and deploy the necessary infrastructure to support V2I applications. The infrastructure needed to support V2I communication includes both road infrastructure and onboard equipment. Over the past 20 years, the U.S. DOT has invested over $700 million in development of V2X through partnerships with industry and state/local governments. As a result of these investments and partnerships, V2X technology is on the verge of wide-scale deployment across the nation. [31] If for-profit AV companies create the need for infrastructure upgrades, the State and County agencies could also consider cost-sharing arrangements where the AV companies may contribute to the costs of the upgrades.

4. State of the Practice

Until now, AVs developments have been proceeding largely in many states (Figure 5). Sound infrastructures and techniques at the state, regional, and local government levels will nudge AVs towards outcomes that would benefit society.

Current Activities

AVs are poised to transform our streets, communities, and personal lives. But before these technologies can be deployed broadly, there are a number of technical, institutional challenges that can only be understood and overcome by putting these emerging technologies to work in real-world situations, solving real problems.

California

On May 31, 2018, the California Public Utilities Commission authorized two pilot programs for the private prearranged transportation of passengers in test autonomous vehicles (AVs) [39]:

- The "Drivered AV Passenger Service" pilot program allows for the provision of passenger service in test AVs with a driver in the vehicle. Under this pilot program, a safety driver is available to assist with operations if needed.

- The "Driverless AV Passenger Service" pilot program allows for the provision of a passenger service in test AVs without a driver in the vehicle. Under this pilot program, a communication link between passengers and "remote operators" of the vehicle must be available and maintained at all times during passenger service.

Major international automotive manufacturers, first-tier suppliers and more general information technology companies have focused much of their research and development activity on road vehicle automation in California because of the highly-skilled workforce and the entire technology innovation ecosystem of Silicon Valley.

- In 2016, the City of Sunnyvale, California served as a real-world V2X testbed with Nissan, Savari, and U.C. Berkeley. The testbed, spanning 4.63 square miles, includes three public intersections equipped with Savari's V2X-enabled road-side units. Data collected through this test program was used to optimize traffic light timing. [40]

- In July 2019, Waymo has received a permit from the California Public Utilities Commission (CPUC) to run its self-driving taxis. In all, the company completed 4,678 passenger trips in July plus another 12 trips for educational purposes. [41]

California was the first state in the country to work on the vital CV technology of 5.9 GHz DSRC. Currently, there are 11 signalized intersections equipped along El Camino Real in Palo Alto and Palo Alto is in the process of expanding to 17. [42]

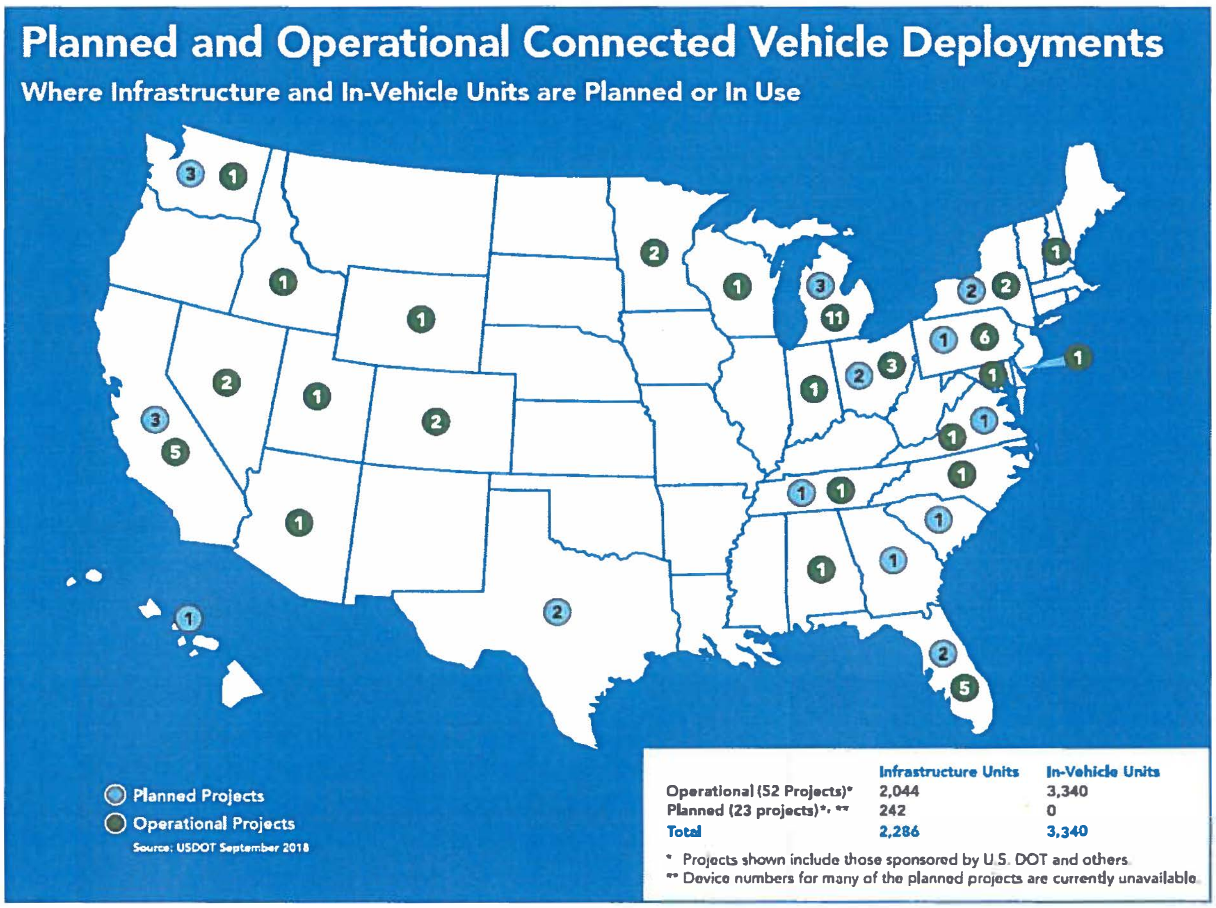


Figure 5. Planned and Operational Connected Vehicle Deployments. (Source: U.S. DOT)

Michigan

Michigan has invested significant public resources to promote the advancement of its research universities and test facilities related to AVs. Michigan established the American Center for Mobility at the former Willow Run aircraft and automotive plant, with seed funding of $50M from the state aimed at attracting matching funds of an additional $30M to build a large-scale test facility on 335 acres where it will be possible to test driving automation systems up to full highway speeds. [42]

Mcity is a 32-acre test facility dedicated to research, development and testing of AVs, which was designed and developed by the Mobility Transformation Center (MTC), in partnership with the Michigan Department of Transportation (MDOT).

- Verizon is working with Mcity to advance transportation safety and shape the future of autonomous vehicles and smart cities using 5G. The Verizon 5G Ultra Wideband network is now live at the Mcity Test Facility where Verizon is testing various 5G solutions designed to boost pedestrian safety and avoid car accidents. [43]

- Mcity's new software interface, OCTANE, allows users to control many aspects of the Mcity Test Facility's infrastructure from a phone, laptop or vehicle computing platform. Mcity has also built a web-based application, called Skyline, using the OCTANE API to enable point-and-click control for test facility features, including roadway intersections, rail crossings, crosswalks, and facility gates. [44]

The Safety Pilot Model Deployment (SPMD) project in Ann Arbor was funded at $30M, producing the highest profile test of connected vehicle technology and a foundation for continuing projects on connected automation. The SPMD program was sponsored by the U.S. Department of Transportation (USDOT) National Highway Traffic Safety Administration, Intelligent Transportation Systems Joint Program Office, Federal Highway Administration, Federal Motor Carrier Safety Administration, and Federal Transit Administration. The objectives of the SPMD program were to [45]:

- Demonstrate connected vehicle technologies in a real-world, multimodal environment

- Determine driver acceptance and adoption of vehicle-based safety systems

- Evaluate the feasibility, scalability, security, and interoperability of DSRC technology

- Assess options to accelerate safety benefits.

Florida

Tampa, Florida is one of three sites in the nation to be selected for the USDOT Connected Vehicle Pilot Deployment Program. Tampa-Hillsborough Expressway Authority (THEA) owns and operates the Selmon Reversible Express Lanes (REL), which is a first-of-its-kind facility to address urban congestion. The Tampa THEA pilot deploys a variety of V2V and V2I applications to relieve congestion, reduce collisions, and prevent wrong way entry at the REL exit. THEA also plans to use CV technology to enhance pedestrian safety, speed bus operations and reduce conflicts between street cars, pedestrians and passenger cars at locations with high volumes of mixed traffic. The THEA CV Pilot employs DSRC to enable transmissions among approximately 1,600 cars, 10 buses, 10 trolleys, 500 pedestrians with smartphone applications, and approximately 40 roadside units along city streets. To support this initiative, THEA works with their primary partners, The City of Tampa (COT), Florida Department of Transportation (FDOT) and Hillsborough Area Regional Transit (HART) to create a region-wide Connected Vehicle Task Force. [46]

Florida DOT has established the Florida Automated Vehicles (FAV) Program to educate the public by engaging stakeholders, developing research and pilot projects, and creating awareness of the technologies and how they support FDOT's vision statement. It has sponsored a variety of automation research projects at Florida universities and organizes an annual "summit" meeting to attract national and international participants as well as in-state participants. [47]

Virginia

The Virginia Smart Roads, located adjacent to Virginia Polytechnic University in Blacksburg,VA, are a unique, state-of-the-art, full-scale, closed test-bed research facility managed by the Virginia Tech Transportation Institute (VTTI) and owned and maintained by Virginia Department of Transportation (VDOT). The Smart Roads are equipped with the following equipment to support the testing and evaluation of AV deployments, additional equipment can be easily added as needed [40]:

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

VDOT and VTTI also developed Virginia Connected Corridor (VCC) to foster an environment that allows research to be conducted on CVs. VCC Environment includes [48]:

- Open Cloud Computing Environment
- Signal Phase and Timing Data
- VCC Monitoring Tools
- VCC Traffic Information Message Generator and Server
- Multi-function VCC App
- Improvements to Signs and Markings

Texas

Smart Mobility Texas is a statewide coalition of automotive interests dedicated to supporting policy advancements that promote the deployment of autonomous vehicles, new transportation technologies, and the infrastructure needed to support them. Cities and regions across Texas are partnering with the Texas A&M Transportation Institute (TTI), the University of Texas at Austin's Center for Transportation Research (CTR), and Southwest Research Institute (SwRI) to form the Texas Automated Vehicle (AV) Proving Ground Partnership. [49]

In July 2019, the Austin-Bergstrom International Airport started testing a self-driving shuttle. The EZ 10, manufactured by French driverless mobility company EasyMile, is taking passengers on the top level of the main parking garage from the far side of the lot to the terminal. [50]

Washington

Washington State Department of Transportation (WSDOT)'s Cooperative Automated Transportation program focuses on how new, semi-automated and automated capabilities can advance the state's multimodal transportation system. Current activities including [51]:

- First/last mile connections – Supporting expansion of pilot programs (including Pierce Transit and King County Metro) to deliver first/last mile service to underserved areas.

- Winter operations – Providing travelers real-time road and weather conditions by sharing connected vehicle data from snow plows and other systems.
-
- Traffic signals – Testing how WSDOT's signal systems can better communicate with vehicles, bicyclists and pedestrians to improve intersection safety and overall traffic operations.

- Active transportation – Investigating use of electric bikes and scooters for first/last mile connections.

- Automated work zone vehicles – Testing how automated vehicles can improve safety by eliminating the need for a driver in some staging vehicles.

Wyoming

The U.S. Department of Transportation (USDOT) selected Wyoming as one of three locations to test and deploy advanced dedicated short-range communication (DSRC) technology to improve safety and mobility. In the Connected Vehicle Pilot (CVP), WYDOT will use V2V, V2I, and I2V connectivity to improve monitoring and reporting of road conditions to vehicles on I-80 that runs 402 miles along

Wyoming's southern border and is an essential east-west connector for freight and passenger travel. [52]

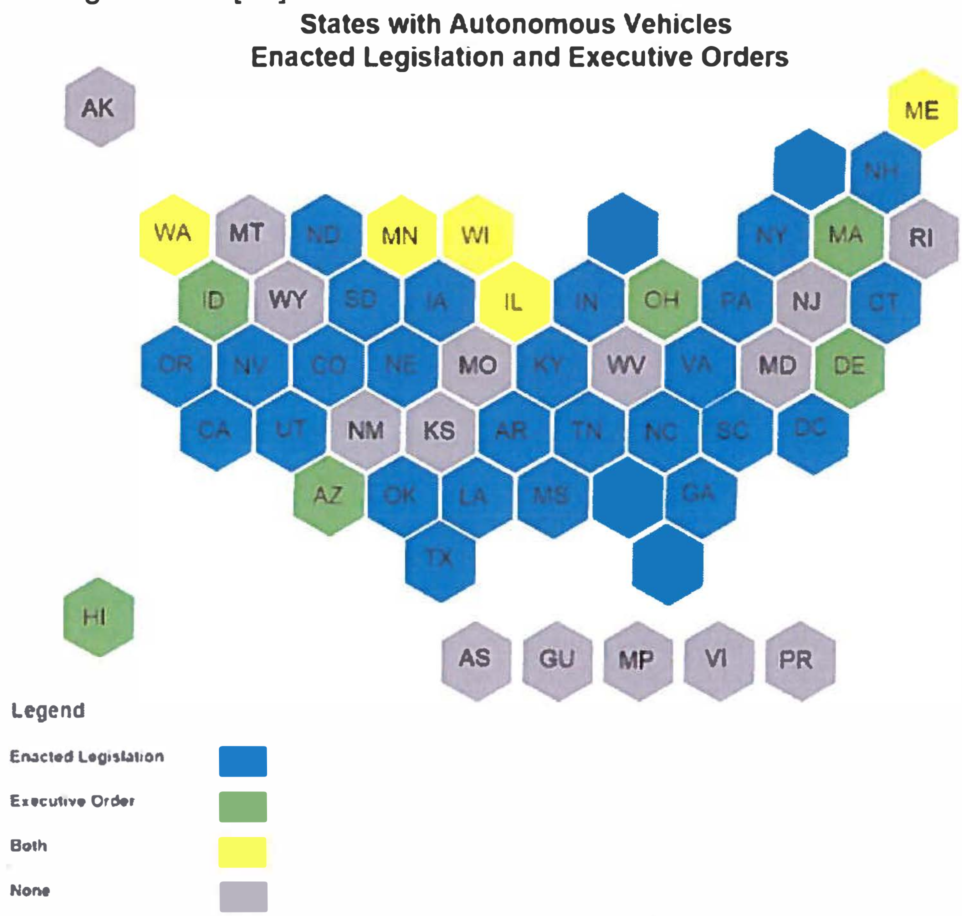


Figure 6. Status of state laws related to autonomous vehicles, as of September 2019 [53] (Source: National conference of State Legislature)

Status of State Laws

To allow society to benefit from AVs technologies, governments can implement policy and planning strategies to reduce negative societal effects and increase positive societal effects of AVs. Although there were some setbacks to the development of AVs, including two fatal accidents involving semi-autonomous cars in Arizona and California in March 2018, many states are still moving forward with effects to encourage the safe testing to prepare for a future.

Twenty-nine states and Washington D.C. have enacted legislation related to autonomous vehicles. Eleven states have issued executive orders (Figure 6). National Conference of State Legislatures (NCSL) has a new autonomous vehicle legislative databases which can provide up-to-data, real-time information about state autonomous vehicle legislation. [53]

5. Public Perceptions of AVs

The Center for Automotive Research (CAR) explored and assessed public perceptions toward AVs. The CAR researchers used a web-based survey to gather quantitative data on the perceptions of the U.S. population of AV technology in 2016. The 114 participants were asked about their impressions, experience, interest, and confidence in AVs, as well as about the benefits and concerns with AVs. The results showed that over half of respondents (59%) had a somewhat or very positive view, and only 14% had a somewhat or very negative view of the technology (Figure 7). [3]

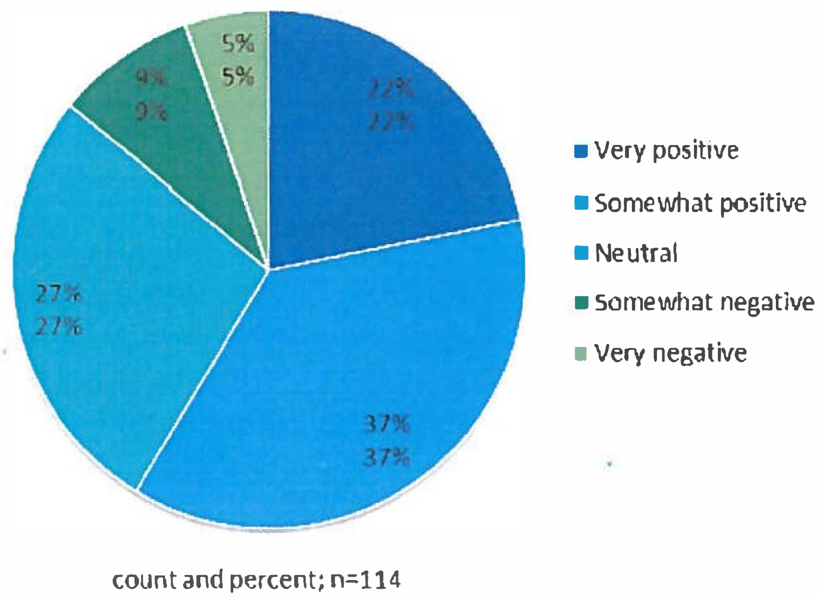


Figure 7. General impressions of AVs [3]

Demographics of the Participants

- Gender: The gender ratio was relatively even. Forty-eight percent of respondents were men and fifty-two percent were women.

- Age: Respondents in this survey skewed older and represents only 18.4 percent of the entire U.S. population.

- Educational attainment: Total 67 percent of respondents had a Bachelor's degree or beyond.

- Amount paid for vehicles: More than a quarter of respondents paid for vehicles between $20,000 and $29,000.

- Geographic location: All United States Census regions were represented in the survey.

Impressions of AVs Technology

- By gender: Men were three times more likely to have a negative impression of AVs. 12 of 54 male participants (22.2%) to have a very negative or somewhat negative impression of AVs, whereas only 4 of 59 female participants (6.8%) had a negative impression.

- By age: 18-29 (9 of 13 participants, 69.2%) age group and 45-59 (22 of 31 participants, 71%) age group were most likely to have a positive impression of AVs.

- By educational attainment: The more educated participants were more likely to have a negative impression of AVs.

Experience with AVs Technologies

Participants were asked if they had any experience with AVs technologies, including Connected technology, Back-up Assistance, Parking Assistance, Blind-Spot Detection, Forward Crash Warning or Automatic Emergency Braking, Adaptive Cruise Control, Lane-Keeping Assistance, and Lane Departure Warning.

- Back-up Assistance is the only technology that a majority of participants (61%) had experience with.

- Parking assistance (5%), Lane-Keeping Assistance (7 %) and Forward Crash Warning/Automatic Emergency Braking (9%) are the three familiar applications.

Most Appealing AVs Applications

Participants were asked which AVs applications they are interested in among Connected technology, Back-up Assistance, Parking Assistance, Blind-Spot Detection, Forward Crash Warning or Automatic Emergency Braking, Adaptive Cruise Control, Lane-Keeping Assistance, and Lane Departure Warning.

- Blind-Spot Detection was the most appealing application, 54 percent of the participants were interested in it.

- Back-up Assistance was the second popular application with 46 percent of the participants.

- Lane-Keeping Assistance, Parking Assistance, and Connected technology were the three least popular applications.

Interest in Owning or Leasing an Autonomous Vehicle

Only a third of the participants were very interested or at least somewhat interested in owning or leasing a fully autonomous vehicle. This would suggest that participants were more comfortable with partial autonomy and connectivity than fully automation.

Perceived Benefits of AVs

Participants were asked to list the top three benefits of AVs (Figure 8). [3]

- 'Increased safety' was the most-selected option with 76 percent of the participants.

- 'Improved emergency response to crashes' and 'lower insurance rates' were the next two benefits with high rating, with 37 percent each.

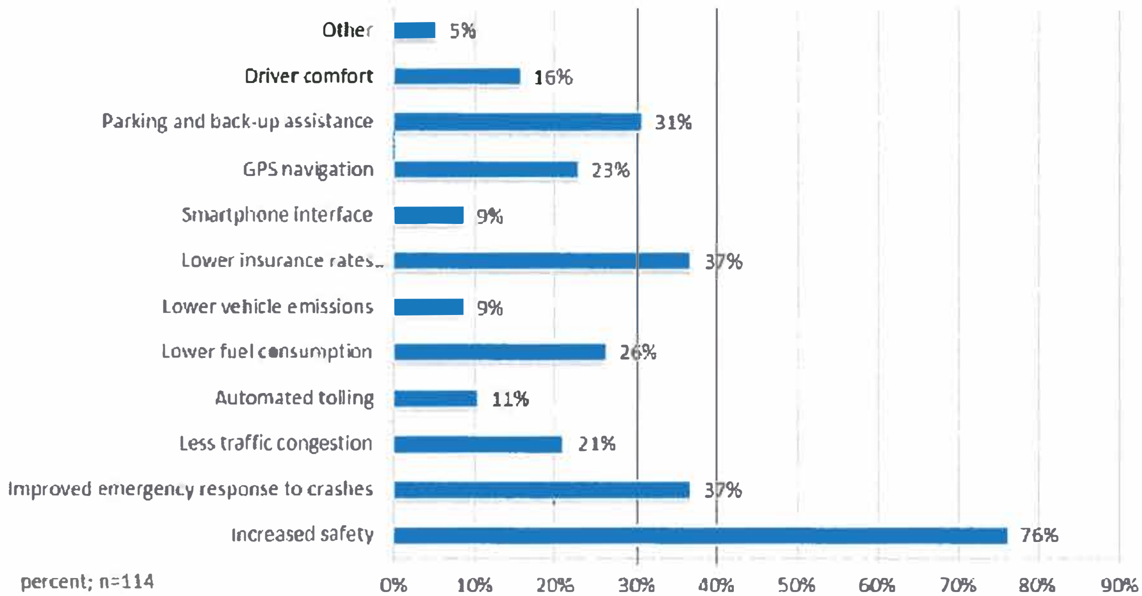


Figure 8. Perceived benefits of AVs [3]

Concerns with AVs

Participants were asked to list their top three concerns with AVs (Figure 9). [3]

- 'Cost' was the highest concern with 67 percent of the participants.

- 'Cyber-security', 'Driver complacency', and 'Product failure/error' were the next most commonly mentioned concerns.

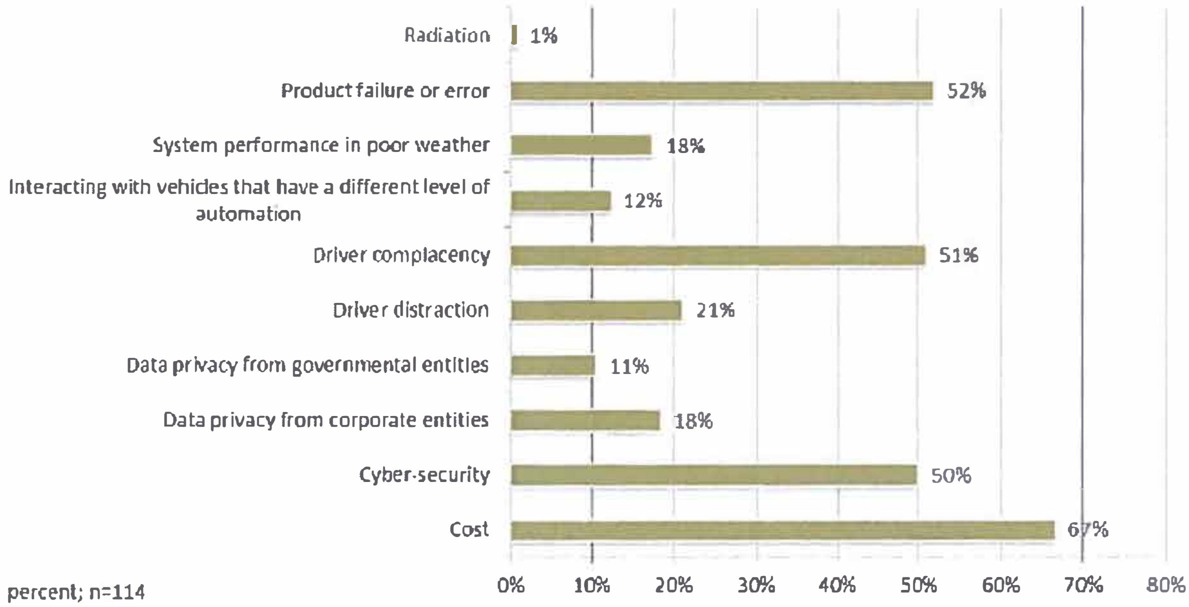


Figure 9. Concerns with AVs [3].

Confidence in AVs Technologies and Systems

Participants were asked the question "What is your opinion of the following statement? 'I trust that a computer can drive my car with no assistance from me.'"

- 56 percent either somewhat or strongly disagreed.
- 40 percent somewhat or strongly agreed.
- 14 percent were neutral.

To the question "What is your opinion of the following statement? 'I would be comfortable entrusting the safety of a close family member to a fully automated car."

- 56 percent somewhat or strongly disagreed.
- 28 percent somewhat or strongly agreed.
- 16 percent were neutral.

Participants were asked the question "What is your opinion of the following statement? 'I would be comfortable allowing my car to transmit encrypted data, such as its current location and speed, to surrounding cars in order to better coordinate its path with those cars and keep me safe from crashes.'"

- 40 percent somewhat or strongly disagreed.
- 37 percent somewhat or strongly agreed.
- 23 percent were neutral.

Willing to Pay for AVs

In general, participants were not willing to pay much more to have AV features on a vehicle.

- More than a third of participants would pay less than $500.
- 28 percent of the participants would pay between $5000 and $999.
- Only ten percent of the participants would pay more than $2,500.

6. The Roles of Local Governments in AVs Deployments

AVs will advance our lives in many ways. However, this emerging technology has far-reaching implications. AVs AVs rely on more public planning and investment than most other technologies. In order to allow the technology to reach its full potential, local governments need to prepare for AV-induced safety issues, autonomous vehicle regulations and infrastructure investments.

2.6.1 Dealing with AV-induced Traffic Safety Issues

AV Certification

Government agencies must assure that they will operate safely before AVs operate. Specifically, an AV must operate properly and safely on the roads when all its hardware and software are functioning as designed. And it must be able to deal safely with hardware or software failures. [54]

AV Registration and Titling

NHTSA suggests that agencies add a new data field and code vehicles, Level 3-5 automation which do not require a human driver for entire trip or a portion of a trip, as HAVs. NHTSA states that it should issue regulations on the labeling and identification of HAVs. Agencies may wish to provide more detail by identifying AVs at each level.

Laws on AV operations

Fully autonomous Level 4 and 5 AVs raise several issues if they were to operate within current traffic laws. Thus, current state laws need to change to accommodate AVs. Several challenges need to be worked on, such as law compliance, speed limits. For law compliance, many traffic laws prohibit certain actions but common-sense exceptions are both recognized and encourages. State should understand how AVs will deal with these conflicts. For speed limits, Google's California AV fleet obeys speed limits, which has raised problems. Specifically, an AV has produced a number of minor crashes when it tried to merge onto a busy highway with traffic moving well above the speed limit. [54]

Crash investigation

In 2016, the Model Minimum Uniform Crash Criteria (MMUCC) developed model crash report data elements and coding for states. The MMUCC Expert Panel proposed three variables for

AV crash investigation. First one distinguishes if the vehicle is no, partial, or full automation. Second one code the automation levels based on SAR Level 1-5. The last one codes if the vehicle's autonomous features were engaged at the time of the crash. [54]

Liability

AVs will be involved in crashes. NHTSA states first need to consider how to determine the AV's responsibility for a crash. Then they need to decide how the liability assigned to the AV, would be allocated among the AV's manufacturers, software providers, owners, operators (if an operator is in the vehicle). Another important consideration in crash causation and liability is the set of decision rules an AV uses to decide what action to take in an emergency situation and others.

2.6.2 Earning Public Trust and Increasing Confidence in AVs

States should create public trust of AVs through effective and clear communications. Several sensational reports of two deaths involving Uber and Tesla vehicles using driverless systems in Arizona and California in March 2018 have gratuitously stoked fear and undermined public support for AVs. Media highlighted the failure of AVs, but chose to ignore the fact that 96 Americans lose their lives everyday on the nation's highways. [55] States should provide the public with comprehensive and effective information of AVs and a glimpse of the future to replace fear with and uncertainty with facts and personal experience.

AVs have been discussed more and more outside of industry circles, the public is increasingly curious about these technologies. Some cities have started collaborating with technology developers to launch public training programs and education campaigns. These activities will help technology developers understand the public's concerns and expectation on AVs, and find ways to work with citizens to gradually overcome some of the most challenging aspects of operating AVs in urban environments.

2.6.3 Infrastructure Investments

U.S. DOT estimated that by the end of 2018, over 18,000 vehicles will be deployed with aftermarket V2X communications devices and over 1,000 infrastructure V2X devices will be installed at the roadside. [31]

Signal Phase and Timing (SPaT) Challenge led by State and local public-sector transportation infrastructure owner operators has plans to deploy a V2X communications infrastructure with SPaT broadcasts in at least one corridor in each of the 50 States by January 2020. The SPaT message is designed to enhance both safety and efficiency of traffic movements at intersections. Over 200 infrastructure communications devices are already deployed today. By 2020, over 2,100 infrastructure communications devices are planned to be deployed under SPaT in 26 States and 45 cities with a total investment of over $38 million. [31] State and local agencies may consider collaborating with automated vehicle developers and testers to identify potential infrastructure requirements that support readiness for automated vehicles and to understand their expectations for automated vehicle operations under varying roadway and operational conditions. [31]

2.6.4 Ensuring Robust Cybersecurity

AVs are reliant on multiple paths of connectivity to communicate and exchange data. Vehicle manufacturers should emphasize the need to enhance cybersecurity practices and supporting the establishment of the Auto Information Sharing and Analysis Center (ISAC) as part of the Department of Homeland Security's critical infrastructure protection program [56]. States should work closely with U.S. DOT and other public agencies to address cyber vulnerabilities and manage cyber risks. States also should consider developing a set of cybersecurity guidelines based on existing international standards to guide vehicle manufacturers in achieving the desirable outcomes.

2.6.5 Understanding and Planning for Economic Disruption and Labor Transition

With the increasing use of AVs, many driving-related jobs will no doubt face elimination. Also, new jobs will be created for the operation and maintenance of self-driving fleets. Dramatic reductions in vehicle crashes will also impact jobs as we transition from the crash economy, including tow truck operators, body shop owners and trauma centers and insurance market. States should undertake a comprehensive analysis to better understand the potential disruption to the labor market. States also should ensure displaced people are treated with dignity and respect with compensations including job training, apprenticeships and transition assistance.

7. Conclusion

Motor vehicle crashes remain a leading cause of death in the United States. AVs AVs have the potential to improve the safety of the transportation system, improve the quality of life, and enhance mobility for all people. Although the implementation of AVs is still facing several kinds of barriers including vehicle costs, legislation and regulation, and unusual risk related to security and privacy, the predictions are still optimistic based on overwhelming benefits of AVs.

The public's views on new technology can change quickly. AVs AVs may be similar to automobiles a century ago or smart phones only 10 years ago, which quickly became both acceptable and highly desirable. Government officials, planners, and economic developers should closely work together to provide sound policies and technologies to build the trust and confidence in the public.

Despite the great promise of AVs technology, important questions remain. Testing AVs on public roads is complicated due to the frequency of interactions with other, often-unpredictable objects including vehicles, pedestrians, cyclists and animals. The cost of AVs is unaffordable for individual users due to expensive sensors equipped on vehicles. However, these barriers will not AVsprevent AVs in our future.

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3. INSURANCE

In this report, we will provide a brief summary of the current development of the autonomous vehicle market and related changes in risk exposures. We will discuss in more detail the increasing challenges that the insurance industry is facing, and the potential contributions that insurance industry can make to the development of the autonomous vehicle market. A tentative conclusion will also be offered at the end.

I. Paradigm Shift for Risk and Liability with Autonomous Vehicles

As discussed in the Technical Summary in Chapter 2 of this preliminary report, there are six levels of automation on the automobile market. Below, we briefly discuss how risk shift from drivers to other parties based on the autonomous level of the vehicle.

In this current state, the vast majority of vehicles on the road are still considered Level 0, where human drivers are in complete control at all times. Risks and liabilities for Level 0 cars are relatively clear and are supported by decades of regulation and case law precedents. While risk and liability discussions will become more complicated for fully autonomous vehicles, the most complex issues arise during the transitional stages of development, when Level 2 and Level 3 vehicles penetrate the market and the vehicles and humans share control over and responsibility for operating the vehicle.

Generally speaking, as automation in vehicles begins to increase, risks and liability for damages may gradually shift from the human driver toward the auto manufacturers (the OEMs), their suppliers (for parts, systems, sensors and cameras, data, algorithm, among others), and infrastructure and network services providers. This paradigm shift may cause fundamental changes in liability assignment and bring about many critical challenges to all parties involved, including the insurance industry. Some of these changes and challenges will be discussed in Sections III and IV. The gradual shifting of risk and liability will also have profound regulatory and legal implications, as the regulators and legislature struggle to incorporate changes and support the development of the autonomous vehicle market. Lastly, the changing landscape may cause much excitement, anxiety, and confusion to consumers of automobile and insurance, as they begin to understand the new products and align their expectations with facts. We will discuss these in the next Section.

II. Legal/Regulatory Environments and Public Perceptions

In this section, we will briefly review the legal and regulatory environments, and summarize current evidence on public perceptions surrounding the autonomous vehicle market.

3.1. Legal and regulatory development

Chapter 1 of this preliminary report has discussed the legal and regulatory environments for autonomous vehicles in great detail. Since this is also related to insurance rate making, underwriting, claims settlement, and new insurance products, we briefly summarize the legal and regulatory environments here for the completeness of this chapter.

It is generally accepted that autonomous vehicles are legal in the United States, unless there are specific laws or regulations to the contrary. The regulatory and legal environment for the autonomous vehicle market is still in its nascent stage despite the wide recognition that faster and continuous development is necessary to support the rapidly changing market. Although two thirds of all states have enacted legislation or issued executive orders related to autonomous vehicles, most of these laws do not impose binding regulatory mandates or provide clear guidelines on liability assignment. Similarly, the federal government, acting through National Highway Traffic Safety Administration (NHTSA), has not initiated any rulemaking in the areas of autonomous vehicles design or operations up to this point. Carp (2018) summarizes the most recent development at the federal and the state level.

3.1.1. Federal Regulation

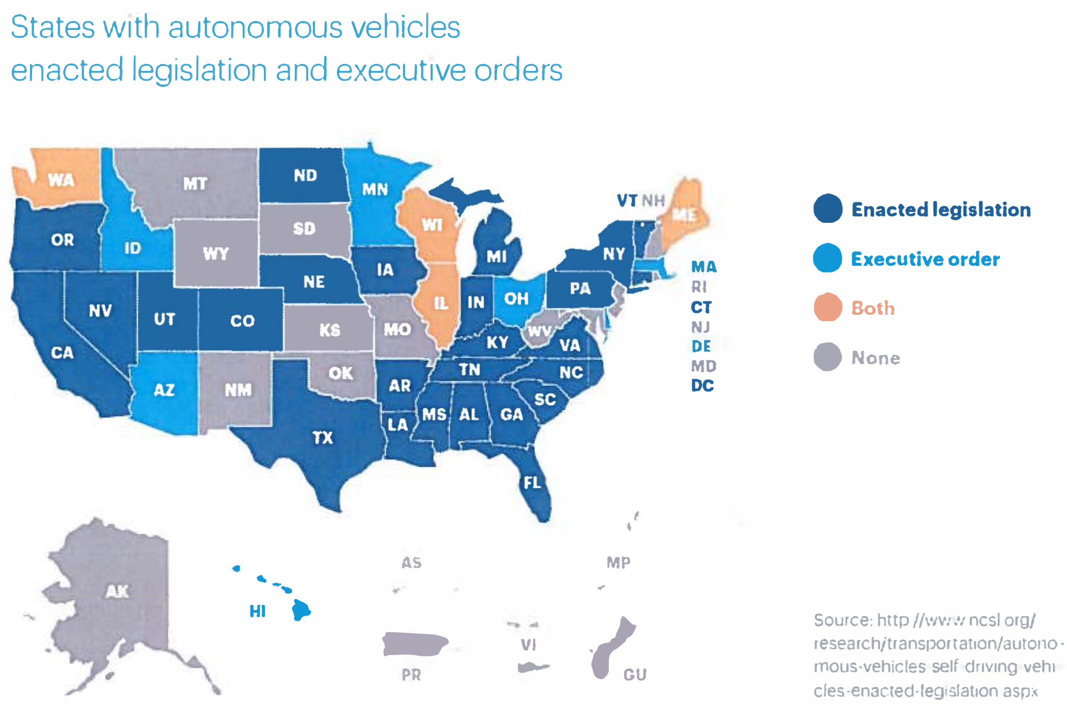
The federal government has maintained a permissive attitude toward autonomous vehicle technology and NHTSA has refrained from mandating technology-specific design features and performance standards. However, this does not mean that autonomous vehicles are not subject to regulations at the federal level. NHTSA has reminded manufacturers that they must comply with existing mandates applicable to conventional vehicles. Congress is also considering two pieces of autonomous vehicle legislation, namely The SELF DRIVE Act, which already passed in the House of Representatives, and The AV START Act, currently pending in the Senate.

3.1.2. State Regulation

As indicated in Figure 1, 35 states and the District of Columbia have enacted legislation or issued an executive order related to autonomous vehicles. However, only a fraction of the enacted state laws impose specific regulatory mandates, instruct state agencies to promulgate such mandates, or expressly authorize autonomous vehicle operation. These state laws can be divided into three categories: (1) laws which mandate specific design features and limit the operation of autonomous vehicles, (2) laws which limit the operation of autonomous vehicles but do not mandate specific design features, and (3) laws which expressly authorize the operation of autonomous vehicles with varying degrees of oversight.

In particular for the State of Hawaii, Executive Order 17-07, signed by Gov. David Ige, signals that the state is "open for business for testing and deploying new driverless vehicles," and directs several state departments to work with any companies wishing to test autonomous vehicles in Hawaii. Despite that, there has not been widespread testing or deployment of driverless vehicles in the state. House Bill 1183 was introduced in January 2019, hoping to change this by implementing a clear and simple regulatory process for autonomous vehicles.

Figure 1: States with Autonomous Vehicles Enacted Legislation and Executive Orders



Source: Dentons (2019) "Autonomous Vehicles: U.S. Legal and Regulatory Landscape"

3.2. Public Perceptions of Autonomous Vehicle, Risks, and Insurance

Consumers and the general public are important stakeholders in the development of the autonomous vehicle market. Public perceptions and attitudes often play an important role when regulations and legislations are contemplated and are often incorporated in corporate strategies.

An increasing amount of studies focus on examining public perceptions of the use of autonomous vehicles, the pace of development, the risks involved, and what insurance products and services are needed.

3.2.1. Public Perception about the Use of Autonomous Vehicles (AV) and the Development of the AV Market

A survey study conducted by Haboucha et al. (2017) with 721 individuals living in Israel and North America found large overall hesitation towards autonomous vehicle adoption, with 44% of survey respondents choosing regular vehicles, 32% choosing privately-owned autonomous vehicles (PAV) and 24% choosing shared autonomous vehicle (SAV). Even if the SAV service were to be completely free, only 75% of individuals would currently be willing to use SAVs. Consumers' attitudes toward autonomous vehicles use also vary largely across different purposes of the driving trip. When asked about their feelings regarding an empty autonomous vehicle picking up groceries, 53% of individuals were comfortable with the idea while 28% of individuals were uncomfortable. When asked about their feelings regarding an empty autonomous vehicle picking up children from school, only 13% of individuals is comfortable and 72% of individuals not being comfortable. 66% of respondents claim to be more comfortable in the autonomous vehicle if they had the ability to take control of the vehicle if needed, with only 7.5% of respondents being more comfortable without the ability to take control.

Another study by Kyriakidis et al. (2015) investigated user acceptance, concerns, and willingness to buy partially, highly, and fully automated vehicles. The authors created an internet-based survey consisting of 63 questions and collected 5,000 responses from 109 countries. Generally speaking, they find that respondents are diverse in their attitudes toward autonomous vehicles. While manual driving was found to be the most enjoyable mode of driving, 33% of respondents indicated that fully automated driving would be highly enjoyable. 22% of the respondents did not want to pay more than $0 for a fully automated driving system, whereas 5% indicated they would be willing to pay more than $30,000. Respondents also seem confident about the rapid development of the autonomous vehicle market, with 69% of respondents estimating that fully automated driving will reach a 50% market share by 2050. Software hacking/misuse, safety and legal issues were among the chief concerns of the respondents.

According to a survey conducted by AIG (2018), there is a wide acceptance of autonomous features in vehicles. 1 in 5 adults in the U.S. self-identify as a current driver of a vehicle with automated assistance systems such as emergency braking, lane departure avoidance, or features that make the vehicle capable of self-driving part of the time. 77 percent of those U.S. drivers said autonomous features had a positive influence on their decision to purchase their current vehicle. Among the 4 in 5 U.S. adults who don't currently drive a vehicle with autonomous features, 44 percent said they would buy, rent, share or travel in a vehicle with those features. However, the public in the U.S. are more conservative than experts when it comes to the wide deployment of driverless vehicles. While experts predict that up to one-third of vehicles are likely driverless by 2035, on average adults in the U.S. think that it will be 2039 before driverless cars represents more than 20 percent of vehicles on U.S. roads and that it will be 2051 before driverless vehicles represent the majority of vehicles on road.

The U.S. general public also tends to disagree with experts on how they will utilize driverless vehicles. When asked to envision how they might use a driverless vehicle most in the future, 40 percent of U.S. respondents said they would expect to own the car, followed by 31 percent who envision using driverless public transit, 15 percent who expect to use a subscription or on-demand service, and 14 percent who expect to participate in a shared-ownership program. This stands in contrast with expectations that most personal vehicle ownership and public transit will decline sharply when autonomous vehicles penetrate the market.

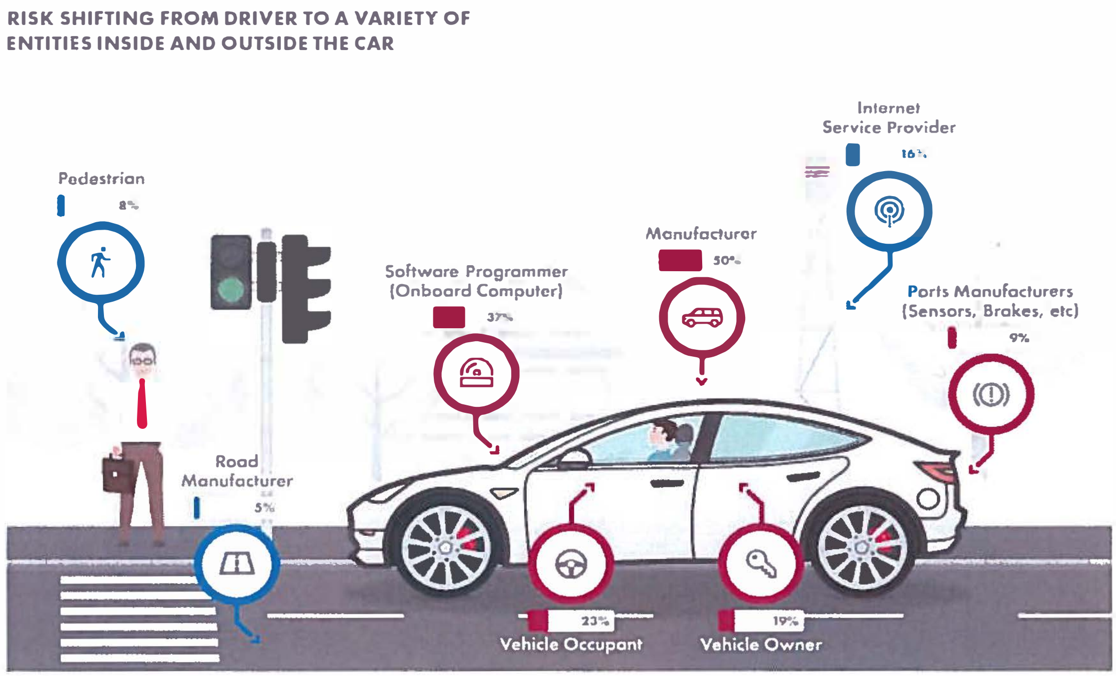
The AIG survey (2018) also identifies factors that the general public feels may delay the use and development of autonomous vehicle market. The survey suggests that consumers are not as convinced as predicted results in studies regarding reduction in loss frequency and severity. 55 percent believe cost is one of the top three factors in delaying or preventing the wide availability of driverless vehicles, while 41 percent identified the security of computer systems to be another top-three factor. Both malicious hacking and privacy of personal data are of concern to the respondents. 41 percent of U.S. adults also cited people's enjoyment of driving as a major factor in delaying adoption. In addition, while 42 percent of adults in the U.S. said they would be comfortable sharing the road with driverless vehicles, 41 percent said they were not comfortable.

3.2.2 Public Perception about the Changing Risk Landscape

Consistent with the experts, the general public also sees liability shifting as autonomous features take more control of the vehicle. This view is illustrated clearly when a pedestrian is involved in an accident. In cases where the respondent operates a vehicle with autonomous features that struck a pedestrian in a crosswalk, 54 percent of the U.S. respondents cited themselves as most liable, compared to 33 percent citing the manufacturer and 27 percent selecting the software programmer. However, when the respondent is an occupant of a driverless vehicle that strikes a child, 50 percent of U.S. respondents named the manufacturer as most liable, followed by 37 percent naming the software programmer, 23 percent naming the vehicle occupant and 19 percent naming the vehicle owner. In cases where driverless vehicles crashed as a result of incorrect or misleading data, 56 percent of U.S. respondents view software programmers as most liable, followed by 42 percent blaming manufacturers, 26 percent selecting network providers and 18 percent naming the vehicle owner.

In general, consumers expect that a variety of entities, including vehicle owners, vehicle operators/occupants, auto and parts manufacturers, network providers, infrastructure providers, and governments will share varying degrees of liability for accidents involving cars with autonomous features and fully driverless cars. (AIG, 2018).

Figure 2: Risk Shifting in a Driverless Vehicle



Source: AIG (2018) "The Future of Mobility and Shifting Risk".

3.2.3. Public Expectations for Insurance Products and Services

In general, AIG (2018) survey respondents feel that with the changing technology, risk and liability landscape, insurance and insurers have a significant role to play in the future of mobility. More than a third of respondents in the U.S. identified "lower insurance costs" as a most-appealing benefit for cars with autonomous features and driverless cars. 81 percent respondents in the U.S. said owners or riders of driverless vehicles in the future should have car insurance. 64 percent said people who use subscription or on-demand driverless services should have their own auto insurance. These suggest a strong future demand from the consumers for personal automobile insurance products even with autonomous vehicles, which is somewhat to the contrary of predictions by many professional studies.

In summary, the attitudes and expectations of consumers and the general public should be well understood and taken into account when designing laws, regulatory policies, and business strategies. The apparent divergence between public opinions and expert predictions in some areas provide an opportunity for all parties to further their inquiry into the true nature of the market dynamics with autonomous vehicles.

III. Anticipated Changes in the Insurance Industry

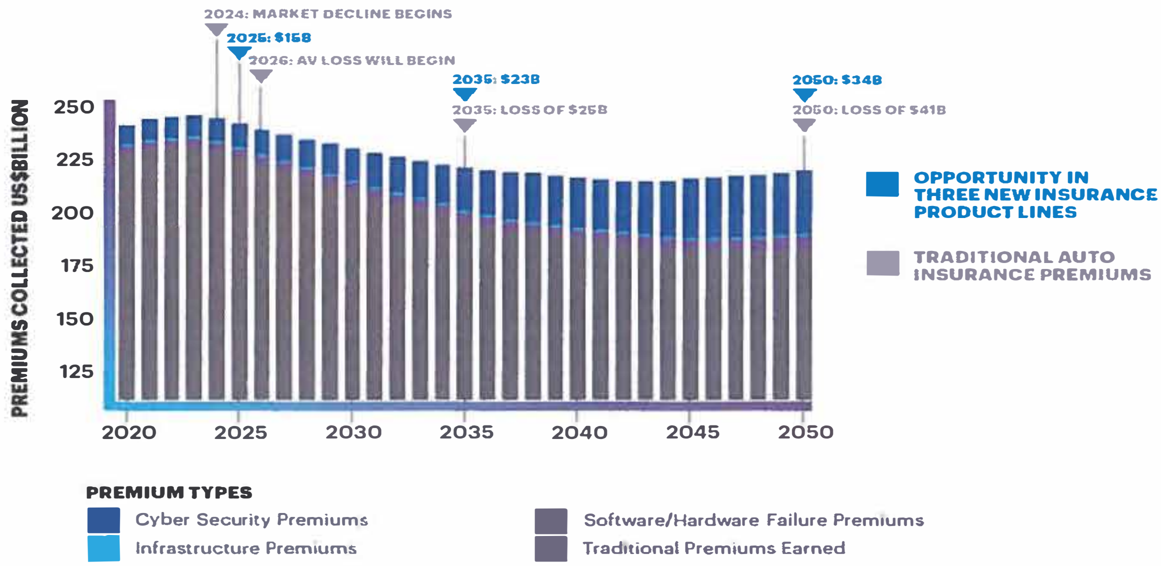
In this section, we will describe the many changes that will take place within the insurance industry when autonomous vehicles begin to enter the market.

3.3 Types of Risk Exposures and Insurance Coverage

The mobility industry is undergoing a major shift as new innovations come on the horizon and the development and testing of autonomous vehicles is one of the most notable. These innovations have led to fundamental changes in vehicle ownership, with lower average rates of household car ownership, higher annual miles driven per vehicle, and shorter vehicle life spans.

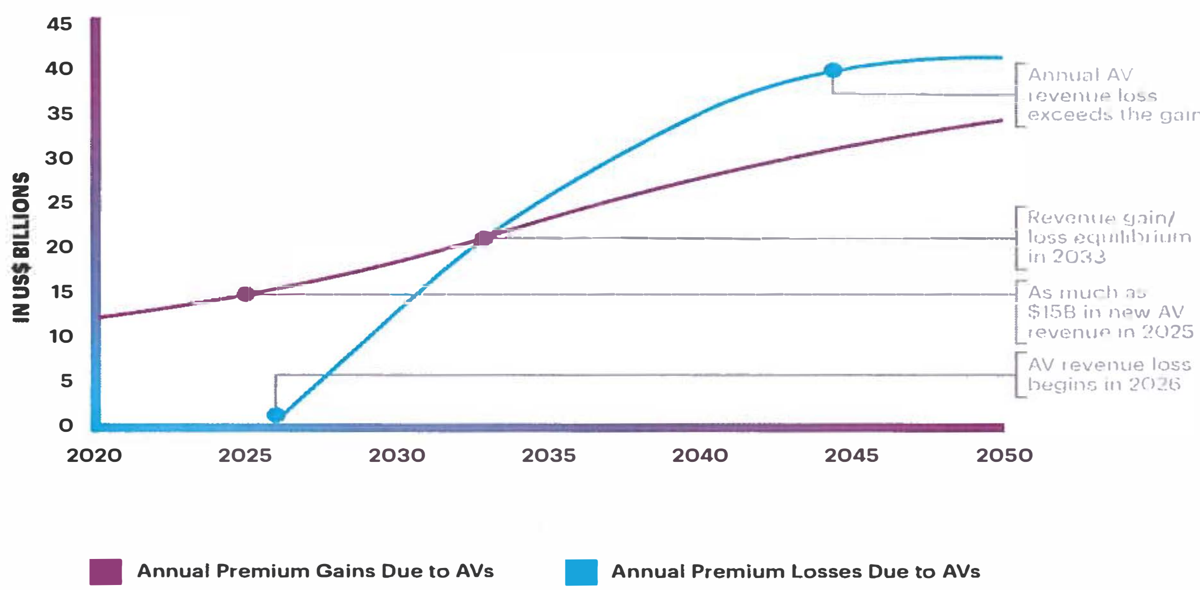
The risk exposures associated with the mobility industry are changing thanks to these innovations. While traditional risk exposures such as first party damages and third party liability may decrease, new exposures such as cyber, product liability, and infrastructure and network exposures present many growth opportunities for the property & casualty insurance industry. See Figure 3 for the projected premium distribution among different types of insurance products and Figure 4 for traditional auto insurance premiums drop and new product lines premiums gain due to the rollout of autonomous vehicles. These changes, along with the impact on loss frequency and severity, are discussed in the rest of this section while resulting challenges facing the auto insurance companies are discussed in the next section.

Figure 3: Projected Distribution of Different Insurance Product Premiums over Time



Source: Accenture and Stevens Institute of Technology, "Insuring Autonomous Vehicle
an $81 Billion Opportunity Between Now and 2025."

Figure 4: Impacts of AVs on insurance premiums (Annual Gain v.s. Loss)



Source: Accenture and Stevens Institute of Technology, "Insuring Autonomous Vehicles an $81 Billion Opportunity Between Now and 2025."

3.3.1 Car Ownership, On-Demand Mobility Services, Ride Sharing, and Insurance Volume

Another trend that has emerged along with the development of the autonomous vehicles is the quickly growing on-demand mobility and ride-sharing services industry. According to KPMG (2017), the total number of connected vehicles used for ride hailing purposes is forecasted to exceed 1.5 million in North America by the end of 2017. Mid-year 2016 estimates show a total of 15.8 million monthly active users (the number of unique users who utilize the Uber app at least once within a 30-day period) for Uber nationally, with a growth rate of 6.6 percent from May to July. Potentially influential partnerships have also been forged between major OEMs such as GM, BMW, Toyota and Volvo and companies such as Lyft, Car2go and Uber to further these trends.

These changes in owning and using a vehicle are persuasive. It is estimated that a millennial is 30 percent less likely to buy a car than someone from a previous generation (KPMG, 2017).2 This rapid and persistent change in car ownership and the usage of on-demand or ride sharing services will result in significant reduction in insurance volume for traditional personal automobile insurance coverage.

Currently, personal auto insurance premiums dominate the auto insurance industry. With the fast arising on-demand mobility and ride sharing services industries, the large autonomous vehicle fleets will lead to a much larger share for the commercial auto line of business. According to a scenario analysis done by the KPMG's actuarial pricing team, by 2050, personal auto insurance may account for only 22 percent of total sector losses, implying a much lower percentage of premium contributions as well. Figure 5 illustrates an allocation between personal auto, commercial auto and products liability losses in 2017 and a predicted allocation of these losses in 2050.

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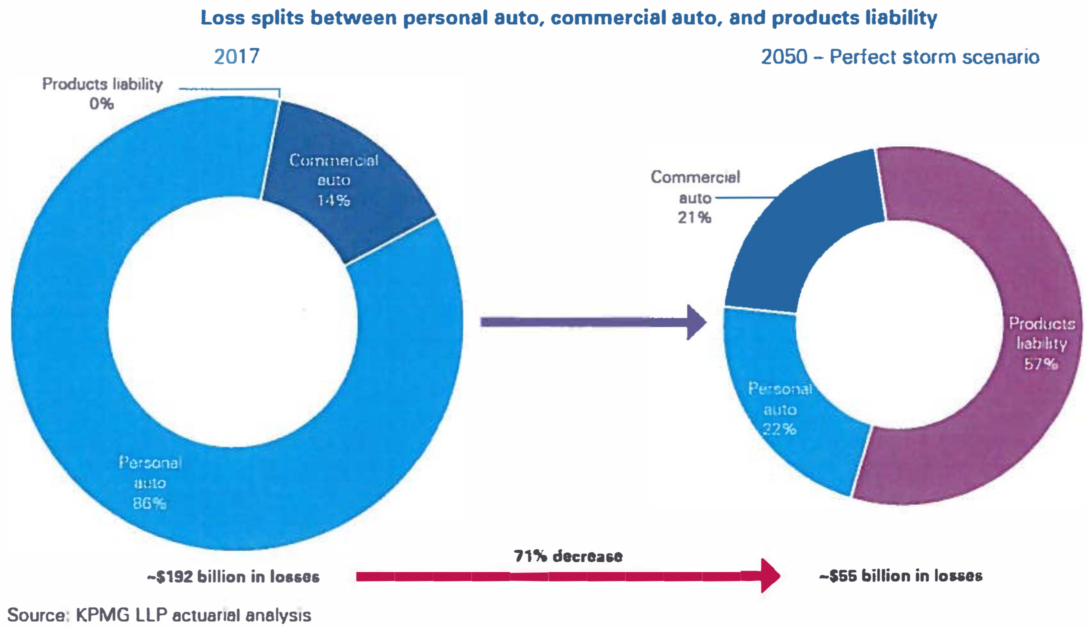
[2] However, according to a new reference from auto analyst Glenn Mercer, this pattern is changing too. In 2018, the millennial generation accounted for 27.2% of the new car registration, almost the same percentage as the generation X (27%).

Figure 5: Loss Splits between Personal Auto, Commercial Auto and Product Liability

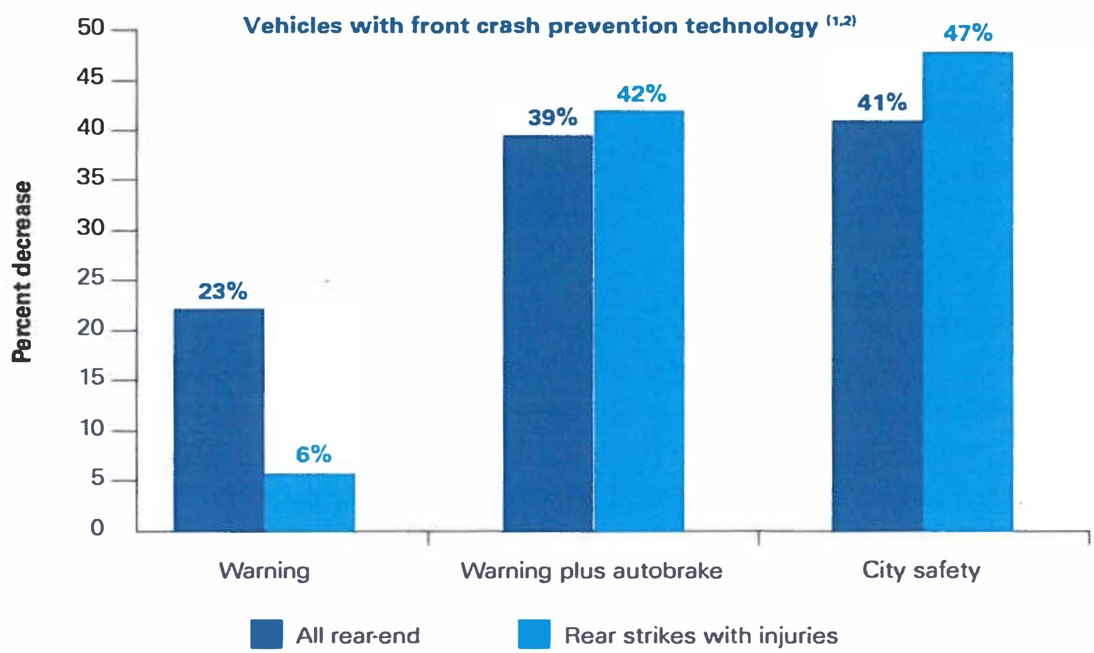


3.3.2 Loss Frequency and Severity

Three driving forces have been identified to potentially bring significant disruptions to the $247 billion premium auto insurance marketplace. First, total losses from auto accidents are predicted to decline substantially due to significantly reduced loss frequency and possibly reduced loss severity. Second, auto insurers may face increased competition from the OEMs and possibly on demand mobility or ride sharing services providers as insurance providers. Lastly, large fleets run by on-demand mobility and ride sharing services will drive the demand for auto insurance from personal lines of business to commercial lines of businesses, changing the composition of the market while potentially driving down the total losses and premiums of the auto insurance market.

Through its sophisticated scenario analysis, supported by proprietary data and actuarial pricing models, KPMG (2017) has predicted that in aggregate, the industry's losses could fall by roughly 63% or $122 billion in nominal dollars by 2050 under a somewhat moderate scenario. This is due, to a large extent, to a 90 percent predicted reduction in loss frequency per vehicle. Adding in the assumption that autonomous vehicles are likely to drive more miles in their lifetime than traditional vehicles, the decrease in loss frequency is even more substantial on a per-mile-driven basis. These predictions are supported by existing data on auto crashes. Vehicles that have a front crash prevention technology are found to engage in significantly less rear-end accidents than other vehicles, according to recent studies by the Insurance Institute for Highway Safety (IIHS). IIHS findings show a reduction in loss frequency of between 23% and 41% depending on the type of prevention system. According to the IIHS, more than 700,000 police-reported crashes in 2013 could have been avoided if the vehicles were equipped with auto brake technology.

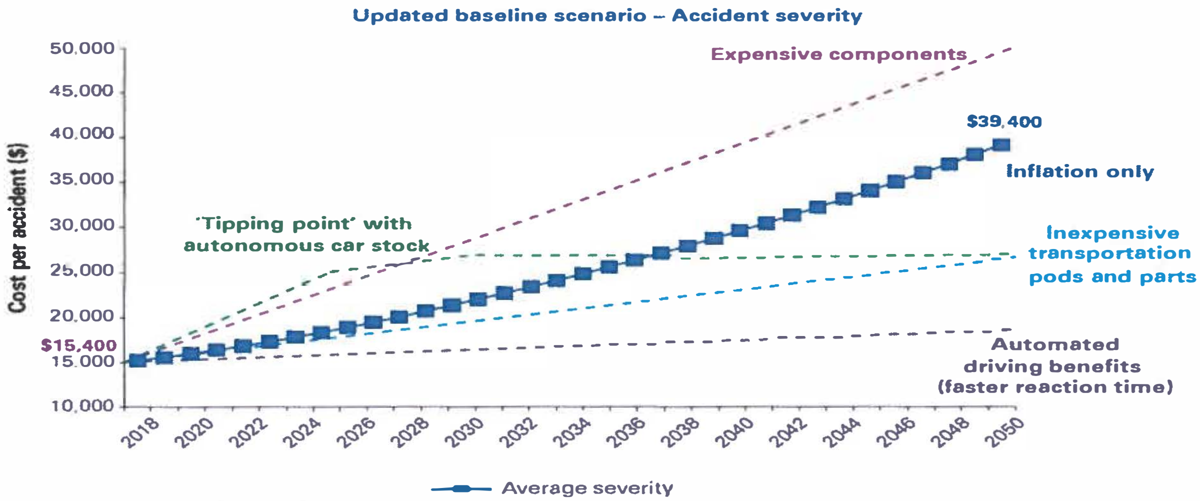
Figure 6: Reduction in Loss Frequency due to Prevention Systems.



Source: Cicchino (2016), "Effectiveness of Forward Collision Warning Systems with and without Autonomous Emergency Braking in Reducing Police-Reported Crash Rates", Cicchino (2016), "Effectiveness of Volvo's City Safety Low-Speed Autonomous Emergency Braking System in Reducing Police-Reported Crash Rates", and IIHS (2016) "Status Report", Vol. 51, No.1, January 2016".

While loss frequency is unambiguously predicted to decline, predicted trends for loss severity are somewhat complex. Human bodily injuries are generally believed to decrease. In addition to generally expected increase in claims due to inflation, however, property damage claims are likely more costly due to the higher production costs of autonomous vehicles. As autonomous vehicles become more ubiquitous and technology evolving, economies of scale in production and improved AV technology will bring down the cost of these property damage claims in time.

Figure 7: Accident Severity in KMPG's updated Baseline Scenario



Source: KPMG LLP actuarial analysis

With predictions on key factors such as predicted loss frequency, loss severity, and annual miles driven, and under other model assumptions, two scenarios were analyzed in the KPMG analysis to arrive at final predictions for total losses and the allocation among different types of coverages (see Figure 8).

Figure 8: Potential Auto Insurance Markets Today and in 2050

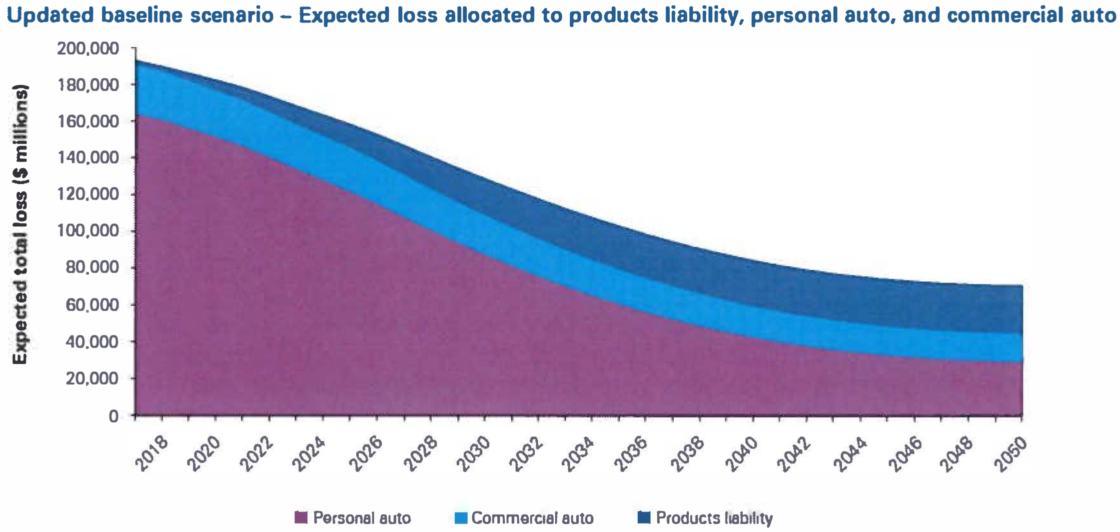
Potential automobile insurance market scenarios: 2050

Key metrics	Today	2050 scenario 1 – Updated baseline	2050 scenario 2 – Perfect storm
Expected total loss (claim $)	$192 billion	$71 billion	$55 billion
Loss by coverage type	Personal: 86% Commercial: 14% Products Liability: 0%	Personal: 44% Commercial: 22% Products Liability: 34%	Personal: 22% Commercial: 21% Products Liability: 57%
Loss frequency (per 100 vehicles)	4.7 accidents	0.5 accidents	0.6 accidents
Loss severity	Total cost per incident: $15k — Bodily injury: $6k — Property damage: $9k	Increase in total cost per incident from $15k to $39k — Bodily injury: $6k to $18k — Property damage: $9k to $22k	Increase in total cost per incident from $15k to $29k — Bodily injury: $6k to $18k — Property damage: $9k to $11k
Annual miles driven per vehicle	12k	Gradual increase from 12k to 14k as the car stock converts to autonomous vehicles	Gradual increase from 12k to 15k as the car stock converts to autonomous vehicles

Source: KPMG LLP actuarial analysis

The more modest “baseline” scenario depicts a market that will experience a more gradual turnover from traditional vehicles to autonomous vehicles, a modest increase in on-demand mobility and ride-sharing services, and a moderate transition from traditional automobile insurance coverages to products liability insurance coverages. Under this set of predictions and assumptions, there will be an estimated decrease of 71 percent per vehicle and a 63 percent decrease in total losses, resulting in $71 billion in total automobile insurance losses or roughly a $122 billion reduction from today's amount. While this scenario still predicts 44 percent of losses attributable to personal automobile insurance in 2050, the significant decrease in total losses leads to an 81 percent decrease in overall personal auto losses, from $165 billion to only $31 billion (see Figure 9). Therefore, even under this rather conservative scenario, insurance companies can expect a substantial loss of businesses from the personal auto line and may need to consider expanding on the commercial auto and products liability lines of businesses to remain profitable and competitive.

Figure 9: Expected Loss Allocated to Different Lines under KPMG's Baseline Scenario

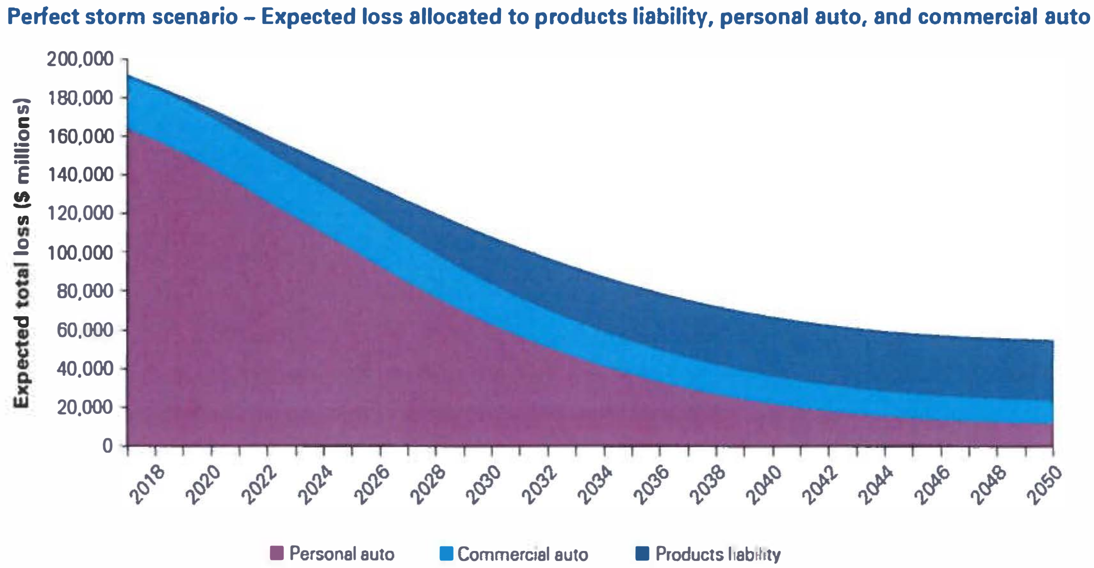


Note: (1) As previously noted, a large portion of commercial fleets may be self-insured, resulting in a further decrease in the commercial insurance market.

Source: KPMG LLP actuarial analysis

A second scenario was considered where anticipated changes are going to realize faster and with a larger force. This would include a significant increase in the number of autonomous vehicles and a more rapid transition from traditional personal car ownership to on-demand and ride-sharing services. As a result, a more drastic set of changes will take place for the auto insurance market, especially the personal auto insurance market. Under this scenario, a higher percentage of overall losses (57%) will be attributed to products liability coverages. While the reduction in loss frequency remains substantial, loss severity increase may be moderated by the efficiencies coming from better technology and large scale implementations. In combination, a cumulative decrease of 71 percent, or roughly a $137 billion reduction in total losses, is predicted under this scenario. Under this scenario, personal auto insurance losses will decrease much more, by an astonishing 93 percent, to just over $12 billion. While this scenario is unlikely to realize due to many practical constraints, the alarming prediction points to the urgency for automobile insurers to evaluate growth and diversification strategies for their portfolios going forward by addressing many challenges they face in the era of autonomous vehicles. We discuss some of these challenges in the next section.

Figure 10: Expected Loss Allocated to Different Lines under KPMG's Perfect Storm Scenario



Source: KPMG LLP actuarial analysis

3.3.4 Additional Considerations

The findings and conclusions regarding risk exposures and insurance premium volume discussed previously were primarily based on aggregated data and rather broad assumptions. From a more focused perspective of the insurance industry, the anticipated changes to the risk and insurance landscape are more nuanced depending on a number of factors. A detailed analysis using actual data and pricing model from an insurer (CAS, 2018) found that insurers' pricing models could take a long time to recognize improved performance resulting from the AV technology and the discount to the insurance premium will depend on the technology's introduction, the number of vehicles with the technology, and the insurer's view of the risk. While a completely crashless car could earn up to a 78 percent discount after four years, the discount likely to be achieved considering the multitude of factors is much smaller in the short run. Therefore, there may be a significant delay in seeing an impact on auto insurance premium after the safer technology is introduced.

Additionally, the liability insurance mechanism is likely to shift from personal automobile to products liability, as described previously. The shift would bring with it greater coverage, but also higher frictional costs due to the differences between these two insurance lines of business. Some of these differences include a transition from a primarily negligence based system for auto liability to a strict liability system for product liability. Additionally, automobile insurance liability (with relatively low limits) often involves liability of an individual but the product liability (with high limits) will be of the auto manufacturers. These could result in a large increase in insurance premiums, despite possibly a smaller percentage going toward claimant compensation. Under some simplifying assumptions, the CAS automated vehicles task force (CAS, 2018) estimate that shifting liability from personal automobile insurance to products liability will increase the average vehicle premiums (in 2011 dollars) from $781 to a range of $1,578 - $2,355.

IV. Challenges Facing the Insurance Industry

In this section, we will discuss in detail the various issues that represent challenges for the insurance industry, resulting in part from the changes that will take place in the auto insurance market, as discussed in the previous section. We will also provide some short discussions on how insurance companies may be able to address these challenges.

3.4 Auto Manufacturers (OEMs) Present a Main Challenge

One of the main challenges the insurance industry is facing may come from the OEMs themselves. Because of the nature of autonomous vehicles, OEMs may possess competitive advantages that they did not have before and could change the dynamics in the insurance marketplace. Auto manufacturers will play a more prominent role in the insurance industry in the autonomous vehicle age for the following reasons.

First, risks associated with the autonomous vehicles may be shifted to the OEMs. In an autonomous vehicle, the proprietary algorithm designed and managed by the OEMs, rather than the human drivers, will make most or all of the driving decisions. As a result, the OEMs and possibly their suppliers will begin to assume increasingly more of the driving risk and associated liability. Although currently different auto manufacturers diverge on how liability may shift, at least some of them took the position to accept full responsibility with regard to product liability. This acceptance of liability makes it more likely for the auto manufacturers to effectively become the insurer for these risk exposures and they may also choose to self-insure their product liability risks and only transfer excess/catastrophic losses to an insurance company.

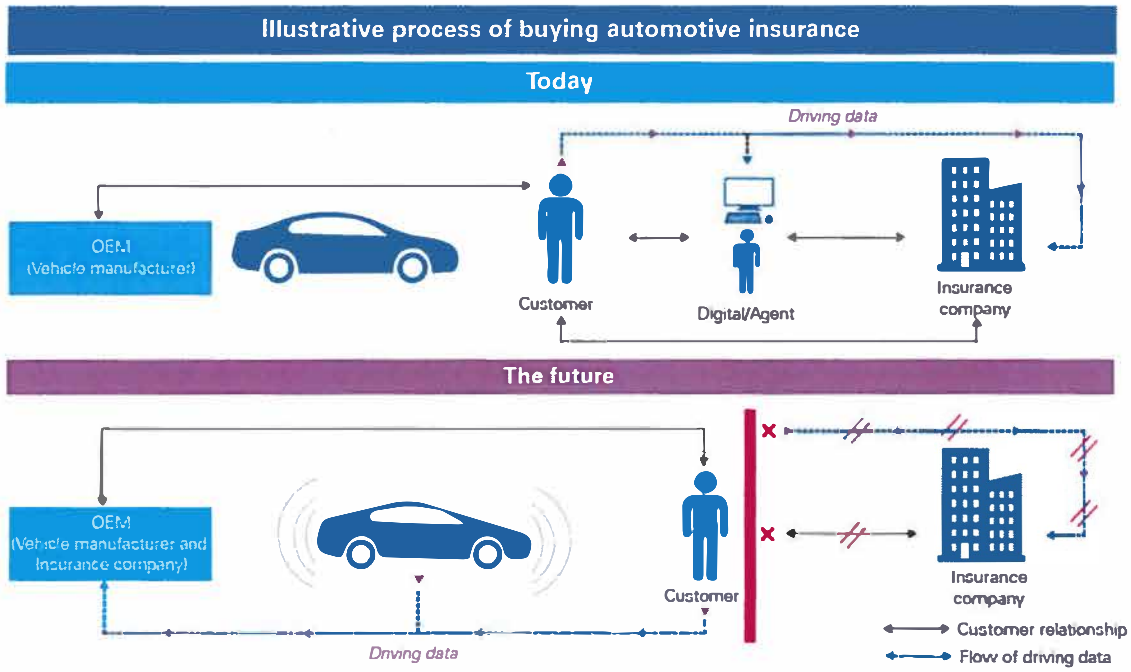
In addition, in a hybrid environment where driving decisions are shared between a partially automated vehicle and the human driver, it may be more efficient to consolidate the insurance coverages provided to both parties to reduce the volume of cross-suits between the driver and manufacturer and help facilitate the negotiations with a third party. This again provides the OEMs with an incentive and possibly a competitive advantage to become the insurance provider.

Second, OEMs may have better access to user data and their private and "black box" type of algorithms. One of the traditional advantages insurers have is their unique access to a vast amount of driving data, including driver characteristic and loss experiences. This data has also been enhanced during the recent years with, for example, the use of telematics and satellite locations data, through collaborations with companies that provide these technologies. However, with the new technology in autonomous vehicles, the next generations of vehicles will likely be able to capture real-time and detailed driving statistics, road conditions, weather information, surrounding environments, etc. It is likely that this new data will be recorded and kept by the OEMs and it provides the OEMs another competitive advantage to better understand and analyze the risk exposures.

In addition, auto manufacturers often use complicated, "black box," type of artificial intelligence algorithms in the design and operation of autonomous vehicle and these algorithms are almost always proprietary due to competitions. This imposes additional difficulties for insurance companies to analyze risk exposures for underwriting and pricing purposes, as they traditionally do, even if they can gain access to the user data.

The OEMs may also choose to bundle the insurance products within the sales process of the vehicles, possibly offering a more competitive price for the insurance products and attract more consumers. If the above described scenarios are to realize, the OEMs can gain substantial market shares of the new insurance market for the autonomous vehicles and possibly drive many of the existing property & casualty insurers out of the market. The aforementioned possible changes are illustrated in Figure 11.

Figure 11: Process of Buying Auto Insurance – Today and the Future



Source: KMPG White Paper (2017) "The Chaotic Middle: the Autonomous Vehicles and Disruption in Autonomous Insurance".

One solution to these challenges is for the insurance companies to seek active and sustained collaborations with the OEMs on data sharing as well as assistance in "de-coding" the algorithms. As will be discussed in the next Section, insurance companies do possess competitive advantages in analyzing risk exposure and loss data and in developing underwriting and pricing models. These advantages are even more substantive during the likely long period of intermediate developmental stages where there will be a mixture of human driven and autonomous vehicles.

3.4.1 Increased Use of On-Demand Mobility Services Is Another Major Challenge

As discussed in Section III, one of the important trends we will see in the age of autonomous vehicles is the increased use of on-demand and ride-sharing services. This trend is predicted to significantly reduce car ownership, substantially increase the miles driven, and further allow certain sectors of the population (such as the under-age and the elderly) to utilize this mode of transportation. This move towards shared vehicles has profound implications for automobile insurance. In particular, on-demand mobility services and ride-sharing will lead to a much reduced amount of personal auto policies and an increased amount of commercial auto policies.

These trends in how vehicles will be owned and used have important implication for the automobile insurance market. In particular, personal auto insurance policies are likely to decline while commercial auto policies are likely to increase. Similar to the discussions in the previous section, there are additional issues regarding if the insurance policies will be provided by the large ride-sharing and on-demand mobility service providers or the traditional insurance companies. These service providers, due to their potentially large scale and existing relationships with the auto manufacturers, may be in a better position to negotiate a favorable deal for insurance offered by the auto manufacturers, or form a data sharing agreement with these OEMs and consequently become an insurance provider themselves.

In response to these changes, insurance companies need to examine their current book of businesses in terms of the product mix and risk exposure distributions and design strategies to gradually accommodate the upcoming changes. As discussed previously, insurers also need to proactively design strategic and tactical responses to compete with OEMs and on-demand mobility and ride-sharing service providers in the new insurance market place. Regulators may play an important role to help define some business boundaries for insurance.

The challenges discussed above are likely to impact most, if not all, areas of operations of an insurance company. While it is perceived by some that certain functional areas (such as claim adjusting) will see the impact first, it is more efficient and effective to address the challenges across the different areas of operations in an Enterprise Risk Management type of holistic framework. First, insurance companies will need to revitalize their product portfolio to provide coverage for the changing loss exposures.

This will include designing products and/or coverages for new or updated risk exposures such as products liability for autonomous vehicles, cyber security losses, infrastructure and network losses, commercial auto insurance losses from large AV fleets, among others. Insurance companies have to also decide whether to institute changes to and how to best service the existing and decreasing number of personal auto insurance policies.

Second, major challenges are present with regard to underwriting and pricing with autonomous vehicles. In addition to overcoming hurdles related to gaining necessary access to data and algorithms likely maintained by the OEMs, insurance companies have to also assess if and what new underwriting and pricing models are needed for the analysis in the new market.

Third, a similar set of challenges are present with regard to claims adjusting, with the added difficulties in complex liability assignment and subrogation.

Fourth, even the sales and production process will experience fundamental changes. With the competition from OEMs and on-demand mobility and ride-sharing services companies, insurers have to find their unique competitive advantage in order to market the insurance products and promote sales. There is also the added issue for those insurers that use agents for product distribution.

Last but not least, insurance companies have to arm themselves with strategies to effectively interact with key stakeholders such as consumer, regulators, OEMs, and on-demand and ride-sharing service providers.

V. Potential Contributions of the Insurance Industry

In this section, we will investigate how the insurance industry can contribute to the healthy development of the autonomous vehicle test site and ultimately an autonomous vehicle market.

Despite the realistic concerns that OEMs and even ride-sharing services providers might possess competitive advantages in the insurance markets with autonomous vehicles, it is important to recognize that traditional insurance companies do have many competencies that can help them compete and contribute to this market.

First and foremost, insurance companies have substantial knowledge and experience in understanding exposure and risk data, as well as owning expertise in predictive modeling techniques specifically designed for underwriting and pricing purposes. This can be illustrated with a pricing example provided by the CAS Automated Vehicle Task Force (CAS, 2018).

In this example, based on one insurer's pricing model, they found that, "if the vehicle is categorized as a "new" model, with no comparable prior model year, then a vehicle that lowers loss costs by 50 percent will only receive an 8 percent premium discount after four years. Even a vehicle with no losses will still only receive a 15 percent premium discount after four years. On the other hand, if the technology is introduced on existing automobile models, the insurance pricing model will give its experience more weight, resulting in a larger premium discount. With this approach, the average premium discount after four years for a vehicle that reduces losses by 50 percent will be 21 percent; the maximum discount will be 38 percent." (CAS, 2018) This set of conclusions stand in sharp contrast with some of the predictions made by others, suggesting a possible competitive advantage in, not general sophistication in data processing and analytical modeling, but specific application to insurance related problem solving. This competitive advantage of insurers will prove to be especially valuable during the transitional stages.

Second, in a world of autonomous vehicles, auto manufacturers have a natural data advantage as describe in Section IV. However, insurers also have a data advantage. Introduction and ongoing risk management for the autonomous vehicles market require a holistic view of not only the technology's performance, but also its impact on comprehensive risk assessment and accurate performance benchmark. Especially for benchmarking, regional or local traffic and accidents data, rather than national averages, are needed to make meaningful comparisons. Insurers seem to be the best source for a large amount of long standing historical data for these tasks, supplemented by their expertise in risk assessment and risk management. Insurers can also provide with the policymakers an independent and relatively unbiased evaluation of AV technology's performance. In the CAS Automated Vehicle Task Force report (CAS, 2018), a simple example was provided to illustrate this point. "Mark Rosekind, the Administrator of NHTSA, stated in 2016 that self-driving cars must start by being twice as safe. However, without the active participation of personal auto insurers, AV performance cannot be effectively measured against even this simple goal."

Third, many insurance companies already have a positive and robust relationship with a large consumer base and some of them have strong brand recognition. Previously discussed survey studies also show that consumers and the general public expect to have insurance products and services reminiscent of the current market. The existing distribution channels can be re-calibrated to sell and service the new products. The brand recognition will also help ease projected anxiety and confusion from consumers when AV products are gradually rolled out to the market.

Fourth, under similar principles of insurance that work in the current market, possible risk pooling by insurance companies across different auto manufacturers, on-demand services and ride-sharing services, and geographies can still represent a powerful tool for efficiently reducing the cost of risks. Even when these entities choose to self-insure, insurance companies may still be able to serve as a backdrop for large and undiversified risk exposures. In addition, many insurance companies have excess capital that will help support the development and service of new AV related products, especially at the beginning stages of transitions.

Overall, the insurance industry can make a positive and substantial contribution to the development and maintenance of the autonomous vehicle industry. They can help bring the technology to market in an efficient and safe manner by providing a financial incentive to introduce and maintain the AV technology through accurate pricing (of insurance), and through their holistic risk assessment and benchmarking to evaluate performance. They can also help delineate the costs and benefits involved in the transition of the liability system, thereby informing the discussions and decision making process involving the general public and the regulators.

VI. Conclusion

The development of autonomous vehicles will bring numerous changes to the mobility industries, the insurance industry, and the society in general. As discussed in this report, these changes bring many challenges as well as new opportunities for the insurance industry. Data and analysis suggest that loss frequency will be significantly reduced with the new technologies, particularly on a per-mile-driven basis. Loss severity, especially losses from personal injuries, is most likely to decrease as well. The same savings may also be achieved for property damage losses when autonomous vehicle productions reach a larger scale.

With deeper penetration of autonomous vehicles in the market, the predicted decrease in car ownership and increase in use of on-demand mobility and ride-sharing services will greatly reduce commute time, decrease traffic congestion, and ease environmental impacts. Altogether, these benefits will provide the motivation and justification needed to facilitate a transition away from human piloting and towards automated operations. The insurance industry needs to be proactive in recognizing these impending changes and reinvent their product lines and core business functions to take full advantage of the new opportunities.

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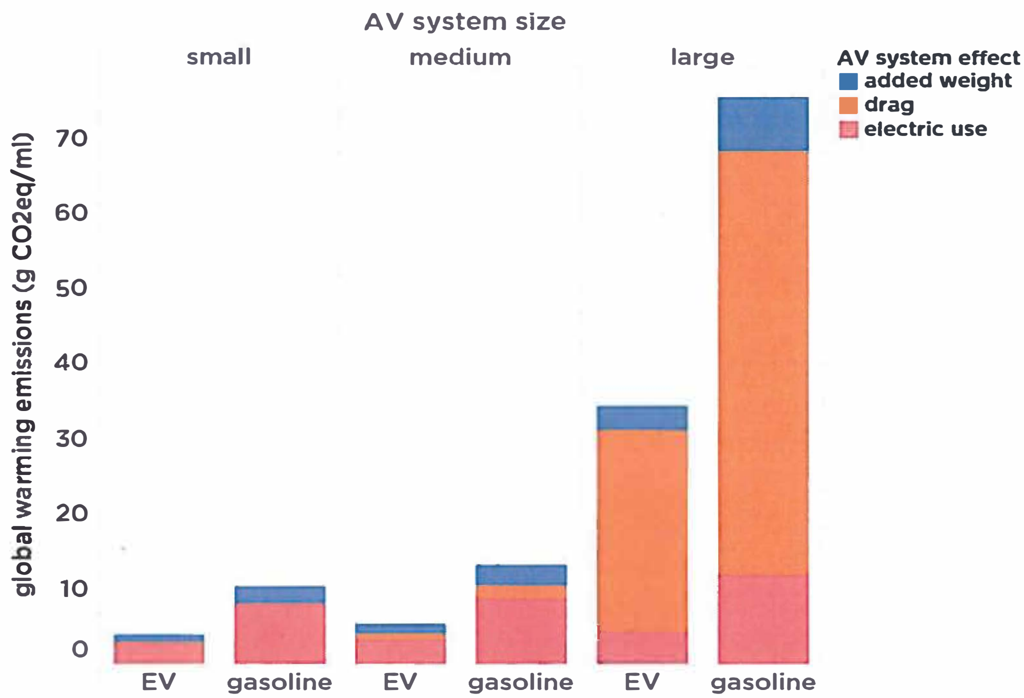
4. Environmental and Energy Use

Autonomous vehicles (AVs) have the potential to significantly change greenhouse gas emissions and petroleum use in the transportation sector. Certain deployment paths will have varying impacts and this section addresses the differences in those paths.

When addressing direct emissions regardless of vehicle usage changes, the added weight and drag from the physical AV technology system itself along with increased need for data transmission could increase operational energy use and GHG emissions of the vehicle by 3-20%. One way to mitigate increased emissions associated with the increased technology and equipment could be to operate the AV system on a battery electric vehicle versus a gasoline-powered vehicle. [1]



[illegible] AV systems can increase greenhouse gas emissions attributed to driving. The largest impact is seen on larger AV systems from the sensor units (Reichmuth, 2018).

In general, the most important determinant of emissions from vehicles is not the AV system but the choice of gasoline or electricity. Therefore, if we have the intention of reducing vehicle emissions by employing AVs, battery electric vehicle platforms should be considered. The addition of AV equipment only increases the existing discrepancy between emissions of an electric vehicle and emissions of a gas-powered vehicle. [2]

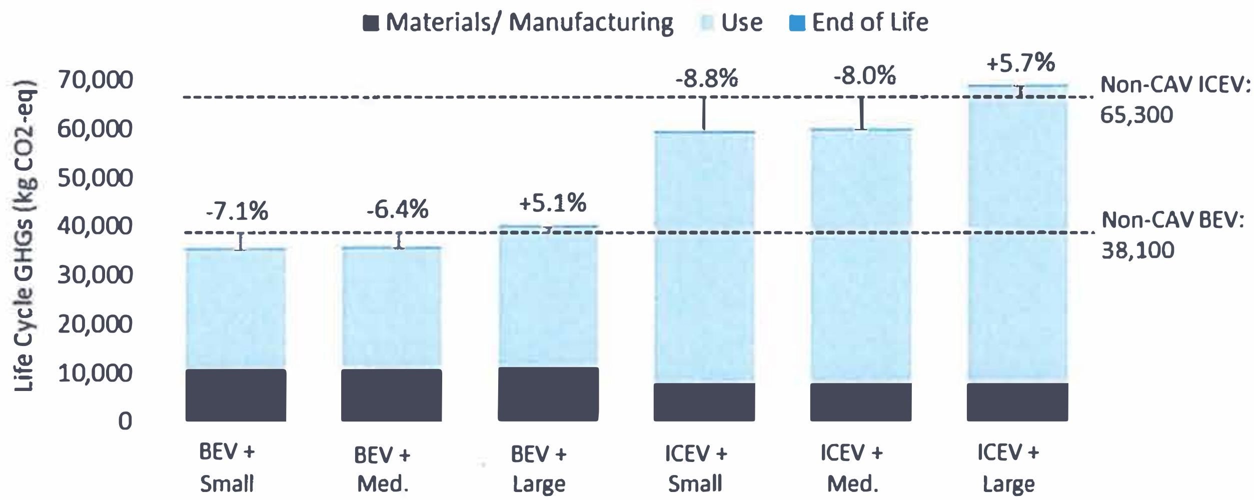


Figure 11 Vehicle-level GHG results for various connected autonomous vehicle scenarios, with direct effects included. Comparison given between lifecycle GHG for various vehicle platforms at various AV technology sizes shows BEV platforms to have much lower GHG emissions. (Gawron, 2018).

Setting aside operational efficiencies, a comparison of lifecycle greenhouse gas emissions for the materials, manufacturing, operation, and end-of-life for autonomous vehicles and their AV subsystem on different vehicle bases shows that battery electric AVs on average will release 40% fewer lifetime GHG than their ICE AV counterparts. [3]

Additionally, electric AVs will have the benefit of providing grid support to the utility as it continues to integrate large scale renewable energy sources into the power grid. These vehicles can help balance loads while supporting a more resilient electrical grid. By both absorbing renewable energy in times of overproduction and transmitting energy back to the grid (if capable of vehicle-to-grid interaction), AVs can provide a smoothing effect for the intermittent nature of renewables and assist with grid-wide management of various power inputs. [4] [5] Fleets of shared autonomous vehicles could be deployed and controlled for large-scale demand response charging, increasing the grid-level benefits when compared even to electric privately-owned AVs. [6]

Potential Technological Efficiencies for Single Vehicles

The simple concept of weight reduction in AVs has potential to save significant fuel. High level AVs can obviate steering wheels, pedals, mirrors, reinforced steel, bumpers and even air bags, though designers must balance efficiency with safety. [7] [8]

Optimized braking and acceleration can also save fuel by anticipating what is happening ahead of a vehicle. With this information, the AV can adjust its driving to minimize acceleration and braking, and can also maximize coasting time, which uses no fuel or kinetic energy. In 2018, University of Michigan researchers demonstrated on public roads that a smoother transition from braking to accelerating improved energy efficiency by as much as 19% for an AV equipped with Vehicle-to-Vehicle communication technology. [9]

Potential Technological Systemic Efficiencies

One of the most evident potential efficiencies of AVs lies in optimized routing. Researchers at MIT have shown that if all drivers used a wider variety of coordinated routes, overall congestion would decrease, saving fuel. In simulations of traffic conditions in cities such as San Francisco and Boston, congestion was reduced up to 30%. [10] By extension, a fleet of connected AVs can be directed to a collective shortest path by analyzing current and anticipated traffic, road conditions, construction, weather and other relevant variables, as well as the AVs' next destinations, current charges, and potential detours to pick up other passengers.

AVs may reduce congestion and the energy it wastes by improving traffic flow and reducing accident frequency (a source of congestion). [11] Additionally, speed harmonization can optimize traffic speed in areas of congestion, bottlenecks, incidents, special events, and other conditions that affect flow. Speed harmonization helps to maintain consistent speeds and reduce unnecessary stops and starts. [12]

The U.S. Department of Transportation approved vehicle-to-vehicle communications (V2V) systems in 2014 and released V2V guidelines in 2017. [13] V2V improves energy efficiency via technologies like cooperative lane changing and merging, which reduces idling and inefficient acceleration; electronic brake lights, which allow AVs to react to vehicles braking that are out of sight; and traffic information systems, which provide up-to-the minute reports on construction, accidents, and obstacles like potholes and debris.

Through vehicle-to-infrastructure communication (V2I), traffic signals have the potential to communicate to AVs to help smooth traffic flow and minimize idling at intersections. In 2012, computer scientists at the University of Texas in Austin began developing software to coordinate intersection traffic enough to render traffic lights and stop signs unnecessary. [14]

In 2012, Volvo deployed a cluster of AVs just 20 feet apart ("platooning") traveling at freeway speeds, by exchanging acceleration and steering information. A University of California study estimates that such vehicle platoons could cut fuel consumption by at least 20%, thanks to reduced aerodynamic drag from leading vehicles. [15] Platooning can allow AVs to follow a leading AV by as little as a few feet, filling empty road space. [16] The materials, manufacturing, and use of the on-board AV system may increase lifecycle greenhouse gases by 3.4% from a baseline battery electric vehicle. Efficiencies such as eco-driving and platooning could balance that increase and create up to a 14% reduction in fuel consumption, but those operational efficiencies must be prioritized in order to see net environmental benefits from the technology. [17]

If implemented with intelligent parking capabilities, AVs have the potential to reduce vehicle miles traveled (VMT) by using shared data to find the nearest parking space that is available currently or in the immediate future, and the nearest available parking space with the charging capabilities an electric vehicle requires. Connected AVs can help to reduce idling, missing an available spot, poor use of parking spaces, and especially VMT while seeking a space.

Potential Induced Inefficiencies

AVs may cause unintended—induced—energy inefficiency in a variety of ways. Only careful planning will minimize these consequences.

AVs could function as competition with public transit, as private companies operate private transit systems with occupancy sometimes higher than today's cars but usually lower than today's mass transit. To ensure AVs support and strengthen a public transit system, instead of pulling away from it, municipalities must continue to invest in mobility and continue to prioritize walking, biking and public transit. [18] Autonomous technologies can be integrated into current transit system vehicles to improve service, increase transportation choices, and reduce cost of mobility. [19] Use of AV technology for first mile and last mile solutions, connecting to transit routes, can be a strategy to increase access to public transit for new populations without increasing competition for public transit. [20]

AVs may drive without passengers over significant distances to "rebalance" an AV fleet for future use, or to avoid paying parking fees. [21] [22] [23] If there is a one-for-one replacement of privately-owned vehicles with autonomous privately-owned vehicles, VMT could increase dramatically, adding to energy consumption and exacerbating congestion. Unfortunately, a recent report by the Victoria Transport Policy Institute highlights that unless public policies favor shared vehicles many users will likely opt for personal autonomous vehicles, increasing total energy consumption and, if electric is not incentivized either, pollution emissions. [24]

Increased convenience, lower travel costs, and broadened vehicle usage by people who currently don't drive could also increase VMT significantly. [25] Also, people may feel more comfortable living farther from their work, since commute time will become free for work or leisure, increasing trip distances. A 2016 study revealed that motivations to carpool include convenience, time savings, and monetary savings, while environmental and community-based motivations ranked low. [26]

AVs include more hardware than non-AVs: LiDAR, radar, cameras and other equipment. This extra weight requires more energy to move the AV. In addition, people may travel greater distances and spend more time in their vehicles. These changes could lead to increased consumer demand for vehicle features and in-vehicle comfort, which could lead to heavier vehicles that consume more fuel. [27]

Additionally, platooning may tempt AV owners to drive at higher highway speeds, which may use energy inefficiently. [28]

Considerations

In view of the above, there are some critical implications for AVs. Broadly, the larger planning community has hypothesized the following broad ends of the spectrum of AV deployment:

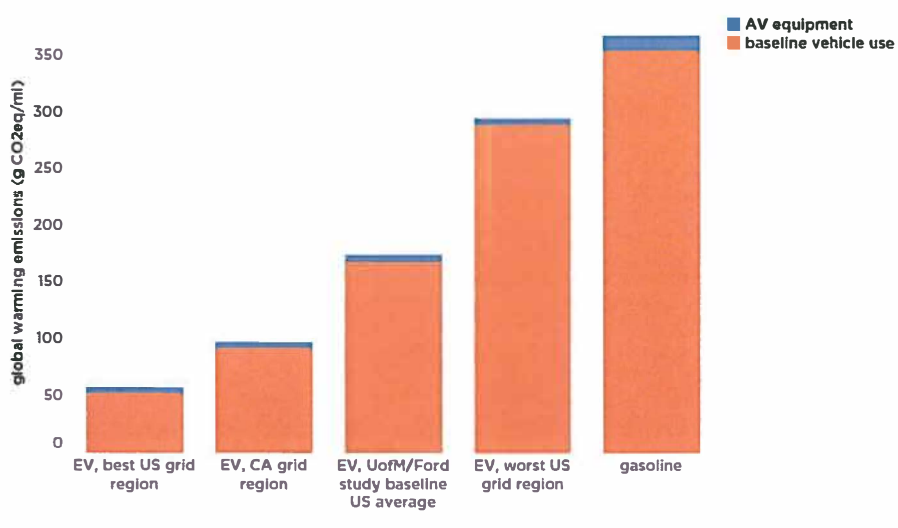
Successfully deploying a combination of automated vehicles, shared mobility systems, and electric/zero emission vehicles could reduce energy consumption and related emissions by 60% over the next 30 years with other benefits in safety and greater access to opportunity for non-drivers.

Conversely, a combination of automated vehicles, zero-occupancy vehicles, increased VMT, access for new user groups, and continued reliance on fossil fuels could increase energy consumption and related emissions by up to 200% over this same time period. [29]

These scenarios vary based on different projections of travel behavior, pricing, technology options, safety benefits, fuel, freight projections, etc. However, it has become increasingly clear that, in order to avoid a "hellish" 200% more VMT scenario, specific policies would help provide a desired community vision around certain AV deployments.

Make them electric

As discussed previously, the most important determinant for direct emissions from AVs is their fuel source. The figure below shows the difference in emissions between an EV powered from a grid fed by renewable resources and a vehicle powered by gasoline, including technology and fuel variations in between, clearly demonstrating how electric matters. [30]

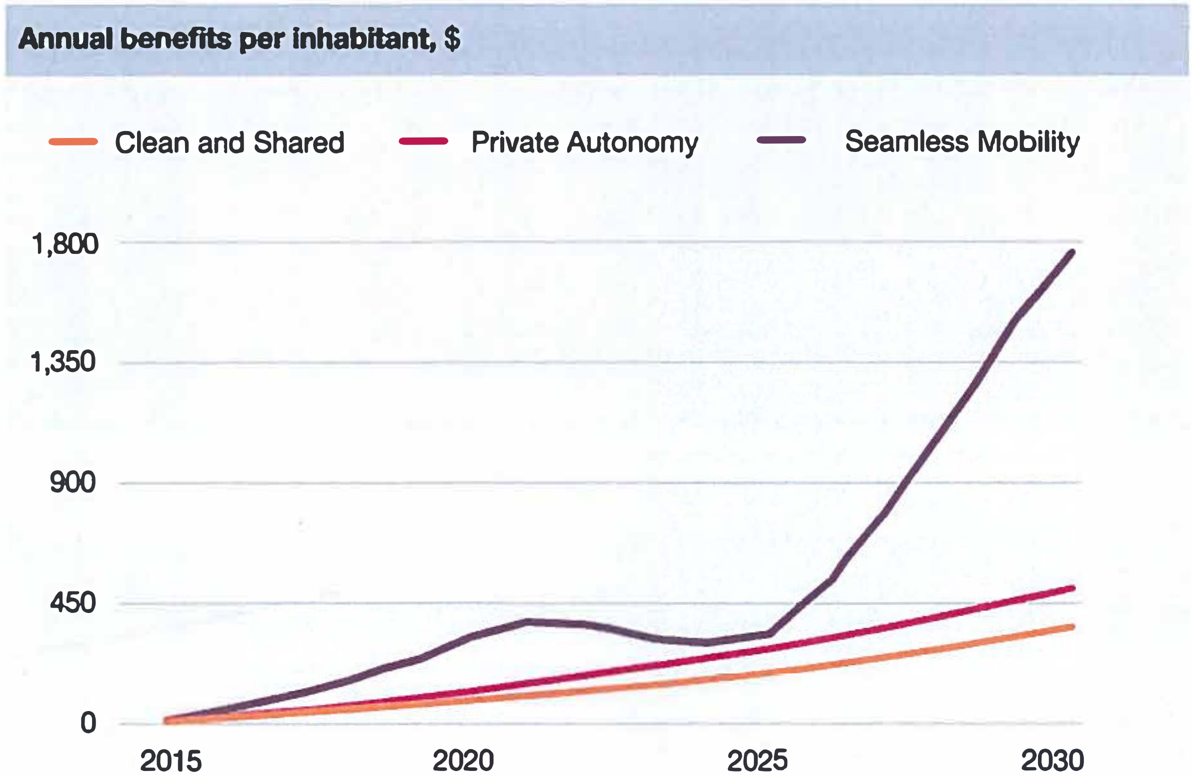


It should not be assumed that all autonomous vehicles of the future will operate on electric powertrains. While GM and Waymo invest in zero-emission autonomous vehicles, other companies like Uber and Ford are piloting AV technology on gasoline-powered vehicles. Boston University's Institute for Sustainability argues that one important way to shape this future is to demand that electric (battery or hydrogen) AVs be part of testing fleets. As companies want to expand testing to new cities, cities have the ability to demand the types of vehicles operated on their roads. [31]

Make them shared

One of the critical concerns with AVs is that they will dramatically increase vehicle miles travelled. What used to be one trip (you going to work) is now two trips (one trip to pick you up via ridehail and then another to get you to your destination). With AVs, those miles driven increase even more as the vehicle circles aimlessly until you are ready to leave your destination. Early estimates suggest that 40% of trips will be of the cruising variety—driving with no passengers. [32] This means that there must be a push from policymakers to make them shared to avoid increased congestion and energy use. Using AV technology for public transit vehicles and microtransit is a key opportunity and will help to ensure that AVs complement pubic transit rather than displace it. It is also important to provide incentives for shared options, which may encourage fleets or AV transportation services rather than individual ownership.

Individually these elements are critical, but collectively they can be even more powerful. McKinsey assessed three potential scenarios for the future of mobility – private autonomy, clean and shared, and then seamless mobility. Seamless mobility is a future in which clean and shared vehicles are deployed within an urban framework to provide the greatest individual and societal benefit. [33]



By combining the emissions reduction potential of electric powertrain technologies with the added benefit of small, shared AVs, and assuming a future low-carbon grid as planned for Hawaii, GHG emissions could be reduced by about 90% when compared with today's vehicles. [34]

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5. SOCIAL SCIENCE RESEARCH

I. Introduction

The social science study of autonomous vehicles is still in its infancy, and there is no established single paradigm for studying the effects of autonomous vehicles on humans and society. That being said, an overarching theme can be identified in much of the existing literature. This is a focus on the potential effects of autonomous vehicles on human mobility systems and the ultimate effect of these systems on social well-being.

This of course can be divided into a number of subthemes. For instance, Bissel et al. (2018) break this down into four categories: transformations to human experiences, differences in experience due to inequalities in access, changes to the labor market, and redesign of transport systems, the first two categories being at the individual behavioral level and the last two at the social structural level. Maurer et al. (2016) discuss human behavioral reaction to autonomous vehicles in historical, ethical and psychological context, then move on analyze various political, legal, social, and sustainability factors in the design of mobility systems incorporating autonomous vehicles.

I will cover similar ground, though with a specific focus on Hawaii, starting with some of distinct mobility issues faced by the state, and then move on to the potential for improvement provided by new integrated mobility systems that include autonomous vehicles.

II. Hawaii, Severe Gridlock, and its Health Effects

The average commute time is 27.2 minutes in Hawaii (national average = 26 minutes), which is about 54.4 minutes a day getting to and from work, or about 330 hours a year spent commuting (Research and Economic Division DBEDT 2015). Urban Honolulu suffers from some of the worst traffic gridlock in the United States. Honolulu was ranked the worst city in the United States for traffic in 2012 and second worst in 2014 (HNN 2014). It is now ranked 19th worst in the U.S. and 116th worst out of 1,360 cities in the world, according to Inrix, a transportation analytics firm (Inrix Inc., 2016). As of 2014, TomTom, another transportation analytics firm, ranked Honolulu's traffic congestion as 3rd worst in the country, after ranking it worst in 2012 (Blair, 2014). A 2018 study by financial site WalletHub ranked Hawaii as the worst state for driving in the United States (Mattison 2018, Wu 2018). Workers living further from the city center were more likely to use cars, 46.1 percent of workers on O'ahu left for work early, before 7 AM, compared to the U.S. average of 31.4 percent, which could lead to sleep deprivation, and it varied by neighborhood. The strain caused by extremely time-consuming daily commutes is a common topic in the local news (Temple, 2010; Associated Press, 2015; Cataluna, 2015).

A variety of studies have established that commuting patterns have a major effect on mental health, particularly via its effects on levels of stress for commuters and for those living near high traffic areas. Considerable research has been done on the relationship between commuting time and mental health, particularly stress (Koslowsky et al., 2013). Commuting by car for such long durations can increase social isolation, which erodes psychological well-being (Roberts et al., 2011). Commuting can be stressful because of its long duration, regular unavoidability, unpredictability, sense of impedance, and perceived loss of control (Evans et al., 2002; Novaco & Gonzalez, 2009; Sposato, Roderer, and Cervinka, 2012). Individuals reporting longer commutes to and from work rated higher in stress and tiredness and lower in meaningfulness (Stone and Scheider, 2016). Beyond commuters themselves, people in neighborhoods near high traffic areas can experience chronic stress from air pollution and traffic noise as precursors for mental health problems, asthma, and other respiratory ailments (Koslowsky et al. 1996). Socioeconomically disadvantaged neighborhoods have a higher prevalence of depression and anxiety than more advantaged neighborhoods (Hill & Maimon, 2013).

There is preliminary evidence suggesting that the health effects of commuting are particularly severe among the Native Hawaiian and Pacific Islander (NHPI) population. In Honolulu County (O'ahu island) they disproportionately reside in the rural Windward and 'Ewa (Northeast and West) districts, comprising 37.7% of the population there as opposed to 24.6% in the county as a whole. These districts are the most distant ones from urban Honolulu, where the vast majority of jobs are located (State of Hawaii Office of Planning, 2016). 12 and 12.2% of the residents of these two districts depart for work between 12 and 5am each morning, far higher than residents of any other district, with a further 22.8 and 22.3% departing between 5 and 6am, again the highest of any area in the county (Research and Economic Analysis Division, 2015). A State DOH study found that clinical depression rates among Native Hawaiians, including that for major depression, was by far the highest among major ethnic groups in the island, with 12.7% experiencing current depression (Cho et al., 2013).

III. Hawaii as a Growth-Constrained Society

We can define growth-constrained societies as those faced with existing overburdened mobility systems, yet for geographic and/or cultural reasons, have very little allocatable space to create new right-of-way or expand existing infrastructure. By that definition, Hawaii certainly meets the criteria as a "model" growth-constrained society.

Recent efforts in Oahu to develop a commuter rail system have dragged on and will run on a limited route that does not reach the most populated business areas, including Waikiki. Failure to expand infrastructure to alleviate gridlock is due both to funding issues and the severe shortage of land to build right-of-way. Only 104,232 of 383,691 Oahu's acres of land, or approximately 27%, is zoned as "urban" land open to large-scale transportation infrastructure development, with rest being zoned as either "agricultural" or "conservation" (State of Hawaii Office of Planning 2014). This approach to land stewardship maintains Oahu's unique physical environment, which in turn greatly contributes to both its residents' quality of life and its desirability as a tourist destination, which is in turn is central to the island's, and the state's, economic survival. On the other hand, it cements Oahu's position as a growth-constrained society, thus forcing the State and City and County governments to turn to unconventional solutions in order to address the gridlock problem that negatively affects both residents and tourists.

IV. Autonomous Vehicles, Mobility as a Service (MaaS), and Sustainable Mobility

Sustainable mobility is typically defined as the development of mobility systems that not only provide universal access to efficient and safe transport but also minimize demands on and potential damage to the environment (Mahieldin and Vandycke 2017). Mobility as a Service (MaaS) is a paradigm that focuses on integrated planning, booking, and payment platforms that automate the process of moving travelers from origin to destination in the most efficient fashion based on their customized needs (Expósito-Izquierdo et al. 2017; De Bont and Oonk 2017). MaaS makes considerable use of new forms of transportation that run on existing roads, and in particular depends on connected and autonomous vehicles (AV), as discussed in the technical section of this document. It also seeks to seamlessly integrate AV with existing transportation options, particularly mass transit. When implemented on a large scale, it can coordinate and optimize travel patterns to make travel faster and easier while minimizing the need to expand existing infrastructure (Burns 2013; Frazer 2019).

With a MaaS system in place, a resident or tourist should be able to use a smartphone application to designate their destination, with the MaaS system determining the best combination of mass transportation and **AVs** to accomplish this in the shortest time at lowest cost, with an all-in-one integrated payment system. It will be connected to a AV system to ensure an autonomous vehicle arrives just in time as a passenger disembarks from mass transport, thus ensuring quick door-to-door service while minimizing unnecessary congestion or parking, MaaS based on connected and autonomous vehicles thus provides a promising paradigm for achieving sustainable mobility in growth-constrained society, reducing gridlock and thus improving population health, while preserving the environment by reducing the need to build out new right-of-way to expand road and rail infrastructure.

Research in sustainable mobility has recently turned its attention to the role of sociocultural variables in the design of autonomous/shared vehicle and MaaS systems. This research has been extremely extensive in Japan (for an overview, see Nakajima 2018. See also Nakajima 2019; Moriguchi 2017; Nakayama et al. 2019; Iriyama and Yasuda 2019). While it has gained less attention in the United States, there is a growing English-language literature from Britain, Australia, and New Zealand (Bissell et al 2018), particularly as it relates to determining consumer uptake (Ho et al. 2018; Lyons et al. 2019) and political feasibility (Li and Voege 2017; Jittrapirom et al. 2018), and with a particular focus on the tourism sector (Higham et al 2013; Cohen et al. 2014; 2016).

V. Connected and Autonomous Vehicles/MaaS as a Solution to other Hawaii-Specific Problems

VI. Tourism

Hawaii is a tourism-dependent economy, and draws over a third of its guests from outside of the U.S. (Chu et al. 2017). Tourists often have particular difficulty in moving from desired point to point, since they are typically unfamiliar with the local geography and transportation system and may also need to contend with a language barrier in learning how to navigate on their own. Connected and Autonomous Vehicles enable a MaaS system, thus reducing the frustration and disruption that can greatly hamper the tourist economy (Signorile et al. 2018).

VII. Elderly Population

In addition, Hawaii has the longest average lifespan of any U.S. state (Lewis and Burd-Sharps 2014) and a sizable and rapidly rising population of senior citizens, growing from 14.3% to 17.1% statewide just between 2010 and 2016 (Research and Economic Analysis Division 2016). MaaS can be particularly useful for senior citizens, who may have difficulties with mobility options that require that they walk between drop off and pickup points, in addition to time-consuming, uncomfortable trips that may significantly degrade their health (Li and Voege 2017).

VIII. Disabled Population and Pedestrians

In Hawaii, an estimated 10 percent of the population are people with disabilities (Claypool et al. 2017); many of whom could have access to new, more affordable options via connected and autonomous vehicles. Nationwide, approximately 40 percent of those who report difficulties accessing transportation are people with disabilities. There are approximately 3.5 million individuals who never leave their home, including

1.9 million with disabilities (Bureau of Transportation Statistics 2003). Many of these individuals tend to be older, have more severe disabilities, and have already expressed mobility difficulties.

It is not a given that these communities will be considered. For example, many web developers did not consider full accessibility of technology products, such as section 508 accommodations, functionally rendering these information sources inaccessible.

It is also possible that connected and autonomous vehicles could help address the rapid increase in pedestrian deaths that have occurred here in Hawaii over the past 10 years. Researchers at University of North Carolina-Chapel Hill assessed this potential by analyzing 5000 fatalities from 2015 through a hypothetical AV scenario. They concluded that anywhere from 30-90% of the fatalities could have been potentially eliminated (Combs et al. 2019).

IX. Natural Disasters

Due to its unique natural environment, Hawaii is prone to various natural disaster risks such as earthquakes, tsunami, and in some of the islands volcanic eruptions. In times of natural disasters, seamless and multiple alternative transportation options for evacuation and emergency supply provision are crucial. MaaS and AV vehicles have been viewed as a solution to evacuation of urban areas during natural disasters due to their ability to direct people to the correct evacuation routes and coordinate travel to reduce traffic jams. (Li et al. 2018). In times of natural disasters, seamless and multiple alternative transportation options for evacuation and emergency supply provision are crucial, particularly for the very young and the aged, as well as for people with disabilities.

X. Conclusion

In a number of ways, Hawaii has many special attributes that increase the potential benefits of adoption of Connected and Autonomous vehicle technology, particularly in conjunction with Mobility as a Service and related integrated transportation system technologies. In particular, the need to preserve protected lands from further development constrains the ability to build out by expanding right-of-way. In a growth-constrained society, autonomous vehicle technology provides a potential way of addressing our very serious gridlock problem without greatly expanding right-of-way. Other factors such as reliance on tourism, aging population, disable persons, and susceptibility to natural disasters, simply increase the potential benefits further, though they also point to the importance of looking at autonomous vehicles as part of a larger transformation to an integrated, connected transportation system that optimizes the use of vehicles and right-of-way to provide fast, efficient, and easy-to-use transportation while preserving the environment.

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XI. CONCLUSION

AVs have the potential to improve the safety of the transportation system, reduce energy consumption, and enhance overall quality of life. Despite concerns about the costs and limits of such vehicles, we believe that the road ahead points to a promising future where the government, planners, and other stakeholders can collaborate to improve the every-day experience of the traveling public. This preliminary report is comprised of chapters, each written by certain stakeholders with varying perspectives. Rather than serving as a consensus on any final recommendations, our hope is that this preliminary report will continue the discussion and serve as a resource for those interested in examining the possibilities for the State of Hawaii.