2015 AUTOMATED VEHICLE LITERATURE REVIEW AS PART OF PREPARING A POSSIBLE OREGON ROAD MAP FOR CONNECTED VEHICLE/COOPERATIVE SYSTEMS DEPLOYMENT SCENARIOS

Task 2 Report

SPR 764

Oregon Department of Transportation

2015 Automated Vehicle Literature Review as Part of Preparing a Possible Oregon Road Map for Connected Vehicle/Cooperative Systems Deployment Scenarios

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16. Abstract: The goal of this project was to lay the groundwork for Oregon to be prepared to lead in the implementation of a connected vehicle/cooperative systems transportation portfolio, and/or to avoid being caught by surprise as developments in this area evolve quickly. The project assessed ODOT's internal mechanisms for addressing connected vehicle/cooperative systems, scanned, reviewed and assessed the technical maturity of potential connected vehicle/cooperative system applications, developed preliminary goals, linked to prospective connected vehicle/cooperative systems applications, and refined/ranked/prioritized those that fit with potential ODOT role in advancing/leading these initiatives. The project identified opportunities for linking ODOT's current programs with national and international connected vehicle/cooperative system research, testing and deployment initiatives, and recommended a final shared vision and "road map" for Oregon's priority connected vehicle/cooperative system applications. This volume contains a literature review and annotated bibliography regarding policy and technical questions about the potential for introducing automated vehicles in the state for research and testing purposes. This includes a discussion of the history and development of automated vehicles for highway use as well as a discussion of the relationship between automated and connected vehicles and the potential for integrating the two technologies. The review also includes an analysis along twelve Oregon-specific dimensions related to specific question about the potential introduction of automated vehicles in Oregon. These dimensions include: liability, implementation, privacy, cyber security, governance, risk, certification, data, legislation, deployment approach, financing and sustainability.

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APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	millimeters squared	mm^2
ft^2	square feet	0.093	meters squared	m^2
yd^2	square yards	0.836	meters squared	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	kilometers squared	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	ml
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	meters cubed	m^3
yd^3	cubic yards	0.765	meters cubed	m^3
NOTE: Volumes greater than 1000 L shall be shown in m^3.				
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
		TEMPERATURE (exact)		
°F	Fahrenheit	(F-32)/1.8	Celsius	°C

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	millimeters squared	0.0016	square inches	in^2
m^2	meters squared	10.764	square feet	ft^2
m^2	meters squared	1.196	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	kilometers squared	0.386	square miles	mi^2
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L	liters	0.264	gallons	gal
m^3	meters cubed	35.315	cubic feet	ft^3
m^3	meters cubed	1.308	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams	1.102	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	Celsius	1.8C+32	Fahrenheit	°F

*SI is the symbol for the International System of Measurement

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1.0 INTRODUCTION

Safety remains a problem on U.S. roadways, with more than 32,000 fatalities, 2.2 million injuries and 6 million crashes each year. Travelers, shippers and the economy are exposed to increasing amounts of congestion, unreliability, delay, emissions and excess energy consumption, which impede the efficient movement of people and goods. The U.S. DOT and its public and private partners have embarked upon a major research program toward implementing connected vehicle safety technologies, applications and systems using dedicated, short-range wireless communications (DSRC). DSRC is necessary for safety critical applications, but can be complemented by other forms of wireless communications for other purposes. Previous research by the National Highway Traffic Safety Administration (NHTSA) demonstrated that 80% of unimpaired driver crash types could be addressed by the connected vehicle technology.

In parallel with advancements in vehicle technology and automation, these cooperative, connected vehicle systems include vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) applications. Additionally, V2X includes an even wider range of applications that link drivers, operators, vehicles, mobile devices and infrastructure/roadside devices, including motorcycles, pedestrians and bicyclists. It is envisioned that DSRC-equipped devices will be standard equipment in new vehicles and also available for after-market installation and even ‘carry-in’ situations. Building on decades of research in the public and private sectors, vehicles with increasing degrees of connectivity and autonomy are now on the market Manufacturers are now testing sensor-rich automated and potentially driverless vehicles that do not rely on connectivity with other vehicles across platforms. These developments present many challenges and opportunities across society, and in particular for state departments of transportation.

In the arena of connected vehicles, through the recently completed Safety Pilot in Ann Arbor, Michigan, the U.S. DOT tested the effectiveness of wireless connected vehicle technology in real-world, multimodal driving conditions, collecting data about how ordinary drivers adapt to connected vehicle technology and identifying potential safety benefits from it. This work was performed in support of the February 2014 (light vehicle) and projected 2015 (commercial vehicle) NHTSA decisions that would launch regulatory processes that require or incentivize all new vehicles are equipped with DSRC devices. In the realm of connected vehicles, the U.S. DOT has published a graphical representation of its vision for rollout, shown in Figure 1.1.

In August 2014, NHTSA published an advance notice of proposed rulemaking (ANPRM) related to: Vehicle-to-Vehicle (V2V) Communications *(NHTSA 2014)*. Due to the significance of this issue, and based on public statements by the Secretary of Transportation and the National Transportation Safety Board, it is likely that the next step in the rulemaking process will occur later in 2015. This would mean that beginning on a future date (possibly in the 2019-2020 model year or earlier), potentially all new vehicles produced for sale in the U.S. would be required to be equipped with DSRC wireless communications capabilities.

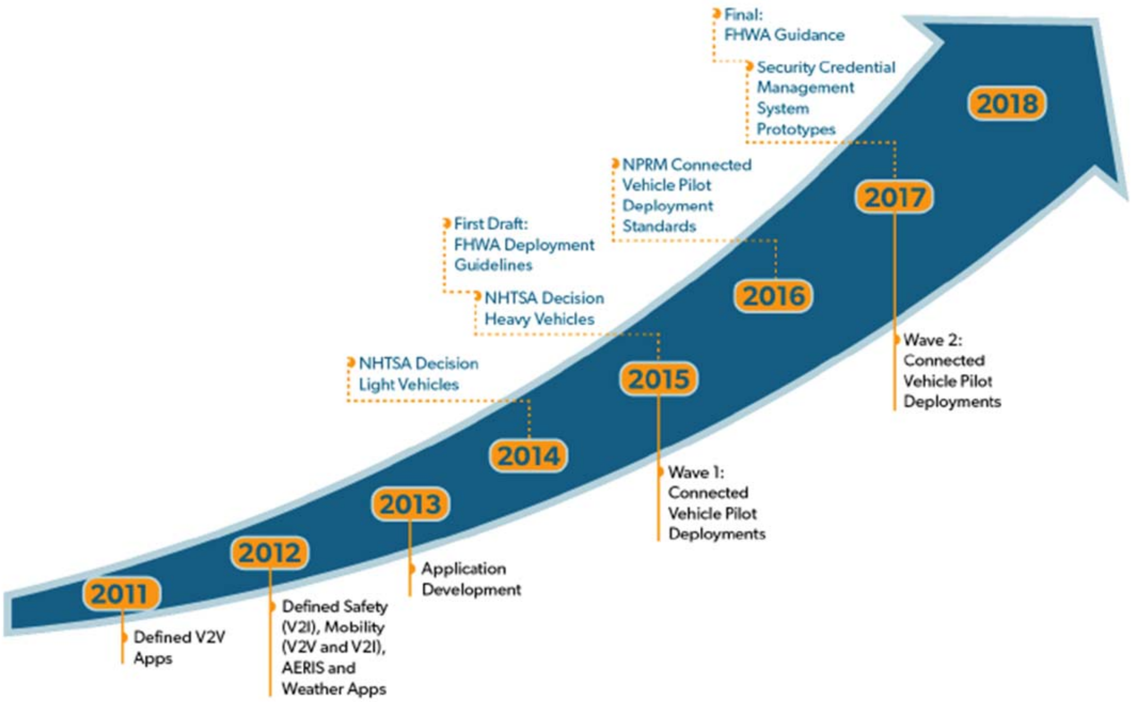


Figure 1.1: U.S. DOT Connected Vehicle Timeline *(U.S. DOT 2014)*

It should be noted that NHTSA's authority includes regulation of automobile safety features, including airbags, seatbelts and electronic stability control, under the Federal Motor Vehicle Safety Standards (FMVSS). NHTSA conducts postproduction testing and also has recall authority. There are currently no federal regulations for self-driving or automated vehicle technologies. NHTSA did release a policy statement in 2013 (NHTSA, 2013) that a definition of automated vehicles and a summary of proposed research activities. NHTSA based its policy statement on four basic principles for vehicle testing:

1. Ensure that the process for transitioning from self-driving mode to driver control is safe, simple, and timely

2. Self-driving test vehicles should have the capability of detecting, recording and informing the driver that the system of automated technologies has malfunctioned.

3. Ensure that installation and operation of any self-driving vehicle technologies does not disable any federally required safety features or systems.

4. Ensure that self-driving test vehicles record information about the status of the automated control technologies in the event of a crash of loss of vehicle control.

At that time NHTSA recommended that states allow only testing of automated vehicles, and not public operation or deployment. NHTSA also stated that a licensed driver should be present in an automated vehicle who is ready to take over control if necessary.

Communication amongst and between vehicles and the infrastructure (including mapping services, traffic signals, work zone equipment, pavement sensors, and other infrastructure elements) would also have data and mobility benefits. These could include data-driven applications such as traveler information for freight and passengers, transit operations, network flow optimization, traffic signal systems and incident response, emergency staging and evacuation, as well as sustainability-related applications such as the AERIS program that aims to reduce emissions, fuel and energy consumption.

The U.S. DOT is now in the process funding pilot deployments of mobility and environmental-related applications and will continue doing so in the upcoming years. These deployments will include a set of regional pilots, as well as smaller and more self-contained projects focused on priority applications. As connected vehicle research moves into deployment, state and local governments, transit agencies, metropolitan planning organizations (MPOs) and the private sector will start feeling the effects of vehicles, after-market devices, mobile devices, and infrastructure with DSRC and other wireless connectivity at their cores.

The Oregon Department of Transportation (ODOT) can benefit from preliminary scoping, evaluation, and assessment of the impact of connected vehicles and infrastructure and a wide range of potential cooperative system applications. The agency can also benefit from being strategic about the impacts and opportunities with vehicles entering the fleet with increasing degrees of automation, as well as how best to enable manufacturers seeking to test automated and driverless vehicles on state-owned roads. With these issues in mind, decision makers in the State of Oregon can determine whether or not to pursue research, development and testing opportunities with automated vehicle developers, as well as the next phases of federal connected vehicle application funding. ODOT has been recognized as a leader in transportation innovation for over a hundred years (most recently and notably with the development of the Road Usage Charge Program) and with additional background, can make informed choices about whether to take a national leadership role in the automated and/or connected vehicle arenas, while assessing opportunities to join projects with other partners.

To better inform future policy directions on automated and connected vehicles in Oregon, this literature review and desk scan highlight an array of issues, categorized in twelve policy areas, about potential opportunities and challenges related to automated and connected vehicles for research, development and testing purposes. It also includes a comprehensive annotated bibliography containing addition literature resources and policy assessments.

New vehicles entering the market are including increasing degrees of automation. They often have automated system components such as:

- Adaptive cruise control
- Forward collision warning
- Blind spot warning
- Rear view camera

- Lane keeping systems
- Parking assist systems
- Traffic sign recognition
- Pedestrian alert systems
- Mayday systems (such as OnStar) with 911 connectivity
- Mobile phone integration with text messaging
- Internet connectivity with email and social media

As these automated system components are introduced to consumers, automobile manufacturers are also developing technologies to warn, assist and even control vehicle movements. This increasing automation will likely provide additional safety benefits while providing consumers with new comforts and conveniences. As no sources for this literature review suggest that future automated vehicles would not be "connected," with a need or ability to communicate with a centralized data repository, the infrastructure and/or other vehicles, it is assumed that V2X will be implemented in all new vehicles in the future, resulting in even greater consumer safety, comfort and convenience. After-market are also expected to be developed that will add necessary communication capabilities to existing vehicles that would result in improved consumer experiences.

Google and other technology manufacturers have drawn significant attention with the development and introduction of the driverless vehicle. This has captured the public's imagination and has led to widespread media coverage. Figure 1.2 shows the number of articles published in the media on the subject of driverless, automated or autonomous vehicles between 2008 and mid-2015, indicating the dramatic rise in numbers (source: LexisNexis).

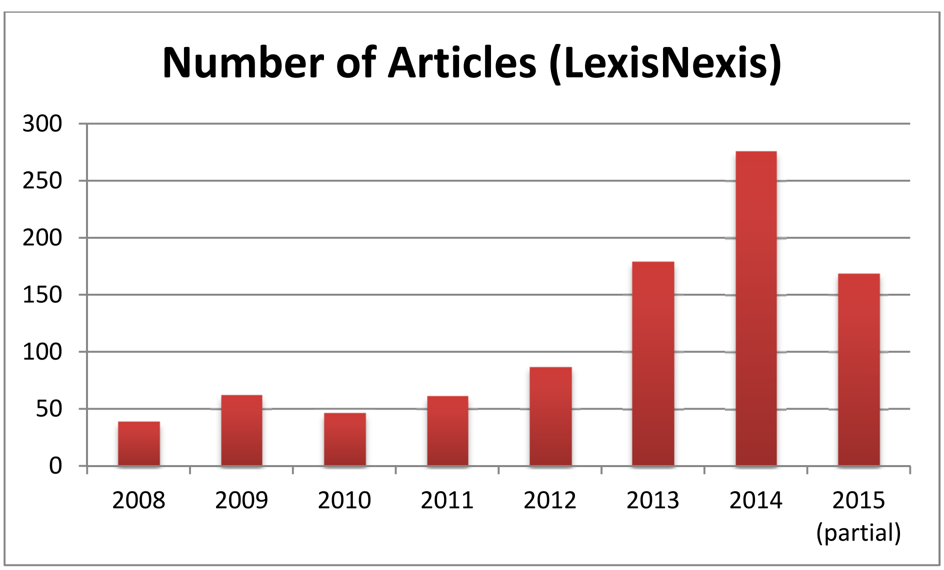


Figure 1.2: Number of Automated Vehicle Articles Published *(LexisNexis 2015)*

Since 2009, Google developed and tested at least a dozen different automated/ driverless vehicles equipped with sophisticated Light Detection and Ranging (LIDAR) range finding systems and high-resolution maps on public and private roads - totaling more than 800,000 test miles. Many auto manufacturers are also developing and testing automated/ driverless vehicles. In response, the California Department of Motor Vehicles issued automated vehicle testing permits to the following manufacturers:

- Audi
- Bosch
- Delphi
- Google
- Mercedes-Benz
- Nissan
- Tesla
- Volkswagen

These recent developments and advancements in vehicle automation build upon the global advancements, research and demonstrations described in the next section.

1.1 SELECTED HISTORY OF AUTOMATED VEHICLES

Increasingly, automated vehicles have received significant attention in the media, and to some degree in the academic literature, in recent years. This section summarizes some key elements in this history *(Godsmark 2014)*, and highlights some concept vehicles by particular manufacturers or research teams. Table 1.1 illustrates a timeline of these advancements with vehicle automation. Many of these advancements have been supported by government investment in research, including the U.S. DOT's Automated Highway System (AHS) research program in the 1990s, and later by the Defense Advanced Research Projects Agency (DARPA). Federal, state and local agencies should continually be aware of technological developments in this area. For the State of Oregon, the introduction of increasingly automated and eventually driverless vehicles will have impacts on driver licensing, vehicle registration, roadway/highway operations, planning, design, data management and many other areas.

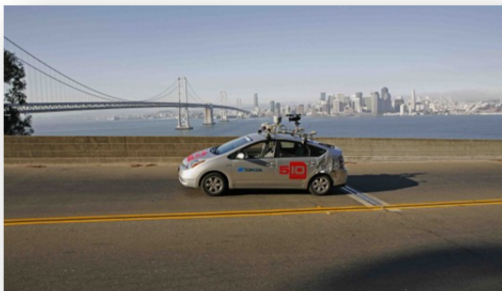
As noted in the table below, advancements in the development of automated individual/private vehicles has been notable over the past 40 years. Auto manufacturers and others are making individual and combinations of automation components available in vehicles that are on the market now. Manufacturers are predicting that increasingly automated vehicles will be available for consumers to purchase in the next few years. More recently, the potential for safety improvements and cost savings due to platooning of commercial trucks with semi-automated features is being discussed. Finally, for safety and cost savings benefits in fleet applications (e.g.

taxis, public transportation including paratransit vehicles, and app-based on-demand ride services such as Uber, Lyft and Sidecar), the potential for automation is also receiving heightened attention *(Rayle et al. 2014)*.

Table 1.1: Automated Vehicle Timeline

	1977 Tsukuba Mechanical Engineering Lab, Japan	Followed a track of white striped lines on the road at speeds of 20 mph
	1985 Universitat der Bundeswehr, Germany	VaMoRs 5 ton van tested at speed up to 100 km/h
	1994 PROMETHIUS Project, Europe	VITA II (Daimler Benz) and VaMP demonstrated with automated driving

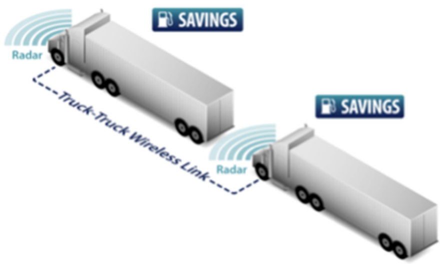
	1996 ARGO, part of the PROMETHIUS Project, Italy	ARGO system followed painted lane markings using vision system, traversed the "Mille Miglia Automatico," average speed 90 km/h for 1900 km
	1997 PATH, University of California - Berkeley and U.S. DOT Automated Highway System (AHS) Demo	Cars, buses and snowplows; included platooning and forward and reverse course runs; used magnets in roadway
	2004 Defense Advanced Research Projects Agency (DARPA) Grand Challenge - Mojave Desert region, California	Carnegie Mellon University Red Team "Sandstorm" 7.32 miles
	2005 DARPA Grand Challenge - Mojave Desert region, California	Stanford Racing "Stanley" 150 miles in 6 hours 54 minutes

	2007 DARPA Urban Challenge – Victorville, California	Carnegie Mellon University Tartan Racing "Boss" 60 miles urban, 4 hours 10 minutes
	2008 Levandowski's Pribot	Delivered pizza across the San Francisco-Oakland Bay Bridge, California *(Harris 2014)*
	2009 Google Prius	Google self-driving car team assembled; LIDAR system as basis for data acquisition - California
	2010 Audi Pikes Peak, Colorado	121 mile hill climb, 156 turns, 27 minutes

	2011 AutoNOMOS Labs Berlin Drive	50 miles of automated driving on urban public streets in Berlin, Germany
	2012 Google Lexus 450h	300,000 miles testing on public roads in California
	2013 Vislab BRAiVE, University of Parma, Italy	Rural-urban demo in real, complex traffic, relies on vision system
	2013 Daimler/Mercedes-Benz Bertha Benz Road Trip - Mannheim to Pforzheim, Germany	60 mile rural-urban demo, vision based

	2013 Scania Transport Laboratory, Sweden	Tested aspects of truck platooning (semi-automated) between Sodertalje and Helsingborg, Sweden
	2014 Induct Navya	Electric, low speed vehicle (12 mph), commercially available
	2014 Google	Mastering city street driving, 700,000 miles, interactions with cyclists, signals, and construction zones
	2014 Google Prototype Vehicle	Neighborhood electric vehicle (NEV), low speed (25 mph)

	2014-2017 Volvo "Drive Me," Gothenberg, Sweden	100 increasingly automated vehicles, toward zero deaths (2020)
	2015 Tesla "Autopilot"	Freeway driving, on-ramp to off-ramp, vision for 2023
	2015 Acura RLX	Honda begins testing automated car features on roads of the Concord Naval Weapons Station in the East Bay area.
	2015 Delphi cross country trip	Delphi drove an Audi from San Francisco to New York, crossing 15 states and 3,400 miles, the car performed 99% of the driving.

	2014 Freightliner Inspiration Truck	First licensed automated commercial truck to drive on a U.S. public highway
	2014 Peloton Truck Platooning	Denso and Intel Capital (and others) invest in Peloton truck platooning technology. Peloton is developing a cloud-based truck operations center and participating in field trials.
	2015 Mercedes-Benz F015 Concept	Concept vehicle
	2015 Uber Advanced Technologies Center	Uber opens Advanced Technologies Center in Pittsburgh, PA, for research and development in mapping, vehicle safety and automation technology.

	2020-2025 Nissan Autonomous Drive	Concept vehicle
	2025 Mercedes-Benz Future Truck	Concept vehicle

1.2 AUTOMATED VEHICLES AND CONNECTIVITY

In December, 2014, the Transportation Research Board (TRB) held a webinar on Automated Vehicles and Connected Vehicles for TRB Standing Committee Chairs (see https://vimeo.com/114264596). This event provided a valuable update on the state of the art of connected and automated vehicles. In this chapter, we have chosen to use the term "automated" vehicle rather than "autonomous," primarily because the word "autonomous" implies a degree of self-government and independence that is not appropriate for our transportation system. According to the Oxford English Dictionary (OED) we have the following definitions for automate and automation *(Shladover 2014)*:

- Automate: to apply automation to; to convert to largely automatic operation.
- Automation: automatic control of the manufacture of a product through a number of successive stages; the application of automatic control; the use of electronic or mechanical devices to replace human labor.

On the other hand the OED includes the following definitions for autonomy and autonomous:

- Autonomy: the right of self-government, of making its own laws and administering its own affairs; the condition of being controlled only by its own laws and not subject to any higher one; a self governing community.

- Autonomous: of or pertaining to an autonomy; possessed of autonomy, self-governing, independent.

From these definitions it follows that for a societal transportation system that includes rules, regulations and laws, that the automation concept is more appropriate, rather than an autonomous concept that aims for self-governance and independence. In our society we currently agree that cooperation is important in transportation, where we share the right of way among a wide range of user types. We accept the need for driver licensing, vehicle registration, planning and design standards, as well as accepted control strategies for intersections and access to the shared network. With the introduction of connected and increasingly automated vehicles, we will experience a transition with a wide range of vehicle types and capabilities. Shladover (2014) indicates that "connectivity integrates vehicles and roadway infrastructure into a transportation system," while automation "overcomes driver limitations." It is this exciting combination that will result in benefits for the systems users.

1.2.1 Automated Vehicles Require Some Degree of Connectivity

In published accounts describing Google's approach toward testing and demonstrating automated vehicles, it is emphasized that the driverless capability is enabled by the combination of data generated in real time by on-board sensors (radar, video, GPS, LIDAR, inertial measurement, and wheel encoder) **plus** high-resolution maps obtained and recorded previously through other sources and by other vehicles *(Guizzo 2011)*.

What is not often mentioned or emphasized is that each vehicle via the "Cloud," or through wireless connectivity acquires the high-resolution map data. This is further expanded upon in an article *(Madrigal 2014)* that describes the "virtual track" that Google has created in Silicon Valley, which by itself would not allow the Google car to perform as well in other locations. The "virtual tracks" are described as "ultra-precise digitizations of the physical world, all the way down to the tiny details like the position and height of every single curb" *(Madrigal 2014)*. These digital maps are continuously augmented by each driverless vehicle's experience, and thus require a form of "connectivity" among similarly equipped vehicles. It appears that Google has digitized approximately 2,000 miles of roadways (of the total 4 million in the U.S. as of 2014 *(Madrigal 2014)*. According to Google, some level of processing happens on board each vehicle, while other "big" computation and data processing are "done by the teams back at Google's server farms." This implies that a wireless connection needs to be in place in order for automated vehicles to be operated. It has also been mentioned that knowledge of each road's speed limit is included in the automated vehicle map database *(Markoff 2010)*.

1.2.2 Automated Vehicles May Derive Additional Safety Benefits through Connectivity

As currently conceived, automated vehicles rely on detailed prior map data plus real time high resolution sensing in order to safely navigate through the traffic stream. There are still many research questions that will need to be answered regarding the deployment of automated vehicles, but it is reasonable to expect that there may be limitations to their ability to perform in certain weather conditions. For example rain and snow will obscure road markings. In addition physical obstructions to sensor "sight" lines, such as buildings, trees, highway structures, vertical and horizontal curvature, and other geometric elements cannot be penetrated. These issues may be resolved technically in the future.

These examples reveal that it may be beneficial for automated vehicles to also take advantage of safety benefits enabled through connectivity using DSRC. It is by no means definitive, but it is hard to imagine that manufacturers and consumers of future automated vehicles would not want to take advantage of DSCR enabled applications that could dramatically improve safety, particularly under inclement weather conditions and in situations where sight lines are obscured.

Additionally, Schladover *(Schladover 2014)* states that "anything you can do unconnected you can do better connected." From a user standpoint, connectivity can provide better information and guidance about traffic, highway and weather conditions (I2V) as well as better information about vehicle movements to other vehicles and drivers (V2V).

1.2.3 New Automated Vehicles May Be Required to Be DSRC Enabled

As noted earlier, the U.S. DOT is considering a rule that would require (or possibly incentivize) DSRC connectivity in all new vehicles. Thus, logically, if a new automated vehicle is produced in the U.S. after such a rule is in effect, then that automated vehicle would also be required to be connected. Figure 1.3 below illustrates a logical tautology that explores the possible options.

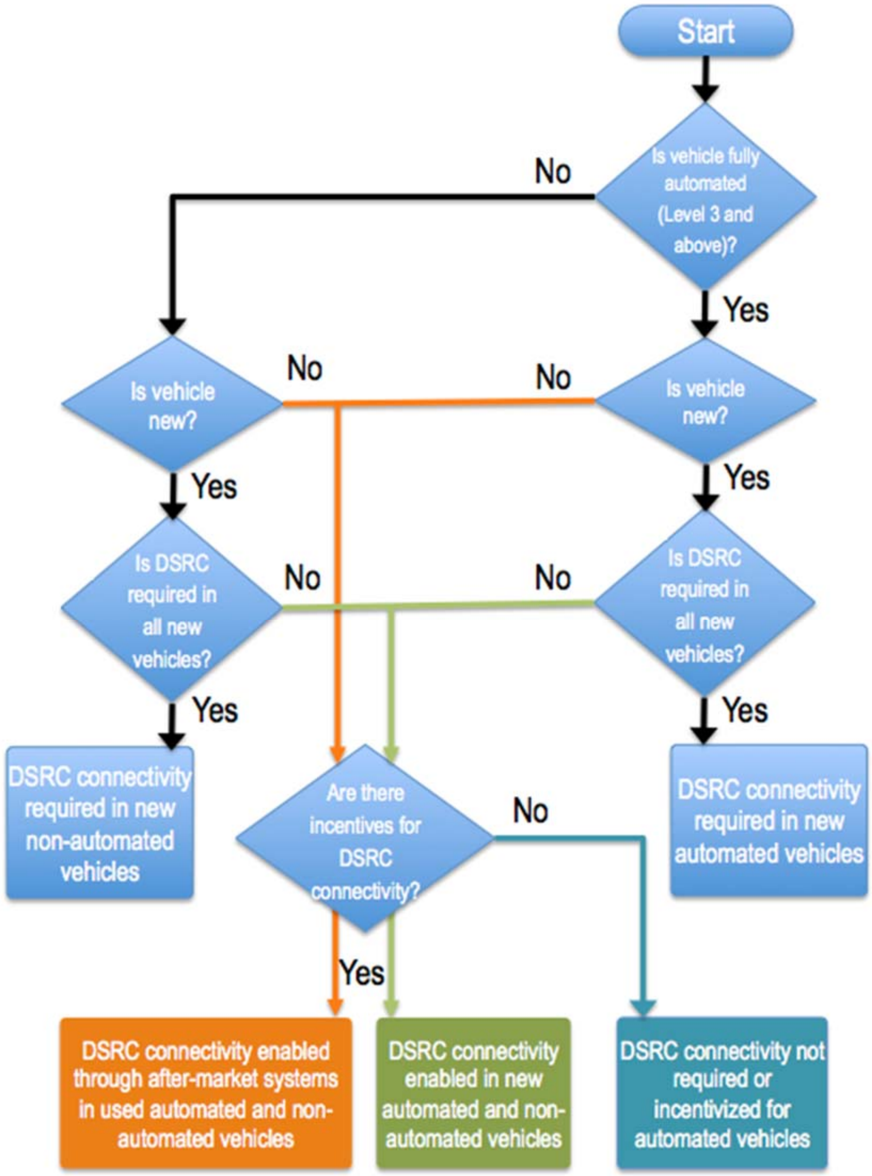


Figure 1.3: Logical Tautology for the Potential for Automated Vehicles to Be Connected

As indicated, if NHTSA does not pursue a rule requiring or incentivizing new vehicles to be connected with DSRC then automated vehicles would likely not be connected. However with such a requirement it would be expected that new automated vehicles would be connected, and possibly used vehicles would also achieve connectivity via after-market solutions. In accordance with this, the U.S. DOT has stated that the future focus is on connected automation, as shown in Figure 1.4.

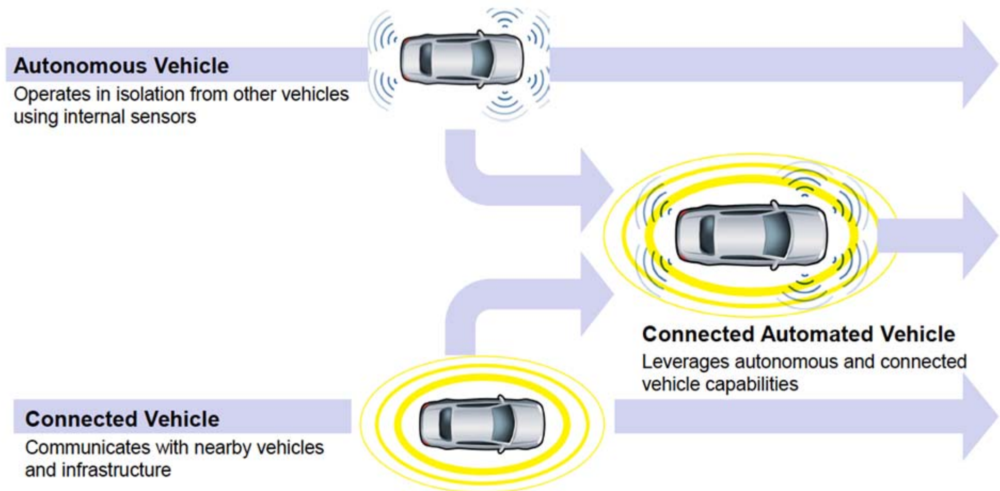


Figure 1.4: U.S. DOT Approach to Connected Automation

1.3 COMBINED BENEFITS OF AUTONOMY AND COOPERATION

A key feature of automated vehicles is that they are not reliant on the existence of technology in other vehicles or on the roadside. In Figure 1.5 below *(Wallace and Silberg 2014)* this feature is represented along the vertical axis, where a vehicle becomes increasingly automated without any cooperation from other vehicles or infrastructure. This does not imply that a fully automated vehicle is not "connected," as most automated vehicle concepts rely on a very detailed "map" for the vicinity that a vehicle can operate within. “Cloud”-based map data will be complemented with high-resolution data sourced at the vehicle’s position through LIDAR or video imaging.

Given such systems, many predict that the future will include increasing degrees of automation with increasing degrees of connectivity.

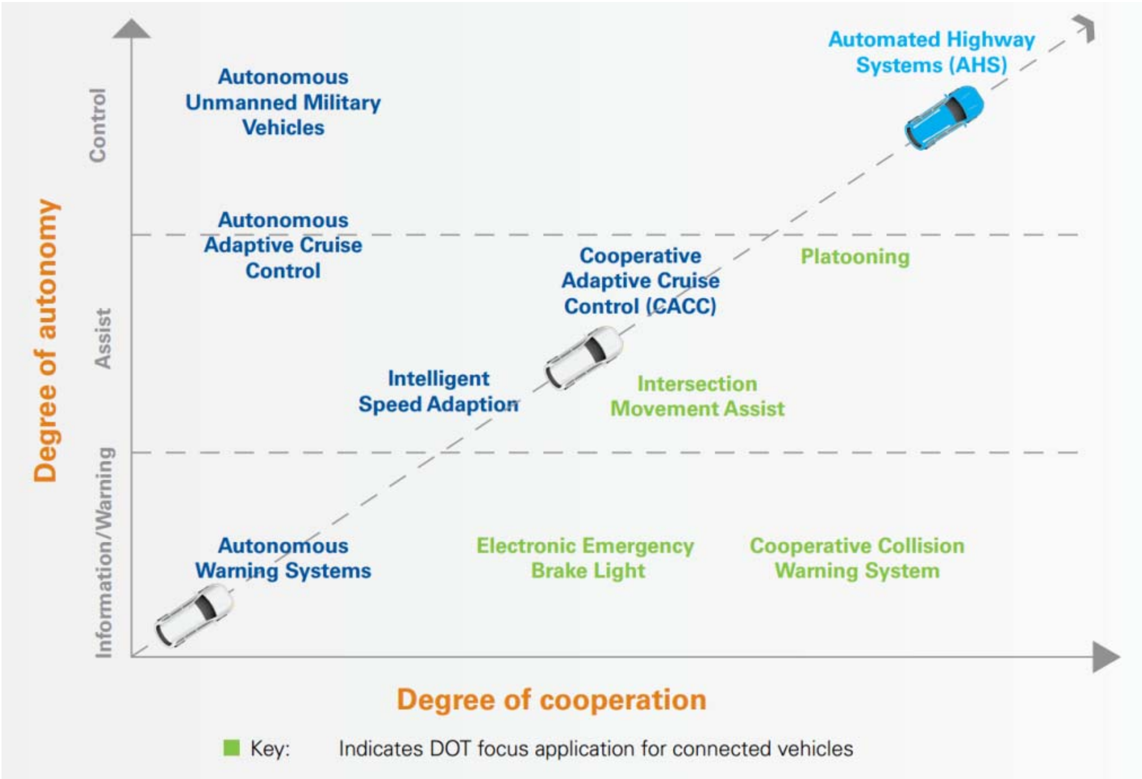


Figure 1.5: Degrees of Autonomy and Cooperation *(Wallace and Silberg 2014)*

Increasing along the horizontal axis illustrates that the U.S. DOT's connected vehicle initiatives rely on increasing connectivity and cooperation with use of relatively low cost in-vehicle and roadside devices to achieve safety benefits plus additional advantages in mobility, efficiency, comfort, convenience and sustainability (reduced emissions, fuel and energy consumption). Increasing levels of automation and connectivity may converge with increasing levels of cooperation in the future. Cooperative systems may also be available to a larger number and wider spectrum of consumers at an increasingly lower cost.

1.4 PREDICTIONS

As an output of the 2014 Automated Vehicle Symposium *(AVS 2014)*, participants completed a survey designed to gauge the potential for automated vehicle deployment. Figure 1.6 below illustrates the distributions of responses among symposium attendees regarding the likely deployment timelines for vehicle automation systems falling within SAE levels 3 (conditional), 4 (high) and 5 (full automation).

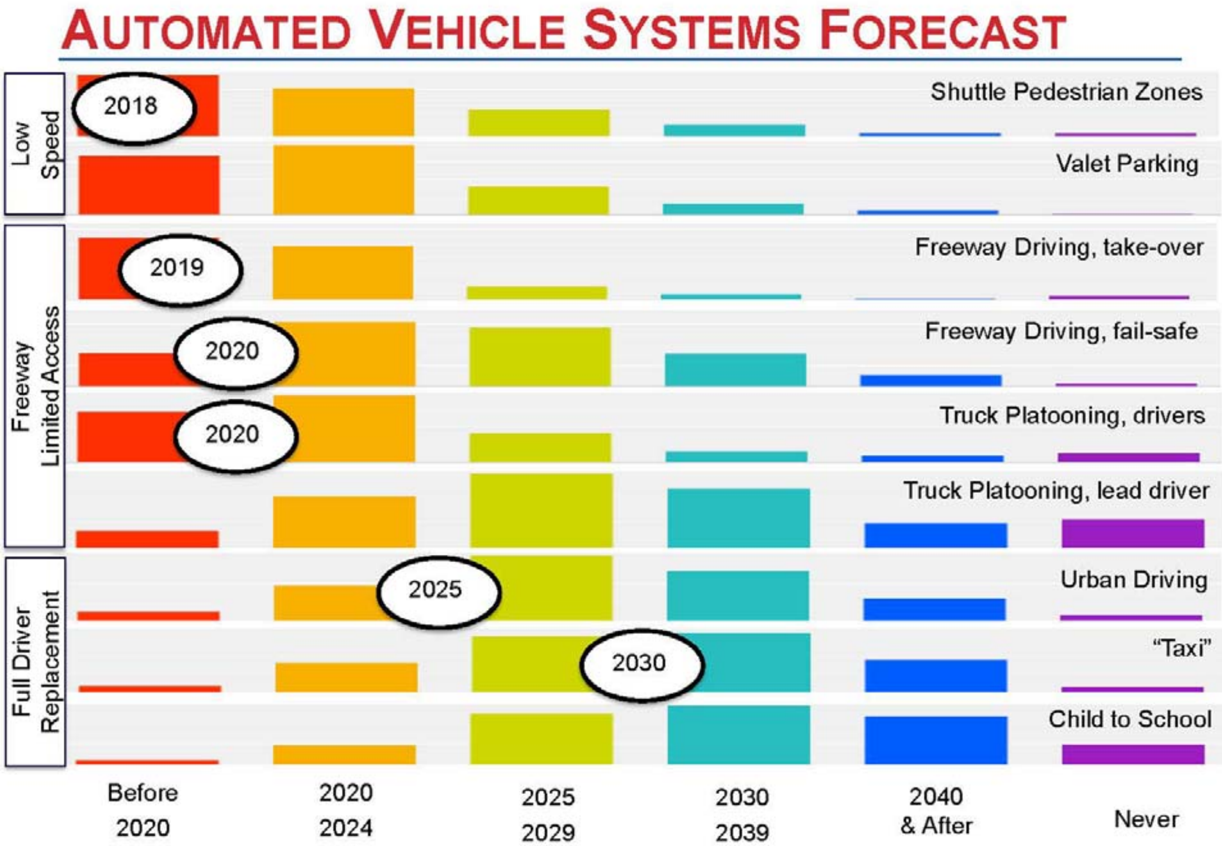


Figure 1.6: Potential Automated Vehicle Systems Deployment Forecast *(AVS 2014)*

Claims by manufacturers, while informative, should also be interpreted with some degree of caution. A selective scan of manufacturer's public statements reveals the following predictions *(Bierstedt et al. 2014)*:

- 2015: Audi plans to market vehicles that can autonomously steer, accelerate and brake at lower speeds, such as in traffic jams.

- 2015: Nissan expects to sell vehicles with autonomous steering, braking, lane guidance, throttle, gear shifting, and, as permitted by law, unoccupied self-parking after passengers exit.

- 2016: Mercedes plans to introduce "Autobahn Pilot" (Highway Pilot) which will enable, hands-free highway driving with autonomous overtaking of other vehicles.

- 2016: General Motors plans to offer Cadillac model vehicles with "Super Cruise," which includes autonomous steering, braking, speed control and lane guidance (2017 model year). Some parts of trips could be even made without the driver touching the steering wheel or pedals.

- Mid-2010s: Toyota plans to launch near-autonomous vehicles dubbed “Automated Highway Driving Assist” with lane trace control and cooperative-adaptive cruise control.

- 2016: Tesla expects to develop technology that operates autonomously for 90 percent of distances driven.

- 2017: U.S. DOT anticipates enacting a rule that mandates V2V technology in all new vehicles.

- 2017: General Motors intends to equip the Cadillac CTS with V2V technology.

- 2018: Nissan anticipates offering a feature that enables vehicles to autonomously maneuver on multi-lane highways.

- 2018: Google expects to release autonomous car technology.

- 2020: Volvo envisions cars that make drivers and passengers immune from crash-related injuries and fatalities.

- 2020: General Motors, Mercedes-Benz, Audi, Nissan, BMW, Renault, Tesla and Google all expect to be selling vehicles (or enabling components in vehicles) that can drive themselves at least part of the time.

- 2024: Jaguar expects to release an autonomous car.

- 2025: Daimler and Ford expect autonomous vehicles on the market.

- 2025: Most new General Motors vehicles will have automated driving functions and V2V technology.

For insight on achieving these predictions, the proceeding Automated Vehicles Desk Scan highlights the current state of automated vehicles, with emphasis on twelve key policy areas.

2.0 AUTOMATED VEHICLES DESK SCAN

"Maybe five or six years from now I think we'll be able to achieve true autonomous driving where you could literally get in the car, go to sleep and wake up at your destination." – Elon Musk as told to Bloomberg Television, October 10, 2014.

As discussed in the previous sections, the Google driverless car has arrived on the scene and vehicles with increasing amounts of automation are on the market. Yet few state, regional, or local agencies enacted planning, operations, policies, or legislation in preparation for the arrival of connected and/or automated vehicles. With this in mind, according to a 2013 article by the Cable News Network (CNN), documenting an inaugural 'FutureCast' event featuring fifty innovative entrepreneurs, executives, policy makers and writers gathered "to discuss how online technology is transforming transportation" and rethink travel in today's networked society [and] the digital age *(Keen 2013)*. The underlying theme of the event was how leaders could avoid succumbing to a 'Kodak Moment,' "referring to the way in which the photography company Kodak was catastrophically blindsided by the digital revolution in photography, [a poster child for] every traditional CEO's worst nightmare." *(Keen 2013)*

Leaders at the FutureCast event recognized that society is on the cusp of a significant paradigm shift as transportation safety innovation and digital communication technology converge. "We can't go on as we have," one participant indicated. "We are running out of fuel; the current set of technologies we have are reaching a natural limit" while undesirable transportation externalities, like vehicular crashes, continue to persist. *(Keen 2013)*

Given this, and that two of Oregon's bordering states – California and Nevada – have already enacted recent legislation for licensing and testing automated vehicles, Oregon policymakers may seek to consider the extent of leadership and participation that the State of Oregon will have in the technology's development, and also assess resources it could dedicate to secure future federal pilot opportunities related to connected/automated vehicles, create strategic partnerships and begin discussions with constituents of opportunistic state investments in vehicle connectivity and automation.

The U.S. DOT, in collaboration with organizational, agency and private-sector partners, has been taking an active leadership role in advancing research and deployment concepts for connected and automated vehicles. The U.S. DOT also continues to firmly defend a 2004 Federal Communications Commission (FCC) decision to reserve the 5.9 GHz broadband spectrum – often recognized as a critical component to successful connected vehicle deployment – for sole use in vehicle safety applications to help ensure low latency and reliability for connected vehicles *(AASHTO tech memo n.d.)*. According to a February 2014 U.S. DOT press release, "NHTSA will [also] begin working on a regulatory proposal that would require [V2V] devices in new vehicles in a future year, consistent with applicable legal requirements, Executive Orders, and guidance," a statement which the agency believes "will significantly enhance development of this technology and pave the way for market penetration of V2V safety applications" *(Naylor 2014)*.

Decoupling automated vehicles from connected vehicles is difficult from a policy perspective, because many of the benefits and implementation issues overlap. The enabling technologies for each type, such as advanced mapping, sensing, communications and data processing capabilities are all complimentary. Meaningful academic literature on these two topics is still developing and is complimented by numerous articles and publications in the popular trade magazines and mainstream media. Establishment of rigorous and definitive gathering places for researchers, institutions and manufacturers interested in and working on automated vehicles is a relatively recent phenomenon. Transportation Research Board (TRB) committees on intelligent transportation systems (AHB15) and vehicle-highway automation (AHB30) began collaborating in 2012 when they jointly held the first Road Vehicle Automation Workshop in Irvine, California. The Second Workshop on Road Vehicle Automation held in 2013 at Stanford University and the 2014 Automated Vehicles Symposium held near San Francisco, California followed. The 2015 Automated Vehicles Symposium will be held in Ann Arbor, Michigan. These forums are adding to the foundation of knowledge on autonomous vehicles and will ideally increasingly stimulate more academic research in the future. *(TRB 2014)*

In order to provide a collective framework for exchanging information on vehicle automation, the international Society of Automotive Engineers (SAE International) has published a taxonomy (J3016) for automated driving *(SAE International 2014)*, defined in six categories. The first three levels include human drivers monitoring the driving environment (levels 0, 1 and 2). The other three levels (3, 4 and 5) define automated systems that monitor the driving environment. The taxonomy levels include:

> ***No Automation (SAE Level 0):*** The full-time performance by the *human driver* of all aspects of the *dynamic driving task*, even when enhanced by warning or intervention systems.
>
> ***Driver Assistance (SAE Level 1):*** The *driving mode*-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*
>
> ***Partial Automation (SAE Level 2):*** The *driving mode*-specific execution by one or more driver assistance systems of both steering and acceleration/ deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task.*
>
> ***Conditional Automation (SAE Level 3):*** The *driving mode*-specific performance by an *automated driving system* of all aspects of the dynamic driving task with the expectation that the *human driver* will respond appropriately to a *request to intervene*.
>
> ***High Automation (SAE Level 4):*** The *driving mode*-specific performance by an *automated driving system* of all aspects of the *dynamic driving task*, even if a *human driver* does not respond appropriately to a *request to intervene*.

> ***Full Automation (SAE Level 5):*** The full-time performance by an *automated driving system* of all aspects of the *dynamic driving task* under all roadway and environmental conditions that can be managed by a *human driver*.

NHTSA similarly defined categories to establish common vocabulary for vehicle connectivity between stakeholders. These levels include:

> ***No-Automation (Level 0):*** The driver is in complete and sole control of the primary vehicle controls – brake, steering, throttle, and motive power – at all times.
>
> ***Function-specific Automation (Level 1):*** Automation at this level involves one or more specific control functions. Examples include electronic stability control or pre-charged brakes, where the vehicle automatically assists with braking to enable the driver to regain control of the vehicle or stop faster than possible by acting alone.
>
> ***Combined Function Automation (Level 2):*** This level involves automation of at least two primary control functions designed to work in unison to relieve the driver of control of those functions. An example of combined functions enabling a Level 2 system is adaptive cruise control in combination with lane centering.
>
> ***Limited Self-Driving Automation (Level 3):*** Vehicles at this level of automation enable the driver to cede full control of all safety-critical functions under certain traffic or environmental conditions and in those conditions to rely heavily on the vehicle to monitor for changes in those conditions requiring transition back to driver control. The driver is expected to be available for occasional control, but with sufficiently comfortable transition time. The Google car is an example of limited self-driving automation.
>
> ***Full Self-Driving Automation (Level 4):*** The vehicle is designed to perform all safety-critical driving functions and monitor roadway conditions for an entire trip. Such a design anticipates that the driver will provide destination or navigation input, but is not expected to be available for control at any time during the trip. This includes both occupied and unoccupied vehicles *(RITA 2014)*.

To build on the strong leadership already taken by the U.S. DOT, there is a range of issues that states like Oregon could begin assessing to help better inform the federal government and its partners on state-specific needs and opportunities in the context of automated and connected vehicle deployment. To aid in this effort, this desk scan includes a summary of twelve categories of contemporary literature to help the State of Oregon explore policy and technical questions related to the upcoming, near-term deployment of automated vehicles. Many of the issues framed here also apply to connected vehicles and cooperative systems more broadly. Building on a policy research framework developed at the U.S. DOT, these key categories include:

1. Liability
2. Implementation
3. Privacy

4. Cyber Security
5. Governance
6. Risk
7. Certification
8. Data
9. Legislation
10. Deployment Approach
11. Financing
12. Sustainability

As these categories are closely linked it's difficult to draw perfect policy boundaries between them. The categories may be better understood as a twelve piece jigsaw puzzle (see Figure 2.1) that need to fit cohesively together at the governmental, technological and private sector levels. Each of the pieces is described in further detail below.

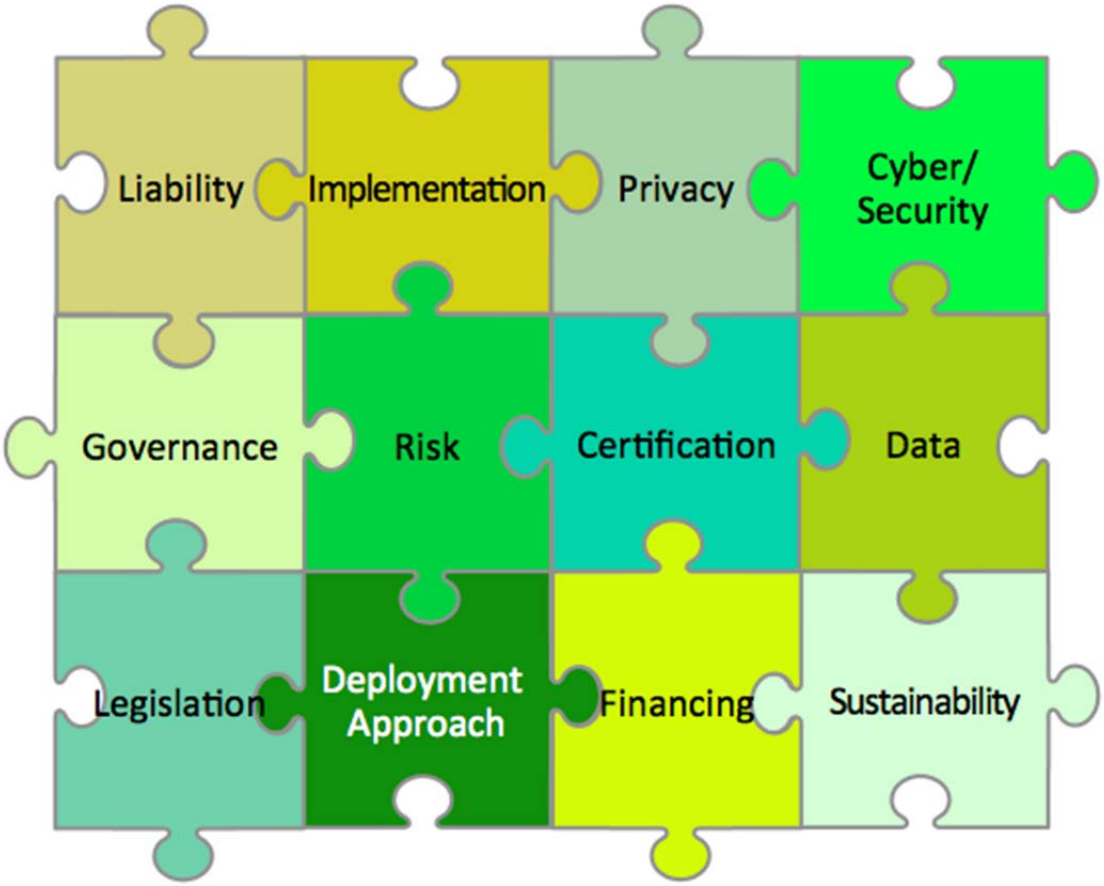


Figure 2.1: Policy Issues to be Considered

While thinking about particular policy issues to be considered, we recognize that in the U.S. some policy issues fall to particular levels of government and thus require different timeless, processes, and inputs, as well as requiring different types of leadership. As noted earlier, there are currently no federal regulations related to automated vehicles. According to Lappin *(Lappin 2014)*, Table 2.1 demonstrates one potential way of thinking about state and local agency policy roles.

Table 2.1: State and Local Policy Roles *(Lappin 2014)*

		Vehicle Operation, Safety and Accountability	Infrastructure Planning, Development, Operation and Maintenance
STATE	State Legislature	✓	✓
	State DMV	✓	
	State Police	✓	
	State Insurance	✓	
	State DOT		✓
LOCAL	Regional Planning (MPO)		✓
	Transit		✓
	County		✓
	Municipality		✓
	Toll Authority		✓
	Port		✓

2.1 LIABILITY

Liability is a significant concern regarding automated and connected vehicles. Who is legitimately at fault in a crash involving an automated vehicle or a vehicle equipped with vehicle-to-vehicle/infrastructure/person (V2X) technology that temporarily or permanently takes control from human driving remains a legal uncertainty. The topic is commonly cited as a primary challenge for widespread automated vehicle and V2X deployment.

A 2013 report on connected vehicles by the U.S. General Accounting Office (GAO) specifically identifies four key liability questions that should be explicitly addressed by the U.S. DOT (presumably with consultation from agency partners like state and local DOTs) to provide automobile and V2X communication device manufacturers the full confidence to move forward on technology development without inefficient delay *(GAO 2013)*. These questions, which should also be extended to automated vehicles, include:

- Who is at fault when a crash a crash occurs between two automated or V2X-equipped vehicles – one of the drivers, one of the automobile manufacturers, one of the [automated or] V2X device manufacturers, or another party?

- Who owns and/or has access to the data transmitted between automated and V2X-equipped vehicles?

- Who is liable in a crash when automated or V2X technologies are not functioning properly, including factors like data transmission delay, hacking and inaccurate GPS readings?

- Will aftermarket devices installed on existing vehicles provide the same quality of data as automated or V2X factory-equipped vehicles, and who liable in a crash when such inconsistency exists? *(GAO 2013)*

The same GAO report also suggests that existing in-vehicle automation applications on the market today (such as adaptive cruise control) already have associated liability and that “if the automobile industry ensures that [automated or V2X] technologies work properly before deployment, [they] should not pose any greater liability risks than existing sensor-based crash avoidance technologies” and may not demand additional legislation. *(GAO 2013)*

Despite this viewpoint from the GAO, a 2014 report on automated vehicles by the RAND Corporation predicts that manufacturer liability will likely increase *(Andersen 2014)* as automated vehicles are introduced in the market. Manufacturers, the report indicates “are likely to understate system capabilities during advertising, educate owners when purchasing vehicles with these capabilities, and require drivers to acknowledge that they understand the limitations in some way before the [automatic driving or V2X] technologies can be activated” and insisting that drivers remain responsible for the actions of their vehicles. *(Andersen 2014)* This is consistent with existing state motor vehicle registration and licensing actions, which require the presence of a licensed driver in a moving vehicle with the ability to take control if needed.

Still, the authors of the RAND report, through their exploration of tort law in the U.S., expect liability for drivers and owners of automated and V2X-equipped vehicles to decrease given the predicted reduction of crashes (NHTSA forecasts a reduction of 80% of unimpaired driver crashes) and lower insurance costs that are expected to result from automated vehicle and V2X deployment. This decrease will presumably spur some demand for automated vehicle and V2X technology by consumers and insurance companies, and motivate manufacturers to push for near-term solutions to deployment uncertainties. *(Andersen 2014)* Possible legislative solutions identified in the RAND report are discussed more in section 2.9 – Legislation.

Liability issues regarding automated and connected vehicles have also catalyzed a substantial amount of literature on moral decisions that automated and V2X-equipped vehicles might have to make, especially when these vehicles are nearer to the fully automated and driverless end of the spectrum, where human drivers (or occupants in the case of driverless vehicles) would presumably be less at fault. A 2014 report by Fagnant and Kockelman for the Eno Center for Transportation, for example, questions the degree that automated vehicles should prioritize minimizing injuries to its occupants versus to others parties involved in an inevitable crash, and even whether vehicle owners would be allowed to adjust vehicle settings for the automated system to determine this *(Fagant and Kockelman 2014)*. As vehicles become increasingly programmed to make more informed decisions, such philosophical discussions may help inform near-term decisions while setting a foundation for the evolution toward fully automated and driverless transportation in the future.

While liability issues present challenges to widespread adoption of automation and V2X technology in vehicles, recent reports and articles nearly unanimously indicate that informed and collaborative decision making that results in clear and consistent federal and/or state legislation on liability is worth the effort to gain the transformative benefits provided by automation and V2X. Sensor-based, semi-automated vehicle technology available today will likely also provide increasing insights into how liability will impact vehicles sold with more extensive automated features in years to come. *(Fagant and Kockelman 2014)*

2.2 IMPLEMENTATION

In many regards, vehicle automation and connected vehicle technologies are already being implemented. Most major automobile manufacturers have released or are in the process of introducing sensor-based, driver-assist functions such as traffic jam assist, adaptive cruise control, front end collision warning with automated braking, parking assist, lane keeping and blind spot warnings. An advertisement by Hyundai promoting auto-emergency braking on its Genesis models even appeared during the 2014 Superbowl XLVIII broadcast, illustrating how one car company is confident enough to highlight its driver-assist technology to 167 million viewers in the United States. Automobile manufacturers, as well as other key players such as Google, are predicting their release of fully automated driving functionality by 2020 *(Berman 2013)*. Clearly there are multiple unresolved implementation steps between now and that time.

Likewise, innovations in wireless technologies and wireless data communications have fundamentally transformed the lives of many people. Despite concerns for driver workload, driver distraction and lack of true standards for human machine interfaces (HMI), these innovations have been integrated into vehicles. Bluetooth technology allows people to adjust radio stations or engage in hands-free conversations with their smartphones. Global Positioning Systems (GPS) enable drivers to navigate to their destinations without the long-revered practice of pulling a paper map out of the glove box or asking for directions. Internet communication allows a quick search of restaurants and hotels, or check near real-time weather and travel conditions ahead. Some unintended consequences, such as the perils of distracted driving, have been addressed through NHTSA guidelines *(NHTSA 2013)*.

Given this, it may not be a stretch for some to imagine widespread vehicle automation and V2X applications. The U.S. DOT and organizations like the American Association of State Highway and Transportation Officials (AASHTO) already have done so, as illustrated in their Connected Vehicle Field Infrastructure Footprint Analysis. This footprint analysis identifies three primary milestones: a NHTSA decision to consider DSRC rulemaking for light vehicles (delivered in February 2014); a NHTSA decision to consider DSRC rulemaking for heavy vehicles (expected in 2015); and FHWA infrastructure development deployment guidance (also expected in 2015) *(AASHTO undated)*. According to AASHTO, "vehicles equipped with DSRC may begin rolling off the production line in late 2019 [and will] broadcast information such as their location, speeds, and direction of travel through the high-speed communication of DSRC." *(AASHTO undated)* This analysis will serve as a guide for state and local transportation agencies, describing collaborative public and private sector multimodal V2X applications and infrastructure needs regardless of the type of wireless communication technology utilized. *(AASHTO undated)*

Until now, AASHTO has not produced a comprehensive guidance document for state DOTs regarding automated vehicles. However, the National Cooperative Research Program (NCHRP) project 20-24(98) has developed a Connected/Automated Vehicle Research Roadmap for AASHTO, which maps out 23 projects that it predicts will bring results to fruition over the next five years. These projects will likely include:

- Institutional and Policy
  1.1 Implications of Automation for Motor Vehicle Codes
  1.2 Business models for CV/AV infrastructure deployment
  1.3 Public agency actions to facilitate CV/AV implementation
  1.4 Harmonization of state regulations
  1.5 Federal-state-local boundaries of responsibility
  1.6 Lessons learned from other transportation technology rollouts
  1.7 Lessons learned from CV Pilot Deployments

- Infrastructure Design and Operations
  2.1 Roadway infrastructure design
  2.2 Tools for predicting CV/AV impacts
  2.3 CV/AV applications for maintenance fleets
  2.4 Relationships of CV and AV systems
  2.5 Traffic control strategies with consideration of AV
  2.6 Dedicated lanes for CV/AV operation
  2.7 Geometric design concepts for AV systems
  2.8 Cyber security implications of CV/AV on state and local operating agencies
  2.9 Workforce capability strategies for state and local agencies
  2.10 Data management strategies for CV/AV applications

- Planning Issues
  3.1 Including consideration of AV systems in the regional planning process
  3.2 Assessing transportation system impacts of CV/AV
  3.3 Effects of CV/AV on land use, travel demand, and traffic impact models

- Modal Applications
  4.1 Impacts of transit system regulations and policies on CV/AV technology introduction
  4.2 CV/AV applications for Long-haul freight operations
  4.3 Benefit/Cost analysis of AV transit systems

As indicated most of these topics address both connected and automated vehicles. Several, including 1.1, 2.1, 2.5, 2.7, 3.1, and 4.3 deal specifically with automated vehicle technology. There is an opportunity for ODOT to recommend staff members or stakeholders to serve on NCHRP panels that will be formed to select contractors and oversee the progression of the research efforts. The results of this work will materialize several years in the future, well beyond some of the projected dates mentioned in section 1.3 - Predictions.

Completed in 2013, the U.S. DOT's National Connected Vehicle Field Infrastructure Footprint Analysis identified nine deployment concepts, describing each concept in detail, the current state of its development and its applicability *(U.S. DOT 2013)*. The analysis also highlights considerations common to all concepts, which are in some cases also relevant to automated vehicle deployment, including required system architecture, service, siting and components, as well as privacy, cyber security, certification and data management, topics also described in more detail in later sections of this literature review. *(U.S. DOT 2013)* The deployment concepts include:

1. Rural roadway
2. Urban highway
3. Urban intersection
4. Urban corridor
5. International land border crossing
6. Freight intermodal facility
7. Smart roadside freight corridor
8. DOT operations and maintenance
9. Fee payment

Most of these concepts are seemingly directly applicable to Oregon – the exceptions being the international land border crossing, and possibly fee payment, which would require state legislative commitment to the tolling of state roadways. All concepts suggest maximizing optimization of V2X benefits through a combination of DSRC and cellular communications to ensure minimal latency and redundancy while also maintaining financial viability. *(U.S. DOT 2013)*

According to the Connected Vehicle Field Infrastructure Footprint Analysis, state and local DOTs may have specific interest in elements such as "traffic signal interfaces or roadside equipment to send infrastructure information or to receive DSRC messages broadcast from vehicles" *(AASHTO undated)*. It suggests that these DOTs consider private sector partnerships to help implement some of these elements, as well as to aid vehicle-based safety applications and data security management. *(AASHTO undated)*

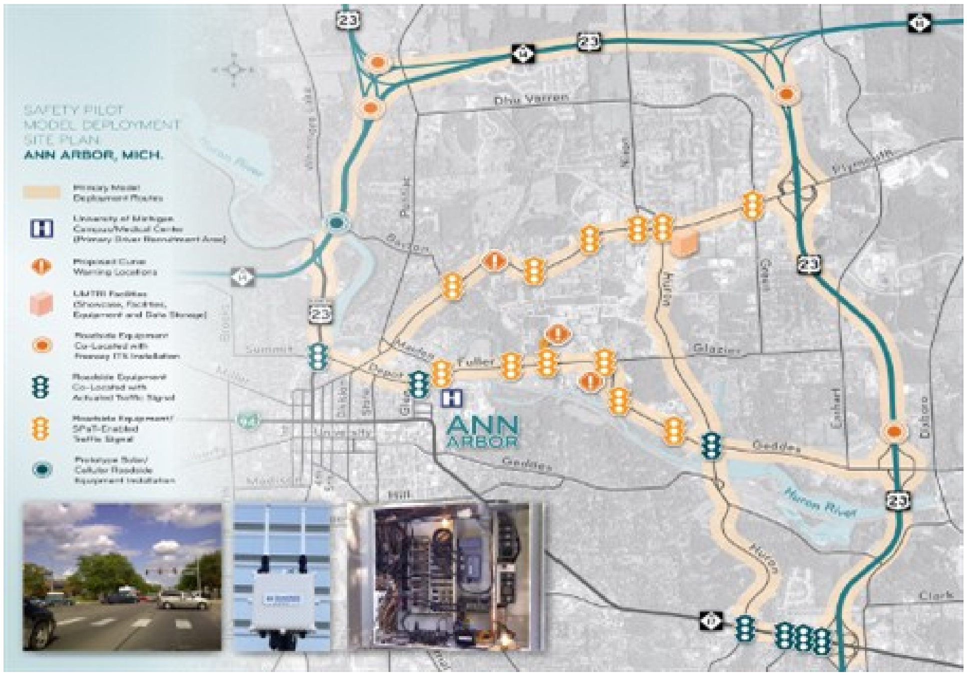


Figure 2.2: Map of the Safety Pilot Model Deployment. ***Source:*** University of Michigan Transportation Research Institute

Also guiding V2X implementation is extensive scientific research that was performed in 2013 as part of the 3,000-vehicle Safety Pilot project hosted by the U.S. DOT with research and development partners from University of Michigan's Transportation Research Institute and private industry *(FHWA 2014)*. The pilot, conducted in Ann Arbor, Michigan (see Figure 2.2) over the course of a year (later extended), tested multiple real-world V2X components and applications using actual drivers in a data-rich environment. *(FHWA 2014)*

Collaborative partnerships are an overarching theme in federal documents related to the effective implementation of V2X. The Connected Vehicle Field Infrastructure Footprint Analysis highlights the importance of state and local DOT guidance to develop the partnerships and testing opportunities that will inform V2X implementation. "The more [V2X] infrastructure is deployed nationwide using common standards" the footprint analysis states, "the more likely applications will be developed to take advantage of new safety, mobility, and environmental opportunities… deploying on a broad scale improves the benefits for all." *(AASHTO undated)*

Despite the many government- and industry-led efforts to bring V2X technology closer to implementation, many reports and articles still recognize significant deployment obstacles. The RAND report on automated vehicles states that despite the tangible benefits of connected and automated vehicles, "At this stage, there are still more questions than answers" on their widespread implementation *(RAND 2014)*.

One of the greatest implementation questions is whether the significant projected benefits can be achieved at a cost that is affordable for most people. "The increased freedom granted to the elderly and disabled cannot be overemphasized, but these populations are also poorer and often on a fixed income," according to one article. "Could they afford a driverless car?" *(Blumgart*

2014). Cost challenges could presumably raise concerns about equity. But at the same time, innovations such as car sharing, other forms of mobility services provided in the shared economy, or even application-based on-demand ride services involving automated vehicles could provide more equitable options for users in the future.

While literature that explores implementation of connected and automated vehicles generally concurs that there remain many unanswered questions, it also commonly acknowledges the steadily increasing progress that is being made on implementation by government agencies, transportation organizations, freight advocates, automobile companies and technology manufacturers. The federal government recognizes the importance of effective partnership building, as well as developing and rigorously testing of vast array of beneficial applications. Building connected vehicles and engineering a V2X system are seemingly much less of an overall concern than overcoming likely and potentially yet unforseen challenges that government decision making will need to address. Likewise, gaining and maintaining public trust in V2X technology through successful performance, according to much literature, will better ensure its seamless integration.

2.3 PRIVACY

The 2014 RAND Corporation report on automated vehicles indicates that data ownership and user privacy are inextricably linked *(Andersen 2014)*. Automated vehicle and V2X data would presumably be of high value to entities such as the insurance industry, retailers and law enforcement agencies, yet much uncertainty exists on exactly who will own, maintain legal control of and have the ability to destroy collected data. *(Andersen 2014)* As such, ensuring privacy from collected automated vehicle and V2X data is a key policy area demanding considerable analysis.

According to the 2013 GAO report on connected vehicles, V2X communication security systems "would contain multiple technical, physical, and organizational controls to minimize privacy risks—including the risk of vehicle tracking by individuals and government or commercial entities" *(GAO 2013)*. The report also indicates that the U.S. DOT will be required by law to develop a comprehensive privacy impact assessment and will, in the interest of ensuring transparency, "communicate what V2V data is generated by a vehicle, the extent to which it can be linked to drivers, and who or what entities—both legally and technologically—will be able to collect, use, and share the data," although it may seek from Congress "limitations on the use of V2V data by entities over which the department lacks regulatory authority." *(GAO 2013)*

A 2013 report by the Eno Center for Transportation indicates that, with regard to automated vehicles, like legislative debates in places like California other U.S. states will likely deliberate widespread public concern over data privacy during their own legislative processes *(Fagnant and Kockelman 2013)*. While automobile manufacturers will likely be the sole owners of data from automated vehicles, data from vehicles where drivers maintain some level of vehicular control will likely be made available only at the discretion of drivers or vehicle owners. *(Fagnant and Kockelman 2013)* The Eno Center report states that 96 percent of new vehicles sold in the U.S. already come equipped with event data recorders that track vehicle actions moments before and after a crash, and that NHTSA is considering near-term mandates that event data recorders be factory-installed in all new vehicles under 8,500 lbs. *(Fagnant and Kockelman 2013)* The report also indicates that, "while some states restrict insurance company access to such data (and require a warrant for access), in much of the U.S. data ownership and control remain undefined." *(Fagnant and Kockelman 2013)* Clearly this is an arena where much additional work remains to be done.

As is the case with other automated vehicle-related policy issues, unresolved privacy concerns pose a potential barrier to widespread automated vehicle implementation. Federal policymakers should examine the potential for uniform national guidance that minimizes wide ranging and inconsistent state-specific responses while providing and maintaining consumer confidence in data security – particularly given the recent attention from privacy encroachments by the federal government – and that personal privacy inherent in collected automated or connected vehicle data is not being abused. *(Fagnant and Kockelman 2013)* "Unless strong protections are enacted in the new regulations, once again society will be forced to play catch-up in dealing with the impact of the privacy-invading aspects of a new technology" one article warns *(Heller 2014)*. The RAND report cites that solutions that "anonymize vehicle data and aggregate them so that it does not reveal drivers' personally identifiable information" are already in use in some capacities *(Andersen 2014)*. Insistence that collected V2X data is anonymous in all but critical circumstances or in instances, such as tolling and traffic enforcement that result from a vetted and transparent public processes, is imperative.

2.4 CYBER SECURITY

In world all too familiar with computer viruses, hacks and cyber attacks, as well as terrorist threats – whether actual or perceived – regularly appearing in national headlines, its no surprise that ensuring vigorous cyber security is a primary expectation for widespread automated vehicle and V2X connected vehicle implementation. Cyber attacks on vehicle networks causing personal data theft, traffic congestion and even crashes that result in serious injuries or fatalities are not unfathomable, particularly given that each connected or automated vehicle or infrastructure component represents a potential access portal for illicit system disruption (*Fagnant and Kockelman 2013*). "[The] threat is real and a security breach could have lasting repercussions." (*Fagnant and Kockelman 2013*) "The security requirements for [connected and automated vehicle] communications may be a potential inhibitor to mass deployment" (*Andersen 2014)*. It is understood that "all vehicle-related data needs to be transmitted through secured networks, and all individuals interacting with the vehicle need to be authenticated." *(Miller 2014)* In addition, all "vehicle-related data will need to be secured across inter-vehicle communications, as well as device-to-vehicle, vehicle-to-vehicle and infrastructure-to-vehicle communications." *(Miller 2014)*

As positive public perception of vehicle automation and V2X applications is critical for the technology's widespread implementation, fully understanding of people's concerns is critical when developing an effective implementation strategy. A recent study performed by the University of Michigan's Transportation Research Institute does just that, as indicated in Table 2.2. When respondents in the United States, United Kingdom and Australia were asked how concerned they were about system and vehicle security issues related to connected vehicles, a majority of respondents indicated that they were 'moderately concerned.' Over one-third of respondents in the United States, however, specifically indicated that they were 'very concerned' about system and vehicle security related to connected vehicles, as well as "data privacy location and speed tracking" and "drivers relying too much on the technology." *(Schoettle and Sivak 2014)* Similarly, another recent study concluded that 52 percent of adults in the United States "fear a hacker could breach the driverless car's system and gain control of the vehicle" *(Seapine 2014)*.

Table 2.2: Percentage of responses, by country, to: "*How concerned are you about the following issues related to connected vehicles?*" (The most frequent response is shown in bold.) *Source: Schoettle and Sivac*, University of Michigan Transportation Research Institute (UMTRI)

Possible concern	Response	U.S.	U.K.	Australia	*Total*
System security (from hackers)	Very concerned	**36.5**	24.8	28.4	*29.9*
	Moderately concerned	35.1	**39.0**	**37.6**	***37.2***
	Slightly concerned	22.0	25.0	23.8	*23.6*
	Not at all concerned	6.4	11.2	10.2	*9.3*
Vehicle security (from hackers)	Very concerned	**35.4**	24.6	28.2	*29.4*
	Moderately concerned	35.2	**40.8**	**36.8**	***37.6***
	Slightly concerned	22.7	24.6	24.4	*23.9*
	Not at all concerned	6.6	10.0	10.6	*9.1*

Interestingly, the U.S. might actually be uniquely well positioned to successfully address security challenges. According the 2013 Eno Center for Transportation report:

> Fortunately, robust defenses should make attacks even more difficult to stage. The U.S. has demonstrated that it is possible to maintain and secure large, critical, national infrastructure systems, including power grids and air traffic control systems. The National Institute of Standards and Technology (NIST) is currently developing a framework to improve critical infrastructure cyber security, and recommendations that stem from this framework may be incorporated into automated and connected vehicle technologies. While security measures for personal computers and Internet communication were implemented largely as an afterthought, and in an ad-hoc manner, V2V and V2I protocols have been developed with security implemented in the initial development phase. These and other security measures (like the separation of mission-critical and communication systems) should make large-scale attacks on [automated vehicles] and related infrastructure particularly difficult… there is no "silver bullet," [and] such measures make attacks much harder to pull off while limiting the damage that can be done *(Fagnant and Kockelman 2013)*.

Connected/cooperative vehicle security systems must also "be capable of detecting, reporting, and revoking the credentials of vehicles found to be sharing inaccurate information" *(GAO 2013)*. According to the 2013 GAO report on connected vehicles, balancing individual privacy while successfully maintaining extensive and ever-changing information – and doing for multiple device and communication types at a deployment magnitude that has never been done before – presents very significant technical challenges. *(GAO 2013)* An effective nationwide or worldwide V2X management structure may pose an even greater challenge given its magnitude and that no similar institutions even exist (Ibid.), drawing parallel comparisons to the federal Patient Protection and Affordable Care Act ('Obamacare'), which was confronted with similar challenges of balancing individual privacy with institutional management needs and a multi-sourced data-intensive network, while some states also implemented their own additional rules.

Miller *(Miller 2014)* recommends a comprehensive interoperability structure or platform, placing the owner at the center (rather than the vehicle). This type of security platform would provide different authorization levels, plus connectivity and privacy protection. The platform would need the following functions:

- "Risk-based authentication.
- Centralized, cloud-based management of digital identities and rules governing authentication and vehicle usage.
- A centralized secure token service to protect the vehicle and vehicle-connected devices each time an action is requested." *(Miller 2014)*

There is overwhelming agreement in contemporary literature that cyber security is a primary – and possibly the largest – hurdle to mass deployment connected and automated vehicles. In addition to overcoming its technical challenges, gaining and maintaining public confidence will be critical. Despite the many lives that could be saved through V2X and as other benefits of the technology, one fatal V2X-related crash resulting from a security breach (which presumably will happen) could have catastrophic impacts on the public perception of the technology *(Ali 2014)*.

2.5 GOVERNANCE

According to the AASHTO Connected Vehicle Deployment Analysis, successful V2X deployment demands "commitment to the [V2X] program by [automobile manufacturers] to address broader governance," and effectively develop federal policy guidance establishing competent and consistent management structures capable of addressing and responding to key issues like liability, security, privacy and certification *(AASHTO 2011)*. The document's deployment scenarios "assume that state and local agencies will favor deployment approaches that provide compliance with a national [V2X] system architecture and national standards." *(AASHTO 2011)*

In contemporary V2X literature, there seems to be some doubt, despite a real possibility that automobile and V2X communication device manufacturers will soon have resolved nearly all of the major technical challenges to connected and automated vehicles, that federal legislators will lack the ability to effectively develop the necessary guiding policies to establish new V2X governance structures. In addition to ensuring implementation consistency across 50 U.S. states (and 52 state DOTs), governance structures to ensure seamless integration across national borders to avoid "creating a patchwork of standards that has the potential to create private sector headaches" is a significant challenge that could negatively impact widespread V2X deployment *(Ali 2014)*.

When federal policy on governance is established, according to one article, legislators should be guided by an important principle. "Policy decisions about [information technology, or IT] in the vehicle should be driven, not by narrow interests and concerns, but rather by a broad government mandate to foster innovation in the transportation sector" *(Castro 2013)*. "The federal government has played an active role in vehicle safety since the National Traffic and Motor Vehicle Safety Act was passed in 1966, carving out this regulatory responsibility for the National Highway Traffic Safety Administration (NHTSA). Ensuring that automobile manufacturers build safe vehicles and that policies are in place to prevent accidents remains a priority today" and should be remain a prerequisite on governance of connected and automated vehicles *(Castro 2013)*.

> The priorities of the dominant stakeholders will likely shape both the development of the rules governing the use of IT in vehicles and the institutions used to enact and enforce these rules. Other interests may also shape the debate, including private-sector motivations to obtain an advantage over competitors and/or reduce liability for accidents or malfunctions. Finally, external factors, including the saliency of the different issues and the venue of public debate, will likely affect the final policy outcomes. *(Castro 2013)*.

Successful deployment of connected and automated vehicles will require explicit federal policy guidance developed through an informed and transparent decision making process to promote effective V2X governance at state and local levels. These levels of government should be aware of and be available to assist in the ongoing development of sound federal policy guidance of V2X (including promotion of V2X through outreach and demonstrations, as well as pilot deployments and research), but ensure that state-level V2X decisions not conflict or cause undue deployment delay *(Andersen 2014)*.

The U.S. DOT Intelligent Transportation Systems (ITS) Joint Program Office (JPO) has recently released their 2015-2019 strategic plan *(ITS JPO 2014)*. In this document they promote one pillar for connected vehicles and one for automation. The focus within the ITS program will be on advancement of technology and systems to enable smooth and safe introduction of automated features into the nation's vehicles and transportation systems. The ITS strategic plan envisions asking some of the following questions in the area of automation:

Research

- What should be the role of the Federal government in automation research and development?
- What policies are needed to harness benefits from automated vehicles?
- What are the benefits from establishing connected automation?
- What are users' expectations for automated vehicles?
- What are the security needs for various levels of automated environments?
- What are the liability issues related to automation?
- How to define characteristics for the automation environment?

- What are the core elements and the performance criteria for automation?
- What are the risks associated with automation applications?
- What role will infrastructure play in an automated environment?

Development

- What are the non-technical barriers to deployment of automated systems?
- What automated vehicle applications can be demonstrated before 2019?
- What technical challenges are barriers to deployment of automated systems?
- What aspects of automated vehicles impact current law enforcement activities?
- How does data produced from "opt in" systems or applications impact policy?
- How do vehicle automation systems leverage connectivity to improve their performance and reliability?
- What type of naturalistic testing should the USDOT support for automated vehicle systems?
- Is there a consolidated focus between CV pilots and automation?

Adoption

- What is the appropriate Federal role in facilitating and encouraging deployment of automated systems? Is this different at different levels of automation?
- What is the role of early adopters (specialized drivers) in automation adoption and deployment?

It is clear from the wide range of these topics that many questions remain from the federal perspective. States will need to remain engaged with the U.S. DOT in this arena and contribute their perspectives and priorities as the strategic plan is implemented.

2.6 RISK

The 2014 RAND Corporation report suggests that while there are considerable projected benefits associated with connected and automated vehicles to improve social welfare, there remains many risks, whose disadvantages are presumably outweighed by potential gains from automation and V2X technology *(Andersen 2014)*. Risk types, according to the report, include:

1. Risks from market failure
2. Risks from regulation
3. Risks from liability *(Andersen 2014)*

As discussed earlier, consumer cost of connected and automated vehicles presents a potential barrier to widespread V2X deployment. “While the combination of the existing technologies of [adaptive cruise control] and lane keeping could create Level 2 [‘combined function’] automation relatively simply, it is unclear how much consumers would be willing to pay for a systems that requires constant vigilance of the road and the ability to take over the driving task in a split second,” particularly given that not all benefits will directly be realized by the actual purchaser of the technology *(Andersen 2014)*. Government subsidies may be required to address the risk of market failure and aligning “market forces with appropriate policy outcomes, policymakers might consider using a [vehicles miles travelled-based] taxation system.” *(Andersen 2014)*

Risks from regulation result partially from the current regulatory structure of driving in the United States; vehicle performance is regulated by the federal level and registration and licensing is regulated at the state level. *(Andersen 2014)*. When automation and/or V2X technology removes some or all of a driver’s decision making, government roles become less defined and abundant and potentially conflicting federal, state and local regulations could delay or stifle automated vehicle and/or V2X deployment *(Andersen 2014)*. The 2014 RAND report suggests that since the NHTSA and the federal regulatory process explicitly acknowledge the risk associated with premature regulation, risk of negative impacts should be minimal, especially if states follow the federal government’s lead on regulation. *(Andersen 2014)*. Related to the regulation risks, explicit clarity from federal regulators that the 5.9 GHz band will remain reserved solely for DSRC will minimize risk that this critical V2X component remains viable. *(Andersen 2014)* It's possible that automated vehicles may also benefit from the availability of the 5.9 GHz band.

Risks from liability were discussed in 2.1 – LIABILITY. The 2014 RAND report indicates that while automated vehicle manufacturer risks from liability remain uncertain, federal policymakers could address them by implementing a statue limiting torts against manufacturers; developing a no-fault system approach to crashes (similar to what 12 states already have implemented); requiring that, in all instances, a single person be responsible for the control of the vehicle; or demanding that appropriate cost-benefit tests are incorporated in all liability determinations. *(Andersen 2014)*. While state and local governments could also implement these solutions to address liability risk concerns, a consistent nationwide policy will minimize manufacturer uncertainty that could slow automated vehicle and V2X deployment.

Despite potential risks associated with connected and automated vehicles – and, as with implementing most any new technology, there presumably will be some – their impact on any one sector should be minimized due the wide array of public and private stakeholders and other advocates across the world who are becoming increasingly invested in seeing automated vehicle and V2X technology take hold. A cautious and steady approach to automated vehicle and V2X implementation that effectively and collaboratively mitigates deployment challenges as they arise could also ease their extent.

2.7 CERTIFICATION

In the context of connected vehicles, certification refers to "an external communication security system [that] is needed to ensure that data being transmitted among vehicles are secure and trusted and have not been altered in the transmission process." *(GAO 2013)* V2X certification pilot projects are using 'public key' security systems, similar to what is in place for secured transactions for banking and Internet commerce. *(GAO 2013)* A V2X system would include "in-vehicle V2V equipment [that] must be able to detect and automatically report potentially misbehaving devices—such as devices that are malfunctioning, used maliciously, or hacked—to a communication security system" and "also detect and automatically revoke certificates from vehicles with such devices." *(GAO 2013)* Automated vehicles' reliance on digital maps that also would be obtained through an external communication system may also require certification elements. Portions of infrastructure that are set aside for automated vehicles (e.g. managed automated lanes) would also likely require digital certification transactions as a means of providing vehicular access.

The specifics of how certificates will be provided and validated at implementation and by who remain undefined, as do the specifications for factory and aftermarket communication devices on new and currently operating vehicles. *(GAO 2013)* According to the 2013 GAO report, the U.S. DOT and the automobile industry are closely collaborating with international standards organizations to standardize communication data for automated vehicle and V2X certification and the means of how it is transmitted. *(GAO 2013)* As indicated in section 2.2 – Implementation, the vast magnitude of a widespread V2X certification system is a significant challenge to successful implementation of V2X *(GAO 2013)*, as would a certification system for automated vehicles. A federal model, a public-private model and a fully private model are certificate systems models being explored by the U.S. DOT and its partners *(GAO 2013)*. Cost will likely be a significant factor, but system uncertainties related to volume, timeframe, degree of integration and federal requirements will also impact it. *(GAO 2013)*

According to the 2013 U.S. DOT Connected Vehicle Field Infrastructure Footprint Analysis, public sector mobile equipment and public and private sector field equipment is much simpler since existing certification processes can be used given their "inherently trackable and non-anonymous" attributes that do not need anonymous certification – an important consideration when determining system costs *(U.S. DOT 2013)*.

An effective certification system for connected and automated vehicles is imperative when maintaining cyber security and user privacy. Like many other automated vehicle and V2X components, the certification system should be a result of extensive stakeholder collaboration to determine the most functional and most cost-efficient business model, be integrated with international standards and be meticulously researched and tested to identify and resolve flaws that could easily diminish public trust in automated vehicle and V2X technology.

2.8 DATA

Previous sections discussed data transmission, security and privacy. Just as important to how V2X data is transmitted and secured is determining what data is collected and how it is generated, archived and managed. Similar data issues will arise with automated vehicles. In the case of V2X, it is the data transfer between vehicles and between vehicles and the infrastructure that will enable the many possible applications. In the case of automated vehicles, data transfers are envisioned to provide the source of the detailed maps required for automated driving. Automated vehicles will also be 'connected', and as vehicles regulated by NHTSA it is likely that they will also contain DSRC devices if and when that federal regulation goes into effect. Automated vehicles may also serve as 'probes', helping to enable a range of safety, mobility and sustainability applications as well. Therefore, data policy issues apply to the wide range of future vehicle deployments.

It may be the case that minimizing data collection and storage can simplify automated vehicle and V2X systems, making them more insulated from security threats and minimizing potential risks associated with data overload.

As highlighted in 2.3 – Privacy, data security systems can be designed to anonymize data, ensuring "data privacy through a structure that prevents the association of a vehicle's [V2X] communication security certificates with any unique identifier of drivers of their vehicles" *(GAO 2013)*. Collecting and storing only basic data needed to better ensure widespread vehicle safety and mobility is a common sentiment shared in contemporary V2X literature, particularly as public trust in V2X technology can be easily eroded if personal data is used for unintended purposes like traffic enforcement or direct consumer marketing.

The U.S. DOT's 2013 Connected Vehicle Field Infrastructure Footprint Analysis provides an extensive compilation of the possible V2X data needs of its priority deployment applications and categorized application bundles *(U.S. DOT 2013)*. Three framework categories of V2X data collected include:

- Vehicle to Vehicle (V2V) data generally consists of kinematic data from nearby vehicles that will enable a receiving vehicle to understand the current state of the transmitting vehicle and to project its trajectory a few seconds into the future so as to assess potential conflicts.

- Vehicle to Infrastructure (V2I) data includes data describing road and traffic conditions observed by the vehicle along sections of road traveled at some earlier time.

- Infrastructure to Vehicle (I2V) data includes data generally associated with the roadway on which the vehicle is or will likely be traveling. This data may be transmitted locally from roadside equipment units (RSE) to vehicles in the local vicinity of the RSE (i.e., in range of the wireless local link) or may be transmitted to the vehicle directly by the center element using the wide area wireless link *(U.S. DOT 2013)*.

Appendix B: Applications in the U.S. DOT's 2013 Connected Vehicle Field Infrastructure Footprint Analysis contains brief descriptions of 91 connected vehicle applications discussed and demonstrated in its analysis, grouped under headings for:

- Safety
- Mobility
- Applications for the Environment: Real-Time Information Synthesis (AERIS)
- Smart Roadside
- International Border Crossing (IBC)
- Road Weather
- Agency Data Applications
- Fee Payment

The analysis suggest that "a more complete data needs discussion necessarily extends beyond what can be transmitted to what will be transmitted," and that probe data collected from private vehicles must be stored only long enough to transit to RSE units, at which time it should be encrypted – possibly through a third-party source – to be used in anonymity for V2I applications. *(U.S. DOT 2013)*

Moving forward, data collection may vary depending on the production year of the vehicle. While new factory-built vehicles (automated or not) can fully integrate V2X technology into their internal electronic and networks, existing vehicles would need to be retrofitted with aftermarket V2X devices *(GAO 2013)*. According to the 2013 GAO report, aftermarket devices might not be fully integrated with existing vehicles and may provide significantly less data than new factory-integrated vehicles. *(GAO 2013)* Some aftermarket devices may "neither receive data from other vehicles nor provide a [non V2X integrated vehicle] driver with a warning message, but would interact with the communication security system" (Ibid.). The U.S. DOT "is now working with the automobile industry to determine additional standards for such devices to ensure that they work on all types of vehicles and adhere to communication standards to ensure the integrity and security of their data transmission." *(GAO 2013)*

V2X components, as well as GPS and automated sensor devices will collect vehicle data that will be certified and transmitted via the V2X network. By providing redundancy to better ensure data accuracy, the 2013 GAO report indicates that "the convergence of sensor-based crash avoidance technologies and connected vehicle technologies will [also] be needed to enable truly [automated] vehicles, given the benefits and downsides of each type of technology." *(GAO 2013)*

V2X implementation will result in a substantial amount of data, demanding networks capable of transmitting, processing, archiving and managing needed data. The U.S. DOT's 2013 Connected Vehicle Field Infrastructure Footprint Analysis cautions local and state agencies from assuming costs of V2X network components until a much more vetted process has been completed at a federal level to better determine minimum data needs *(U.S. DOT 2013)*.

2.9 LEGISLATION

"Careful policymaking will be necessary to maximize the social benefits that [*automated vehicle] technology will enable, while minimizing the disadvantages. Yet policymakers are only beginning to think about the challenges and opportunities this technology poses" (Andersen 2014)*. **–** 'Autonomous Vehicle Technology: A Guide For Policymakers' by the RAND Corporation

While this statement specifically refers to limited self-driving automation and full self-driving automation (levels three and four of the NHTSA's defined vehicle automation levels), it can also be applied to non-semi or non-fully self-driving connected vehicles. Connected vehicles with active safety systems or driver assistance systems (such as emergency braking, parking assistance and automated cruise control) but without at least level three automation, according to the 2014 RAND Corporation report, are assumed to be fully excluded from the few state laws regulating level three and four automated vehicles *(Andersen 2014)*, but would presumably still benefit from a limited and careful policymaking at the federal and state levels to maximize benefits and minimize disadvantages, particularly as they will set the foundation for increasingly more fully automated vehicles in the not-too-distant future.

Even so, on roadways in the United States, according to a 2012 report on automated vehicles produced for the Center for Internet and Society at Stanford Law School and the Center for Automotive Research at Stanford, state vehicle laws neither explicitly enable nor prohibit driverless automated vehicle technology *(Smith 2012)*. Yet to date, four states and the District of Columbia have enacted legislation related to automated vehicles – all since 2011. California, and Nevada enacted legislation allowing limited automated vehicle licensing, while Michigan, Florida and Washington, D.C. allow conditional automated vehicle testing *(Andersen 2014)*. Similar legislation has been proposed but failed in other states. "While these laws may prompt an important conversation between regulators and stakeholders, it is not clear that they are necessary at this point" *(Andersen 2014)*.

Additionally, the 2013 Eno Center for Transportation report stipulates that reciprocity agreements in all but five states (Georgia, Wisconsin, Massachusetts, Michigan, and Tennessee) already allow drivers licensed in one state to legally operate their vehicles in other states, and that current state law "probably does not prohibit [automated] vehicles in states without their explicit licensing, though failure to clarify regulations may discourage their introduction or complicate their operation." *(Fagnant and Kockelman 2013)*

While state legislation on connected and automated vehicles may not be needed for its testing and implementation, or even, as the 2014 RAND Corporation report suggests, to address any real automated vehicle problems, it provides one notable and significant benefit: "[It] begins the conversation between legislators, stakeholders, and regulators about how these vehicles and their operators should be regulated." (*Andersen 2014)* Proposed 2013 legislation in Oregon (HB 2428) would have established procedures and requirements for testing automated vehicles in the state while collecting data and absolving some manufacturer liability terms. (*Andersen 2014)* Despite the proposed bill stalling in a House committee, ODOT soon afterwards initiated development of this roadmap for connected vehicle deployment to help inform the state on whether or not to be proactive on partaking in the development of V2X technology *(Region 1 2013)*.

Other states have demonstrated similar successes in laying the foundation for conversations about preparing for connected and automated vehicles. Figure 2.3 shows a map of the U.S. with the current status of legislation related to automated vehicles. Currently legislation has passed in five jurisdictions:

- California – Testing and operation (2012)
- Florida – Testing only (2013)
- Michigan – Testing only (2013)
- Nevada – Testing and operation (2011)
- Washington DC – Testing and operation (2013)

As shown, there has been legislative activity related to automated vehicles in 23 other states. Florida, which enacted legislation in 2013 to allow automated vehicle testing on its roadways, launched the Autonomous Vehicle Institute through the Center for Urban Transportation and Research (CUTR) at the University of South Florida "to begin to develop a framework for implementation of the technology" *(Hennig 2013)* that, according to then-Director Jason Bittner, could bring substantial benefits to the State of Florida "not to work [only] on [automated] technology, but [also] the implementation of those technologies on the policy and planning side." *(Hennig 2013)*

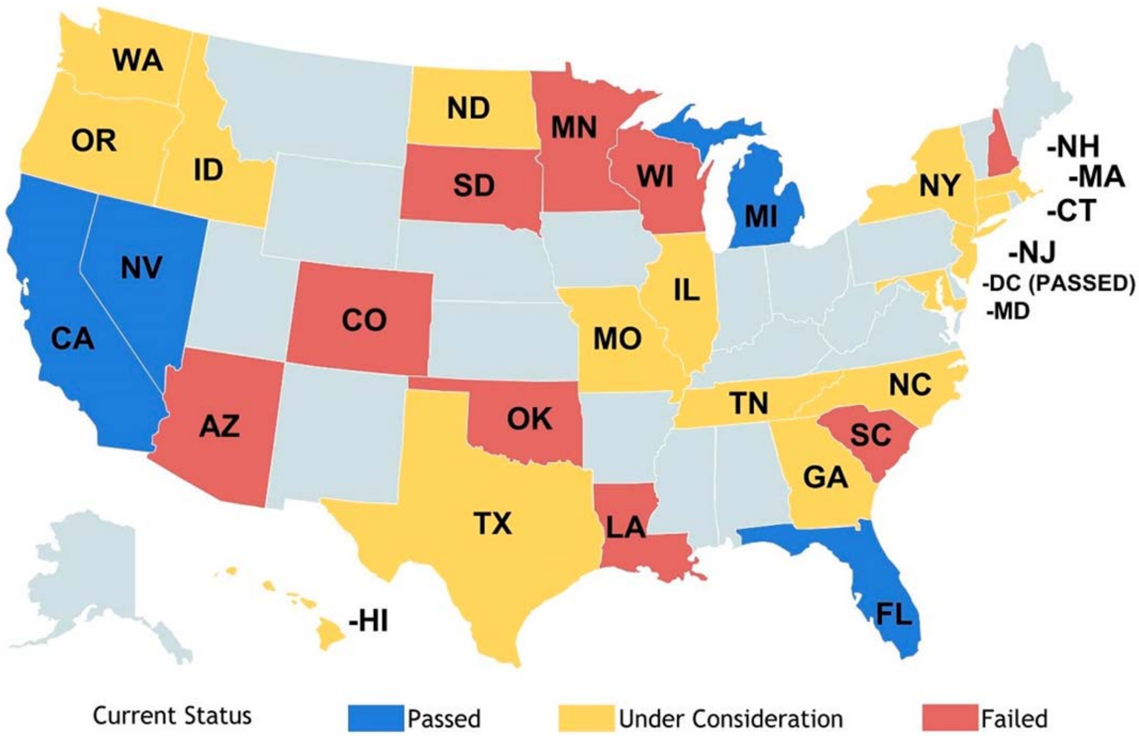


Figure 2.3: Map of U.S. states where connected and automated vehicle-related legislation has passed or failed. Source: The Center for Internet and Society

In California there has been significant activity in the area of automated vehicles in the past several years *(California DMV 2015)*. California has approximately 38 million residents, with 29 million licensed drivers (includes identification cards), and 33 million registered vehicles. In 2012 the legislature passed and the Governor signed Senate Bill (SB) 1298 Vehicles: autonomous vehicles: safety and performance requirements. This law requires the Department of Motor Vehicles (DMV) to adopt regulations establishing requirements for manufacturer testing and operation of automated vehicles on public roadways. The California legislation defines an automated vehicle as one equipped with technology that has the capability to drive a vehicle without the active physical control or monitoring by a human operator. The legislation specifically states that this definition does not include vehicles equipped with one or more collision avoidance systems (e.g. SAE Levels 1-2) such as: electronic blind spot assistance, automated emergency braking systems, parking assist, adaptive cruise control, lane keeping assistance, lane departure warning, and traffic jam/queuing assist.

To aid in the development of the regulation, California has set up a statewide steering committee made up of representatives of Caltrans, the California Highway Patrol, DMV, the California Department of Insurance, the California Office of Traffic Safety, NHTSA and the California State Transportation Agency. DMV has also embarked on extensive public outreach through in-person meetings, workshops and via social media. After two pre-notice workshops, a 45-day public comment period, a formal public hearing followed by a 15-day public comment period, the regulatory package for automated vehicle testing was approved in May 2014, and took effect on September 16, 2014. The testing regulations include the following elements:

- Insurance, bond, or self-insurance required ($5 million).
- Test drivers must be employees, contractors or designees of manufacturer.
- Test drivers must successfully complete test driver training program.
- Test drivers may not have a DUI, may not be an at-fault driver and have no more than 1 point against their driving record.
- Test drivers must be seated in driver's seat during testing.
- Any crash must be reported within 10 days.
- Any unanticipated disengagement of automated technology must be reported annually.
- Testing permit is valid for one year.
- Commercial vehicles (>10,000 GVW) and motorcycles are excluded from testing.

As noted in Section 1.0, currently eight manufacturers have received approved testing permits in California.

The California DMV is currently developing regulations for post-testing deployment, including considerations of vehicle safety certifications, the definition of the operator, licensing and registration requirements, cybersecurity and privacy protection. DMV has held two pre-notice workshops and once published the regulations will undergo a 45-day public comment period and a formal public hearing. Components of the deployment regulations may include:

- Insurance, bond, or self-insurance required ($5 million).
- Specification whether vehicle is capable of operating without a driver inside.
- Disclosure of designated areas of operation.
- Confirmation that automation technology meets and does not invalidate any FMVSS.
- Inclusion of mechanism to easily engage/disengage automated technology.
- Visual indicator that automated technology is engaged.

- System to alert operator when a failure of automated technology is detected.
- Sensor data recorded 30 seconds prior to a collision.

Once the regulations are in effect, Oregon should monitor progress of automated vehicle deployment in California, and in other states.

Yan Holeywell, in a 2013 article in Governing Blog highlighted one significant and overarching legislative challenge for states. "Historically, states have regulated drivers, and the feds have regulated vehicles," but "what happens when the vehicle *is* the driver?" *(Holeywell 2013)*. Holywell, like many other writers engaging in lively discussions regarding the emergence of automated vehicles, identifies a list of questions that he believes must be answered before widespread automated vehicle deployment. Who answers them (federal, state or local government, or a combination of these entities) is seemingly yet to be determined. Given the diverse issues that semi- or fully-automated vehicles present, particularly given their potentially unprecedented transformational impacts on over two hundred million licensed drivers across the United States, increasing legislative discussion and strategically implementing foundational measures that guide connected and automated vehicles can play a key role in effectively preparing states for significantly more advanced vehicle communication in the future.

According to some sources on automated vehicles, however, unique legislation enacted by individual states may be premature and carry potential risks. "Without a consistent [nationwide, and even global] licensing framework and standardized set of safety for acceptance, [connected and automated vehicle] manufacturers may be faced with regulatory uncertainty and unnecessary overlap, among other issues," according to the 2013 Eno Center for Transportation report on automated vehicles, potentially resulting in deployment delays and increased production and testing costs (*Fagant and Kockelman 2013)*.

Ideally, a collaborative and cross-border solution for widespread implementation of automated vehicles will prevail. A 2014 press release by the International Telecommunication Union (ITU) even suggests that it already has. The ITU highlights a recent high-level discussion and session involving leaders from industry, international agencies and motorsports who agreed that technical capabilities have now reached maturity and that "agreements on international technical standards and putting in place regulatory requirements are already under way to make [automated driving] a reality." *(ITU 2014)*

According to the press release, "To realize [automated driving] benefits, it will be first necessary to address issues including software reliability, legal frameworks and cybersecurity." *(ITU 2014)* A 2013 report by the Information Technology and Innovation Foundation – a Washington, D.C.-based think tank catalyzing innovative "strategies and technology policies to create economic opportunities and improve quality of life in the United States and around the world" – indicates the same.

> Federal and state lawmakers have also expressed interest in enacting broad privacy legislation to better protect consumers, such as by creating a consumer privacy "Bill of Rights," and these laws would likely affect vehicle data. In addition, most states have implemented data breach notification laws that require businesses and government

> agencies to notify individuals if [personally identifiable information (PII)] has been lost or stolen. Congress has also considered multiple proposals to implement national data breach legislation as well as other privacy legislation, such as to restrict the use of geo-location data. These existing and proposed laws would likely apply to vehicle location information and other related PII. States have also considered privacy laws specific to drivers. For example, as of 2012, at least thirteen states have passed legislation governing the use of data from event data recorders *(Castro 2013)*.

In conclusion, literature suggests that states be proactive in discussions on connected and automated vehicles, yet also be aware of potential risks to efficient industry deployment when creating legislation unique and possibly inconsistent from other states. Maintaining robust partnerships with federal officials, manufacturers and IT organizations involved with connected and automated vehicle development can help states secure needed research opportunities that could result in economic investment within a state. Likewise, states should become well versed in issues of privacy and data security, as it remains a consistent consumer concern and poses some of the greatest legislative challenges.

2.10 DEPLOYMENT APPROACH

Much of the literature discussing deployment approaches for connected and automated vehicles shares a signature commonality: its success is directly dependent on human perception and acceptance. As indicated in 2.2 – Implementation, automated vehicle technology is already being implemented through the slow and steady release by automobile manufacturers of sensor-based, driver-assist functions and by tech device manufacturers that increasingly allow consumers to access more information – often in real time – much more easily and at significantly higher speeds. As indicated in one study, "… as technology and data become more engrained in consumers' daily lives the request for data and information around driving and the increased knowledge of driver safety will likely be driving forces to deploy [an automated vehicle or V2X] concept on a wide scale" *(National Petroleum Council 2012)*.

That tech-hungry consumers in the United States do not yet have ready access to connected and automated vehicles may be testament itself to the hurdles that key issues like personal privacy and data security truly present. Consumer trust is fundamental yet fragile and, as can ascertained from recent news stories on government infringements on personal privacy and fatalities resulting from improperly recalled technology in vehicles, strategic deployment of revolutionary technology can have a strong and prolonged impact on consumer perceptions. Despite automated vehicle technology's potential to cause catastrophic damage while also preventing countless crash fatalities and minimizing immeasurable injuries, widespread negative perception of the technology can presumably delay and even derail its eventual deployment.

At the far end of the automation spectrum, driverless vehicles present a vast activity of discussion on whether Americans will ever be ready to give up complete control of the act of driving, an act deeply engrained in Americana. Similarly, will Americans – *and specifically, Oregonians* – ever be able to overcome a perception that driverless robotic driving is safer than human driving, or outright embracing the extensive individual freedoms that driverless vehicles could potentially bring? *(Tannert 2014)*.

Closer to nearer term debate, a 2011 report by the Cisco Internet Business Solutions Group suggests that there is a strong business case for connected and automated vehicles that, if implemented strategically, could create increasingly positive public perception that could lead to efficient and effective deployment while enabling new business models and creating substantial value for society *(Mai and Schlesinger 2011)*.

"Today, the value system of personal mobility is under attack by a new generation of drivers that cherishes social media and technology more than a car." *(Mai and Schlesinger 2011)* The report continues, "It is no longer enough to sell personal transportation; people want a personalized driving experience that keeps them connected to everything that is important to them—friends, information, music, maps, schedules, and more… Ubiquitous vehicle connectivity not only allows automakers to ride the wave of smart mobile technology, but also enables a fundamental strategy shift from merely building cars to selling personal travel time well-spent." *(Mai and Schlesinger 2011)*.

The 2011 Cisco report presents an interesting analysis, particularly in light of recent trends that younger generations in the United States are less likely to prioritize possession of a driver's license or a car than older generations, and that new mobility concepts like car sharing, mobile-app based shared ride services, and bike share are becoming increasingly commonplace on U.S. city streets *(Mai and Schlesinger 2011)*.

Perhaps the title of a 2014 National Public Radio story is most applicable to connected and automated vehicles and V2X technology, "By the Time Your Car Goes Driverless, You Won't Know the Difference." This broadcast and accompanying article suggest that given the advanced safety technologies that are slowly being introduced by nearly all automobile manufacturers, truly connected, semi-automated and even driverless vehicles may be met with much less consumer shock and media attention than if the technology was suddenly available today *(Madrigal 2014)*.

> This is how the future creeps into the present. While it might seem like your main computing device transformed from a Dell desktop into a smartphone overnight, there were thousands of little steps along the way that lead to the moment when you realized the world has changed beyond recognition *(Madrigal 2014)*.

As illustrated in the AASHTO Connected Vehicle Deployment Analysis, there are many connected vehicle applications that state DOTs can employ on their fleet vehicles and introduce to drivers via road pricing or tolling. Likewise, state DOTs can work with the freight community, who already uses and benefits from extensive ITS systems that help improve delivery efficiency *(AASHTO 2011)*. Extending this steady approach to deployment can allow motorists, travelers and shippers to become more acclimated to changes and illustrate to them the benefits and minimal risk that connected and automated vehicles may provide.

In summary, effective deployment of connected and automated vehicles may consist of addressing public perception of connected and automated vehicle technology. "It's all about the T word—trust," notes an opinion in a 2014 Consumer Reports article by Toyota's national manager for advanced technology and business communications, John Hanson *(Consumer*

Reports 2014). "There has to be a level of trust that you have that the vehicle is going to perform the way you think it's going to perform." *(Consumer Reports 2014)*

2.11 FINANCING

If vehicles equipped with automated driving capabilities are priced equivalent to vehicles without the technology, according to a recent survey by J.D. Power and Associates and highlighted in the 2013 Eno Center report, 37 percent of responders would "definitely" or "probably" prefer automated driving capabilities, but only 20 percent responders would do so if having to pay an additional $3,000 – a cost estimated by Volvo *(Fagant and Kockelman 2013)*. Affordability has an obvious impact on consumer's automobile purchase decisions. Widespread implementation of connected and automated vehicles will remain a likely barrier unless the purchase price is reduced through technical advances and mass-production efficiency, government mandates and/or subsidies *(Fagant and Kockelman 2013)*. Depending on the level of vehicle autonomy, "insurance, fuel, and parking-cost savings may [also] cover much of the added investment." *(Fagant and Kockelman 2013)*

The 2013 GAO report on connected vehicles indicates that costs associated with a V2X communication security system are relatively unknown as the U.S. DOT, the Crash Avoidance Metrics Partnership (CAMP) and automobile manufacturers have been yet unable to move ahead on a preferred technical and management option *(GAO 2013)*. Likewise, the GAO team that produced their report was neither able to locate any studies that determined V2X costs, nor could any of the automobile manufacturers or 21 industry experts that the GAO interviewed for their report *(GAO 2013)*. The report indicated that non-resolution of some factors – volume of connected vehicles influenced highly by federal mandates; deployment time frames; and degree of V2X integration with existing vehicle technologies – are limiting the ability to successfully estimate costs *(GAO 2013)*.

"Furthermore," according to the 2013 GAO report, "it is currently not only difficult to estimate the potential [V2X communication security system] costs, but [it is] unclear who or what entity—consumers, automobile manufacturers, DOT, state and local governments, or others—would pay the costs" *(GAO 2013)*. Determining who will fund the all or portions of a V2X system will likely present a major challenge *(GAO 2013)*.

Regardless of whether state and local DOTs must carry some or most of cost burdens of V2X communication security systems, as well as other costs of installing, operating, and maintaining V2X infrastructure, they will "need to identify a funding mechanism for the capital and ongoing operations and maintenance costs" *(AASHTO undated)*.

> Depending on the type of Connected Vehicle infrastructure and the applications it supports, agencies can consider various funding categories to support deployment. For example, Connected Vehicle systems are a form of ITS technology, so an agency might use an ITS budget or any category of federal or state funds for which ITS is eligible. Connected Vehicle systems are expected to have significant impacts on vehicle and highway safety, so deployment with funds intended for safety systems might be appropriate. Mobility impacts of Connected Vehicle technologies and consequent emission reductions could warrant funding some deployments with funds set aside for congestion mitigation or air quality improvement projects *(AASHTO undated)*.

> There will be ongoing day-to-day operations costs (e.g., staffing; power and backhaul communications from Connected Vehicle field sites), maintenance costs (both scheduled and unscheduled), and the costs of replacement of field and back-office equipment at the end of its life. For Connected Vehicle systems, agencies may wish to explore public–private partnerships or asset and revenue sharing mechanisms to acquire the desired Connected Vehicle infrastructure *(AASHTO undated)*.

One of the primary drivers for the connected vehicle is that crash reduction and other benefits can be achieved at relatively low cost per vehicle, making the technology (factory equipped or after-market) affordable to all users. In the context of automated vehicles, according to the 2013 Eno Center report, widespread deployment of automated vehicles may present different cost and equity related challenges. The LIDAR systems used for Google's automated vehicles cost about $70,000, "and additional costs will accrue from other sensors, software, engineering, and added power and computing requirements," significantly more than "2012 sticker prices for the top 27 selling vehicles in America ranging from $16,000 to $27,000." *(Fagant and Kockelman 2013)* This highlights an important contrast between connected and automated vehicles. It is also worth noting that the impact of these cost differentials on a fleet vehicle such as a commercial truck or a bus may be proportionally less than on a privately owned automobile. This could imply that barriers to deployment of automated heavy vehicles may be lower than for light vehicles. The lower price points and greater network efficiencies makes it possible that automated vehicle deployment will be led by the freight community, and other fleet vehicles (rental car companies, taxis, DOTs, etc.) and not necessarily privately-owned passenger vehicles.

In summary, V2X costs and agreeable allocation of costs are needed for widespread V2X to take hold and have its benefits realized. Close collaboration is occurring and should continue. The willingness of consumers to bear some of the costs of V2X deployment should also not be overestimated; if consumer willingness to pay an additional few thousand dollars extra is minimal, legislative mandates or new cost allocation models may be needed to advance connected and automated vehicles.

2.12 SUSTAINABILITY

Perhaps unsurprisingly, contemporary literature on sustainability issues related to connected and automated vehicles is heavily weighted towards the automated end of the connected vehicle spectrum, and much of it on fully-automated, driverless vehicles. As U.S. cities continue to witness a paradigm-shifting evolution of how people drive via widespread acceptance of new and 'sustainable' systems like car sharing, ride sharing, and TNCs (transportation network companies) or high-tech, unlicensed taxis like Lyft and Uber, exciting visions of fully-automated vehicle deployment are ripe for debate.

"If automated vehicles significantly enhance the user experience for drivers, then automated vehicles owners may travel more than they currently do," concludes a 2014 white paper on automated vehicles *(Bierstedt et al. 2014)*. "Instead of exploring more effective solutions that could carry more people from one destination to the next, the driverless car, by definition, keeps the car as the No. 1 choice for getting from A to B," suggests a 2014 New York Times article *(Arieff 2014)*. Other writers predict the end of taxis or the current auto insurance industry, fully automated or driverless vehicles enhancing density or suburban sprawl, and paradigm shifts where nobody owns their own car. Social inequity could result from a shift away from transit, while equity could be gained through significantly improved safety for all roadway users and providing an ability for seniors and people with almost any form of disability to independently reach their preferred destinations. Automated transit and shared mobility will lead to blurring of the lines between taxis, private vehicles and public transportation *(Lappin 2014)*, and will also provide improved opportunities for what we refer to as the "first mile/last mile" problem.

It's important to remember that federal, state, regional and local transportation and community planning efforts have not yet incorporated the potentially disruptive changes that connected and automated vehicles may bring about. Nor should we forget that planning processes include stakeholder and community outreach, and that most planners and planning processes focus on designing communities where people want to live and interact with one another. With this in mind it is important to remember that technology by itself will not define our future.

Much broader morality-based sustainability debates around automated vehicles are also common. A 2013 Wired Magazine article highlights “a school-bus variant of the classic trolley problem in philosophy” where a driver facing a moral dilemma during an approaching and inevitable crash must make a decision on whether to run into a bus full of children or into a pitch or tree and potentially killing its driver *(Lino 2014)*. “It’s one thing when you, the driver, make a choice to sacrifice yourself. But it’s quite another for a machine to make that decision for you involuntarily” concludes the article. *(Lino 2014)*

Moving further away from the extreme side of the spectrum and more towards near-term V2X and limited automated vehicle technology, one can see other challenges when assessing its sustainability. ‘Meeting the needs of the present without compromising the ability of future generations to meet their own needs’ is a long-accepted definition of sustainability, as are ‘the three pillars: economy, society and the environment.’ Yet, the definition manifests conflict if a technology is more successful than the status quo by one sustainability measure, but less successful in another. Similarly, connected and automated vehicles likely have both positive and negative externalities that could contradict one another when a sustainability lens is applied. Regardless, assessing net sustainability, or net success of achieving sustainability guidelines inherent in Oregon’s Statewide Planning Goal 12: Transportation, illustrates that benefits of connected and automated vehicle technology far outweigh drawbacks.

Numerous positive externalities are regularly cited in the literature. A 2013 article in Technology Review suggests that V2X communication could be “synonymous with technology that makes driving safer, less polluting, and certainly less antagonistic” *(Knight 2013)*. The U.S. DOT indicates that V2V technologies have the potential to address “76 percent of all potential multi-vehicle crashes involving at least one light-duty vehicle,” *(GAO 2013)* which, even if partially off-target, is still a significant safety improvement. If vehicles are enabled to travel closer together through adaptive cruise control, spend less time idling through interactive signal timing, and take the shortest route possible based on real-time information, there would be significantly less fuel consumption and fewer emissions *(Fagant and Kockelman 2013)*. In theory, people would be happier and less antagonistic resulting from more predictive and efficient mobility with less congestion. *(Fagant and Kockelman 2013)* Increased predictability, and efficiency will also provide cost-saving and timesaving benefits, while less congestion would improve community livability, collectively advancing the well-being of all people and businesses.

In summary, recent literature indicates that the spectrum of connected and automated vehicles will provide different degrees of positive and negative externalities in regards to sustainability. Based on literature reviewed, the benefits of the technology are overwhelmingly positive, but may not be gained until deployment is widespread. *(Fagant and Kockelman 2013)* As the level of automated driving increases, a complexity of issues related to sustainability arises, with potential impacts on the pillars of economy, society and environment. Potential impacts vary in scale and severity, and pose real challenges for decision makers tasked with improving the economic, equitable and ecological wellbeing of Oregonians.

3.0 CONCLUSIONS AND NEXT STEPS

Recent literature on connected and automated vehicles is focused much more on technical and theoretical issues of fully automated or driverless vehicles. This could be due to a long-held fascination people seem to have with future technology and, as with any good science fiction narrative, the complexity of challenges and moral dilemmas they present. Yet, it is clear from this literature review and desk scan that discussion of partially and ultimately fully automated vehicles is not futuristic speculation but a likely reality in the coming decade. This is demonstrated by the actions of the federal government and national governments across the globe, as well as leaders from automobile manufacturing and high-tech sectors, embodied by the significant financial investments being directed at automated vehicle development.

While a seemingly less engaging topic of discussion, connected vehicles deployment will likely provide much of the foundation to how semi- and fully-automated vehicles will eventually be implemented. As reported in the GAO report *(GAO 2013)*, “the range of V2V communications is not only greater than that of existing sensor-based technologies, but due to the sharing of data between vehicles, V2V technologies are capable of alerting drivers to potential collisions that are not visible to existing sensor-based technologies, such as a stopped vehicle blocked from view or a moving vehicle at a blind intersection.” Connectivity provides the essential high-resolution map data recorded by other vehicles on the network, and appears to be a key ingredient in the operation of automated vehicles currently being tested on public roadways. Regardless of whether or not the technological, legislative and policy issues will be resolved in the coming decades, focus on partnership building, public engagement and concept refinement in the near term can help inform effective connected and automated vehicle deployments.

As suggested in much of the literature reviewed, state and local governments should act to educate themselves, their constituents and other stakeholders while treading carefully when developing laws and policies that create potential obstructions to deployment, particularly if they are out of sync with laws and policies of other governments. Maintaining consistency and increasing consumer acceptance and demand for automated vehicle and V2X benefits will produce market confidence needed for robust, effective and timely connected and automated vehicle deployment. The range of policy issues analyzed in this chapter is a starting point for discussions and action at varying levels of government, and in collaboration with a range of public and private stakeholders. There are also interesting ethical issues that arise when thinking about automated vehicles *(Lin 2013)*, and these should also be openly debated. Ultimately, transportation agencies and transportation professionals should remain vigilant so that we are not blindly led by technology to outcomes that society does not want. It's important to continue to work toward designing communities where people want to live, work and play, and to emphasize the importance of human interactions for the success of our economy and our culture.

The U.S. Department of Transportation has launched a new Strategic Plan *(U.S. DOT 2014)* that contains a plan for an automation research program within the overall program. The goal of the automation program is to "enable safe, efficient and equitable integration of automation into the transportation system." The program contains eight objectives:

1. Facilitate development and deployment of connected automated transportation
2. systems that enhance safety, mobility, and sustainability
3. Assess implications of emerging enabling technologies
4. Research transportation system-level operational impacts of automation applications
5. Assess the need for new vehicle performance guidelines and requirements
6. Develop stakeholder guidance for automated vehicle operations
7. Develop appropriate testing methods and objective test procedures
8. Estimate the potential safety, mobility, energy, and environmental benefits of automation technologies
9. Identify and address policy, institutional, and regulatory challenges to safe automated vehicle operations.

Under this umbrella, the U.S. DOT has organized research initiatives under the categories of: enabling technologies, safety assurance, transportation system performance, testing and evaluation and policy and planning. In order to accelerate the development and deployment of automated vehicles in a way that maximizes public benefits and ensures safe and efficient operations, Figure 3.1 shows the types of research projects currently underway through the U.S. DOT' programs.

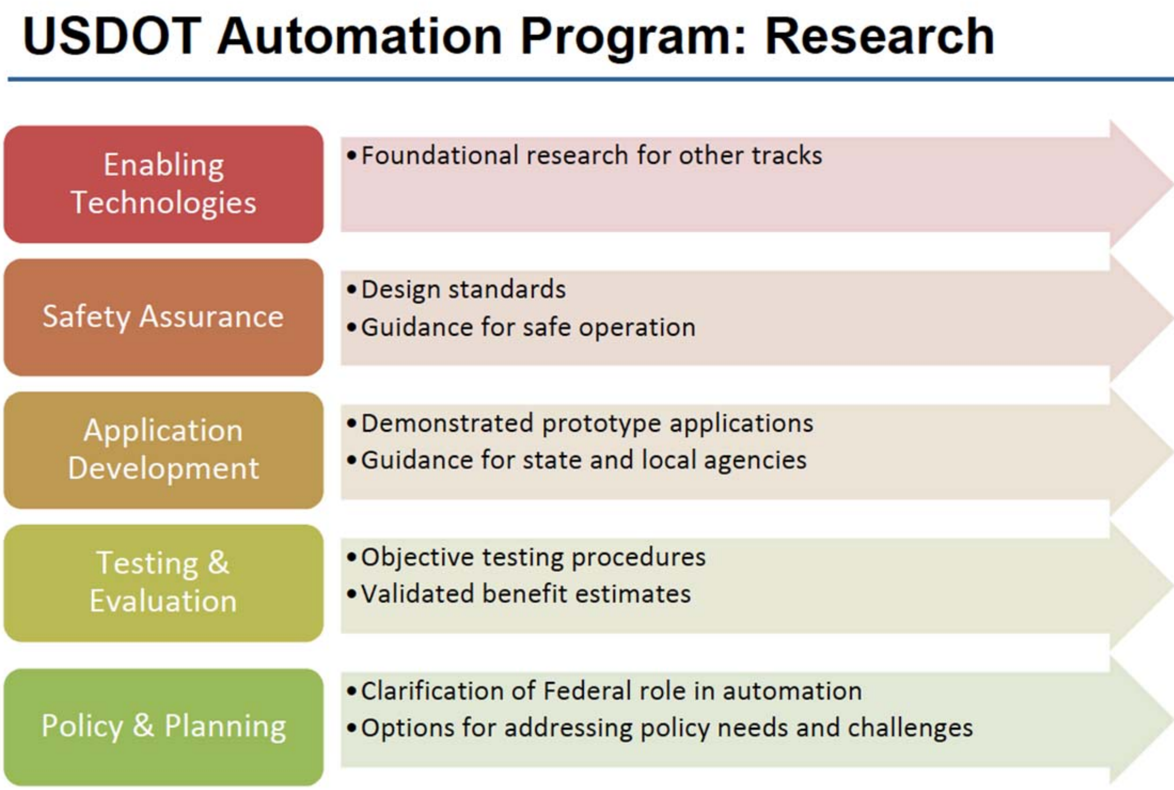


Figure 3.1: U.S. DOT Automation Research Program Areas

4.0 REFERENCES

AASHTO. *AASHTO Connected Vehicle Field Infrastructure Deployment Analysis*. Report No. FHWA-JPO-11-090, Final Report. FHWA, U.S. Department of Transportation, AASHTO, 2011. http://ntl.bts.gov/lib/43000/43500/43514/FHWA-JPO-11-090_AASHTO_CV_Deploy_Analysis_final_report.pdf. Accessed May 7, 2014.

AASHTO. *AASHTO Connected Vehicle Field Infrastructure Footprint Analysis: Preparing to Implement a Connected Vehicle Future*. American Association of State Highway and Transportation Officials (AASHTO), undated. http://ssom.transportation.org/Documents/Executive%20Briefing.pdf. Accessed May 7, 2014.

Ali, A. *Government Hitting the Brakes on Driverless Cars*. Ozy Blog, March 20, 2014, www.ozy.com/fast-forward/government-hitting-the-brakes-on-driverless-cars/30434.articleWeb. Accessed April 18, 2014.

Andersen, C. Linking Drivers and Roads. *Public Roads Magazine*, 2013. www.fhwa.dot.gov/publications/publicroads/13janfeb/01.cfm. Accessed January 24, 2014.

Andersen, J., N. Kalra, K.D. Stanley, P. Sorensen, and C. Samaras. *Autonomous Vehicle Technology: A Guide for Policymakers.* RAND Corporation, 2014. www.orfe.princeton.edu/~alaink/SmartDrivingCars/PDFs/Rand_Anderson_AutonomousVehicleTechnology.pdf. Accessed May 7, 2014.

Arieff, A. *Driving Sideways*. The New York Times Blog, Jul. 23, 2013. www.opinionator.blogs.nytimes.com/2013/07/23/driving-sideways/?_php=true&_type=blogs&_r=0. Accessed March 7, 2014.

Automated Vehicles Symposium (AVS) 2014, Proceedings. http://higherlogicdownload.s3.amazonaws.com/AUVSI/3a47c2f1-97a8-4fb7-8a39-56cba0733145/UploadedFiles/AVS%202014%20Proceedings%20-%20Final%20(Dec%202014).pdf. Accessed June 18, 2015.

Berman, B. Why Driverless Cars Won't Save The Environment: Safer, Lighter and Networked Electric Cars Will Be More Efficient. And Then People May Just Drive More. *Readwrite Magazine*, 2013. www.readwrite.com/series/drive#awesm=~orVSTXSWcWpbbv. Accessed January 9, 2014.

Bierstedt, J., A. Gooze, C. Gray, J. Peterman, L. Raykin, and J. Walters. *Effects of Next-Generation Vehicles on Travel Demand and Highway Capacity*. FP Think Working Group, 2014. www.orfe.princeton.edu/~alaink/Papers/FP_NextGenVehicleWhitePaper012414.pdf. Accessed May 7, 2014.

Blumgart, J. Whither the Driverless Car. *Next City Magazine*, 2013, www.nextcity.org/daily/entry/whither-the-driverless-car. Accessed March 3, 2014.

California Department of Motor Vehicles (California DMV). Autonomous Vehicles in California. Status update presentation at City of Carlsbad, June 2015.

Castro, D. *The Road Ahead: The Emerging Policy Debates for IT in Vehicles*. The Information Technology & Innovation Foundation, 2013. www.2.itif.org/2013-road-ahead.pdf. Accessed May 7, 2014.

Consumer Reports. The Road to Self-Driving Cars: Today's Crash-Avoidance Systems are the Mile Markers to Tomorrow's Autonomous Vehicles. *Consumer Reports Magazine*. 2014. www.consumerreports.org/content/cro/en/consumer-reports-magazine/z2014/April/theRoadToSelfDrivingCars.print.html. Accessed April 18, 2014.

Fagnant, D.J., and K.M. Kockelman. *Preparing a Nation for Autonomous Vehicles: Opportunities, Barriers and Policy Recommendations*. Eno Center for Transportation, 2013. www.enotrans.org/wp-content/uploads/wpsc/downloadables/AV-paper.pdf. Accessed May 7, 2014.

Government Accountability Office (GAO). Report to Congressional Requesters - Intelligent Transportation Systems: Vehicle-to-Vehicle Technologies Expected to Offer Safety Benefits, but a Variety of Deployment Challenges Exist. United States Government Accountability Office, Nov. 2013, www.gao.gov/assets/660/658709.pdf. Accessed May 7, 2014.

Godsmark, P. Autonomous Vehicles: Are We Ready? Focus on the Future, Self Help Counties Coalition, Santa Clara, CA, November 17, 2014.

Guizzo, E. How Google's Self-Driving Car Works. *IEEE Spectrum*, 2011. http://spectrum.ieee.org/automaton/robotics/artificial-intelligence/how-google-self-driving-car-works. Accessed June 18, 2015.

Harris, M. The Unknown Start-up That Built Google's First Self-Driving Car. *IEEE Spectrum*. 2014. http://spectrum.ieee.org/robotics/artificial-intelligence/the-unknown-startup-that-built-googles-first-selfdriving-car Accessed May 26, 2015.

Heller, M. California Regulators Consider "Big Brother" Hazards of Driverless Cars: Cars That Drive Themselves Could Be Pulling Out of Sci-Fi Fantasies and Tinseltown Dreams and Into Driveways and Roads Sooner than We Think, Sending Privacy Advocates into Over-drive. *Mint Press News*. 2014, www.mintpressnews.com/california-regulators-consider-big-brother-hazards-driverless-cars/186951/. Accessed April 18, 2014.

Hennig, K. CUTR Launches Automated Vehicle Institute. *University of South Florida News*. 2013. www.news.usf.edu/article/templates/?z=38&a=5884. Accessed April 2, 2014.

Holeywell, R. *FCC Wi-Fi Expansion May Threaten Connected Vehicles*. Governing Blog, Feb. 21, 2013. www.governing.com/templates/gov_print_article?id=190851181. Accessed January 15, 2014.

Intelligent Transportation Systems Joint Program Office (ITS JPO). *ITS Strategic Plan 2015-2019*. 2014. www.its.dot.gov/strategicplan/. Accessed December 20, 2014.
Intelligent Transportation Systems Joint Program Office (ITS JPO). Research and Innovative Technology Administration's Intelligent Transportation Systems (ITS) Joint Program Office. *CV Pilots Deployment Project*. U.S. Department of Transportation, Sep. 23, 2014, http://its.dot.gov/pilots/index.htm. Accessed Sep. 26 2014.

Intelligent Transportation Systems Joint Program Office (ITS JPO). Research and Innovative Technology Administration's Intelligent Transportation Systems (ITS) Joint Program Office (ITS JPO). How Connected Vehicles Work. U.S. Department of Transportation, n.d., http://www.its.dot.gov/factsheets/pdf/connected_vehicles_work.pdf. Accessed May 7, 2014.

ITU Press Release. Standards to Usher in Autonomous Networked Driving: ITU Debate Focused on Innovative ICT for the Future Networked Car. *ITU Press Release*, 2014. www.itu.int/net/pressoffice/press_releases/2014/07.aspx#.U1GkZ01OW72. Accessed April 19, 2014.

Keen, A. *The Future of Travel: Transportation Confronts Its 'Kodak Moment'*. CNN Website. 2013. www.edition.cnn.com/2013/05/13/business/business-traveller-transportation-futurecast/index.html. Accessed March 14, 2014.

Knight, W. The Internet of Cars is Approaching a Crossroads: Wireless Vehicle Networks Could Make Driving Safer and More Efficient, But the Cost of Deployment will be Significant. *MIT Technology Review*. 2013. www.technologyreview.com/news/515966/the-internet-of-cars-is-approaching-a-crossroads/. Accessed April 18, 2014.

Lappin, J. Transportation Research Board (TRB) Symposia on Road Vehicle Automation. TRB Webinar for TRB Standing Committee Chairs, December 10, 2014.

Lin, P. The Ethics of Saving Lives with Autonomous Cars are Far Murkier than You Think. *Wired Magazine*. 2013. www.wired.com/opinion/2013/07/the-surprising-ethics-of-robot-cars/. Accessed March 1, 2014.

Madrigal, A. *By the Time Your Car Goes Driverless, You Won't Know the Difference*. National Public Radio Website. 2014, www.npr.org/blogs/alltechconsidered/2014/03/04/285740673/by-the-time-your-car-goes-driverless-you-wont-know-the-difference. Accessed April 18, 2014.

Madrigal, A. The Trick That Makes Google's Self-Driving Cars Work. *The Atlantic*. 2014.

Mai, A., and D. Schlesinger. *A Business Case for Connecting Vehicles*. Cisco Internet Business Solutions Group. 2011. www.cisco.com/web/about/ac79/docs/mfg/Connected-Vehicles_Exec_Summary.pdf. Accessed May 8, 2014.

Miller, D. Securing the Autonomous Vehicle. *SC Magazine*. 2014. http://www.scmagazine.com/securing-the-autonomous-vehicle/article/376470/. Accessed June 18, 2015.

National Highway Traffic Safety Administration (NHTSA). *Advance Notice of Proposed Rulemaking (ANPRM), Federal Motor Vehicle Safety Standards: Vehicle-to-Vehicle* (V2V) Communications. 2014. http://www.nhtsa.gov/staticfiles/rulemaking/pdf/V2V/V2V-ANPRM_081514.pdf. Accessed June 18, 2015.

National Highway Traffic Safety Administration (NHTSA). *Vehicle-to-Vehicle Communications: Readiness of V2V Technology for Application*. 2014. http://www.nhtsa.gov/staticfiles/rulemaking/pdf/V2V/Readiness-of-V2V-Technology-for-Application-812014.pdf. Accessed June 18, 2015.

National Highway Traffic Safety Administration (NHTSA). *Visual-Manual NHTSA Driver Distraction Guidelines For In-Vehicle Electronic Devices.* 2013, http://www.nhtsa.gov/staticfiles/nti/distracted_driving/pdf/distracted_guidelines-FR_04232013.pdf. Accessed May 7, 2014.

National Highway Traffic Safety Administration (NHTSA). *Preliminary Statement of Policy Concerning Automated Vehicles*. 2013. http://www.nhtsa.gov/staticfiles/rulemaking/pdf/Automated_Vehicles_Policy.pdf, Accessed June 18, 2015.

Naylor, N. *U.S. Department of Transportation Announces Decision to Move Forward with Vehicle-to-Vehicle Communication Technology for Light Vehicles*. NHTSA Website. National Highway Traffic Safety Administration. 2014. www.nhtsa.gov/About+NHTSA/Press+Releases/2014/USDOT+to+Move+Forward+with+Vehicle-to-Vehicle+Communication+Technology+for+Light+Vehicles. Accessed April 12, 2014.

Rayle, L., S. Shaheen, N. Chan, D. Dai, and R. Cervero. *App-Based, On-Demand Ride Services: Comparing Taxi and Ridesourcing Trips and User Characteristics in San Francisco*. University of California Transportation Center, UCTC-FR-2014-08, 2014, http://www.uctc.net/research/papers/UCTC-FR-2014-08.pdf. Accessed June 18, 2015.

Region 1. Connected Vehicles: Region 1 Briefing, Oregon Department of Transportation, 2013.

SAE International. *Summary of SAE International's Levels of Driving Automation for On-Road Vehicles*. 2014. http://www.sae.org/misc/pdfs/automated_driving.pdf. Accessed March 8, 2015.

Schoettle, B., and M. Sivak. *A Survey of Public Opinion about Connected Vehicles in the U.S., the U.K., and Australia.* University of Michigan Transportation Research Institute, 2014.

Shladover, S. Connected and Automated Vehicle Systems: State of the Art. TRB Webinar for TRB Standing Committee Chairs, 2014.

Smith, B.W. *Automated Vehicles Are Probably Legal In The United States. The Center for Internet and Society at Stanford Law School*. 2012. www.cyberlaw.stanford.edu/files/publication/files/2012-Smith-AutomatedVehiclesAreProbablyLegalinTheUS_0.pdf. Accessed May 8, 2014.

Seapine Software. *Study Finds 88 Percent of Adults Would Be Worried about Riding in a Driverless Car*. Sea-pine Software Website. 2014. www.seapine.com/pr.php?id=217. Accessed February 21, 2014.

Tannert, C. Can Computers Drive Better than Humans? If Riding in an Autonomous Car Feels Like Ceding Control to a Computer, Humans Will Never Do It. That's Why the Big Brains at QNX and Nvidia Are Working on the Technology That Feels More Human than Human. *Fast Company Magazine*, 2014. www.fastcompany.com/3023164/innovation-agents/can-computers-drive-better-than-humans. Accessed April 18, 2014.

National Petroleum Council. *The Connected Car: Smart Technologies to Reduce Congestion (Intelligent Transport Sys-tems)*. National Petroleum Council, Topic Paper #5. NPC Future Transportation Fuels Study. 2012. www.npc.org/FTF_Topic_papers/5-The_Connected_Car.pdf. Accessed May 8, 2014.

Transportation Research Board (TRB). Webinar on Automated Vehicles and Connected Vehicles for TRB Standing Committee Chairs. 2014. https://vimeo.com/114264596. Accessed June 18, 2015

U.S. Department of Transportation (U.S. DOT). *National Connected Vehicle Field Infrastructure Footprint Analysis: Deployment Concepts.* American Association of State Highway and Transportation Officials, DTFH61-11-D-00008, Final, Version 2, 2013. www.ssom.transportation.org/Documents/Deployment_Concepts.pdf. Accessed May 8, 2014.

U.S. Department of Transportation (U.S. DOT). Intelligent Transportation Systems (ITS) Strategic Plan 2015-2019. ITS Joint Program Office (JPO), FHWA-JPO-14-145. 2014. http://www.its.dot.gov/strategicplan/. Accessed June 18, 2015.

Wallace, R., and G. Silberg. *Self-Driving Cars: The Next Revolution. KPMG and Center for Automotive Research*. 2012, www.cargroup.org/?module=Publications&event=View&pubID=87. Accessed May 8, 2014.

Zax, D. A World Without Car Crashes. *The Atlantic Cities Magazine.* 2014, www.theatlanticcities.com/commute/2014/02/world-without-car-crashes/8353/. Accessed February 17, 2014.

APPENDIX A

COMPLETE ANNOTATED BIBLIOGRAPHY

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1 AASHTO Connected Vehicle Field Infrastructure Deployment Analysis. FHWA-JPO-11-090, Final Report. FHWA, U.S. Department of Transportation, Jun. 17, 2011, http://ntl.bts.gov/lib/43000/43500/43514/FHWA-JPO-11-090_AASHTO_CV_Deploy_Analysis_final_report.pdf. Accessed May 7, 2014.

> **Policy Issue: Implementation, Governance, Deployment Approach**
>
> "This report was developed by [AASHTO's] Connected Vehicle Working Group with support from U.S. DOT. The purpose of the report is to explore infrastructure deployment approaches and potential issues for state and local transportation agencies, primarily from a state DOT perspective… The report covers connected vehicle applications of most interest to the states, current state and local programs underway, deployment readiness in the vehicle market, aftermarket devices and communications, the magnitude of effort to upgrade the nation's signal controllers with [DSRC] capabilities, and a set of deployment scenarios with corresponding strategies and actions for the state and local transportation community." – From Preface

2 AASHTO Connected Vehicle Field Infrastructure Footprint Analysis: Preparing to Implement a Connected Vehicle Future. American Association of State Highway and Transportation Officials, n.d., http://ssom.transportation.org/Documents/Executive%20Briefing.pdf. Accessed May 7, 2014.

> **Policy Issue: Governance, Deployment Approach, Financing**
>
> This six-page pamphlet provides a synopsis of NHTSA's recent and proposed rulemaking milestones around connected vehicles, the benefits of its deployment (safety, mobility and environmental), AASHTO guidance, deployment needs and funding.

3 Ackerman, Evan. Tesla Working Towards 90 Percent Autonomous Car within Three Years. IEEE Spectrum, Sep. 18, 2013, www.spectrum.ieee.org/automaton/robotics/artificial-intelligence/tesla-working-towards-90-autonomous-car-within-three-years. Accessed Feb. 21, 2014.

> **Policy Issue: Implementation**
>
> Tesla is developing a 90 percent automated vehicle (the Model F) within three years. Its technology is being developed internally. Elon Musk, Tesla's CEO and Chief Project Architect, believes that fully automated cars are not yet feasible.

4 Albanesius, Chloe. Mercedes, Nokia Partner on Maps for Self-Driving Cars. PC Magazine, Sep. 10, 2013, www.pcmag.com/article2/0,2817,2424211,00.asp. Accessed Jan. 10, 2014.

Policy Issue: Implementation, Data

Nokia has teamed up with Mercedes-Benz to develop smart maps intended to spur the development of self-driving cars. The maps contain precise road data with geographic coordinates.

5 Aldana, Karen. U.S. Department of Transportation Releases Policy on Automated Vehicle Development: Provides Guidance to States Permitting Testing of Emerging Vehicle Technology. National Highway Traffic Safety Administration Website, May 30, 2013, www.nhtsa.gov/About+NHTSA/Press+Releases/U.S.+Department+of+Transportation+Releases+Policy+on+Automated+Vehicle+Development. Accessed Jan. 24, 2014.

Policy Issue: Implementation, Governance, Legislation, Deployment Approach

In May 2013, the NHTSA announced a new policy concerning vehicle automation, including plans for research on related safety issues and recommendations for states related to the testing, licensing, and regulation of automated vehicles. It provides guidance to states seeking to permit testing of this technology and describes NHTSA's related research efforts. While the technology remains in the early stages, NTHSA aims to be well prepared for when automated vehicle technology does become commercially available.

6 Ali, Ambreen. Government Hitting the Brakes on Driverless Cars. Ozy Blog, Mar. 20, 2014, www.ozy.com/fast-forward/government-hitting-the-brakes-on-driverless-cars/30434.articleWeb. Accessed Apr. 18, 2014.

Policy Issue: Implementation, Governance, Legislation, Deployment Approach

The U.S. Congress stands as a major hurdle towards automated vehicles. As many technical issues related to these cars are near resolution, policymaking needs to catch up. “[A]utomakers and tech companies are pressing federal policymakers to set uniform guidelines for testing and, ultimately, operating driverless cars across the country.”

7 Andersen, Carl. Linking Drivers and Roads. Public Roads Magazine, Jan. /Feb. 2013, www.fhwa.dot.gov/publications/publicroads/13janfeb/01.cfm. Accessed Jan. 24, 2014.

Policy Issue: Implementation, Governance, Data

The US is taking a giant leap toward a nationwide wireless system of connected vehicles and smart infrastructure by means of the world's largest real-world test. The USDOT has invested in research to make a vision of connected vehicles and smart infrastructure a reality in the near future. The article discusses benefits of connected vehicle technology, including how infrastructure can be coordinated with vehicular data. It also highlights how cooperative systems offer the advantage of enabling the collection and sharing of real-time data. In addition, the article also considers how best to provide specific, dynamic warnings that are more reliable than static signs and more likely to capture drivers' attention. The article also highlights FHWA-partner studies on automated vehicle wireless connectivity, intersection control, freeway merging and advanced traffic signal control. It illustrates FHWA's study of vehicle-highway automation research and development activities outside the United States as an initial-stage international scan whose purpose is to summarize the current state of cooperative vehicle-highway automation systems in Europe and Asia, and help inform decisions about future related activities in the United States.

8 Andersen, James. et al. Autonomous Vehicle Technology: A Guide For Policymakers. RAND Corporation, 2014, www.orfe.princeton.edu/~alaink/SmartDrivingCars/PDFs/Rand_Anderson_AutonomousVehicleTechnology.pdf. Accessed May 7, 2014.

Policy Issue: Liability, Implementation, Privacy, Cyber Security, Governance, Data, Legislation, Deployment Approach

Careful policymaking is necessary to maximize social benefits that automated vehicle technology will enable, while minimizing disadvantages. The aim of the report is to assist policymakers at the state and federal levels to make informed policy decisions on automated vehicles.

9 Arieff, Allison. Driving Sideways. The New York Times Blog, Jul. 23, 2013, www.opinionator.blogs.nytimes.com/2013/07/23/driving-sideways/?_php=true&_type=blogs&_r=0. Accessed Mar. 7, 2014.

Policy Issue: Implementation, Cyber Security, Risk, Deployment Approach, Sustainability

The means to manufacturing a car that drives autonomously have been figured out. Allstate is preparing actuarial tables; car manufacturers have developed working prototypes. The debate is now about when it will all happen, not how. However, the enthusiasm overlooks serious challenges with regard to urban design, social equity and the American dream. There are some very good things automated vehicles might possibly provide, yet the obstacles to their integration seem insurmountable. The author is frustrated that innovation brain power is not being used for creating a world without cars, "The utopian notion that these vehicles would eliminate danger from the driving equation is naïve at best — it's not difficult to imagine how easily the freeway's computer networks could be hacked." Long commutes are no longer a disincentive to driving, while equity — particularly for those who are most often passengers today — is absent from most discussions on driverless cars.

10 Arnold, James. A. and Persaud, R. Mapping Technology Assessment for Connected Vehicle Highway Network Applications. U.S. Department of Transportation, Jul. 13, 2012, http://www.gps.gov/cgsic/states/2012/seattle/arnold.pdf. Accessed May 8, 2014.

Policy Issue: Deployment Approach

This was a project overview. It talks about Bernhart, how to create a mapping technology for the use of connected vehicles. It talks about the current technology that is in play and what other technologies that could be applied to it. They ran a field test and talked about what technologies were used in it and the software process. The results were mostly encouraging, and they concluded automated sensor-based mapping would be necessary to create maps for incoming infrastructure. They concluded with saying that a larger computer would be necessary to map large environments and that the mapping process needed to become fully automated.

11 Badger, Emily. What Will Happen to Public Transit in a World Full of Autonomous Cars? The Atlantic Cities Magazine, Jan. 17, 2014, www.theatlanticcities.com/commute/2014/01/what-will-happen-public-transit-world-full-autonomous-cars/8131/. Accessed Mar. 1, 2014.

Policy Issue: Implementation, Risk, Legislation, Deployment Approach, Sustainability

If the automated cars of the future will look a lot like transit, then what will become of the transit we know now? This isn't an entirely silly question. We make billion-dollar investments in new transit infrastructure because we expect to use it for decades. If automated vehicles will be available in the next decade, what does this mean for current transit planning efforts? The article explores this in more detail and identifies potential ways that transit and automated cars might coexist.

12 Bamonte, Thomas J. Drivers of Change: Highway Authorities Need to Start Preparing Now for the Inevitability of Driverless Vehicles. TM&E Magazine, Summer 2013, www.roadsbridges.com/sites/default/files/05_autonomous%20vehicles.pdf. Accessed May 7, 2014.

Policy Issue: Implementation, Governance, Risk, Legislation, Deployment Approach

Auto manufacturers are starting to roll out consumer models semi-automated technology packages, an intermediate step towards driverless vehicles. In addition to consumers, demand for driverless vehicles is coming from fleet operators, heavy-equipment users (e.g., mining, agriculture) and the military, all of which would benefit from driverless vehicle technology in different ways. Infrastructure providers, such as highway authorities, are conspicuously absent from this discussion. Regardless, driverless vehicle innovators are not waiting for transportation authorities to build out automated vehicle infrastructure before rolling out their new technologies. When putting together long-range capital plans, transportation authorities need to begin considering the possibility that investing in infrastructure and organizational practices that facilitate the deployment of driverless-vehicle technology may be a better investment than lane widening and new highway construction projects. Metropolitan regions that embrace driverless-vehicle technology will be a step ahead of other regions, becoming increasingly attractive to the 'connected' persons who make up much of today's creative class.

13 Barrett, Rick. Oshkosh works to develop driverless trucks for Marine Corps. Milwaukee Journal Sentinel, May 12, 2014, www.jsonline.com/business/oshkosh-lands-contract-to-develop-driverless-trucks-for-marine-corps-b99268052z1-258925051.html. Accessed May 13, 2014.

Policy Issue: Implementation

U.S. truck maker Oshkosh Corp. "is working with the U.S. Office of Naval Research to produce an unmanned vehicle that would be used by the Marines Corps in supply-line convoys, including trips into combat zones… The Pentagon wants the unmanned vehicles, often at the front of a convoy, to detect — or absorb the damage from — improvised explosive devices, or IEDs, saving the lives of troops in vehicles that follow. That kind of capability is more important than just having a driverless truck that can cover long distances and never gets tired." Young (technically adept) Marines are comfortable with using controls for AVs. The extent of human involvement with this deployment is being discussed.

14 Berman, Bradley. Driving and Gaming Still Don't Mix—Though App Makers Keep Trying Turning Real-World Driving into a Game without Distracting Folks behind the Wheel Is Tougher than It Sounds. Readwrite Magazine, Nov. 12, 2013, www.readwrite.com/series/drive#awesm=~orVSTXSWcWpbbv. Accessed Jan. 9, 2014.

Policy Issue: Privacy, Data, Legislation

Cars are becoming "one-ton gaming and social media consoles hurtling through real and virtual space." Paul English (founder of Kayak) believes the texting-while-driving problem is so dangerous that legislators should require that car and cell phone institute a protocol that disables a driver's cell phone while his or her car is moving - a better idea, he believes, than apps like Textlimit that spy and report bad driver behavior to parents or insurance companies.

15 Berman, Bradley. How Lyft and Uber Are Creating Networked Consumer Car Fleets: Ride Sharing Services Are Doing More than Disrupting Taxis—They're Recreating Big Corporate Auto Fleets on a Piecemeal Basis. Readwrite Magazine, Dec. 9, 2013,www.readwrite.com/series/drive#awesm=~orVSTXSWcWpbbv. Accessed Jan. 29, 2014.

Policy Issue: Implementation, Legislation

Transportation apps like Lyft and Uber are blurring the line between private and fleet cars, giving people who need a ride access to those offering one, and bypassing taxi companies and rental agencies. Some taxi drivers dislike the competition. Others are supplementing their conventional fares with app customers or becoming entrepreneurs altogether.

16 Berman, Bradley. How Nissan Will Roll Out Self-Driving Cars: Fricking Lasers - The Automaker Is Betting on 3D Scanners as the Key to Autonomous Vehicles. Readwrite Magazine, Sep. 23, 2013, www.readwrite.com/series/drive#awesm=~orVSTXSWcWpbbv9. Accessed Jan. 29, 2014.

Policy Issue: Implementation

Automobile manufacturers like Nissan are making future visions of self-driving cars a modern-day reality. Many features are already found in cars today. Nissan, for example, uses radar to detect fast moving objects from far away in its Leaf, and is increasingly testing lasers to better ensure accuracy. Their fully-automated features are projected to go on the market in 2020, but not utilizing currently 'imprecise' GPS technology or V2X, which are seen as still many years out.

17 Berman, Bradley. Reinventing a Suburban Business Park with 30 Electric Cars: Sharing Scion IQ EVs Means Employees Can Leave a Car at Home. Readwrite Magazine, Oct. 10 2013, www.readwrite.com/series/drive#awesm=~orVSTXSWcWpbbv. Accessed Jan. 9, 2014.

Policy Issue: Deployment Approach, Financing, Sustainability

A new, 30-car pilot program, aims to bring 21st Century networked mobility to a quintessential 1970s environment: the suburban business park. The cars are on loan to a Bay Area non-profit and will be brought to a city where 18,000 people work, 4,000 people live and 18% use a form of alternative transportation to commute. The goal is to make the vehicles more cost-effective, convenient and desirable than single-occupancy vehicles.

18 Berman, Bradley. The Big Selling Point for Driverless Cars: Safety; The Car Companies Talking the Most about Self-Driving Cars Tomorrow Are Aiming to Stir Vehicles Sales Today. Readwrite Magazine, Dec. 23, 2013, www.readwrite.com/series/drive#awesm=~or VSTXSWcWpbbv. Accessed Jan. 9, 2014.

Policy Issue: Implementation

Safety is a primary reason why driverless cars may be desirable for consumers. Car companies that already lead the way in safety, namely, Audi (Volkswagen), BMW, Daimler, Ford, Nissan and Volvo, will likely be the major driverless car pioneers.

19 Berman, Bradley. The Internet of Cars Draws Nigh: Federal Regulators Are Close to Deciding Whether to Mandate Dedicated Short-Range Communications for U.S. Autos. Readwrite Magazine, Dec. 18, 2013, www.readwrite.com/series/drive#awesm=~or VSTXSWcWpbbv. Accessed Jan. 9, 2014.

Policy Issue: Implementation, Governance, Risk, Data

In 2012, the University of Michigan launched a major project that studied DSRC in future US cars. The federal mandate for DSRC implementation (via the 5.9 GHz band) will be revealed near the end of 2013, determining the future fate of the technology. DSRC for V2V and V2I operation is seen by some as problematic, risking data overload. 4G LTE is often seen as a better alternative.

20 Berman, Bradley. The Supercomputer in Your Driveway: High-Performance System-on-a-Chip Processors Are Leaping from the Desktop to the Blacktop. Readwrite Magazine, Dec. 4, 2013, www.readwrite.com/series/drive#awesm=~orVSTXSWcWpbbv. Accessed Jan. 9, 2014.

Policy Issue: Implementation

Supercomputer processors are revolutionizing cars, helping implement features like cameras, radar, sonar, laser sensors and LiDAR. Radar and LiDAR data are run in algorithms 30 to 60 times a second to keep track of all traffic, differentiating between other cars, or even children running across a street, readying the car to apply brakes as necessary, while running algorithms to determine if the driver is distracted or falling asleep.

21 Berman, Bradley. Why Driverless Cars Won't Save The Environment: Safer, Lighter and Networked Electric Cars Will Be More Efficient. And Then People May Just Drive More. Readwrite Magazine, Dec. 26, 2013, www.readwrite.com/series/drive#awesm=~or VSTXSWcWpbbv. Accessed Jan. 9, 2014.

Policy Issue: Sustainability

Driverless cars will likely cancel out automotive efficiencies and reduced emissions. They will not crash, allowing them to not require many of today’s common safety features that add significant weight. Driverless cars will also likely be powered by electricity, offering even more efficiency, and charged in nearby, off-site charging facilities while allowing their availability to other households. This could actually result in more driving - and perhaps increased sprawl - as self-driving cars become equipped with endless possibilities of otherwise distracting technologies.

22 Berman, Bradley. Zoox's Self-Driving Car: Where It's Going, We Won't Need Steering Wheels - The Driverless-Car Designer Says the Human Driver Is the Biggest Danger in Autonomous Vehicles. Readwrite Magazine, Dec. 16, 2013, www.readwrite.com/series/drive#awesm=~orVSTXSWcWpbbv. Accessed Jan. 9, 2014.

Policy Issue: Implementation

"Safe, simple and timely" was a mandate of the USDOT in May 2013 directed towards driverless cars. When automated systems are not working, drivers must be quickly and effectively alerted. Some, like car manufacturer Zoox, see big challenges with this automated-to-manual handoff of control, preferring instead 'level 4' fully automated cars. Such self-driving cars are seen by some not as improving upon semi-manually cars, but replacing them altogether.

23 Bernhart, Dr. Wolfgang. et al. Connected vehicles: Capturing the Value of Data. Roland Berger Strategy Consultants, Sep. 2012, www.rolandberger.us/media/pdf/Roland_Berger_ConnectedVehicleStudy_20121113.pdf. Accessed May 8, 2014.

Policy Issue: Implementation, Data

"This study discusses the full spectrum of issues relating to connected vehicles, focusing especially on potential business models. It begins with a description of the key drivers for connected vehicles before staking out and discussing the connected vehicles playing field and identifying potential business opportunities across all parts of this field in light of innovative current examples. Chapter 4 concludes with a discussion of the potential opportunities and risks for all players. Chapter 5 investigates the implications of connected vehicles for OEMs and suppliers and identifies the cornerstones of successful strategies, enabling both sets of players to master and 'capture the value of data'."- From Introduction

24 Bertolucci, Jeff. Big Data Drives the Smart Car: The Data-Driven Car Is Coming - Whether You Like It or Not. Information Week Magazine, Mar. 18, 2014, www.informationweek.com/big-data/big-data-analytics/big-data-drives-the-smart-car/d/d-id/1127767. Accessed Apr. 16, 2014.

Policy Issue: Implementation, Privacy, Data

"The smart car of the near future is essentially part of a gigantic data-collection engine." The article briefly touches on what this could mean.

25 Bertolucci, Jeff. Internet of Things Meets Cars: Security Threats Ahead - As the Internet of Things Extends to Automobiles, Security and Privacy Threats Come along for the Ride. Information Week Magazine, Mar. 18, 2014, www.informationweek.com/big-data/big-data-analytics/internet-of-things-meets-cars-security-threats-ahead/d/d-id/1127737?itc=edit_in_body_cross. Accessed Apr. 18, 2014.

Policy Issue: Implementation, Privacy, Cyber Security, Data

The article's author interviews Judith Bitterli, chief marketing officer for security software firm AVG Technologies and recent panelist in a SXSW forum titled "The Car Hacks are Coming -- How the Auto Industry Can Safeguard Connected Cars," about privacy issues related to connected vehicles. Data collection is a top concern.

26 Bierstedt, Jane. et al. Effects of Next-Generation Vehicles on Travel Demand and Highway Capacity. FP Think Working Group, Jan. 2014, www.orfe.princeton.edu/~alaink/Papers/FP_NextGenVehicleWhitePaper012414.pdf. Accessed May 7, 2014.

Policy Issue: Implementation, Governance, Sustainability

The report assesses the most likely effects of automated vehicles on traffic generation and highway capacity and congestion over time, as automated vehicles increasingly represent a greater percentage of vehicles on the road. It estimates that automated vehicle usage will increase overall VMT by as much as 35% and will eventually lead to increasing highway capacity. Benefits will most likely take the form of improved mobility for all, increased safety, reduced incident-related congestion and reduced environmental and social costs. Specifically, the report aims to: 1) clarify the operating characteristics and driver experience likely to become available in next generation vehicles; 2) determine how soon such vehicles will be in common use; 3) predict their effects on traffic generation; and 4) estimate their effects on traffic congestion and congestion. The report also determined that a lack of significant market penetration by automated vehicles in the near-term (despite technologies and regulatory frameworks being in place) means that V2V should "maybe but probably not" be considered in long range plans - plans whose scenarios are around 2035 or 2040.

27 Bigman, Dan. Driverless Cars Coming to Showrooms by 2020, Says Nissan CEO Carlos Ghosn. Forbes Magazine, Jan. 14, 2013, www.forbes.com/sites/danbigman/2013/01/14/driver-less-cars-coming-to-showrooms-by-2020-says-nissan-ceo-carlos-ghosn/. Accessed Mar. 7, 2014.

Policy Issue: Implementation, Sustainability

Nissan CEO Carlos Ghosn believes there is a lot of interest in driverless cars, but that the change towards them won't be driven by Silicon Valley tech types "looking for the next cool thing." Instead, an aging population with significant purchasing power and a strong desire to retain their mobility as they get older will likely be the reason why driverless cars will be adopted into the mainstream.

28 Bilger, Burkhard. Auto Correct: Has the Self-Driving Car at Last Arrived? The New Yorker Magazine, Nov. 25, 2013, www.newyorker.com/reporting/2013/11/25/131125fa_fact_bilger. Accessed Jan. 10, 2014.

Policy Issue: Implementation, Cyber Security, Deployment Approach, Financing

In this article, the author rides with a Google engineer in his semi-automated car. The featured engineer (Anthony Levandowski), and another (Sebastian Thrun), helped develop Google Street View – Google's virtual map of the US. Google would prefer that car companies manufacture the self-driving cars (and not a company like Google). Yet, car manufacturers never began making their own maps. The companies don't even like to use the term 'autonomous car' as it implies that the 'captain' owner – one who presumably loves to drive - is not in charge of 'his own ship'. Auto manufacturers are releasing their technology very slowly – perhaps because technological glitches with self-driving cars have the potential to cause severe accidents, while automated highways may be ripe for cyber terrorism.

29 Blumgart, Jake. Whither the Driverless Car. Next City Magazine, Jan. 23, 2013, www. nextcity.org/daily/entry/whither-the-driverless-car. Accessed Mar. 3, 2014.

Policy Issue: Implementation, Deployment Approach

Automated car manufacturers are currently only trying to phase in their product, easing the more annoying aspects of driving (like finding parking) rather than exploring the outermost limits of the technology. As the technology improves, however, drivers will presumably have the option of not driving at all. The article explores impacts that automated vehicles might have on cities and how they will address common American culture, where cars have long signified freedom and what it means to be an American.

30 Buchholz, Kami. Honda Works to Prevent Vehicle-to-Pedestrian Accidents. SAE International Magazine, Sep. 30, 2013, articles.sae.org/12408/. Accessed Feb. 10, 2014.

Policy Issue: Implementation, Data

DSRC alerts pedestrians via smartphone of moving cars and cars via dashboard warning of approaching pedestrians. A proprietary smartphone application, GPS data, and algorithms are used to determine the location and direction of pedestrians and vehicles, the speed of an approaching vehicle, and the likelihood that the pedestrian is in a distracted state (i.e., texting or talking on the cellphone), making a V2P collision possible. Honda and Qualcomm independently developed the technologies to demonstrate and test this scenario. Key future challenges include enhancing the algorithms to reduce false positives and integrating DSRC with other sensors.

31 Burns, Lawrence D. and Scarborough, Bonnie A. Business Plan for a Sustainable Mobility Initiative. The Earth Institute, Columbia University, Jun. 2012, wordpress.ei.columbia.edu/mobility/files/2012/12/Business-Plan-for-a-Sustainable-Mobility-Initiative.pdf. Accessed May 7, 2014.

Policy Issue: Implementation, Sustainability

Today, due to six converging technologies, a new mobility paradigm is within reach. These technologies are: 1) the 'mobility internet;' 2) self-driving/driverless vehicles; 3) shared vehicle systems; 4) specific-purpose vehicle designs; 5) advanced propulsion systems; and 6) smart infrastructure. Together, they present an opportunity to provide better mobility services at significantly reduced cost. Sustainable mobility will result from an integrated 'system-of-systems' that excites consumers and creates profitable business models for suppliers.

32 Cardinal, David. Autonomous Taxis: Why You May Never Own a Self-Driving Car. Extreme Tech Magazine, Mar. 4, 2014, www.extremetech.com/extreme/176672-autonomous-taxis-why-you-may-never-own-a-self-driving-car. Accessed Apr. 16, 2014.

Policy Issue: Implementation, Sustainability

As we move closer to self-driving cars, will we even ever need to own one? The article discusses aTaxis and how they could change the mobility paradigm associated with car ownership and transit ridership.

33 Carroll, Rory. Tesla Enters Race to Build Self-Driving Car. Reuters Magazine, Sep. 17, 2013, www.reuters.com/article/2013/09/18/us-tesla-selfdriving-idUSBRE98H01720130918. Accessed Feb. 24, 2014.

Policy Issue: Implementation

Tesla Motors is working to produce a car capable of running on 'auto-pilot' within the next three years, joining tech giant Google and rival carmakers in the race to roll a driverless car into the market.

34 Castro, Daniel. The Road Ahead: The Emerging Policy Debates for IT in Vehicles. The Information Technology & Innovation Foundation, Apr. 2013, www2.itif.org/2013-road-ahead.pdf. Accessed May 7, 2014.

Policy Issue: Implementation, Governance, , Data, Legislation, Sustainability

"Policy decisions about IT in vehicle should be driven, not by narrow interests and concerns, but by a broad government mandate fostering innovation in the transportation sector. This will require leadership from both the government and the private sector and cooperation between different stakeholders. The transportation industry and, in particular, the automotive industry, are only now beginning to experience some of the more radical

changes that IT and the internet have brought to other industries. These changes are opening up new possibilities for how individuals use transportation, improving the quality and safety of transportation while creating profound societal shifts that may ultimately impact how and where individuals work and live. And just as IT-driven transformations in other industries have created new policy issues, the same will be true in transportation." The report identifies four important technology trends shaping the next-generation of vehicles: 1) an increase in machine-to-machine communications; 2) development of in-vehicle 'infotainment' systems; 3) increased collection and use of vehicle data; and 4) vehicular automation.

35 Chase, Robin. Will a World of Driverless Cars be Heaven or Hell? The Atlantic Cities Magazine, Apr. 3, 2014, www.theatlanticcities.com/commute/2014/04/will-world-driverless-cars-be-heaven-or-hell/8784/. Accessed Apr. 18, 2014.

Policy Issue: Implementation, Privacy, Cyber Security, Risk, Data, Sustainability

Will the future trajectory of automated cars be 'heaven' or 'hell'? As automated vehicles will be here soon, the author suggests that we should really be thinking more about its implications.

36 Connected Benefits. VDA-Magazin: Vernetzung, Chapter 03, n.d., pp 7, www.vernetzung-vda.de/upload/vda05/downloads/infografiken/eng/VDA_Magazin_Vernetzung_Chapter_03_Infographic_Connected_benefits.pdf. Accessed Apr. 11, 2014.

Policy Issue: Implementation, Data, Sustainability

"Digital connectivity is the revolution surrounding the automobile and the entire traffic system. Communication and information are gaining hugely in importance. The exchange of information between ass road users, and their connection to the Internet, represents a massive evolutionary step towards the resource-conserving and time-saving road traffic of the future." The one-page German infographic (in English) also briefly highlights V2X benefits like safety, economy, time saving, climate action, infotainment and services.

37 Connected Cars: Business Model Innovation. GSMA Connected Living Programme: mAutomotive, Version 1, May 2012, www.gsma.com/connectedliving/wp-content/uploads/2012/05/GSMA-Connected-Cars-Business-Model-Innovation1.pdf. Accessed May 8, 2014.

Policy Issue: Implementation

This report looks at how business models could be developed around a connected car. It talks about what things need to be taken into consideration by the auto manufacturers when deciding how to implement and what to include. It talks about an app store as a way for the consumers to choose what services they want. It argues that recent development in related industries will prompt interest in having connected vehicles which can access all types of travel information. It talks about ways that the manufacturers could lower their service price including advertisements, selling data, and having a premium version. It talks about how connectivity could be built into the vehicle whether it should be embedded, tethered, or integrated. Lastly, it talks about partnerships with other industries that would be beneficial to developing connected vehicles.

38 Connected Vehicle Test Bed. Connected Vehicle Infrastructure & Components - Safety, Mobility, & Environmental Applications - In-Vehicle Devices: Testing Connected Vehicle Technologies In A Real-World Environment. U.S. Department of Transportation, n.d., www.its.dot.gov/connected_vehicle/pdf/DOT_CVBrochure.pdf. Accessed May 7, 2014.

Policy Issue: Implementation, Sustainability

The Connected Vehicle Test Bed is a federally-funded resource available for technology developers to test how new hardware and software associated with connected vehicle technologies will perform under real-world operating conditions. The test bed was established to provide a simulated environment where intersections, roadways and vehicles are able to communicate through wireless connectivity.

39 Connected World Transforming Travel, Transportation and Supply Chains. World Economic Forum Insight Report, May 2013, www3.weforum.org/docs/WEF_MO_ConnectedWorld_Report_2013.pdf. Accessed May 8, 2014.

Policy Issue: Implementation

This report talks about how multiple industry leaders think transportation will change in the near future. It starts out by listing issues with the current transportation system like massive congestion and overburdened roads. There is the opportunity for easier travel by storing information into a global network and just swiping a card to load your data when crossing borders and in airports. The problems with implementing this globally and nationally are that companies must work together and some are unwilling to provide their data in real-time. This may mean a mandate is required for cooperation. There would also be issues with international data charges. However multiple companies are working on devices and apps that would allow users to access real-time traffic information. It also talks about the Condition-based megacity traffic management system which would allow cities to manipulate their traffic management based on real-time information of where vehicles are and traffic flows in different areas. It mentions two places that have Intelligent Transportation Systems in place: Rio de Janeiro and Lanfang. On the idea of swarm cars, there is a research facility in Warwickshire, England that is working on cars that can be controlled or programmed by wireless network.

40 Cosgrove, Christine. Preparing California for Automated Vehicles. Berkeley Transportation Letter. ITS University of California - Berkeley, Jul. 25, 2012, www.its.berkeley.edu/btl/2014/winter/automatedcars. Accessed Jan. 10, 2014.

Policy Issue: Implementation, Governance, Risk, Data, Legislation

In 2012, Governor Jerry Brown signed legislation into law that required its DMV to adopt regulations governing the testing and operation of automated vehicles It should occur in the following three stages by January 1, 2015: 1) on-road testing; 2) sale and operation; and 3) notice to the state when technology allows for driverless vehicles. Potential challenges might include sensor confusion when in a work zone, wet pavement exists or road lines fade. “Despite all the mythology out there, the most sophisticated system in existence today is not nearly as capable as any licensed driver. There may be any number of situations or conditions when the system will cease to be useable, and the driver has to be able to re-engage.” Standardization among manufacturers creates a challenge, as will be the adoption of unique laws governing automated vehicles by different states (which will all be superseded once the NHTSA develops its standard regulations).

41 Cronin, Brian. Connected Vehicle Update. Intelligent Transportation Systems Joint Program Office, Research and Innovative Technology Administration, U.S. Department of Transportation, Jan. 25, 2012, www.its.dot.gov/presentations/pdf/ITS_Update2012v2.pdf. Accessed May 8, 2014.

Policy Issue: Implementation

This is Cronin’s presentation on the connected vehicle. In it he has information on what information could be collected to help the driver and others. He has many applications that are grouped into safety, mobility, and environment. It also talks about how effective BSM would be and how to fix certain flaws with easing it.

42 Davies, Chris. Audi Urban Future Explores Connected Self-Driving Cars. SlashGear Blog, Apr. 11, 2014, www.slashgear.com/audi-urban-future-explores-connected-self-driving-cars-11324821/. Accessed Apr. 18, 2014.

Policy Issue: Implementation, Data, Legislation

This short article highlights Audi’s testing of its connected vehicles in four cities across the world: Berlin, Boston, Mexico City and Seoul, where teams will “compete over the next six months in ways that automated vehicles, car-to-car, and car-to-city communications will benefit the environment, making commuting easier, and even improve community relations.”

43 Driverless Parking for Tomorrow’s Vehicles. Science World Report, Apr. 2, 2014, www.scienceworldreport.com/articles/13823/20140402/driverless-parking-for-tomorrow-s-vehicles.htm. Accessed Apr. 18, 2014.

Policy Issue: Implementation, Data, Sustainability

"Electric vehicles that are able to park and charge themselves could contribute to sustainable mobility in the future. In an EU-funded research project coordinated by ETH Zurich, scientists work on new concepts of transportation and low-cost technologies that enable driverless valet parking and charging… V-Charge, which stands for "valet parking and charging," and it envisions a world in which travelers complete most interurban journeys using a well-developed long-distance transportation network and then switch to comfortable electric vehicles for the last few miles home from the railway station. To support this vision, the researchers are developing V-Charge park & ride car parks, where fully automated electric vehicles will be able to make their way to charging stations or parking spaces. Travelers simply use a smartphone app to send their vehicle to charge itself. Once it is fully charged, they can summon it just as easily via the app to come and pick them up." – From article

44 Edwards, Derek. Self-Driving Cars: 'Freedom' or 'More of the Same?' Progressive Transit Blog, Feb 2, 2012, www.progressivetransit.wordpress.com/2012/02/02/self-driving-cars-freedom-or-more-of-the-same/. Accessed Mar. 7, 2014.

Policy Issue: Implementation

Automated cars are coming; it is only a matter of sorting out the legalities of introducing millions of self-driving cars onto roadways. The article explores two very different possibilities on how driving habits will be impacted: 1) self-driving cars will provide a complete paradigm shift in the way people think about transportation and 2) nothing changes.

45 ETSI and CEN Release 'Connected Car' Standards. Traffic Technology Today Magazine, Feb. 13, 2014, www.traffictechnologytoday.com/news.php?NewsID=56261. Accessed Mar. 1, 2014.

Policy Issue: Implementation, Governance, Certification

Two European standards organizations, ETSI (European Telecoms Standards Institute) and CEN (European Committee for Standardization), recently completed standards requested by the European Commission for connected car implementation. To date, the EU has invested more than EUR $180 million (US $246 million) in research projects on cooperative transport systems. The Release 1 standardization package covers the norms that have been adopted to ensure that vehicles made by different manufacturers can communicate with each other. Work on the Release 2 standardization package has already begun fine-tuning existing standards and dealing with more complex use cases.

46 Expediting Future Technologies for Enhancing Transportation System Performance. National Cooperative Highway Research Program, Transportation Research Board of the National Academies, NCHRP Report 750, Strategic Issues Facing Transportation, Volume 3, 2013, www.onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_750v3.pdf. Accessed May 8, 2014.

Policy Issue: Implementation

This paper is mostly about how to measure how effective different technologies will be. It talks about the four main problems: safety, preservation, sustainability, mobility. It also talks about the different technologies that are in play and that are coming into play. Its final conclusion was that vehicle-to-vehicle and vehicle to infrastructure would be great and the technology is there, but it would be hard to implement policy-wise.

47 Fagnant, Daniel J. and Kockelman, Kara M. Preparing a Nation for Autonomous Vehicles: Opportunities, Barriers and Policy Recommendations. Eno Center for Transportation, Oct. 2013, www.enotrans.org/wp-content/uploads/wpsc/downloadables/AV-paper.pdf. Accessed May 7, 2014.

Policy Issue: Liability, Implementation, Privacy, Cyber Security, Governance, Risk, Certification, Data, Legislation, Deployment Approach, Financing

The proliferation of automated vehicles is far from guaranteed. High costs hamper large-scale production and mass consumer availability. Complex questions remain relating to legal, liability, privacy, licensing, security and insurance regulation. While individual US states have been advancing automated vehicle legislation through incremental measures, federal guidance has not yet been issued either fully, or partially, for automated vehicles beyond testing purposes on public roads. Report authors believe that policymakers need to begin addressing the unprecedented issues that automated vehicles might surface and could potentially aid in the introduction of incremental improvements in the meantime. Without a consistent licensing framework and a standardized set of safety for acceptance, automated vehicle manufacturers may be faced with regulatory uncertainty and unnecessary overlap, among other issues. The report explores feasible aspects of automated vehicles and discusses their potential impacts on the transportation system. It also explores remaining barriers to well-managed, large-scale automated vehicle market penetration and suggests federal-level policy recommendations for an intelligently planned transition. The report contains extensive economic and safety statistics on automated vehicles in the US.

48 Fagnant, Daniel J. and Kockelman, Kara M. The Travel and Environmental Implications of Shared Autonomous Vehicles using Agent-Based Model Scenarios. Transportation Research Part C, Nov. 2013.

Policy Issue: Implementation, Sustainability

“This [research] describes the design of an agent-based model for Shared Automated Vehicle (SAV) operations [short-term vehicle rentals], the results of many case-study

applications using this model, and the estimated environmental benefits of such settings, versus conventional vehicle ownership and use."… "Case studies vary trip generation rates, trip distribution patterns, network congestion levels, service area size, vehicle relocation strategies, and fleet size. Preliminary results indicate that each SAV can replace around eleven conventional vehicles, but add up to 10% more travel distance than comparable non-SAV trips, resulting in overall beneficial emissions impacts, once fleet-efficiency changes and embodied versus in-use emissions are assessed." – From Abstract

49 Fehrenbacher, Katie. Self-Driving Cars Are Coming Soon and Will Revolutionize Cities and Society. Gigaom Blog, Mar. 18, 2014, www.gigaom.com/2014/03/18/self-driving-cars-are-coming-soon-and-will-revolutionize-cities-society/. Accessed Mar. 18, 2014.

Policy Issue: Implementation, Data

"Designer and engineer Bran Ferren says autonomous vehicles will fundamentally change how cities are built and how society interacts, and the emergence of the technology in a meaningful way on our roads is only a few short years away. [He] co-founded Applied Minds and is the former president of research and development for Walt Disney Imagineering… He said there are five things that autonomous cars need."

50 Fitchard, Kevin. Ford Is Ready for the Autonomous Car. Are Drivers? Gigaom Blog, Apr. 9, 2012, www.gigaom.com/2012/04/09/ford-is-ready-for-the-autonomous-car-are-drivers/. Accessed Mar. 3, 2014.

Policy Issue: Implementation

The auto industry has already developed all the technology necessary to create automated vehicles. The reasons there aren't driverless cars all over the road today is in part a cost issue, but mainly one of driver mindset. Ford found that while people are still uncomfortable with the idea of ceding the driver's seat to a computer, they are very open to the idea of their cars becoming more intelligent and aware. New capabilities like collision warning for safety, automatic parallel parking and Ford's Sync voice-control technology have been well received. The company believes that through the gradual introduction of increased automation, drivers will easily adjust to the idea of automated cars.

51 Fitzgerald, Seth. Google Spent $966 Million on Navigation Company Waze. NewsFactor Blog, Jul. 26, 2013. www.newsfactor.com/story.xhtml?story_id=88910. Accessed Feb. 25, 2014. Frazzoli, Emilio. Can We Put a Price on Autonomous Driving? MIT Technology Review, Mar. 18, 2014, www.ecnmag.com/news/2014/03/can-we-put-price-autonomous-driving. Accessed Apr. 18, 2014.

Policy Issue: Implementation

According to the article, Google car manufacturers will be able to profit off driverless cars before the end of the decade. Although Google will likely not manufacture the cars, all of the hardware and software licenses will be licensed to car companies.

52 Frey, Thomas. Driverless Cars: a Driving Force Coming to a Future near You. Futurist Speaker Blog, Jan. 20, 2013, www.futuristspeaker.com/2012/01/driverless-cars-a-driving-force-coming-to-a-future-near-you. Accessed Mar. 14, 2014.

Policy Issue: Implementation, Governance, Data, Deployment Approach, Financing

The first wave of driverless vehicles will be luxury vehicles that allow one to relax or perform other desired activities. This wave will occur within the next ten years. The article speculates how the driverless vehicle industry will develop. While the current technology is sufficient to navigate roadways and recognize obstacles, it will need some refinement before its safe for human use. To gain economic viability, according to the article, component costs of driverless vehicles will need to come down. Regardless of when they're implemented, driverless vehicles will likely become a very disruptive technology.

52x Frazzoli, Emilio. Can We Put a Price on Autonomous Driving? MIT Technology Review, Mar. 18, 2014, www.ecnmag.com/news/2014/03/can-we-put-price-autonomous-driving. Accessed Apr. 18, 2014.

Policy Issue: Implementation, Governance, Sustainability

The article's author asks the question, "What is the point of autonomous cars?" He then lists the commonly stated benefits and puts them in a financial context. "Within the limits of the approximations and assumptions made, the above estimates suggest that automated driving is indeed a transformative technology, with a potential financial benefit to U.S. on the order of more than $3 trillion per year. It is interesting that the benefits due to increased safety and reduced congestion pale in comparison with those due to sharing and increased productivity. In particular, the synergy between autonomy and car sharing is readily apparent."

53 Gissler, A. et al. The Connected Car – Finally Coming True? Arthur D. Little Website, Sep. 2012, www.adlittle.com/downloads/tx_adlreports/AMG_2012_Connected_Car.pdf. Accessed Mar. 28, 2014.

Policy Issue: Liability, Risk, Financing

This article talks about why the connected vehicle is a goal for OEMs, but has a huge risk for them since it has not been done before. It talks about the key problems that need to be solved before connected vehicles will be produced which include the infrastructure and how OEMs are going to implement the production into their product schemes. It also talks about the financial liabilities and how they might be addressed. Lastly it talks about how OEMs should move forward now.

54 Golia, Nathan. 4 Ways Driverless Cars Are Poised to Shake Up Insurance. Insurance & Technology Blog, May 17, 2013. www.insurancetech.com/business-intelligence/4-ways-driverless-cars-are-poised-to-sha/240155042?pgno=1. Accessed Feb. 10, 2014.

Policy Issue: Liability, Implementation, Risk, Data

Drivers can now see the foundation that will eventually lead to fully automated vehicles. In a phase before full autonomy, multiple technologies are coming into adoption that takes control over parts of the driving experience. Eventually, systems will evolve beyond warning systems that spur a driver action to just taking the action themselves. Automobile insurers are actively involved in the innovation process around making cars safer. Even as some technologies reduce the likelihood of certain kinds of accidents, however, others introduce new risk. As new approaches introduce new risks, self-driving vehicles will require different models for insurance.

55 Goodall, Noah J. Ethical Decision Making During Automated Vehicle Crashes. Forthcoming in Transportation Research Record: Journal of the Transportation Research Board, 2014, www.people.virginia.edu/~njg2q/ethics.pdf. Accessed May 7, 2014.

Policy Issue: Liability, Implementation, Data, Deployment Approach

Automated vehicles "have the potential to significantly reduce crashes and improve roadway efficiency by automating the responsibilities of the driver. Still, automated vehicles are expected to crash occasionally, even when all sensors, vehicle control components, and algorithms function perfectly. If a human driver is unable to take control in time, a computer will be responsible for pre-crash behavior. Unlike other automated vehicles—such as aircraft, where every collision is catastrophic, and guided track systems, which can only avoid collisions in one dimension—automated roadway vehicles can predict various crash trajectory alternatives and select a path with the lowest damage or likelihood of collision. In some situations, the preferred path may be ambiguous. This study investigates automated vehicle crashing and concludes the following: (1) automated vehicles will almost certainly crash, (2) an automated vehicle's decisions preceding certain crashes will have a moral component, and (3) there is no obvious way to effectively encode complex human morals in software." – From Abstract

56 Graham, Kyle. Of Frightened Horses and Autonomous Vehicles: Tort Law and Its Assimilation of Innovations. Forthcoming in Santa Clara Law Review, 2012, www.papers.ssrn.com/sol3/papers.cfm?abstract_id=2008507. Accessed May 7, 2014.

Policy Issue: Liability, Implementation, Risk, Legislation

This article emphasizes the uncertainty that surrounds the application of tort law to emerging technologies like V2X. The precise content of the legal rules that will eventually coalesce around automated vehicles is likely to remain quite unclear for some time after these devices first appear on public highways. If the past provides any useful precedent, the law pertaining to automated vehicles may take “at least one wrong turn before heading in what ultimately proves to be the right direction.”

57 Gutman, Steve and Schonberger, Ben. A Drunk Person, a Child, and a Blind Man Get into a Car; who’s Driving? Grist Blog, Jun. 8, 2013, www.grist.org/article/a-drunk-person-a-child-and-a-blind-man-get-into-a-car-whos-driving/?utm_source=syndication&utm_medium=rss&utm_campaign=feed. Accessed Mar. 3, 2014.

Policy Issue: Implementation, Sustainability

While proponents if automated vehicles claim that mass-market automated cars are only three to five years to at least ten years away, few doubt their arrival is quickly approaching. But ideas about how these cars will affect cities and the environment seem to be stuck in the past as many seem to think of the technology as something added onto their personal cars. Perhaps a more likely model is an on-demand car service that offers door-to-door mobility via car travel without the fixed costs and hassles of owning a car, introducing a societal shift away from private car ownership and towards vehicle sharing. Naysayers have questioned the viability of car sharing since the late 1990’s. Just as car sharing has since gained significant popularity, adding self-driving technology could make the next phase of car sharing truly transformative.

58 Halsey III, Ashley. ‘Connected-Vehicle Technology’ Could Cut Crashes while Paving Way for Driverless Cars. The Washington Post, Feb. 3, 2013, www.washingtonpost.com/local/trafficandcommuting/direct-communication-between-car-computers-may-reduce-accidents-by-up-to-80-percent/2014/02/03/b55e9330-8d1a-11e3-833c-33098f9e5267_story.html. Accessed Feb. 10, 2014.

Policy Issue: Implementation, Governance, Risk, Data, Deployment Approach, Sustainability

The USDOT recently announced that it was moving forward with connected vehicle technology, the first step towards driverless vehicles, a watershed moment in the nation’s transportation history. Connecting all of the nation’s vehicles is projected to reduce non-alcohol-related traffic accidents by as much as 80 percent, preventing roughly 5.1 million accidents a year and saving 18,000 lives. However, automotive and technology experts fear that competition for airwaves supporting connected vehicles may impede their visionary future of the automobile. In a letter to the FCC, signed by more than 60 automakers, academics and transportation officials, ITSA appealed to the federal agency to protect the necessary bandwidth from encroachment by other users.

59 Heller, Matthew. California Regulators Consider “Big Brother” Hazards of Driverless Cars: Cars That Drive Themselves Could Be Pulling Out of Sci-Fi Fantasies and Tinseltown Dreams and Into Driveways and Roads Sooner than We Think, Sending Privacy Advocates into Over-

drive. Mint Press News, Mar. 19, 2014, www.mintpressnews.com/california-regulators-consider-big-brother-hazards-driverless-cars/186951/. Accessed Apr. 18, 2014.

Policy Issue: Implementation, Privacy, Data

"The autonomous vehicle (AV) regulations that the [California] DMV is developing must include privacy protections, giving users control over what data is gathered from robot-driven vehicles and how that information is used, John M. Simpson, privacy project director for Consumer Watchdog, told the DMV… Under [California's 2012 AV licensing law,] SB 1298, the DMV has until Jan. 1, 2015 to adopt regulations on the testing and use of self-driving vehicles on public roadways. Simpson anticipates a major fight with Google over privacy protections, noting that the Internet giant's "entire business model is based on building digital dossiers about our personal behavior and using them to sell the most personal advertising to us."

60 Hennig, Katy. CUTR Launches Automated Vehicle Institute. University of South Florida News, Nov. 19, 2013, www.news.usf.edu/article/templates/?z=38&a=5884. Accessed Apr. 2, 2014.

Policy Issue: Implementation, Legislation, Deployment Approach, Sustainability

The Center for Urban Transportation and Research at the University of South Florida launched the Automated Vehicle Institute as part of Florida's effort to be at the forefront of technology exploration and policy implementation. Florida is one of only three states that allow the technology to be tested on roadways.

61 Holdman, Jessica. Group Wants to Build Corridor for Unmanned Vehicles. The Bismarck Tribune, Mar. 17, 2014, www.bismarcktribune.com/business/local/group-wants-to-build-corrid…ticle_d49f597a-ae1f-11e3-b599-001a4bcf887a.html?print=true&cid=print. Accessed Apr. 18, 2014.

Policy Issue: Implementation, Governance, Certification

"A trade group wants to create a pathway for self-driving vehicles from Canada, through North Dakota and other states south to Mexico… One of the issues with the middle part of the U.S. is the lack of north-south avenues to move commerce… The association is starting an initiative to develop regulations for driverless vehicles, whether on the ground or in the air. It will discuss the initiative [in an upcoming forum]." This article highlights a desire for guiding government regulations to aid commercial interests seeking to utilize driverless vehicle technology.

62 Holeywell, Ryan. FCC Wi-Fi Expansion May Threaten Connected Vehicles. Governing Blog, Feb. 21, 2013, www.governing.com/templates/gov_print_article?id=190851181. Accessed Jan. 15, 2014.

Policy Issue: Implementation, Governance, Risk, Data, Legislation

ITSA, state transportation officials and other advocates are asking the FCC to slow down on improving Wi-Fi for faster, more reliable internet connectivity using the 5.9 GHz band currently reserved for V2X technology. Sharing the band would result in V2X's demise due to the sharing resulting in crowding of the band and presenting a significant safety risk.

63 Hoogendoorn, Raymond. Automated Driving, Traffic Flow Efficiency and Human Factors: A Literature Review. Submitted to Transportation Research Board Annual Meeting 2014, Delft, 2013, www.assets.conferencespot.org/fileserver/file/65828/filename/14-3783.pdf. Accessed May 7, 2014.

Policy Issue: Implementation, Risk, Sustainability

"Automation may be assumed to have a beneficial impact on traffic flow efficiency. However[,] the relationship between automation and traffic flow efficiency is [as] complex as [the] behavior [that] road users have [on the] influence on this efficiency as well. In this contribution we review what is actually known about the influence of automation on traffic flow efficiency and behavior of road users in order to formulate a theoretical framework and to identify future research needs. We conclude that automation can be assumed to have an influence on traffic flow efficiency and on the behavior of road users. Nevertheless we also conclude that the performed research has some shortcomings. In this context we formulate directions for future scientific research on automation in relation to traffic flow efficiency and human behavior." – Abstract

64 How Does a Self-Driving Vehicle Work? The Economist Magazine, Apr. 29, 2013, www.economist.com/blogs/economist-explains/2013/04/economist-explains-how-self-driving-car-works-driverless. Accessed Mar. 14, 2014.

Policy Issue: Implementation

Self-driving cars are a logical extension of today's driver assist technology, as computerized control of a car's steering, acceleration and braking is already possible under some circumstances. In the continuum from fully manual to fully automated vehicles, it is becoming increasingly possible to outsource more and more driving tasks to a car, particularly when tightening safety standards make driver aids compulsory.

65 IIHS Issues First Crash Avoidance Ratings under New Test Program; 7 Midsize Vehicles Earn Top Marks For Front Crash Prevention. IIHS News, Sep. 27, 2013, www.iihs.org/iihs/news/desktopnews/iihs-issues-first-crash-avoidance-ratings-under-new-test-program-7-midsize-vehicles-earn-top-marks-for-front-crash-prevention. Accessed Feb. 21, 2014.

Policy Issue: Implementation, Sustainability

A new test program by IIHS rates the performance of front crash prevention systems to help consumers decide which features to consider and encourage automakers to speed adoption of. The rating system is based on research indicating that forward collision warning and automatic braking systems are helping drivers avoid front-to-rear crashes. IIHS rates models with optional or standard front crash prevention systems as superior, advanced or basic depending on whether they offer automated braking. The protocol is similar to procedure that the European New Car Assessment Program uses to evaluate automated braking systems.

66 IIHS. Self-Driving Cars Moving into the Industry's Driver's Seat: New IHS Automotive Study Forecasts Nearly 12 Million Yearly Self-Driving Cars Sales and Almost 54 Million in Use on Global Highways by 2035. IIHS Website, Jan. 2, 2014, www.4-traders.com/IHS-INC-13057/news/IHS-Inc--Self-Driving-Cars-Moving-into-the-Industrys-Drivers-Seat-New-HIS Automotive-study-fore-17747395/. Accessed 21 Feb. 2014.

Policy Issue: Implementation

According to a recent study, automated cars that include driver control are expected to be globally available before 2025; self-driving 'only' cars are anticipated around 2030. In 2035, North America is forecasted to account for 29 percent of worldwide sales of these cars – estimated at 3.5 million vehicles. The article highlights this and other details from this study.

67 Intelligent Transportation Systems Joint Program Office. Applications for the Environment Real-Time Information Synthesis (AERIS). FHWA-JPO-11-124, Research and Innovative Technology Administration, U.S. Department of Transportation, n.d., www.its.dot.gov/factsheets/pdf/AERIS_factsheet.pdf. Accessed May 7, 2014.

Policy Issue: Implementation, Sustainability

This two page fact sheet highlights the USDOT's AERIS Program, which "will lead to the rapid and cost-effective deployment of interoperable technologies and applications [like V2X] that reduce the negative impacts of transportation on the environment. The program will act to promote the highest levels of collaboration and cooperation in the research and development of transformative environmental applications. The AERIS Program positions the Federal Government to take on an appropriate and influential role as a technology steward for a continually evolving integrated transportation system."

68 Intelligent Transportation Systems Joint Program Office. Policy Roadmap for Safety Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I). U.S. Department of Transportation, Research and Innovative Technology Administration, Draft, May 19, 2010, www.its.dot.gov/press/2010/policy_roadmap.htm. Accessed Apr. 16, 2014.

Policy Issue: Implementation, Sustainability

"The purpose of this paper is to describe a roadmap for conducting the policy research under the IntelliDriveSM Safety Program, a program focused on the technical research needed to develop, demonstrate, and test vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) technologies for safety." – From Purpose

69 Jaffe, Eric. Imagine: A World Where Nobody Owns Their Own Car. The Atlantic Cities Magazine, Feb. 13, 2014, www.theatlanticcities.com/commute/2014/02/imagine-world-where-nobody-owns-their-own-car/8387/. Feb. 17, 2014.

Policy Issue: Implementation, Governance, Risk, Sustainability

A world without car crashes may just be the first step to a world without car-ownership. Google's significant investment for a car/ridesharing service illustrates how serious some stakeholders are to making this happen. As less than 17 percent of U.S. household vehicles are in use at a time, there is reason to think that markets might aptly respond to this inefficiency. One may also ponder how such a network perpetuates car travel to the point that it even eliminates the need public transportation.

70 Jin, Peter J. et al. Developing Emerging Transportation Technologies in Texas. CTR Technical Report: 0-6803-1, Center for Transportation Research, University of Texas at Austin, Dec. 2013, www.library.ctr.utexas.edu/ctr-publications/0-6803-1.pdf. Accessed May 7, 2014.

Policy Issue: Implementation, Deployment Approach, Financing, Sustainability

"Through guidance from a technology industry expert panel, the [Texas Technology Task Force, or] TTTF[,] has developed a vision for the future Texas transportation system that furthers these goals via technology-based solutions. This document presents a synthesis of the TTTF's discussions and efforts between place from March and August 2103. [It] conducts an evaluation of emerging transportation technologies, identifying key issues and concerns, from prototype testing to implementation, and presents a basis for developing a preliminary roadmap to implementation in order to best serve Texas' strategic transportation and economic development goals." – From About This Document

71_Jootel, Paviter S. Safe Road Trains for the Environment Project (SARTRE) Final Report. SARTRE Oct. 31, 2012, www.sartre-project.eu/en/publications/Documents/SARTRE_Final-Report.pdf. Accessed May 7, 2014.

Policy Issue: Implementation

The SARTRE project aims to develop strategies and technologies to allow vehicle platoons to operate on public highways while also providing significant environmental, safety and comfort benefits. This concept consists of a group of vehicles driving closely together with small longitudinal gaps between and behind a lead vehicle driven by a trained professional driver. This platoon model brings benefits in fuel consumption, safety and driver convenience. The project investigated the human factors aspects of platooning from the point of view of the lead driver, the following drivers, and the other road users. Safety analyses have been carried out on the system considering not only the effects of potential faults, but also the effects of potential misinterpretation by a driver as well as deliberate malicious actions by third parties.

72 Kang, Cecelia and Fletcher, Michael. As Automakers Tap Smartphone Technology, Concerns Grow About Use of Drivers' Data. The Washington Post, Jan. 9, 2014, www.washingtonpost.com/business/economy/as-automakers-tap-…-data/2014/01/09/91a505f2-78a0-11e3-b1c5-739e63e9c9a7_print.html. Accessed Apr. 18, 2014.

Policy Issue: Implementation, Privacy, Risk, Data, Financing

"A series of deals [recently announced] between technology firms such as Google and automakers is bringing services previously aimed at smartphones right into the dash of cars that connect directly to the Web. The growing alliance between Silicon Valley and Detroit has executives in both places excited over the technological and money-making opportunities. But the fast-emerging trend also has raised questions about whether consumers will be able to control the massive trove of personal data that cars are expected to generate in the coming years. U.S. laws are vague about who can harness all that information."

73 Kastrenakes, Jacob. Ford Unveils Self-Driving Research Car. The Verge Magazine, Dec. 12, 2013, www.theverge.com/2013/12/12/5204256/ford-unveils-automated-fusion-hybrid-research-vehicle. Accessed Jan. 10, 2014.

Policy Issue: Implementation

Ford unveiled the Fusion Hybrid, a modified 'highly-automated' research car that it is now testing it for incremental near- and mid-term deployment and expects to be fully deployed after 2025. The testing is being done in collaboration with the University of Michigan and State Farm. Ford is also actively exploring public perception and legislative issues around such vehicles.

74 Keen, Andrew. The Future Of Travel: How Driverless Cars Could Change Everything. CNN Website, May 15, 2013, www.edition.cnn.com/2013/05/14/business/bussiness-traveller-futurecast-driverless-car/. Accessed Mar. 14, 2014.

Policy Issue: Implementation, Risk

Intelligent cars are arriving in the shape of collision-proof, driverless automobiles. While we're about to enter into a great social experiment, not all think that the experiment is all that great. The article explores both sides of this discussion.

75 Keen, Andrew. The Future of Travel: Transportation Confronts Its 'Kodak Moment'. CNN Website, May 14, 2013, www.edition.cnn.com/2013/05/13/business/business-traveller-transportation-futurecast/index.html. Accessed Mar. 14, 2014.

Policy Issue: Implementation, Risk, Deployment Approach

The author documents a recent event held in Silicon Valley called FutureCast, where fifty entrepreneurs, investors, technologists and writers discussed the impact of the digital revolution on transportation. The event's goal was to rethink travel in today's networked society and re-imagine the future of cars, buses and trains in the digital age. The article highlights how Kodak was catastrophically blindsided by the digital revolution in photography - a CEO's worst nightmare – and how this lesson may apply to transformative vehicle technology.

76 Knight, Will. Driverless Cars Are Further Away than You Think. MIT Technology Review, Oct. 22, 2013, www.technologyreview.com/featuredstory/520431/driverless-cars-are-further-away-than-you-think/. Accessed Apr. 18, 2014.

Policy Issue: Implementation, Deployment Approach, Financing

"[P]rojections tend to overlook just how challenging it will be to make a driverless car. If autonomous driving is to change transportation dramatically, it needs to be both widespread and flawless. Turning such a complex technology into a commercial product is unlikely to be simple. It could take decades for the technology to come down in cost, and it might take even longer for it to work safely enough that we trust fully automated vehicles to drive us around."

77 Knight, Will. Proceed with Caution toward the Self-Driving Car: Completely Autonomous Vehicles will Remain a Fantasy for Years. Until they're Here, We Need Technology that Enhances Human Drivers' Abilities rather than Making Those Abilities Increasingly Obsolete. MIT Technology Review, Apr. 16, 2013, www.technologyreview.com/review/513531/proceed-with-caution-toward-the-self-driving-car/. Accessed Apr. 18, 2014.

Policy Issue: Implementation, Deployment Approach

"[D]espite such progress and the attention surrounding Google's "self-driving" cars, full autonomy remains a distant destination. A truly automated car, one capable of dealing with any real-world situation, would require much smarter artificial intelligence than Google or anyone else has developed. The problem is that until the moment our cars can completely take over, we will need automotive technologies to strike a tricky balance: they will have to extend our abilities without doing too much for the driver… "The difficulty lies in the transition toward full automation, when only some things will be automated.""

78 Knight, Will. The Internet of Cars is Approaching a Crossroads: Wireless Vehicle Networks Could Make Driving Safer and More Efficient, But the Cost of Deployment will be Significant.

MIT Technology Review, Jun. 27, 2013, www.technologyreview.com/news/515966/the-internet-of-cars-is-approaching-a-crossroads/. Accessed Apr. 18, 2014.

Policy Issue: Implementation, Deployment Approach, Financing

"John Maddox, director of collaborative program strategies at the University of Michigan's Transportation Research Institute, says the effect [of V2V deployment] could be comparable to that of networking together personal computers over the Internet. "The connection itself is low-tech," he says, "but the intelligence and the value that it brings are extremely powerful and should not be underestimated." The author is a proponent of V2V and lists many benefits, but fears high deployment costs by governments could pose problematic.

79 Koch, Wendy. Self-Driving Cars Hold $87B Market Potential But Face Hurdles. USA Today: Money Website, May 20, 2014, www.americasmarkets.usatoday.com/2014/05/20/self-driving-cars-hold-87b-market-potential-but-face-hurdles/. Accessed May 30, 2014.

Policy Issue: Implementation, Legislation

Self-driving cars are being developed but will not be completely automated anytime soon as a result of public policy challenges and consumer preferences.

80 Koebler, Jason. Driverless Cars Are Going to Kill Insurance Companies. Motherboard Blog, Feb. 27, 2014, www.motherboard.vice.com/read/driverless-cars-are-going-to-kill-insurance-companies. Accessed Apr. 17, 2014.

Policy Issue: Liability, Implementation, Deployment Approach

Many industries will be negatively impacted through deployment of automated vehicles. Insurance companies will be one. The article discusses this and others.

81 Koebler, Jason. Driverless Cars Can Never Be Crashproof, Physics Says. Motherboard Blog, Apr. 9, 2014. www.motherboard.vice.com/read/driverless-cars-can-never-be-crashproof-physics-says. Accessed Apr. 17, 2014.

Policy Issue: Implementation, Risk

"Just because we can't guarantee that a driverless car will never crash doesn't mean that driverless cars won't be much safer than human drivers—that much is obvious. But much of the promise of autonomous cars lies in the ability to completely take a human out of the equation so they can do that whole robot taxi thing on their own." The article briefly talks about the reality of crashes of driverless cars.

82 Koebler, Jason. You Can Already Buy a Driverless Vehicle. Motherboard Blog, Mar. 27, 2014, www.motherboard.vice.com/read/you-can-already-buy-a-driverless-vehicle. Accessed Apr. 18, 2014.

Policy Issue: Implementation

Navia is already selling a driverless car to businesses and universities - it's more of a trolley or shuttle. While very limited, its availability provides some visible, real-world automated vehicle technology in streets.

83 Kopp, Craig. Florida at Vanguard of Autonomous Car Future. Tampa Bay Times, Aug. 29, 2013, www.tampabay.com/features/humaninterest/florida-at-vanguard-of-autonomous-car-future/2138950. Accessed Apr. 2, 2014.

Policy Issue: Legislation, Deployment Approach

Florida is vying to be a primary testing ground for automated vehicles. Whether implementation is eight or 15 years from now, Florida believes that it needs to be ready for it. The article features an interview with State Senator Jeffrey Brandes, R-St. Petersburg, who co-sponsored Florida's automated-vehicle law when he served in the House in 2012.

84 Kornhauser, Alain. et al. Deliberations from an Expert Workshop on Vehicle Automation, Public Transportation, and Shared Mobility. Submitted for presentation at the 93rd Annual Meeting of the Transportation Research Board, Washington D.C., Jan. 2014, www.orfe.princeton.edu/~alaink/SmartDrivingCars/Videos/TRB2014/TRB%202014%20%20Deliberations%20from%20Expert%20Workshop%20on%20Automation,%20Transit%20and%20Shared%20Mobility.pdf. Accessed May 7, 2014.

Policy Issue: Implementation, Deployment Approach, Financing

"Google has reaffirmed its commitment to public Level 4 vehicles in mixed traffic by 2018. While some public-sector transit agencies have already started to think about the impacts of increasing levels of vehicle-automation, many have limited awareness of the mobility opportunities these technologies can offer that may impact structurally on planned investment programs. While, over the last decade, our European counterparts have been planning for these new technologies and implementing many site demonstrations. Automation also offers opportunities for shared-mobility models currently coming on board, such as car share programs. Shared-mobility providers are generally private-sector entities facing a different competitive environment; there are both far-reaching visions of fully-automated taxi-style services and more near-term opportunities for shared-mobility fleets to serve as testbeds for moderate levels of automation. This paper synopsizes the workshop's scientific content and outcomes [TRB's Road Vehicle Automation Conference - July 15th to 20th, 2013 at Stanford University – "a two-day expert workshop took place addressing automation, shared-mobility and transit"], including identified research needs and plans for a Task Force to advance the required program of research." – From Abstract

85 Lederman, Jaimee and Taylor, Brian D. Fault-Y Reasoning: Navigating the Intelligent Transportation Systems Liability Quagmire. Nov. 15, 2013.

Policy Issue: Liability, Governance, Risk, Certification, Legislation, Deployment Approach

"[ITSs] hold great promise to increase the efficiency and effectiveness of personal and commercial travel, but intelligently linking vehicles, [by] way [of] increasingly complex and interconnected real-time data systems[,] creates a host of new and largely untested questions of liability when something goes wrong. And as the pace of ITS implementation quickens, uncertainty over liability grows. Accordingly, this article examines the current status of federal and state laws and administrative codes guiding the deployment of ITS. Through a careful review of both the scholarly literature and case law in the U.S., we find (1) a patchwork of industry self-regulation, (2) tort case law with few clear parallel precedents and which varies substantially from state to state, (3) a waxing number of looming, never-before tested ITS liability questions, and (4) no prospect of guiding federal legislation on the horizon. While the fanciful appeal of driverless cars and the fascinating liability questions they raise are undeniable, we argue that the ultimate liability schema for ITS technologies is likely to depend heavily on the liability issues that arise out of the sorts of navigation and collision-avoidance systems being installed in new vehicles today – issues that are often settled by the courts on decidedly narrow grounds. Uncertainty abounds, and we argue that ITS liability decisions made in the near term will undoubtedly affect, and could possibly even halt, the deployment of intelligent transportation systems for many years to come." – From Abstract

86 Le Vine, Dr. Scott and Polak, Professor John. Automated Cars: A Smooth Ride Ahead? ITC Occasional Paper Number Five, Independent Transport Commission, Feb. 2014, www.theitc.org.uk/docs/114.pdf. Accessed May 7, 2014.

Policy Issue: Implementation, Risk, Deployment Approach

This paper looks at the implications of automated vehicle technology in Britain. "On the policy issues that automation raises, it is clear that much more than purely technological solutions are needed; and we must also reflect on the length of time it will take for customs, social mores and legal regulations to change. We have been able to receive news on tablets and smartphones for several years, yet many of us can still be seen flicking through paper newspapers on our regular commute. Like these two 'modes' of reading that exist side-by-side, we must consider what a dual-track road network will entail – this will depend on the number of 'manual' cars on the system and the ability to retrofit them… [C]hanges brought about by increasingly sophisticated vehicle automation will appear in an evolutionary pattern… [This paper] highlights many of the second-order impacts that will arise, including improved mobility and capacity on existing networks (especially the Strategic Road Network); the release of time when travelling; improved safety; and extending our driving life further into old age." – From Preface

87 Lino, Patrick. The Ethics of Saving Lives with Autonomous Cars are Far Murkier than You Think. Wired Magazine, Jul. 30, 2013, www.wired.com/opinion/2013/07/the-surprising-ethics-of-robot-cars/. Accessed Mar. 1, 2014.

Policy Issue: Implementation

Self-driving cars could save a lot of lives. Traffic accidents kill about 32,000 people every year in America alone. That's about 88 deaths per day in the U.S., or one victim every 15 minutes - nearly triple the rate of firearm homicides. Few assume that automated cars will end all roadway deaths as, even if every vehicle on the road were instantly replaced by its automated counterpart, there would still be accidents due to things like software bugs, misaligned sensors, and unexpected obstacles. The article raises many interesting ethical issues, such as when self-driving cars face two obstacles that it must make an ethical choice in responding to, such as a hitting a school bus or a sidewalk full of pedestrians in order to avoid a crash with a single-occupancy vehicle.

88 Lino, Patrick. What if Your Autonomous Car Keeps Routing You past Krispy Kreme? The Atlantic Cities Magazine, Jan. 22, 2014. www.theatlantic.com/technology/archive/2014/01/what-if-your-autonomous-car-keeps-routing-you-past-krispy-kreme/283221/. Accessed Mar. 1, 2014.

Policy Issue: Implementation, Privacy

The article highlights an interesting scenario: connected vehicles that communicate with our social media and web habits to inform us of business locations we may be interested in when approaching them. How will online adverting be integrated into connected vehicles? As existing apps on our mobile phones and computers are already doing now, in-car apps will raise a host of legal and ethical dilemmas, from privacy and beyond.

89 Litman, Todd. Autonomous Vehicle Implementation Predictions: Implications for Transport Planning. Victoria Transport Policy Institute, Mar. 31, 2014, www.vtpi.org/avip.pdf. Accessed May 7, 2014.

Policy Issue: Implementation, Governance, Risk, Deployment Approach, Financing

This report explores the impacts that automated vehicles will likely have on transportation planning. It discusses automated vehicle benefits and costs, predicts their likely development and implementation based on experience with previous vehicle technologies, and explores how they will affect planning decisions such as road and parking supply and public transit demand. The report also lists benefits and costs/problems, related equipment and service requirements and table of implementation projections. It also identifies many realistic scenarios that bring attention to potential 'social implementation' and financial challenges. Report authors presume the unlikelihood that most motorists will shift from owning vehicles to relying on self-driving taxis (one of the commonly espoused visions of automated vehicle technology).

90 Lutin, Jerome M. et al. The Revolutionary Development of Self-Driving Vehicles and Implications for the Transportation Engineering Profession. ITE Journal, Jul. 2013, www.digitaleditions.sheridan.com/display_article.php?id=1446463&id_issue=165937. Accessed Mar. 24 2014.

Policy Issue: Implementation, Governance, Legislation, Sustainability

This paper documents self-driving vehicle technology developments and potential safety and mobility benefits. It also presents questions and proposes initial actions to prepare transportation professionals for challenges associated with this new technology, and highlights an urgency for the development of new dialogues and partnerships with diverse stakeholders, including software and systems developers, auto manufacturers, and regulatory bodies.

91 Madrigal, Alexis. By the Time Your Car Goes Driverless, You Won't Know the Difference. National Public Radio Website. Mar. 4, 2014, www.npr.org/blogs/alltechconsidered/2014/03/04/285740673/by-the-time-your-car-goes-driverless-you-wont-know-the-difference. Accessed Apr. 18, 2014.

Policy Issue: Implementation, Governance, Risk, Deployment Approach, Financing

"Carmakers need to figure out how to make vehicle-to-vehicle communication work, prove the safety and reliability of new technologies, and make them cheaper." While the article is not too in depth, it highlights that V2V is becoming an issue significant to warrant public interest and debate on a nation-wide scale.

92 Madrigal, Alexis. The Trick That Makes Google's Self-Driving Cars Work. The Atlantic Website, May 15, 2014, www.theatlantic.com/technology/archive/2014/05/all-the-world-a-track-the-trick-that-makes-googles-self-driving-cars-work/370871/. Accessed May 30, 2014.

Policy Issue: Implementation

After a ride in one of Google's self-driving cars, the article's author agrees that they're boring, as they drive so safely. The author speculates whether this would still be the case beyond Silicon Valley.

93 Mai, Andreas and Schlesinger, Dirk. A Business Case for Connecting Vehicles. Cisco Internet Business Solutions Group, Apr. 2011, www.cisco.com/web/about/ac79/docs/mfg/Connected-Vehicles_Exec_Summary.pdf. Accessed May 8, 2014.

Policy Issue: Deployment Approach

This is a point of view of why to use connected vehicles. It argues that there is wasted productivity and resources related to personal transportation due to congestion. It talks about how current policies to fix congestion are flawed and that connectivity would have many benefits if implemented for many different groups involved. Connectivity would allow the government to impose a road tax in order to charge the true value of using road. This might promote less driving on stressed roads. Lastly it talks about how globally people are shifting to more connected cars and states how all the different providers will be affected by a more connected vehicular market.

94 Mai, Andreas and Schlesinger, Dirk. Connected Vehicles and Government: A Catalyst to Unlock the Societal Benefits of Transportation. Cisco Internet Business Solutions Group, Apr. 2011, www.cisco.com/web/about/ac79/docs/mfg/Connected-Vehicles_Government.pdf. Accessed May 8, 2014.

Policy Issue: Deployment Approach

This is a point of view for the government for why to support connected vehicles. It talks about how people are willing to drive a lot sometimes because they perceive the roads as free, and how that causes our roads to be underfunded leading to decreased mobility. Connected Vehicles would allow the government to charge a road tax based on how many miles people drive. It includes estimates for how much the infrastructure required would cost. Other benefits included multispace parking and early detection of road wear. Lastly, it talks about how privatizing part of the highway system could lead to great increases in funding for roads and connected infrastructure, and that it should be considered.

95 Mai, Andreas and Schlesinger, Dirk. Connected Vehicles and Government: Service Providers at a Crossroads. Cisco Internet Business Solutions Group, Apr. 2011, www.cisco.com/web/about/ac79/docs/mfg/Connected-Vehicles_Service_Provider.pdf.

Policy Issue: Deployment Approach, Risk

This is a point of view targeting service providers on why they should support connected vehicles. This is targeting the data providers and manufacturers. Connected vehicles offer a platform where multiple service packages could be offered, but since each car would need one, servicers could profit off of that. It also lists some risks about having the services being provided in the car which include areas with little service or better service with a certain provider, needing a minimum package that comes with the car, manufacturers needing to support multiple carriers, and needing to be able to use multiple connectivity technology like wireless at home and DSRC on the road.

96 Mai, Andreas and Schlesinger, Dirk. Connected Vehicles: From Building Cars to Selling Personal Travel Time Well-Spent, Cisco Internet Business Solutions Group, Apr. 2011, www.cisco.com/web/about/ac79/docs/mfg/Connected-Vehicles_Automotive.pdf. Accessed May 8, 2014.

Policy Issue: Deployment Approach

This is a point of view for why connected cars would be an effective business model now or soon in the future for OEMs. It talks about how people are much more connected nowadays and cars should evolve to meet the personality of current customers. It talks about how driving can be an experience for people instead of just a way to travel. People would be able to customize their cars to be perfect for them. It also offers different business models where cars are shared and people pay for the miles they drive.

Promoting connectivity in this fashion would help everyone enjoy the benefits of connectivity without necessarily having to own a car themselves.

97 Malone, Kerry. et al. Defining the Required Infrastructure Supporting Co-Operative Systems. SMART 2010/0063, Final Report, TNO-060-DTM-2011-03163, European Commission, Brussels, 2011.

Policy Issue: Implementation, Certification, Deployment Approach

The standardization and design of communication systems and components are now mature enough for large-scale field operational testing, such as those that are taking place in the European Union. Yet, challenges still remain on the pan-European roll-out (likely after 2020). This research aims to clarify for all stakeholders what infrastructure would be necessary for the deployment of 'Day-1' systems and explores the roles that various stakeholders need to play. The specific objective of the study was to: 1) better describe the scope of required infrastructure, 2) recommend a realistic step-by-step road map and 3) identify existing gaps in knowledge and future research needs. The research also explores related developments happening around the world.

98 Markoff, John. At High Speed, On the Road to a Driverless Future. The New York Times, May 27, 2012, www.nytimes.com/2013/05/28/science/on-the-road-in-mobileyes-self-driving-car.html?pagewanted=all&_r=0. Accessed Mar. 3, 2014.

Policy Issue: Implementation

While many automated test vehicles have various sensors, cameras and LiDAR, Mobileye technology in the Audi A7 is distinctive because of the simplicity and relative low cost of its system (a few hundred dollars). Mobileye-equipped vehicles are capable of driving in a single lane at freeway speeds, as well as identifying traffic lights and automatically slowing, stopping and then returning to highway speeds. Like Google, Mobileye is not an automobile manufacturer, but a technology firm intensely focused on developing the next generation of artificial intelligence software to advance automated vehicles.

99 Markoff, John. Collision in the Making between Self-Driving Cars and How the World Works. The New York Times, Jan. 23, 2012, www.nytimes.com/2012/01/24/technology/googles-autonomous-vehicles-draw-skepticism-at-legal-symposium.html. Accessed Mar. 3, 2014.

Policy Issue: Liability, Implementation, Privacy, Risk, Deployment Approach

Legal scholars and government officials are warning that society has only begun wrestling with the changes that would be required in a system created a century ago to meet the challenge of horseless carriages. Questions of legal liability, privacy and insurance regulation around self-driving cars have yet to be adequately addressed and might pose far more problems than technological issues.

100 Mead, Derek. Elon Musk Says Self-Driving Teslas are Three Years Away. Motherboard Blog, n.d., www.motherboard.vice.com/blog/elon-musk-says-self-driving-teslas-are-three-years-away. Accessed Feb. 24 2014.

Policy Issue: Implementation

Automated vehicles have been on the horizon for many decades, but only recently has it become clear that they're actually going to be on the market in the foreseeable future. Tesla says it expects to have a car with its version of autopilot (a car that can handle ninety percent of the driving duties) within three years (Nissan and Daimler AG, both have said they'll have automated cars by the end of the decade). The article highlights this reality.

101 Mead, Derek. It's Time to Start Talking about Cars Talking to Each Other. Motherboard Blog, n.d. www.motherboard.vice.com/blog/its-time-to-start-talking-about-cars-talking-to-each-other. Accessed Feb. 10, 2014.

Policy Issue: Implementation, Governance, Deployment Approach, Financing, Sustainability

The realization of the automated vehicles is a great achievement, because moving towards zero emission and zero roadway fatalities is major objective for Nissan. A recent USDOT announcement represents a significant step forward in advancing the next generation of vehicle safety and automotive innovation - the result of years of collaboration between the transportation and high-tech industries and our federal, state and local partners. The announcement makes clear that automakers won't have to develop a working automated vehicle grid on their own, a significant task. Instead, human-driven cars will likely get smarter and better able to communicate with themselves and their surroundings, spurred by innovation from government and the private-sector.

102 Mead, Derek. Nissan Plans to Sell a Self-Driving Car in just Seven Years. Motherboard Blog, n.d. www.motherboard.vice.com/blog/nissan-plans-to-sell-a-self-driving-car-in-just-seven-years. Accessed Feb. 10, 2014.

Policy Issue: Implementation

Nissan announced that it will have multiple models of self-driving cars on the market by 2020. It will also open an automated car proving ground in 2014. Nissan already has a working test bed vehicle with adaptive cruise control and automatic parking technology. Effectively interfacing with human drivers – and making one affordable enough for humans to pay for it - is a main challenge for Nissan to overcome in its development of self-driving cars.

103 Merchant, Brian. By 2035, Nearly 100 Million Self-Driving Cars Will Be Sold per Year, Report Says. Motherboard Blog, n.d., www.motherboard.vice.com/blog/its-time-to-start-talking-about-cars-talking-to-each-other. Accessed Feb. 10, 2014.

Policy Issue: Liability, Implementation, Governance, Legislation, Deployment Approach

The rise of automated cars might be more rapid than anyone expected, as figures indicate that nearly 130 million will be sold annually. Many of these sales will include used vehicles, with some estimates placing the number of used cars sold in the US alone at 40 million per year. Despite a few state laws legalizing driverless cars, there is still an issue of making them street legal and insuring them. Governments will need to explicitly identify who is liable when two driverless cars crash into each other. As hurdles are increasingly cleared, however, we should expect to see more and more automated cars on the roads.

104 Millard, Rachel. Passengers Only: As Autonomous Vehicle Technology Evolves, the Effects will Be Seen at Every DMV. MOVE Magazine, Nov. 2013, www.movemag.org/highway-safety/181-passengers-only.html. Accessed Feb. 19, 2014.

Policy Issue: Liability, Implementation, Legislation, Deployment Approach

US states are increasingly studying the potential effects of connected and automated vehicle technology on their transportation systems, with some states even permitting the operation of automated cars in testing scenarios on public roads. State governments will need to explore many legislative issues like: 1) Who will have the authority to regulate issues like privacy and liability?; 2) If not the DMV, is there another government agency that should be involved?; 3) What laws need to change?; and 4) What should be allowed on public roadways?

105 Miller, Claire Caine. When Driverless Cars Break the Law. The New York Times Website, May 13, 2014, www.mobile.nytimes.com/2014/05/14/upshot/when-driverless-cars-break-the-law.html?_r=2&referrer=. Accessed May 30, 2014.

Policy Issue: Liability, Implementation, Legislation

Who is responsible when something goes wrong with a driverless car? As product liability law “tends to adapt well to new technologies,” it will likely be the driver, particularly as a car cannot be held liable.

106 Morgan, Richard. The Practical Path to Driverless Cars. The Atlantic Cities Magazine, Apr. 1, 2014, www.theatlanticcities.com/commute/2014/04/practical-path-driverless-cars/8759/. Accessed Apr. 2, 2014.

Policy Issue: Implementation, Legislation, Deployment Approach

Only four states allow driverless cars. The federal government has only authorized a handful of test beds for connected vehicles on public roads. California is hoping to fast-forward to a driverless future by changing car commutes from active driving to passive riding almost overnight. The University of South Florida's Center for Urban Transportation Research (and the state of Florida in general) is embracing a far more practical, level-by-level approach. Tampa is seeking to become the primary locale synonymous with V2X technology.

107 Mui, Chunka. Fasten Your Seatbelts: Google's Driverless Car Is worth Trillions - Part 1. Forbes Magazine, Jan. 22, 2013, www.forbes.com/sites/chunkamui/2013/01/22/fasten-your-seatbelts-googles-driverless-car-is-worth-trillions/. Accessed Feb. 24, 2014.

Policy Issue: Implementation, Sustainability

V2V can reduce by ninety percent all traffic accidents, wasted commute time and energy and the overall number of cars. Google claims it can also reduce accident-related expenses by at least $400 billion a year in the US. Even if Google's projections are significantly off, the improvement in safety will likely still be startling. Google's driverless car has worldwide social and economic benefits that could amount to trillions of dollars per year.

108 Mui, Chunka. Google's Trillion-Dollar Driverless Car - Part 2: The Ripple Effects. Forbes Magazine, Jan. 24, 2013, http://www.forbes.com/sites/chunkamui/2013/01/24/googles-trillion-dollar-driverless-car-part-2-the-ripple-effects/3/. Accessed Feb. 17, 2014.

Policy Issue: Liability, Implementation, Governance, Legislation

A driverless car would slash hundreds of billions - or even trillions - of dollars of annual revenue, from a variety of entities. In addition, it will create enormously lucrative business opportunities to serve new customer needs. Insurance and government agencies would need to restructure their resources to fully reap benefits from driverless cars.

109 Mui, Chunka. Google's Trillion-Dollar Driverless Car - Part 3: Sooner Than You Think. Forbes Magazine, Jan. 30, 2013, www.forbes.com/sites/chunkamui/2013/01/30/googles-trillion-dollar-driverless-car-part-3-sooner-than-you-think/2/. Accessed Feb. 17, 2014.

Policy Issue: Implementation, Deployment Approach, Financing

The pace of progress of driverless car technology also means that disruptive ripple effects might soon have strategic relevance for companies participating in the multi-trillion dollar car-related economy. The article discusses many questions associated with driverless cars and V2V technology implementation, such as: 1) "How soon could the driverless car become a reality?" and 2) "When should incumbents, venture capitals and entrepreneurs start paying serious attention?" The cost of a gigabyte dropped from

$300,000 to a dime in three decades, indicating the possibility of a similar trajectory for driverless cars.

110 Muller, Joann. No Hands, No Feet: My Unnerving Ride in Google's Driverless Car. Forbes Magazine, Mar. 21, 2013, www.forbes.com/sites/joannmuller/2013/03/21/no-hands-no-feet-my-unnerving-ride-in-googles-driverless-car/. Accessed Mar 3, 2014.

Policy Issue: Implementation

The head of Google's driverless car project took the author for a freeway drive in one of its vehicles. Google engineers are currently working to perfect single-lane highway driving, but with improved programming, Google's driverless car could be driven soon under any circumstances.

111 Mulligan, Casey B. Self-Driving Cars Will Make Accident Claims Easier. The New York Times, Apr. 2, 2014, www.economix.blogs.nytimes.com/2014/04/02/self-driving-cars-will-…ollection=Business%20Day&action=Click&pgtype=Blogs&region=Body&_r=0. Accessed Apr. 18, 2014.

Policy Issue: Liability, Implementation

"[S]elf-driving cars… will be welcome, but their achievements may ultimately be more heavily weighted toward passenger convenience than safety." One convenience – albeit not always in the benefit of the consumer: "insurance companies may have an easier time settling claims against robot-driven vehicles."

112 Narla, Siva R.K. The Evolution of Connected Vehicle Technology: From Smart Drivers to Smart Cars to… Self-Driving Cars. ITE Journal, Jul. 2013, www.ite.org/membersonly/itejournal/pdf/2013/JB13GA22.pdf. Accessed May 7, 2014.

Policy Issue: Implementation, Governance

V2X technology promises to change the way we move on our roads. The author discusses how research on these technologies is shaping the travel paradigm across the world. The article highlights the Connected Vehicle Safety Pilot Model Deployment Program, a recent NHTSA decision on connected vehicles, the Maricopa County Department of Transportation's SMARTDrive program, Car2x technology developments in the EU and the ITSA Technology Scan and Assessment.

113 National Connected Vehicle Field Infrastructure Footprint Analysis: Applications Analysis. American Association of State Highway and Transportation Officials, DTFH61-11-D-00008, Version 3, Jul. 31, 2013, www.ssom.transportation.org/Documents/Applications_Analysis%20v3%20july%202013.pdf. Accessed May 8, 2014.

Policy Issue: Implementation, Deployment Approach, Financing

"The purpose of this document is to provide a summary analysis of connected vehicle applications and their deployment needs to be considered in the Footprint Analysis. These applications and needs have been previously described in an extensive collection of other documents focused on particular functional, modal and programmatic approaches. This document surveys those references from the perspective of connected vehicle system deployments to identify what kind of operational needs might be addressed by CV applications, what aspects of deployment are shared by the applications, and how those common attributes might be leveraged to reduce costs and increase deployment benefits." – From Objective

114 National Connected Vehicle Field Infrastructure Footprint Analysis: Deployment Concepts. American Association of State Highway and Transportation Officials, DTFH61-11-D-00008, Final, Version 2, Sep. 20, 2013, www.ssom.transportation.org/Documents/Deployment_Concepts.pdf. Accessed May 8, 2014.

Policy Issue: Implementation, Certification, Deployment Approach

"This technical memo is part of a study sponsored by the [USDOT] and Transport Canada and performed by [AASHTO]. The purpose of this study is to conduct analyses leading to a preliminary, general concept of a national connected vehicle field infrastructure footprint."… It "describe[s] a set of high-level, generic connected vehicle infrastructure deployment concepts." – From Introduction

115 National Connected Vehicle Field Infrastructure Footprint Analysis: Deployment Scenarios. U.S. Department of Transportation, Final Report, Dec. 27, 2013, www.ssom.transportation.org/Documents/Task%206a%20AASHTO_CV_Footprint_Deployment_Scenarios_v2.pdf. Accessed May 8, 2014.

Policy Issue: Implementation, Governance, Deployment Approach

"This document, one of several products of the National Connected Vehicle Field Infrastructure Footprint Analysis, describes a set of scenarios illustrating how state and local agencies might deploy connected vehicle technology and applications. The scenarios build upon the prior Applications Analysis and the Deployment Concepts developed as part of this Connected Vehicle Infrastructure Footprint Analysis." – From Abstract

116 Naylor, Nathan. U.S. Department of Transportation Announces Decision to Move Forward with Vehicle-to-Vehicle Communication Technology for Light Vehicles. NHTSA Website. National Highway Traffic Safety Administration, Feb. 3, 2014, www.nhtsa.gov/About+NHTSA/Press+Releases/2014/USDOT+to+Move+Forward+with+Vehicle-to-Vehicle+Communication+Technology+for+Light+Vehicles. Accessed Apr. 12, 2014.

Policy Issue: Implementation, Governance, Data

"The [NHTSA] announced that it will begin taking steps to enable [V2V] communication technology for light vehicles. This technology would improve safety by allowing vehicles to "talk" to each other and ultimately avoid many crashes altogether by exchanging basic safety data, such as speed and position, ten times per second."

117 Newcomb, Doug. Will Congress Slam the Brakes on Self-Driving Cars? PC Magazine, Dec. 12, 2013, www.pcmag.com/article2/0%2c2817%2c2428228%2c00.asp. Accessed Jan. 10, 2014.

Policy Issue: Liability, Implementation, Risk

2013 was a momentous year for the automated car. Google logged 150,000 miles testing its self-driving Toyota Prius. Automakers got into the game too, including Audi (A7), Cadillac (Super Cruise system), Ford (Fusion Hybrid Automated Research Vehicle), Mercedes-Benz (S-class), Nissan (Leaf EV), Tesla (Model S), Toyota (Lexus-based vehicle using LiDAR) and Volvo. Legal and liability issues – not technology development - will likely be its biggest implementation hurdle.

118 Office of Transportation Policy Studies. Future Uses of Highway Rights of Way - Report Summary. Federal Highway Administration, U.S. Department of Transportation, Apr. 2012, www.fhwa.dot.gov/policy/otps/rowstudyproj.htm. Accessed May 7, 2014.

Policy Issue: Governance, Deployment Approach, Sustainability

The report highlights a federal study on the future use of highways. The study was launched in November 2010 and includes feedback from three visioning sessions held across the country, six case studies, and future scenario development. The final report broadly discusses highway rights of way in six contexts, including three opportunities for connected vehicles: 1) Transportation and non-transportation uses; 2) Energy production and distribution and 3) Emerging technologies. Workshop participants looked favorably upon automating highway ROW to improve network safety and efficiency. Presumably, this includes connected vehicles. As automated technologies continue to advance, it is very likely that future transportation system design will need to accommodate them.

119 Ohnsman, Alan. Tesla CEO Talking with Google about 'Autopilot' Systems. Bloomberg Sustainability Blog, May 7, 2013, www.bloomberg.com/news/2013-05-07/tesla-ceo-talking-with-google-about-autopilot-systems.html. Accessed Mar. 3, 2014.

Policy Issue: Implementation

Elon Musk, the California billionaire who leads Tesla Motors Inc., said the electric-car maker is considering adding driverless technology to its vehicles and discussing the prospects for such systems with Google Inc. "I like the word autopilot more than I like the word self-driving," Musk said in an interview. "Self-driving sounds like it's going to do something you don't want it to do. Autopilot is a good thing to have in planes, and we should have it in cars."

120 Olia, Arash, et al. Assessing the Potential Impacts of Connected Vehicles: Mobility, Environmental and Safety Perspectives. Nov. 14, 2013, www.assets.conferencespot.org/fileserver/file/64486/filename/14-2348.pdf. Accessed May 8, 2014.

Policy Issue: Implementation, Sustainability
The focus of this research is to assess 43 the potential impacts of connected vehicle on mobility, safety and environment under non-recurrent congestion. To assess the benefits associated with connected vehicle, a micro-simulation traffic modeling framework was developed to test the interaction between vehicles and infrastructure. The research quantifies the performance of a system under different scenarios, including differing congestion levels and market penetration of connected vehicles subject to non-recurrent congestion, such as lane closures due an incident. The findings of this research indicate that connected vehicles have potential to reduce travel time by 37%, reduce emissions by 30% and improve safety indicators by 45%. It also shows that market penetration of connected vehicles will have the most significant impact on the performance within the transportation network.

121 Oracle for the Connected Vehicle: Turning Data into Business. Oracle White Paper, Mar. 2010, www.connectedvehicle.org/Oracle_Connectedvehicle.pdf. Accessed May 8, 2014.

Policy Issue: Implementation

This is a company's report on why people should use their connected vehicle technology. It talks about how Oracle provides a base for the manufacturers that is cheap and gives them updates on when the car may need maintenance. It states reasons for why you would want a connected vehicle insurance and manufacturer side. It shows that people think this market will be here soon and have already developed software and technology for it.

122 O'Rourke, John F. and Soon, Patrick. Driverless Technology and the Issue of Liability: Who's Responsible? InsideCouncil Magazine, Mar. 14, 2014, www.insidecounsel.com/2014/03/14/driverless-technology-and-the-issue-of-liability-w. Accessed Apr. 18, 2014.

Policy Issue: Liability, Implementation

This article is a 'nuts-and-bolts' synopsis of driverless vehicle technology.

123 Pan, Juan (Susan). et al. Proactive Vehicular Traffic Re-routing for Lower Travel Time. New Jersey Insti-tute of Technology, n.d., www.cs.njit.edu/~borcea/papers/ieee-tvt13.pdf. Accessed May 8, 2014.

Policy Issue: Implementation, Sustainability

"This paper presents five traffic re-routing strategies designed to be incorporated in a cost-effective and easily deployable vehicular traffic guidance system that reduces travel time. The proposed strategies proactively compute individually- tailored re-routing guidance to be pushed to vehicles when signs of congestion are observed on their route." – From Abstract

124 Parliamentary Office of Science & Technology. Autonomous Road Vehicles. POST Note, Number 443, Houses of Parliament, Sep. 2013, www.parliament.uk/business/publications/research/briefing-papers/POST-PN-443/autonomous-road-vehicles. Accessed Jan. 24 2014.

Policy Issue: Liability, Implementation, Governance, Risk, Legislation, Deployment Approach, Sustainability

Automated vehicles are an emerging area of technology; it is uncertain to what extent the potential benefits will be realized in the UK. How automated vehicles could interact safely with other road users, and how they would communicate with each other, are the focus of ongoing research. There is no UK legislation governing automated vehicles and there are no EU standards (Spain, Italy, Finland and Greece all have some degree of legislation governing their use). UK traffic regulations are based on the Vienna Convention on Road Traffic (1968) which requires the driver be in control of his or her vehicle at all times. The main policy challenges are verifying the safety and reliability of automated road vehicles and creating a legal framework to allow their testing and deployment on public roads.

125 Parsons Brinckerhoff. et al. Connected Vehicle Infostructure Plan, Oct. 2012, www.michigan.gov/documents/mdot/10-09-2012_Connected_Vehicle_Infostructure_Plan_401340_7.pdf?20140412002552. Accessed May 7, 2014.

Policy Issue: Deployment Approach

"This report [provides] a proposed framework for developing the Michigan Department of Transportation's (MDOT) Infostructure Deployment Plan and provide[s] a roadmap for deployment within the state to prepare for the department's connected vehicle program." – From Introduction

126 Passchier, Igor. et al. New Services Enabled by the Connected Car, European Commission, SMART 2010/0065 Final Report TNO-RPT-2011-01277, Final Report, TNO-RPT-2011- 01277, 2011, www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=2&ved=0CCkQFjAB&url=http%3A%2F%2Fbookshop.europa.eu%2Fen%2Fnew-services-enabled-by-the-connected-car-pbKK0113887%2Fdownloads%2FKK-01-13-887-EN-N%2FKK0113887ENN_002.pdf%3Bpgid%3Dy8dIS7GUWMdSR0EAlMEUUsWb0000BQoigG_%3Bsid%3D3TpsYjOb6BNsbWFEQm_yxVGkFlyEH74w0g%3D%3FFileName%3DKK0113887ENN_002.pdf%26SKU%3DKK0113887ENN_PDF%26CatalogueNumber%3DKK-01-13-887-EN-N&ei=Vw1sU-6aEdDAoATc_oCoCA&usg=AFQjCNH7N1qVd_OoaL_Y7e_rumyJLydtw&bvm=bv.66330100,d.cGU. Accessed May 8, 2014.

Policy Issue: Implementation, Governance, Legislation, Deployment Approach, Sustainability

The objective of this study is to identify and analyze the needs of both the public and private sectors for the services enabled by the paradigm shift to the connected car to all road users. The study identifies necessary technologies, and defines the functionality of the needed platform and of the potential services enabled by the connected car. The report includes comprehensive sample roadmaps for connected vehicles in Europe for the following six categories: 1) eco-centric motoring; 2) active safety protocols; 3) smart transportation; 4) mobility-integrated services; 5) cooperative traffic intelligence and 6) agile navigation systems. “Technological development will not stand still; new services and applications will be developed, with or without the help of the EC. However, some technological developments may not provide sufficient economic advantage for manufacturers to pursue, and the EC can play a key role in ensuring that these are addressed.”

127 Plungis, Jeff and Shield, Todd. Lobby Fight to Decide if Airwaves Talk to Cars or People. Bloomberg Businessweek Magazine, Feb. 19, 2014, www.businessweek.com/news/2014-02-19/lobby-fight-to-decide-if-airwaves-talk-to-cars-or-people#p2. Accessed Feb. 19, 2014.

Policy Issue: Implementation, Governance, Data, Legislation

Automobile manufacturers and technology companies are battling over coveted airwaves currently set aside for connected vehicle technology.

128 Pritchard, Justin. California Crafting Driverless Car Regulations; Vehicles Could be Available in Several Years. Winnipeg Free Press, Mar. 11, 2014, www.winnipegfreepress.com/business/california-plans-driverless-cars-regulation-commercial-vehicle-could-come-in-several-years-249445801.html. Accessed Apr. 18, 2014.

Policy Issue: Liability, Implementation, Governance, Risk, Legislation, Deployment Approach

“[The] California [DMV recently] held an initial public hearing [on] how to regulate the public's use of the technology that is still being tested. Among the complex questions officials wanted to unravel: [1)] How will the state know the cars are safe?[; 2)] Does a driver even need to be behind the wheel? [and 3)] Can manufacturers mine data from onboard computers to make product pitches based on where the car goes or set insurance rates on how it is driven?” Given that California is the only state to mandate rules for operation of driverless cars and that the federal government is years away from completing similar laws, the article highlights that California’s law will likely have significant influence on the formation of federal policy.

129 QNX Technology Powers Mission-Critical Systems in VisLab Autonomous Car Project: New Autonomous Vehicle Research Project from University of Parma's Vislab Now Includes Highly Reliable QNX Operating System. IT Business Website, Apr. 8, 2014, www.itbusinessnet.

com/article/QNX-Technology-Powers-Mission-Critical-Systems-in-VisLab-Autonomous-Car-Project-3172694. Accessed Apr. 18, 2014.

Policy Issue: Implementation

"QNX Neutrino operating system is powering mission-critical systems in a new autonomous vehicle project developed by the Artificial Vision and Intelligent Systems Laboratory (VisLab) of the University of Parma… VisLab chose the QNX OS because of its reliability, realtime performance, and long history in safety-critical systems."

130 Region 1. Connected Vehicles: Region 1 Briefing, Oregon Department of Transportation, 2013.

Policy Issue: Implementation, Legislation, Deployment Approach

This September 2013 brief indicates that Oregon 'road map' for connected vehicles will be delivered in a draft final state by the end of FY 2015 (June 2015). No specific actions are recommended at this time.

131 Report to Congressional Requesters - Intelligent Transportation Systems: Vehicle-to-Vehicle Technologies Expected to Offer Safety Benefits, but a Variety of Deployment Challenges Exist. United States Government Accountability Office, Nov. 2013, www.gao.gov/assets/660/658709.pdf. Accessed May 7, 2014.

Policy Issue: Implementation, Data, Legislation, Deployment Approach, Sustainability

In recent years, the USDOT and the automobile industry have been conducting research on new types of V2X technologies to prevent crashes. These technologies facilitate the sharing of data, such as vehicle speed and location, among vehicles to warn drivers of potential collisions. If V2V technologies are widely deployed, they have the potential to address 76 percent of multi-vehicle crashes involving at least one light vehicle by providing warnings to drivers, assuming their full deployment across the US vehicle fleet. This comprehensive federal report highlights many of the challenges associated with implementing V2X technology, as well as government action that will influence its adoption.

131x Research and Innovative Technology Administration's Intelligent Transportation Systems (ITS) Joint Program Office. CV Pilots Deployment Project. U.S. Department of Transportation, Sep. 23, 2014, http://its.dot.gov/pilots/index.htm. Accessed Sep. 26 2014.

Policy Issue: Implementation, Governance, Deployment Approach

This is a 2014 policy statement by the NHTSA that articulates its goals for connected vehicles moving forward.

132 Research and Innovative Technology Administration's Intelligent Transportation Systems (ITS) Joint Program Office. How Connected Vehicles Work. U.S. Department of Transportation, n.d., http://www.its.dot.gov/factsheets/pdf/connected_vehicles_work.pdf. Accessed May 7, 2014.

Policy Issue: Implementation, Governance, Deployment Approach

The two-page infographic highlights why connected vehicles are needed, how a system will work and the roles of government agencies involved in its development.

133 RPT-Fitch: Autonomous Driving not a Short-Term Boost for Automotive Companies. Reuters Magazine, Mar. 4, 2014, www.in.reuters.com/assets/print?aid=INFit69174720140304. Accessed Apr. 18, 2014.

Policy Issue: Implementation, Governance, Risk, Deployment Approach, Financing

"[The report author] believes that automated driving is a central research and development topic for automotive manufacturers and suppliers that could generate major revenue and profit growth in the medium to long term. However, [they] caution against the potential disappointment regarding the scale and speed of return on investment that some investors may expect in the near future." The article highlights that, like electric vehicles, demand is a result of consumer acceptance, not just technology development.

134 S, Julie. Google's New Ad Patent Offers Free Taxi Ride to the Store. HNGN Magazine, Jan. 26, 2014, http://www.hngn.com/articles/22958/20140126/google-new-ad-patent-offers-free-taxi-ride-to-the-store.htm. Accessed Feb. 10, 2014.

Policy Issue: Implementation

Google may soon offer a new transportation service as it combines its online advertising with local transport options like taxis and possibly automated cars. Google was recently granted a patent for arranging free/or minimally priced transportation to advertiser's business locations. With the new service, stores can begin offering not just discounts but also a free taxi ride in a driverless vehicle to those seeking to visit the store.

135 Santo, David. The Self-Driving Car Will Watch Your Every Move. EE Times, Dec. 20, 2013, www.eetimes.com/author.asp?section_id=36&doc_id=1320470. Accessed Feb. 21, 2014.

Policy Issue: Implementation, Privacy, Governance, Risk, Data

According to the article, full autonomy still requires constant driver supervision. There exists no system that can yet match a human driver's ability to respond to the unexpected. As a result, there should be mechanisms in place that allows a car to know when and how much control to relinquish to the driver based on our physical and emotional states. Cars should gather data on the status of the driver so that it can determine his or her concentration, attention, and emotional state that might demand a need for the car to take over control under varying conditions. It also involves the car safely and effectively gaining the driver's attention to inform them that human control is required in a particular situation.

136 Schaen, Scott. Hands-On: 2015 Hyundai Genesis Flirts with Autonomous Driving. Chip Chick Website, Apr. 7, 2014, www.chipchick.com/2014/04/2015-hyundai-genesis.html. Accessed Apr. 18, 2014.

Policy Issue: Implementation

Hyundai is the latest manufacturer to enter the automated vehicle market. The article is a review of all new Genesis features.

137 Schoettle, Brandon and Sivak, Michael. A Survey of Public Opinion about Connected Vehicles in the U.S., the U.K., and Australia. University of Michigan Transportation Research Institute, Apr. 2014.

Policy Issue: Implementation, Privacy, Cyber Security, Governance, Risk, Data, Deployment Approach, Financing

"This survey examined public opinion regarding connected-vehicle technology across three major English-speaking countries—the U.S., the U.K., and Australia. The survey yielded useable responses from 1,596 persons over the age of 18. The main results were as follows: [1)] The majority of respondents had not previously heard of connected-vehicle technology; however, most had a positive initial opinion of the technology[; 2)] The majority felt that the expected benefits presented in the survey are likely to occur[; 3)] Respondents generally expressed a high level of concern regarding the security and performance issues presented in the survey[; 4)] The majority of those surveyed stated that safety was the most important aspect of connected vehicles[; 5)] Most individuals said that it is important for personal communication devices to integrate with connected vehicles, as well as for such vehicles to have Internet connectivity[; 6)] The majority of respondents expressed a desire to have this technology in their vehicle[; and 7)] Willingness to pay for connected-vehicle technology was very similar across the three countries. The main implications of these results are that the general public in the three countries surveyed feel positive about connected vehicles, have optimistic expectations of the benefits (while still maintaining some concerns), and generally desire connected-vehicle technology when it becomes available." – Abstract

138 Schumer Reveals: Cars Collecting Data on Drivers, Allowing Companies to Sell Data to Highest Bidder. LongIsland.com Website, Feb. 15, 2014, www.longisland.com/news/02-25-14/schumer-cars-collecting-data.html?print=1&page=1. Accessed Apr. 18, 2014.

Policy Issue: Implementation, Privacy, Governance, Risk, Data, Legislation

"U.S. Senator Charles E. Schumer [recently] announced that, in light of cars that are collecting reams of data on where Americans drive, he is calling on the [FTC] and [NHTSA] to establish clear guidelines that will require carmakers to notify drivers when they are being tracked and allow drivers to opt out completely from sharing information… The Senator is urging the FTC and NHTSA to work together with the auto industry – and other companies that track vehicular data – to establish clear guidelines around what can and cannot be tracked, and to provide clear opt-out opportunities for drivers. According to a December 2013 report by the [GAO], the collection of location data by carmakers and developers of 'smart-car' technology is a widespread practice. The report revealed that 90% of the companies studied (9 out of 10) share the data they collect with third-party companies."

139 Schwarze, Kelly. Engines Ready: 5 Concept Cars (and Gadgets) We Want to Speed Away in. We Might See These Highlights from the International Motor Show on the Road ... Some Day. Readwrite.com Website, Sep. 20, 2013, www.readwrite.com/series/drive#awesm=~or VSTXSWcWpbbv. Accessed Jan. 9, 2014.

Policy Issue: Implementation

Volvo P1800, Lexus LF-NX, Mercedes Concept S-Class Coupe, Nissan Nismo (with Smartwatch) and Smart Fourjoy all employ futuristic and innovative technology on the road today. The article highlights their systems in more detail.

140 Shaheen, Susan. et al. Survey of U.S. Transportation Officials on the Future of Integrated and Active Transportation Systems. Submitted for consideration for presentation and publication to the 2014 Transportation Research Board Annual Meeting, Washington D.C., Nov. 15, 2013.

Policy Issue: Implementation, Governance, Deployment Approach, Financing

"Recent developments in [ITS] and autonomous and connected vehicles could improve transportation safety and mobility in the [U.S.]. One such development is Integrated Active Transportation Systems (IATS) an integrated, active, and advanced transportation system with the goal of optimizing safety and mobility. Questions remain as to the preparedness of transportation stakeholders and agencies in implementing IATS. This paper presents the results of a survey of U.S. transportation stakeholders. The survey goals include: 1) investigating geographic regions best suited for initial IATS deployment, 2) identifying IATS elements that could be feasibly implemented in the near future, and 3) determining obstacles to deployment in the best suited regions." -Abstract

141 Sharma, Aroma. "Driving the Future: The Legal Implications of Autonomous Vehicles' Conference Recap. Santa Clara Law Review, n.d., www.law.scu.edu/hightech/ autonomousvehicleconfrecap2012/. Accessed Mar. 3, 2014.

Policy Issue: Liability, Implementation, Governance, Risk

In early 2012, the Santa Clara Law Review hosted its annual symposium on the topic of "Driving the Future: The Legal Implications of Autonomous Vehicles." The symposium was one of the first major academic events to explore the legal issues raised by automated vehicles. It featured much discussion on whether existing laws may hinder the realization of automated vehicle benefits. This report is a recap of the symposium.

142 6 Questions States Need to Ask about Self-Driving Cars: As More States Pass Laws Authorizing Testing of Autonomous Vehicles, Key Legal Questions Need to Be Answered. Governing Blog, Aug. 13, 2013, www.governing.com/blogs/fedwatch/gov-six-questions-that-need-to-be-answered-about-self-driving-cars.html. Accessed Mar. 3, 2014.

Policy Issue: Implementation, Risk, Legislation, Deployment Approach

Historically, states regulate drivers and the federal government regulates vehicles. Who should regulate when the vehicle is the driver? The article highlights six key legal questions that states should act when passing laws regarding self-driving cars. They include: 1) "Will drivers need any sort of training?"; 2) "Is it possible to speed?"; 3) "Is distracted driving allowed?"; 4) "Who's liable for accidents?"; 5) "What kind of registration would the vehicle have?" and 6) "How to transition from manual to auto-pilot?"

143 Smith, Aaron. U.S. Views of Technology and the Future: Science in the Next 50 Years. Pew Research Center, Apr. 17, 2014, www.pewinternet.org/files/2014/04/PIP_US-Views-of-Technology-and-the-Future_041714.pdf. Accessed May 8, 2014.

Policy Issue: Implementation, Deployment Approach

"The American public anticipates that the coming half-century will be a period of profound scientific change, as inventions that were once confined to the realm of science fiction come into common usage. This is among the main findings of [this research], which asked Americans about a wide range of potential scientific developments—from near-term advances like robotics and bioengineering, to more "futuristic" possibilities like teleportation or space colonization. In addition to asking them for their predictions about the long-term future of scientific advancement, we [the research] asked them to share their own feelings and attitudes toward some new developments that might become common features of American life in the relatively near future. Overall, most Americans anticipate that the technological developments of the coming half-century will have a net positive impact on society." – From Findings. While not specifically on driverless cars (that "48% [of Americans] would be interested in, while 50% would not"), the research is relevant to American perceptions and desires of technology in the future.

144 Smith, Bryant Walker. Automated Vehicles Are Probably Legal In The United States. The Center for Internet and Society at Stanford Law School, Nov. 1, 2012, www.cyberlaw.stanford.edu/files/publication/files/2012-Smith-AutomatedVehiclesAreProbablyLegalinTheUS_0.pdf. Accessed May 8, 2014.

Policy Issue: Liability, Implementation, Governance, Risk, Legislation

"An invention is not illegal simply because it is new, and a novel activity is not prohibited just because it has not been affirmatively permitted." The study raises a number of questions about both the ultimate design of these automated vehicles and the duties of their human operators, it finds no law that categorically prohibits automated driving. It concludes that even without specific legislation, automated vehicles are probably legal in the United States. Nevada, Florida, and California (states that have already enacted pertinent legislation) did not really ‘legalize’ automated vehicles, as has been popularly reported. Instead, their recent laws primarily regulate automated vehicle technologies. They also endorse the potential of, catalyze important discussions about, and establish basic safety requirements for these long-term technologies. The article explores more detail on legal issues that states may or may not need to address.

145 Smith, Bryant Walker. Driving at Perfection. The Center for Internet and Society at Stanford Law School Blog, Mar. 11, 2013, www.cyberlaw.stanford.edu/blog/2012/03/driving-perfection. Accessed Apr. 2, 2014.

Policy Issue: Liability, Implementation, Governance, Risk, Legislation

In response to the Google Car, the author asks, “Systems fail. Engineers know this. So do lawyers. How can we credibly say, at this point or perhaps at any point, that “[n]othing is going to catch this car by surprise”?”

146 Smith, Bryant Walker. How Do You Ticket a Driverless Car? You May Be Allowed to Text While Outside the Car, But You Can’t ‘Drive’ Drunk. Slate Magazine, Dec. 30, 2012, www.slate.com/articles/health_and_science/new_scientist/2012/12/laws_for_driverless_cars_who_is_responsible_for_crashes_and_traffic_violations.html. Accessed Apr. 2, 2014.

Policy Issue: Liability, Implementation, Governance, Risk, Legislation, Deployment Approach

The article poses one major question: Will tomorrow's cars and trucks have to adapt to today's legal infrastructure, or will that infrastructure adapt to them? Also unclear is the precise responsibility of the human user, assuming one even exists. Under Nevada law, the person who tells a self-driving vehicle to drive legally becomes its driver; these ‘drivers’ can text but cannot ‘drive’ drunk, even if not in the car. For now, the appropriate role of a self-driving vehicle's human operator is not merely a legal question; it is also a technical one. Fortunately, resolving seemingly endless technical questions will allow governments to buy enough time so that they can also address the major legal ones. According to the article, the uncertainty that surrounds these answers will affect the speed and price at which these new technologies are introduced.

147 Smith, Bryant Walker. Planning for the Obsolescence of Technologies Not Yet Invented. The Volokh Conspiracy Blog, Oct. 4, 2013, www.volokh.com/2013/10/04/planning-obsolescence-technologies-yet-invented/. Accessed Apr. 2, 2014.

Policy Issue: Liability, Implementation, Governance, Deployment Approach

Cars of the early 20th Century were essentially beta products, with customers providing the only successful means of vehicle improvement. The author believes that automated vehicles will experience a similar process. Whether through recall, remediation or restitution, this will likely be very costly and difficult. Additional concerns include: 1) isolated incidents involving new products will create feelings of helplessness and panic that unjustifiably stymie their wider adoption and 2) early products will be around years later when they are much less safe than whatever has since become state-of-the-art. Actively managing both sudden and creeping obsolescence within these systems demands the integration of key legal and technological tools into their design and marketing. Foremost are the technical ability and the legal authority to 'virtually' recall a product to automatically update it or remove it altogether.

148 Smith, Bryant Walker. The Impact of Automation on Environmental Impact Statements. The Center for Internet and Society at Stanford Law School Blog, Oct. 1, 2013, www.cyberlaw.stanford.edu/blog/2013/10/impact-automation-environmental-impact-statements. Accessed Mar. 18, 2014.

Policy Issue: Liability, Implementation, Governance, Risk, Deployment Approach

Potential highway expansions typically use a planning horizon of at least twenty years, and yet several automakers now forecast that they will market vehicles with some level of advanced automation within a decade. The ongoing automation of the transportation system in the US could change land use patterns, increase both travel demand and roadway vehicular capacity, and improve the vehicular level of service at capacity. Some of the basic assumptions upon which a project's EIS alternatives analysis is based may be outdated by the time a project alternative is implemented. Currently, a plaintiff may find it difficult to ultimately persuade a court that automated vehicle-based alternatives or impacts require consideration as radical and distant forms of vehicle automation are probably too 'uncommon or unknown' for most courts to reject an EIS that fails to consider them. But this, according to the article, will someday change.

149 Smith, Bryant Walker. The Reasonable Self-Driving Car. The Volokh Conspiracy Blog, Oct. 3, 2013, www.volokh.com/2013/10/03/reasonable-self-driving-car/. Accessed Apr. 2, 2014.

Policy Issue: Implementation, Deployment Approach, Financing

Technologies necessary for full vehicle automation are not yet ready. Engineering challenges will be overcome eventually, but at this point they are varied and very real. A more pressing issue, which manifests itself in law, engineering, and economics, is the imperfect and inconsistent societal view of what is reasonably safe, which determines when a technology is ready in a more meaningful sense. Responsible engineers will not approve, responsible companies will not market, responsible regulators will not tolerate, and responsible consumers will not operate vehicles they believe could pose an unreasonable risk to public safety.

150 Snyder, Tanya. How the Self-Driving Car Could Spell the End of Parking Craters. Streets Blog USA, Mar. 26, 2014, www.usa.streetsblog.org/2014/03/26/how-the-self-driving-car-could-spell-the-end-of-parking-craters/. Accessed Apr. 18, 2014.

Policy Issue: Liability, Implementation, Privacy, Cyber Security, Governance, Risk, Certification, Data, Deployment Approach, Financing

While the author highlights a recent and comprehensive RAND study, the article brings up many commonly heard concerns regarding self-driving vehicles. The article is from an active transportation activist source – a relatively silent stakeholder on this topic. Thus, the article does posed some nuances aimed specifically at bicyclist and pedestrian interface, such as whether an automated car could, like a human driver, identify a bicyclist's or pedestrian's intent.

151 Spieser, Kevin. et al. Toward a Systematic Approach to the Design and Evaluation of Automated Mobility-on-Demand Systems: A Case Study in Singapore, Apr. 2014, www.hdl.handle.net/1721.1/82904. Accessed May 8, 2014.

Policy Issue: Implementation, Data, Financing

"The objective of this work is to provide analytical guidelines and financial justification for the design of shared-vehicle mobility-on-demand systems. Specifically, we consider the fundamental issue of determining the appropriate number of vehicles to field in the fleet, and estimate the financial benefits of several models of car sharing. As a case study, we consider replacing all modes of personal transportation in a city such as Singapore with a fleet of shared automated vehicles, able to drive themselves, e.g., to move to a customer's location. Using actual transportation data, our analysis suggests a shared-vehicle mobility solution can meet the personal mobility needs of the entire population with a fleet whose size is approximately 1/3 of the total number of passenger vehicles currently in operation." – From Abstract

152 Standards to Usher in Autonomous Networked Driving: ITU Debate Focused on Innovative ICT for the Future Networked Car. ITU Press Release, Mar. 11, 2014, www.itu.int/net/pressoffice/press_releases/2014/07.aspx#.U1GkZ01OW72. Accessed Apr. 19, 2014.

Policy Issue: Implementation, Governance, Certification, Data, Legislation

This press release notes the recent symposium where "dynamic high-level discussion involving industry, international agencies and motorsports bodies focused on Innovation for the Future Car… Experts participating in the technical sessions agreed that the technological components for automated driving have reached a level of maturity that will allow rollout in the near future. Agreements on international technical standards and putting in place regulatory requirements are already under way to make it a reality. Participants called for ITU, in collaboration with UNECE, to host a dialogue of senior executives of vehicle manufacturers to identify the activities needed to consider future steps to realize the potential of fully autonomous driving."

153 Study Finds 88 Percent of Adults Would Be Worried about Riding in a Driverless Car. Seapine Software Website, Feb. 3, 2014, www.seapine.com/pr.php?id=217. Accessed Feb. 21, 2014.

Policy Issue: Liability, Implementation, Privacy, Cyber Security, Governance, Risk, Data, Deployment Approach

88 percent of US adults would be worried about riding in a driverless car. 79 percent of US adults think that the equipment in a driverless car will fail, such as a braking software glitch or failed warning sensor that alerts the driver of danger. 59 percent are worried about liability issues, such as who would be responsible if a driverless car is involved in an accident. 52 percent fear a hacker could breach a driverless car's system and gain control of the vehicle. 37 percent worry that automotive companies, insurers, advertisers and municipalities may collect personal data such as where the car goes and how fast it's traveling. Only 12 percent said they would not be worried about riding in a driverless car. The article expands on these statistics.

154 Tannert, Chuck. Can Computers Drive Better than Humans? If Riding in an Autonomous Car Feels Like Ceding Control to a Computer, Humans Will Never Do It. That's Why the Big Brains at QNX and Nvidia Are Working on the Technology That Feels More Human than Human. Fast Company Magazine, Jan. 8, 2014, www.fastcompany.com/3023164/innovation-agents/can-computers-drive-better-than-humans. Accessed Apr. 18, 2014.

Policy Issue: Implementation

Automated cars must be able to react quickly in life-threatening situations. Complicated algorithms demand complicated software that demands a large amount of processing power "to pull off complicated computations so that the car can get you from point A to B without any hiccups… The big challenge is to teach the car to make complex decisions based on all of the input it senses". The article discusses the need for technology power to match 'huManpower'.

155 Tannert, Chuck. Inside the Road Revolution. Fast Company Magazine, Jan. 8, 2014, www.fastcompany.com/3022489/innovation-agents/self-driving-cars-let-go-of-the-wheel. Accessed Apr. 12, 2014.

Policy Issue: Implementation,

"Automakers are sneaking features into their newest models that could earn them billions and save 30,000 lives a year--but only if they can convince you to give up control of your car. Our writer road tests the boldest autonomous innovations." **–** Subtitle

156 Tannert, Chuck. Our Ultimate Driverless Car Report Card. Fast Company Magazine, Apr. 4, 2014, www.fastcompany.com/3028586/most-innovative-companies/our-ultimate-driverless-car-report-card. Accessed Apr. 12, 2014.

Policy Issue: Implementation, Deployment Approach

Before connected vehicles can have much impact on the built environment, 'selling' the concept to drivers must be achieved. This is no easy task. The article highlights efforts

that are being made in the automobile industry to ease the transition (and gives each a letter grade).

157 Tannert, Chuck. Self-Driving Cars: A Crash Course in Communication. Fast Company Magazine, Jan. 8, 2014, www.fastcompany.com/3024360/tech-forecast/driverless-cars-a-crash-course-in-communication. Accessed Apr. 18, 2014.

Policy Issue: Implementation, Governance, Risk, Certification, Legislation, Deployment Approach

The article explores why it has a taken so long for self-driving cars to come to fruition. "[T]he speed at which [V2X] communications come into the mainstream is determined by the speed at which we accept the technologies--a true chicken-and-egg conundrum." The article discusses what needs to happen before vehicles that are equipped with V2X technology are available.

158 Tesla Partners with Israeli Firm for 'Driverless' Cars. Street Insider Website, Feb. 12, 2014, www.streetinsider.com/Insiders+Blog/Tesla+%28TSLA%29+Partners+with+Israeli+Firm+for+Driverless+Cars/9160297.html. Accessed Feb. 21, 2014.

Policy Issue: Implementation

According to the article, Tesla Motors might be able to meet its goal of a mostly-automatic car by 2016. The company has entered into a partnership with Jerusalem-based vehicle safety systems manufacturer Mobileye with the goal developing a driverless car.

159 The Connected Car: Smart Technologies to Reduce Congestion (Intelligent Transport Systems). National Petroleum Council, Topic Paper #5, NPC Future Transportation Fuels Study, Aug. 1, 2012, www.npc.org/FTF_Topic_papers/5-The_Connected_Car.pdf. Accessed May 8, 2014.

Policy Issue: Implementation, Data

This report looks at different ways telematics has been applied across the world, and it looks at the technologies that have been implemented. It talks about the necessary vehicle technology and the necessary vehicle technology required to make Intelligent Transportation System a reality. It covers a few case studies and the challenges associated with them.

160 The Next Generation of Travel: Research, Analysis and Scenario Development - Literature SCAN Report Summary. FHWA Website, Federal Highway Administration Office of Policy and Governmental Affairs, Transportation Studies (HPTS), United States, 2011, www.fhwa.dot.gov/policy/otps/nextgen_htps_scan.htm. Accessed May 8, 2014.

Policy Issue: Implementation, Data, Deployment Approach, Sustainability

The article focuses on youth, but relates to connected vehicles in that young generations are more likely to advocate for and utilize connected vehicle technologies. Mobile phone applications that provide travel information have enabled people to become smarter and more efficient travelers. With these, people can map out routes instantly, avoid congestion, find parking, pay for a transit trip, arrange for carpooling and locate a vehicle using a car sharing service. Younger populations have been especially noted for their preference in using digital directions, rather than reverting to a map or stopping at a gas station. Technologies like GPS, electronic toll collection, vehicle tag recognition, variable message signs and HOT lanes may also become increasingly accepted. As of 2010, over 50 percent of freeway miles have real-time data collection activities, and dynamic message signs have been deployed in nearly 95 percent of all freeway miles.

161 The Road to Self-Driving Cars: Today's Crash-Avoidance Systems are the Mile Markers to Tomorrow's Autonomous Vehicles. Consumer Reports Magazine, Feb. 2014, www.consumerreports.org/content/cro/en/consumer-reports-magazine/z2014/April/theRoadToSelfDrivingCars.print.html. Accessed Apr. 18, 2014.

Policy Issue: Implementation, Deployment Approach

Automated vehicles are not coming, they're already here. At least significant components of them are. Typical of this magazine, the article highlights features that are available on different models. Consumer trust will be key to large-scale deployment.

162 Thurston, Susan. Selmon Expressway Becomes Testing Ground for Automated Vehicles. Tampa Bay Times, Jan. 31, 2014, www.tampabay.com/news/business/autos/selmon-expressway-becomes-testing-ground-for-automated-vehicles/2163702. Accessed Feb. 10, 2014.

Policy Issue: Implementation

Selmon Expressway in Tampa, Florida has become one of ten sites nationwide where researchers can study the safety and performance of automated vehicles. The expressway authority is working with the University of South Florida's Center for Urban Transportation Research to further develop the Selmon Expressway as an automated vehicle test site.

163 Tientrakool, Patcharinee. et al. Highway Capacity Benefits from Using Vehicle-to-Vehicle Communication and Sensors for Collision Avoidance, Columbia University, New York, 2011, www.ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=06093130. Accessed May 8, 2014.

Policy Issue: Implementation,

"Several automobile manufacturers are offering assisted driving systems that use sensors to automatically brake automobiles to avoid collisions. Before extensively deploying these systems, we should determine how they will affect highway capacity. The goal of

this paper is to compare the highway capacity when using sensors alone and when using sensors and vehicle-to-vehicle communication. To achieve this goal, the rules for using both technologies to prevent collisions are proposed, and highway capacity is estimated based on these rules. We show that both technologies can increase highway capacity. The increase in capacity is a function of the fraction of the vehicles that use a technology. If all of the vehicles use sensors alone, the increase in highway capacity is about 43%. [If] all of the vehicles use both sensors and vehicle-to-vehicle communication, the increase is about 273%." - Abstract

164 Van Schijndel-de Nooij, Margriet. et al. Definition of Necessary Vehicle and Infrastructure Systems for Automated Driving. SMART 2010/0064 Study Report (Smart 64), European Commission, Brussels, 2011, www.ec.europa.eu/information_society/activities/esafety/doc/studies/automated/reportfinal.pdf. Accessed May 8, 2014.

Policy Issue: Implementation, Risk, Certification, Legislation, Deployment Approach

Driving is increasingly becoming more complex given electronic technologies and wireless communication. Exchanging information between vehicles, beings and other objects is on the near horizon. While there is some hesitance to completely remove the driver from driving, automated vehicle technology is continuing to develop regardless. This report addresses the challenges of different levels of automated cars and builds upon the state of the art in ADAS, V2V and V2I technologies. Five main conclusions are: 1) there exists an increasing need for deploying the automated driving applications cost-effectively, at the right time, with the right partners, and maybe in a more pragmatic manner; 2) acting in a more resolute manner at the legislative level will make it possible to break the issue of 'public vs private' investment into solvable situations, which could easily be agreed upon for the benefit of all participants in traffic, of the manufacturing industry, and of legislators; 3) implementing a mandatory introduction plan for automated driving does not suffice if the appropriate standardization is not in place at the right time; 4) some missing links exist in the technology, although the world is moving towards filling these gaps through various roadmaps and 5) legislators should embrace now the challenge of preparing in due time an adequate legislative framework that covers maybe more complex issues than liability alone, while allowing for sufficient innovation freedom to enable new technical developments and business models. The report also highlights a list of innovative systems/projects occurring worldwide aimed at implementing semi-automated driving.

165 Volvo Car Group Tests Road Magnets for Accurate Positioning of Self-Driving Cars. Volvo Car Group Global Newsroom Website, Mar. 11, 2014, www.media.volvocars.com/global/en-gb/media/pressreleases/140760/volvo-car-group-tests-road-magnets-for-accurate-positioning-of-self-driving-cars. Accessed Apr. 18, 2014.

Policy Issue: Implementation

This press release highlights a recent "research project using magnets in the roadway to help the car determine its position. The research, which has been financed in strategic cooperation with the Swedish Transport Administration (Trafikverket), is a potential key to the implementation of self-driving vehicles. Reliable and highly accurate positioning is one of the crucial issues in the development of self-driving cars. While established positioning technologies such as GPS and cameras have limitations in certain conditions, road-integrated magnets remain unaffected by physical obstacles and poor weather conditions."

166 Wald, Matthew L. U.S. Plans Car-to-Car Warning System. The New York Times, Feb. 3, 2014, www.nytimes.com/2014/02/04/business/us-plans-car-to-car-warning-system.html?ref= business &_r=1. Accessed Feb. 10, 2014.

Policy Issue: Implementation, Privacy, Governance, Risk, Certification, Data, Deployment Approach, Financing

The article highlights NHTSA's February press release on their decision to move ahead with connected vehicle research. A future report will outline the costs and benefits of a connected vehicle transportation system. Privacy, costs and consistent international adaption remain issues to address.

167 Wallace, Richard and Silberg, Gary. Self-Driving Cars: The Next Revolution. KPMG and Center for Automotive Research, Aug. 2012, www.cargroup.org/?module=Publications& event=View&pubID=87. Accessed May 8, 2014.

Policy Issue: Implementation, Deployment Approach, Sustainability

The automotive industry has always been a force for innovation and economic growth. In the early 21st Century, the pace of innovation is increasing while the industry is on the brink of a new technological revolution with self- driving vehicles. This technology could provide solutions to many transportation-related problems, such as the high costs of traffic crashes and transportation infrastructure, the millions of hours spent in traffic jams, and the wasted urban space dedicated to parking lots. If self-driving vehicles become a reality, the implications would also be profoundly disruptive for nearly every stakeholder associated with the automotive industry – or as one industry executive states, "Everything, from how we move goods to how we move ourselves around, is ripe for change." This paper, includes interviews with more than 25 'thought leaders,' automotive and high- tech executives, and government officials, analyzing industry trends and emphasizing the convergence of sensor-based and communication-based vehicle technologies and its implications.

168 Wang, Ucilia. Driverless Cars are Data Guzzlers: The Self-Driving Car of the Future Will Consume an Enormous Amount of Information. The Wall Street Journal, Mar. 23, 2014, www. online.wsj.com/news/articles/SB10001424052702304815004579417441475998338#printMode. Accessed Apr. 18, 2014.

Policy Issue: Implementation, Privacy, Cyber Security, Risk, Data, Deployment Approach

The article highlights these data-related issues: 1) data gathering; 2) split-second analysis; 3) computing power and 4) security and privacy, to demonstrate challenges to driverless vehicle deployment.

169 Waytz, Adam. How to Stop Worrying and Love the Robot That Drives You to Work. Kellogg Insight Blog, Mar. 3, 2014, www.insight.kellogg.northwestern.edu/article/how_to_stop_worrying_and_love_the_robot_that_drives_you_to_work. Accessed Apr. 18, 2014.

Policy Issue: Implementation

This article is regarding research about how human response to accepting 'robots' performing human-like functions is based largely on how they are able to personally interact with the machine.

170 White, Joseph. The Future, Coming Soon: Self-Driving Cars Mainstream by 2025. The Wall Street Journal Blog, Apr. 17, 2013, www.blogs.wsj.com/corporate-intelligence/2013/04/17/the-future-coming-soon-self-driving-cars-mainstream-by-2025/. Accessed Mar. 14, 2014.

Policy Issue: Implementation, Governance, Risk, Certification

Automobile manufacturers and safety regulators in the U.S. and Europe say they're serious about installing more automated braking and steering systems in cars and trucks for one main reason: most humans are depressingly bad drivers. The article discusses this in more detail.

171 Winter, Drew. U.S. Must Make Safer Cars, Not Wealthier Lawyers. Ward's Auto Blog, Apr. 3, 2014, www.wardsauto.com/blog/us-must-make-safer-cars-not-wealthier-lawyers. Accessed Apr. 18, 2014.

Policy Issue: Liability, Implementation, Risk

"What auto CEO will sign off on an autonomous car if he or she knows they could be thrown in jail for defects real or imagined?" Given recent automotive history, the author thinks the future of automated vehicles may proceed slower than expected.

172 Woodhouse, Kellie. U-M to Triple Number of Talking Cars in Ann Arbor to 9,000 as Connected Vehicle Research Ramps Up. MLive Website, Mar. 25, 2014, http://www.mlive.com/news/ann-arbor/index.ssf/2014/03/university_of_michigan_wants_t_1.html#incart_river_default. Accessed Apr. 2, 2014.

Policy Issue: Implementation, Deployment Approach

Nearly 3,000 wirelessly connected cars, buses, trucks, motorcycles and bikes are already operating throughout northeastern Ann Arbor as a part of a research project conducted by the University of Michigan's Transportation Research Institute (UMTRI) with significant funding from the USDOT. The university wants 9,000 intelligent vehicles operating in Ann Arbor within the next two years. Over the past year and a half, the USDOT closely observed the model deployment and concluded that V2V technology improves road safety - a consideration that may well cause the federal government to require wireless technology in all new cars by the end of the decade. In tripling the number of V2V cars on the road, UMTRI seeks to expand the research to get a more accurate understanding of large-scale connected vehicles deployment.

173 Worstall, Tim. What's the Biggest Obstacle to Google's Driverless Cars? Maybe the Taxi Drivers? Forbes Magazine, Jun. 9, 2013, http://www.forbes.com/sites/timworstall/2013/06/09/whats-the-biggest-obstacle-to-googles-driverless-cars-maybe-the-taxi-drivers/. Accessed Mar. 3, 2014.

Policy Issue: Implementation

The article highlights how self-driving cars have the possibility of entirely transforming (and destroying) the taxi business.

174 Zax, Davis. A World without Car Crashes. The Atlantic Cities Magazine, Feb. 11, 2014, www.theatlanticcities.com/commute/2014/02/world-without-car-crashes/8353/. Accessed Feb. 17, 2014.

Policy Issue: Implementation, Legislation

The University of Michigan's Transportation Research Institute is completing an 18-month large-scale trial of connected vehicle technology. 2,800 vehicles in Ann Arbor participated in the safety pilot, including cars, trucks, tractor trailers, and even a bicycle. The NHTSA has estimated that V2V technology could reduce non-impaired crash scenarios (crashes caused by sober drivers) by 80 percent, greater than seatbelts and airbags. NHTSA recently announced that given the overwhelming safety benefits of connected vehicles, it would soon propose mandating such technology in all new cars.