FUTURE ENVIRONMENT NET ASSESSMENT

Autonomous Vehicles

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Autonomous Vehicles

Executive Summary

Autonomous vehicles collect and process data from their environments, taking actions that can either help or replace drivers. OCIA assesses that these vehicles will benefit society by improving road safety and reducing deaths, injuries, and costs associated with collisions. Autonomous vehicles will also likely lead to a decrease in traffic congestion, decreasing fuel consumption and emissions per mile, and helping save drivers' money and time. However, as vehicles become increasingly connected and a part of the Internet of Things, vulnerabilities and potential consequences are likely to increase unless cybersecurity is better integrated into vehicle design and development. Legal and regulatory gaps exist on issues such as collision liability and safety standards; if these gaps are not addressed, cities and states might implement their own laws and regulations, creating inefficiencies for automobile manufacturers, shipping companies, and drivers. Moreover, fully autonomous vehicles will likely have an adverse effect on the professional driver workforce when bus, taxi, and truck drivers are eventually replaced.

Purpose

Many risks to critical infrastructure that are insignificant in 2017 will evolve and grow in 5 or more years. The U.S. Department of Homeland Security (DHS)/Office of Cyber and Infrastructure Analysis (OCIA) conducts net assessments to help Federal, State, and local decision makers understand these emerging risks and take action to prepare for the future.[1] Autonomous vehicles are an emerging risk that will affect critical infrastructure. This study identifies and examines risks and issues likely to develop as autonomous vehicles become more common throughout the United States, and is intended to help decision makers mitigate potential consequences before they become significant problems.

Background

Autonomous vehicles fall into two classes: fully autonomous or semiautonomous. This report focuses on the consequences from the widespread adoption of fully and semiautonomous vehicles. Further, this report ties in aspects of emerging technologies associated with autonomous vehicles, such as vehicle-to-vehicle (V2V) communication, vehicle-to-infrastructure (V21) communication, and intelligent transportation systems (ITS). ITS gather and use real-time data to inform automated decisions about the function of traffic-related infrastructure and hardware, such as traffic signals.

What Issues are Likely to Develop as Autonomous Vehicle Become Pervasive?

Safety Concerns and Regulations Development: One of the strongest drivers for autonomous vehicle adoption is the vision of fundamental improvements in traffic safety and major reductions in deaths, injuries, and costs associated with motor vehicle collisions. Although many benefits exist, autonomous vehicles will not eliminate all collisions. Some states have proposed or enacted legislation to improve safety, including by requiring these vehicles to meet baseline technological standards. If states develop regulations independently, a variety of inconsistent laws, regulations, and standards might increase costs and uncertainties for vehicle manufacturers and operators, likely impeding autonomous vehicle development and adoption.

Liability Across the Spectrum of Autonomy: Liability and related laws might need updating as vehicle autonomy increases and the level of driver engagement decreases. As of May 2017, laws regarding collision liability rest primarily with vehicle operators, but it is uncertain who will be liable as operators cede more control to vehicles. Liability is particularly complex for semiautonomous vehicles, which differ in their capabilities and require a driver to

[1] Net assessment is an analytic practice that began in the U.S. Department of Defense and emphasizes long-term, strategic analysis. It examines how multiple, competing, and complementary factors and narratives interact and how those interactions are likely to affect the future strategic environment.

be engaged in some role. Laws and regulations in place in some states (or those under consideration) require autonomous technologies to automatically cede full control to human operators in an emergency. This raises concerns, because liability is not always clear for a collision occurring during this transfer. Autonomous vehicle development and adoption could slow depending on how these issues are settled.

Cyber Risk in Autonomous Vehicles: Autonomous vehicles will have many positive benefits for society, but they also introduce new cybersecurity risks. Non-autonomous vehicles are already highly computerized, but components such as tire pressure sensors and braking systems were designed to function independently of each other and other vehicles. As components become more integrated and extend into external networks such as drivers' smartphones and other connected devices, they will become more vulnerable and attractive to hackers. Risks include potential attacks against multiple vehicles at once and an increasing attack surface as more vehicle components become a part of the Internet of Things. A number of stakeholders are working to address autonomous vehicle vulnerabilities, including through improved collaboration among auto manufacturers and the Federal Government. Despite this trend, cybersecurity researchers, consumers, and others expect more progress from regulators and automakers.

Workforce and Industry Displacement, and New Market Creation: Autonomous vehicles might have significant economic benefits among highly concentrated groups of businesses and industries, whereas industry disruption and job losses will produce negative effects spread across a large group of interests. Some industries, including shipping, transit, and technology, are likely to benefit from the growth of autonomous vehicles. However, these same benefits are likely to negatively affect the workforce; many professional drivers will likely lose their jobs, and by some estimates car purchases will drop by nearly two thirds by 2040, affecting auto manufacturers. Uncertainty exists about what new industries will develop and what existing industries will expand. For example, shipping industries might need fewer drivers for their trucks, but they will still need workers to load and unload trucks.

Upfront Investment and Downstream Cost Savings: Autonomous vehicles will likely have many cost-saving benefits in the long term because of fewer collisions and reduced congestion. Vehicle collisions and traffic delays are expensive and cost Americans billions of dollars and hours of wasted time annually. Some stakeholders, however, might be discouraged from investing in autonomous vehicles and supporting technologies because of significant upfront costs. State and local governments, for example, will be key investors in ITS. Their investments will increase the cost savings and safety benefits of autonomous vehicles. However, they might have difficulty justifying spending significant taxpayer dollars on technology that will be beneficial only in the long term.

Changes in Mobility and Urbanization: Autonomous vehicles that allow hands-free driving or provide wireless Internet might result in urban sprawl, widespread movement to suburbs, or both, if commuters realize increased productivity. Autonomous vehicles could also lead to an increase in productivity or new social engagement for populations that face barriers to driving, including people with disabilities and older adults. However, because different segments of the population are likely to adopt autonomous vehicles at different rates, regional, demographic, or other divides could occur.

Changes to Physical Infrastructure Systems: By some estimates, car ownership will drop by more than one-third by 2040. A significant reduction in the number of vehicles within urban areas could lead to a decline in parking lots—a change that would not only affect physical infrastructure and aesthetics of cities, but also inspire economic growth. Additionally, the adoption of autonomous vehicles in urban areas could change the way planners integrate buildings into the surrounding environment. Many of the possible benefits will not be fully realized until a threshold of sufficient smart technology infrastructure is implemented, delaying the need for significant investment. Early planning will be important for decision makers to be able to make smart and timely investment prioritization decisions.

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PURPOSE

Many risks to critical infrastructure that are insignificant in 2017 will evolve and grow in 5 or more years. The U.S. Department of Homeland Security (DHS)/Office of Cyber and Infrastructure Analysis (OCIA) conducts net assessments to help Federal, State, and local decision makers understand these emerging risks and take action to prepare for the future. Although many autonomous vehicle technologies and prototypes exist, they have not been fully implemented throughout the United States. This study is identifies and examines risks and issues likely to develop as autonomous vehicles become more common throughout the United States, and is intended to help decision makers mitigate potential consequences before they become significant problems.

SCOPE

OCIA performed a net assessment that considers issues and interactions at play in the future encompassing various stages of autonomous vehicle implementation. A net assessment is an analytic practice that began in the Department of Defense and emphasizes long-term, strategic analysis. It examines multiple competing and complementary factors and how those interactions are likely to affect the future strategic environment. The net assessment is intended to provide decision makers a more complete understanding of the issues that are likely to arise as autonomous vehicles are adopted and implemented widely throughout the United States.

The net assessment was informed by OCIA research, subject matter expert interviews, and an analysis of the narratives (strongly held beliefs) surrounding autonomous vehicles. Monitor 360, in support of OCIA, used a combined qualitative and quantitative approach to review of thousands of online traditional media and social media to identify and understand the importance of each narrative (see Appendix A for the analysis of the narratives). Understanding the narratives can help decision makers better understand the forces driving autonomous vehicle development, as well as the impediments to adoption.

BACKGROUND

The U.S. Department of Homeland Security (DHS)/Office of Cyber and Infrastructure Analysis (OCIA) produces Infrastructure Risk Assessments to evaluate risks to critical infrastructure. This report addresses how the adoption of autonomous vehicles presents opportunities and risks for critical infrastructure security and resilience.

This report primarily assesses the risks, vulnerabilities, and benefits of autonomous vehicles and analyzes intelligent transportation systems (ITS) issues that overlap with autonomous vehicles. The goal is to help Federal, State, and local analysts and planners incorporate anticipatory thinking into critical infrastructure protection and resiliency efforts relating to autonomous vehicle implementation. The Argonne National Laboratory, DHS/Transportation Security Administration, U.S. Department of Transportation, and the Volpe National Transportation Systems Center provided feedback on this report.

Autonomous vehicle technology enables automobiles to collect and process data from the environments in which they operate and execute safe and efficient commands. Autonomous vehicles can assume decision-making and operational tasks, enabling drivers to become passengers entirely disengaged from the demands of driving. Autonomous vehicles can steer, select optimal speeds, avoid obstacles, choose efficient routes, park themselves, and warn passengers of imminent danger. The majority of autonomous vehicles in development use a deliberative architecture, meaning they are capable of making decisions entirely based on onboard technology—though many are also capable of incorporating external inputs. Autonomous vehicles use a variety of sensors to gather the data necessary for operation, including the following:

- Light detection and ranging (LIDAR) technology uses light pulses to identify lane and road markings and boundaries.
- Global positioning system (GPS) devices gather specific geographic data to inform route selection and other location-based decision-making, often in combination with onboard tachometers, altimeters, and gyroscopes.

- Video cameras track other vehicles and pedestrians while capturing information on traffic lights and road signs.
- Radar sensors track other objects, including vehicles and pedestrians.
- Ultrasonic sensors support parking by capturing data on objects in proximity to autonomous vehicles, including people, curbs, and vehicles.
- A central onboard computer processes inputs from the sensors and issues commands to a vehicle's steering, acceleration, braking, and signaling systems.[2]

The National Highway Traffic Safety Administration (NHTSA) delineates five different levels of vehicle automation (table 1). The taxonomy used by the Society of Automotive Engineers (SAE) International to describe autonomous vehicles varies slightly from that of NHTSA. SAE International uses six levels to distinguish the degree of automation in a vehicle (table 2); however, fully autonomous, driverless vehicles occupy the highest level of automation in both systems.[3] Federal and State regulators typically refer to the NHTSA automation levels, whereas vehicle manufacturers refer to the SAE International automation levels.[4] For this report, OCIA uses the NHTSA automation levels.

TABLE 1—DESIGNATIONS AND DEFINITIONS FOR NHTSA LEVELS OF VEHICLE AUTOMATION[5]

DESIGNATION	NAME	DEFINITION
Level 0	No automation	"The driver is in complete and sole control of the primary vehicle controls—brake, steering, throttle, and motive power—at all times."
Level 1	Function-specific automation	"One or more specific control functions. Examples include electronic stability control or precharged brakes, where the vehicle automatically assists with braking to enable the driver to regain control of the vehicle or stop faster than possible by acting alone."
Level 2	Combined function automation	"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."
Level 3	Limited self-driving automation	"Vehicles…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."
Level 4	Full self-driving automation	"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."

[2] Eddy, John. (2014). "Road Diets and Car Clouds: Shaping the Driverless City." http://doggerel.arup.com/road-diets-and-car-clouds-shaping-the-driverless-city/. Accessed April 8, 2016.
[3] Glancy, Dorothy; Peterson, Robert; and Graham, Kyle. (2015). "A Look at the Legal Environment for Driverless Vehicles." *NCHRP Legal Research Digest* (Pre-publication Draft). http://orfe.princeton.edu/~alaink/SmartDrivingCars/PDFs/LegalNCHRP69Pre.pdf. Accessed August 2, 2016.
[4] Ibid.
[5] U.S. Department of Transportation. (2013). "U.S. Department of Transportation Releases Policy on Automated Vehicle Development." https://www.transportation.gov/briefing-room/us-department-transportation-releases-policy-automated-vehicle-development.. Accessed June 13, 2017.

TABLE 2—DESIGNATIONS AND DEFINITIONS FOR SAE LEVELS OF VEHICLE AUTOMATION[6]

DESIGNATION	NAME	DEFINITION
Level 0	No automation	"the full-time performance by the human driver of all aspects of the dynamic driving task,[7] even when enhanced by warning or intervention systems"
Level 1	Driver assistance	"the driving mode[8]-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"
Level 2	Partial automation	"the driving mode-specific execution by one or more driver assistance system 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"
Level 3	Conditional automation	"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"[9]
Level 4	High automation	"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 quest to intervene"[10]
Level 5	Full automation	"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"

ITS gather and use real-time data to inform automated decisions regarding the function of traffic-related infrastructure. ITS typically include four main elements: sensors that gather information on traffic conditions; automated or manually operated controllers that make changes to traffic control devices (e.g., traffic lights); a central computer to analyze data and suggest system adjustments; and a communications system to link the various components.

ITS will be important for helping cities realize all the potential benefits of autonomous vehicles. For example, an ITS-enabled intersection could have a video camera or an in-ground induction loop sensor to detect the presence of vehicles. These sensors would transmit data to a controller, which could then optimize the function of a traffic signal for traffic conditions. These benefits would further increase as vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication systems are integrated into ITS.[11] For example, a traffic signal could suggest a speed that would allow an approaching autonomous vehicle to arrive at the light as it changes to green, reducing stop and start times and overall congestion.

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[6] Society of Automotive Engineers International. "Automated Driving: Levels of Driving Automation are Defined in New SAE International Standard J3016." http://www.sae.org/misc/pdfs/automated_driving.pdf. Accessed November 30, 2016.

[7] A "dynamic driving task includes the operational (steering, braking, accelerating, monitoring the vehicle and roadway) and tactical responding to events, determining when to change lanes, turn, use signals, etc.) aspects of the driving task, but not the strategic (determining destinations and waypoints) aspect of the driving task." Ibid.

[8] "Driving mode is a type of driving scenario with characteristic dynamic driving task requirements (e.g., expressway merging, high speed cruising, low speed traffic jam, closed-campus operations, etc.)." Ibid.

[9] "Request to intervene is notification by the automated driving system to a human driver that s/he should promptly begin or resume performance of the dynamic driving task." Society of Automotive Engineers International. "Automated Driving: Levels of Driving Automation are Defined in New SAE International Standard J3016." http://www.sae.org/misc/pdfs/automated_driving.pdf. Accessed November 30, 2016.

[10] "Driving mode is a type of driving scenario with characteristic dynamic driving task requirements (e.g., expressway merging, high speed cruising, low speed traffic jam, closed-campus operations, etc.)." Society of Automotive Engineers International. "Automated Driving: Levels of Driving Automation are Defined in New SAE International Standard J3016." http://www.sae.org/misc/pdfs/automated_driving.pdf. Accessed November 30, 2016.

[11] V2V technology uses dedicated short-range communications—similar to Wi-Fi with a range of about 3,000 feet—to allow vehicles to "talk" to one another. Vehicles and trucks on a V2V communication network can send and receive data about their location, speed, and distance relative to other connected cars. V2I technology allows vehicles to communicate with physical infrastructure, such as traffic signals.

Optimism about autonomous vehicles and ITS is widespread among the government, private sector, and others for the safety, productivity, mobility, environmental, and other benefits they will bring. However, significant concerns exist regarding costs, cybersecurity, economic effects, and cultural barriers, among others.

What Issues are Likely to Develop as Autonomous Vehicle Become Pervasive?As part of the net assessment, OCIA examined seven issues that are likely to develop as autonomous vehicles become pervasive in the United States:

- Autonomous vehicles and safety
- Liability across the spectrum of autonomy
- Cyber vulnerabilities in autonomous and semiautonomous vehicles
- Workforce and industry displacement and new market creation
- Upfront investment and downstream cost savings
- Changes in mobility and urbanization
- Changes to physical infrastructure systems

Safety Concerns and Regulations Development

One of the strongest drivers for adopting autonomous vehicles is the vision of fundamental improvements in traffic safety and major reductions in deaths, injuries, and costs associated with motor vehicle crashes.[12]

By some estimates, driver error contributes to more than 90 percent of vehicle collisions, which resulted in more than 33,000 deaths in the United States in 2014.[13,14] More than 29,000 American lives could therefore be saved each year if fully autonomous vehicles eliminate human error as a cause of vehicle collisions. Semiautonomous vehicles will also likely reduce the frequency of collisions through collision detection technologies, automatic braking, and other tools. An analysis by the NHTSA found that the crash rate for semi-autonomous Tesla vehicles installed with Autopilot technology dropped by nearly 40 percent.[15]

Reducing the number of collisions would also have many economic benefits. According to a 2011 study by the American Automobile Association, traffic collisions cost $299.5 billion annually.[16] There would also be longer term cost savings from collision avoidance. In 2014, more than 2.3 million drivers and passengers were treated in U.S. emergency rooms because of motor vehicle collisions. Reducing the number of collisions would decrease immediate healthcare spending both immediately following a collision and long-term spending resulting from permanent or lingering injuries.[17]

Although autonomous vehicles are expected to have an overall positive effect for vehicle safety, they will not eliminate all collisions.[18] Many states are working to enact rules that enhance safety and limit the risk of technology-caused collisions.

[12] *Victoria Transport Policy Institute*; Litman, Todd. (2016). "Autonomous Vehicle Implementation Predictions." http://www.vtpi.org/avip.pdf. p. 4. Accessed December 22, 2016.
[13] Ibid.
[14] Centers for Disease Control and Prevention. "Accidents or Unintentional Injuries." https://www.cdc.gov/nchs/fastats/accidental-injury.htm. Accessed May 22, 2017.
[15] Geuss, Megan. (2017). "After fatal Tesla crash probe, US regulators conclude there's no need for recall." *Ars Technica*. https://arstechnica.com/cars/2017/01/after-fatal-tesla-crash-probe-us-regulators-conclude-theres-no-need-for-recall/. Accessed March 7, 2017.
[16] Cambridge Systematics. (2011). "Crashes vs. Congestion – What's the Cost to Society?" *American Automobile Association*. http://newsroom.aaa.com/wp-content/uploads/2011/11/2011_AAA_CrashvCongUpd.pdf. p. ES-2. Accessed December 23, 2016.
[17] Centers for Disease Control and Prevention. (2016). "Injury Prevention & Control: Motor Vehicle Safety." https://www.cdc.gov/Motorvehiclesafety/seatbelts/facts.html. Accessed December 19, 2016.
[18] Valdes-Dapena, Peter. (January 19, 2017). "Tesla Autopilot not defective in fatal crash." *CNN*, http://money.cnn.com/2017/01/19/technology/tesla-investigation-closed/index.html. Accessed March 7, 2017.

As of 2016, at least 33 states and Washington, D.C. have proposed or enacted legislation related to autonomous vehicles, some of which requires automakers to comply with a range of specific design requirements.[19] Some lawmakers and regulators are developing safety requirements in an attempt to ensure that autonomous vehicles meet baseline technological standards.[20,21] Some state transportation departments argue that a priority is to adopt laws to ensure drivers have a proper understanding of autonomous vehicles, and in some cases, laws that define safe autonomous vehicle technological function. Examples of the former include modifications to driver training and education and revised insurance requirements.

If states develop regulations independently, it is possible that a variety of inconsistent laws, regulations, and standards will create uncertainties for vehicle manufacturers and drivers. This would potentially impede autonomous vehicle development and adoption.[22] Some groups, therefore, argue for a national approach that standardizes minimum safety requirements across the United States, although concern exists that this would reduce flexibility, which OCIA assesses could increase costs for automakers.[23] The NHTSA is recommending a framework for states to help take a common approach to autonomous vehicle operator-licensing programs and on-road testing.[24] This approach includes developing a model state policy on automated vehicles as a path to a national policy, and suggests that a focus on policy homogeneity must increase.[25,26]

Liability Across the Spectrum of Autonomy

Liability and related laws might need updating as vehicle autonomy increases and the level of driver engagement in the operation of the vehicle decreases.

As of 2017, laws related to collision liability rest primarily with the operator of a vehicle; but, as operators cede more control to vehicles, liability is uncertain. Some automakers—including Volvo and Mercedes-Benz—anticipate liability shifts and have pledged to accept more responsibility for collisions that occur while using their technologies. However, many other automakers have yet to make similar pledges.[27,28] Florida's proposed legislation includes requirements that operators obtain, "an instrument of insurance, surety bond or self-insurance," and other states have included provisions that ensure drivers have some degree of responsibility for an autonomous vehicle's safe operation.[29]

Liability is particularly complex for semiautonomous vehicles, which differ in their level of autonomy capabilities and require a driver to be engaged in some role.

Some related laws and regulations (or those under consideration) require autonomous technologies to cede full control of the vehicle to a human operator in an emergency. Jim McBride, autonomous vehicles expert at Ford, notes that this "can pose difficulties" and is why he is "focused on getting Ford straight to Level 4 [full-automation,

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[19] National Conference of State Legislators. (2016). "Autonomous - Self-Driving Vehicles Legislation." http://www.ncsl.org/research/transportation/autonomous-vehicles-legislation.aspx. Accessed February 23, 2016.
[20] Ibid.
[21] General Assembly of North Carolina Session 2015. (2015). Senate Bill 600 – A Bill to be Entitled an Act to Direct the Division of Motor Vehicles to Study How to Implement Autonomous Vehicle Technology on the Roads and Highways of this State, as Recommended by the Department of Transportation. http://www.ncga.state.nc.us/Sessions/2015/Bills/Senate/HTML/S600v2.html. Accessed December 23, 2016.
[22] Monitor 360 interview with expert in subject matter. (2016).
[23] Golson, Jordan. (2015). "California wants to keep autonomous cars from being autonomous." https://www.theverge.com/2015/12/16/10325672/california-dmv-regulations-autonomous-car. Accessed April 10, 2016.
[24] U.S. Department of Transportation. (2016). "Secretary Foxx Unveils President Obama's FY17 Budget Proposal of Nearly $4 Billion for Automated Vehicles and Announces DOT Initiatives to Accelerate Vehicle Safety Innovations." https://www.transportation.gov/briefing-room/secretary-foxx-unveils-president-obama%E2%80%99s-fy17-budget-proposal-nearly-4-billion. Accessed May 5, 2017.
[25] Ibid.
[26] U.S. Department of Transportation. (2013). "U.S. Department of Transportation Releases Policy on Automated Vehicle Development." https://www.transportation.gov/briefing-room/us-department-transportation-releases-policy-automated-vehicle-development. Accessed May 13, 2016.
[27] Korosec, Kirsten. (2015). "Volvo CEO: We Will Accept All Liability When Our Cars are in Autonomous Mode." http://fortune.com/2015/10/07/volvo-liability-self-driving-cars/. Accessed April 8, 2016.
[28] Bigelow, Peter. (2015). "Can't Accept Autonomous Liability? Get Out of the Game, Says Volvo." http://www.autoblog.com/2015/10/09/volvo-accept-autonomous-car-liability/. Accessed April 8, 2016.
[29] National Conference of State Legislators. (2016). "Autonomous - Self-Driving Vehicles Legislation." http://www.ncsl.org/research/transportation/autonomous-vehicles-legislation.aspx. Accessed February 23, 2016.

driverless]…we're not going to ask the driver to instantaneously intervene—that's not a fair proposition."[30] Depending on how laws and regulations are written, even fully autonomous vehicles could be required to cede vehicle control to a human driver, potentially increasing the risk of a collision. If a collision occurs as an autonomous vehicle is transferring control to a human operator, it could fall into a liability grey area.[31,32]

Autonomous vehicle development and adoption could slow depending on how these issues are settled, especially when a collision occurs. Auto manufacturers may slow the development of autonomous vehicles if they are to be liable, but drivers could become more wary of autonomous vehicles if they are liable.

Cyber Risk in Autonomous Vehicles

Newer vehicles are no longer solely physical assets, but are now part of the Internet of Things.[33] This has many benefits, but also introduces new cyber risks.

Vehicles are highly computerized with anti-lock brake systems, tire pressure sensors, rear-view cameras, and other technologies, but until recently they functioned independently of other networks and other vehicles. In 2017, automobile manufacturers often advertise how their vehicles can connect to Bluetooth enabled devices, the Internet, or a central computer that monitors multiple systems within a vehicle. Apple and Google have developed apps for integrating their iOS and Android mobile operating systems into more than 100 models of automobiles.[34,35]

As these and other new technologies become more integrated within vehicles, the risks of cyber attacks will increase. Cybersecurity researchers, Charlie Miller and Chris Valesek, demonstrated in 2015 that they could hack a 2014 Jeep Cherokee and control the vehicle's transmission and brakes.[36] Several days after this demonstration, Chrysler announced a 1.4 million vehicle recall.[37] Additionally, as vehicles integrate extended networks and more personal information from drivers' smartphones and other connected devices, they could become more attractive to cyber criminals seeking to steal personal information.

A range of stakeholders are working to address autonomous vehicle vulnerabilities, including improved collaboration among auto manufacturers and the Federal Government.

According to a U.S. Department of Transportation (DOT) official, "cybersecurity is a difficult area from a regulatory standpoint, because it moves so quickly. Having guiding principles and best practices developed with the industry that everyone buys into…will lead to action more quickly than through the regulatory process."[38]
In response to the growing cyber risk, automakers are collaborating with regulators, cybersecurity researchers, and the DOT to address the known and emerging cybersecurity issues. In January 2016, General Motors implemented a vulnerability disclosure program, which encourages security researchers to disclose the results of their hacking research to General Motors.[39] Also in 2016, the DOT and 18 automakers pledged to, "develop appropriate means for engaging with cybersecurity researchers as an additional tool for cyber threat identification

[30] Reese, Hope. "Autonomous Driving Levels 0 to 5: Understanding the Differences." http://www.techrepublic.com/article/autonomous-driving-levels-0-to-5-understanding-the-differences/. Accessed December 23, 2016.
[31] Yeomans, Gillian. (2014). "Autonomous Vehicles – Handing Over Control: Opportunities and Risks for Insurance." *Lloyd's*. http://www.lloyds.com/~/media/Lloyds/Reports/Emerging%20Risk%20Reports/Autonomous%20Vehicles%20FINAL.pdf. p. 15. Accessed December 23, 2016.
[32] Monitor 360 interview with subject matter expert. (2016).
[33] The Internet of Things is "the connection of systems and devices with primarily physical purposes (e.g., sensing, heating and cooling, lighting, motor actuation, transportation) to information networks (to include the Internet)…" U.S. Department of Homeland Security. (2016). Strategic Principles for Security the Internet of Things. U.S. Department of Homeland Security. https://www.dhs.gov/sites/default/files/publications/Strategic_Principles_for_Securing_the_Internet_of_Things-2016-1115-FINAL_v2-dg11.pdf. p. 2. Accessed March 8, 2017.
[34] Yeomans, Gillian. (2014). "Autonomous Vehicles – Handing Over Control: Opportunities and Risks for Insurance." *Lloyd's*. http://www.lloyds.com/~/media/Lloyds/Reports/Emerging%20Risk%20Reports/Autonomous%20Vehicles%20FINAL.pdf. p. 18. Accessed December 23, 2016.
[35] Monitor 360 interview with expert in subject matter.
[36] Greenberg, Andy. (2016). "Feds Prod Automakers to Play Nice with Hackers." http://www.wired.com/2016/01/feds-prod-automakers-to-play-nice-with-hackers/. Accessed April 8, 2016.
[37] Ibid.
[38] Ibid.
[39] Ibid.

and remedy."[40] A DOT representative remarked on the pledge stating that, "We think it's a fairly significant change in tone: There have been mixed approaches in the industry as to how to interact with independent researchers who find [security] exploits."[41] The NHTSA and the broader DOT have expressed a continued commitment to work with the auto industry to publish a specific set of best practices on cybersecurity.[42]

Despite the trend toward collaboration, cybersecurity researchers and consumers expect more progress from regulators and automakers.

There are concerns that government and automakers are moving too slowly to address cybersecurity issues. A January 2016 WIRED article noted that, "when researchers from the University of California at San Diego and the University of Washington revealed a hacking technique that would allow dangerous levels of control over OnStar-enabled General Motors vehicles, NHTSA allowed General Motors to take nearly 5 years to fully patch its flaws."[43] One of the cybersecurity researchers who hacked the Jeep Cherokee expressed a view on public-private sector cybersecurity progress stating that, although "I hope there will be more interaction between the security community and manufacturers and OEMs [Original Equipment Manufacturers]… I'll believe it when I see it," indicating the researcher might believe that automakers are not serious about cybersecurity.[44]

Workforce and Industry Displacement, and New Market Creation

Autonomous vehicles might have significant economic benefits among highly concentrated groups of businesses and industries, whereas a large but disparate group of interests could be negatively affected through industry disruption and job losses.

Some industries, including shipping, transit, and technology companies, are likely to benefit from the growth of autonomous vehicles. In 2015, a study by the Boston Consulting Group predicted that autonomous vehicles could create a $42 billion market by 2025.[45] Shipping companies will move toward autonomous vehicles to reduce the costs of labor.[46] The use of specialized automated trucks in Australia and Chile have encouraged autonomous trucking tests in the United States by Freightliner-Daimler, Volvo, and Peterbilt.[47] Autonomous freight trains and unstaffed cargo vessels might also be on global sea lanes by 2020.[48] New pathways for autonomous vehicle technology might include crowdsourced autonomous taxi fleets like Uber and Lyft, and autonomous buses or shuttles.[49,50] According to a January 2016 report from the *Economist*, "Once [these organizations] are able to dispense with drivers for their vehicles, the taxi, car-club and car-sharing businesses will in effect merge into one big, convenient and affordable alternative to owning a car," suggesting that one consolidated industry might emerge where there are currently several, likely putting companies out of business and some people out of work.[51]

Autonomous vehicles are highly likely to negatively affect some industries and workforces. Many professional drivers—such as commercial truckers and shippers, public transport operators, and taxi drivers—will likely lose their jobs. According to the U.S. Bureau of Labor Statistics, close to 4 million people drive for a living, not including

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[40] Greenberg, Andy. (2016). "Feds Prod Automakers to Play Nice with Hackers." http://www.wired.com/2016/01/feds-prod-automakers-to-play-nice-with-hackers/. Accessed April 8, 2016.
[41] Ibid.
[42] Ibid.
[43] Ibid.
[44] Ibid.
[45] Green, Jeff. "Driverless-Car Global Market Seen Reaching $42 Billion by 2025." http://www.bloomberg.com/news/articles/2015-01-08/driverless-car-global-market-seen-reaching-42-billion-by-2025. Accessed April 8, 2016.
[46] Kuehn, Jason and Reiner, Juergen. (2015). "Self-Driving Trucks Could Rewrite the Rules for Transporting Freight." http://www.forbes.com/sites/oliverwyman/2015/12/08/self-driving-trucks-could-rewrite-the-rules-for-transporting-freight/#20234cc168e4. Accessed April 8, 2016.
[47] Ibid.
[48] Tovey, Alan. "Crewless 'Drone Ships' will be Sailing the Seas by 2020." http://www.telegraph.co.uk/business/2016/04/09/crewless-drone-ships-will-be-sailing-the-seas-by-2020/. Accessed December 27, 2016.
[49] Shahani, Aarti. (2016). "Lyft, GM Team Up to Create Fleet of Driverless Cars." http://www.npr.org/sections/thetwo-way/2016/01/04/461922098/lyft-gm-teaming-up-to-create-fleet-of-driverless-cars. Accessed December 22, 2016.
[50] Hars, Alexander. "Baidu Expects Autonomous Buses to Become First Wave of Self-Driving Vehicles." http://www.driverless-future.com/?m=201601. Accessed April 8, 2016.
[51] *The Economist*. (2016). "The Driverless, Car-Sharing Road Ahead." http://www.economist.com/news/business/21685459-carmakers-increasingly-fret-their-industry-brink-huge-disruption. Accessed December 23, 2016.

Uber and Lyft.[52] These drivers, who earn an average of $37,280 annually, could be displaced by the introduction of autonomous vehicles.[53] Automakers and their employees could also be adversely affected, especially if private vehicle ownership and annual vehicle purchases decrease. Barclays Bank predicts that U.S. household car ownership will drop from 2.1 to 1.2 vehicles by 2040, and annual sales of personal vehicles will decline from 11 million to 3.8 million.[54] This expected decline is in part based on analysis that millennials drive less than baby boomers; but, competing analysis reported by Kelley Blue Book suggests that 92 percent of millennials own or are planning to own a car.[55,56]

Uncertainty also exists for what new industries will develop, and what existing industries will expand. Shipping companies might not need drivers for their trucks, but they will still need workers to load and unload trucks. This is similar to the online shipping revolution, which reduced employment in brick and mortar shops but increased the number of jobs on the backend, either in customer service or in warehouses. Automated shipping could reduce the number of jobs for drivers, but could increase the number of jobs in other related fields.

Upfront Investment and Downstream Cost Savings

Autonomous vehicles will likely have many long-term cost-saving benefits because of fewer collisions and reduced congestion.

A 2015 report by the NHTSA quantified the economic effect of vehicle collisions annually at $242 billion, "the equivalent of nearly $784 for each of the 308.7 million people living in the United States, and 1.6 percent of the $14.96 trillion real U.S. Gross Domestic Product for 2010."[57] The report also concluded that public revenue pays for 7 percent of vehicle collision costs, federal entities pay 4 percent, and states and localities provide the remaining 3 percent.[58] A Brookings Institution study from 2015 estimates that based on these numbers, the adoption of autonomous vehicles and the decline in crashes would save taxpayers an estimated $10 billion each year.[59] Additionally, in 2014, vehicles were delayed by 6.9 billion hours, wasting approximately 3.1 billion gallons of fuel, and this number is projected to rise to 8.3 billion by 2020.[60] Studies by the Texas A&M Transportation Institute and the American Society of Civil Engineers estimate that congestion in the United States costs more than $140 billion per year because of lost productivity, extra fuel used, and additional vehicle maintenance.[61,62]

A 2013 study by McKinsey and Company estimates savings between $200 billion and $1.9 trillion per year by 2025 as a result of autonomous and semiautonomous vehicle adoption, whereas Morgan Stanley estimates economic savings of $1.3 trillion per year adoption.[63,64] In 2015, the Brookings Institution concluded that autonomous

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[52] *Bureau of Labor Statistics*. (2017). "May 2016 National Occupational Employment and Wage Estimates United States." http://www.bls.gov/oes/current/oes_nat.htm#53-0000. Accessed May 22, 2017.
[53] *Bureau of Labor Statistics*. (2017). "May 2016 National Occupational Employment and Wage Estimates United States." http://www.bls.gov/oes/current/oes_nat.htm#53-0000. Accessed May 22, 2017.
[54] *The Economist*. (2016). "The Driverless, Car-Sharing Road Ahead." http://www.economist.com/news/business/21685459-carmakers-increasingly-fret-their-industry-brink-huge-disruption. Accessed December 23, 2016.
[55] Sivak, Michael; Schoettle, Brandon. (2016). "Recent Decreases in the Proportion of Persons with a Driver's License across All Age Groups." http://www.umich.edu/~umtriswt/PDF/UMTRI-2016-4_Abstract_English.pdf. Accessed December 22, 2016.
[56] DeLorenzo, Matt. (2016). "Shocker! Gen Z Wants Cars." https://www.kbb.com/car-news/all-the-latest/this-week-in-car-buying-shocker-gen-z-wants-cars/2100000447/. Accessed December 27, 2016.
[57] U.S. Department of Transportation. (2015). "The Economic and Societal Impact of Motor Vehicle Crashes, 2010 (Revised)." *National Highway Traffic Safety Administration*. https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812013. p. 5. Accessed December 27, 2016.
[58] Ibid.
[59] Desouza, Kena; Fedorschak, Kevin. (2015). "Autonomous Vehicles Will Have Tremendous Impacts on Government Revenue." http://www.brookings.edu/blogs/techtank/posts/2015/07/07-autonomous-vehicle-revenue. Accessed April 8, 2016.
[60] Texas A&M Transportation Institute and INRIX. (2015). "2015 Urban Mobility Scorecard." http://d2dtl5nnlpfr0r.cloudfront.net/tti.tamu.edu/documents/mobility-scorecard-2015.pdf. Accessed March 16, 2017.
[61] Ibid.
[62] The Economic Development Research Group, Inc. (2016). "Failure to Act: Closing the Infrastructure Investment Gap for America's Economic Future." American Society of Civil Engineers.
[63] Morgan Stanley Research Global. (2013). "Self-Driving the New Auto Industry Paradigm." *Morgan Stanley*. http://orfe.princeton.edu/~alaink/SmartDrivingCars/PDFs/Nov2013MORGAN-STANLEY-BLUE-PAPER-AUTONOMOUS-CARS%EF%BC%9A-SELF-DRIVING-THE-NEW-AUTO-INDUSTRY-PARADIGM.pdf. p. 7. Accessed April 8, 2016.
[64] Manyika, James, et al. (2013). "Disruptive Technologies: Advances That Will Transform Life, Business, and the Global Economy," *McKinsey Global Institute*. http://www.mckinsey.com/business-functions/digital-mckinsey/our-insights/disruptive-technologies. p. 78. Accessed December 27, 2016.

vehicles will lead to cost savings for governments even if the public sector does not innovate, but OCIA assesses these cost savings will be less significant or slower to realize without government support.[65]

Some stakeholders, however, might be discouraged from investing in autonomous vehicles and their supporting technologies because of significant upfront costs or lack of public support.

State and local governments will be key investors in ITS, and when joined with autonomous vehicle technologies, cost savings and safety benefits will increase. However, they might have difficulty justifying spending significant taxpayer dollars, especially if existing infrastructure is in good condition. This is especially true given that economic benefits will most likely be distributed unevenly, with a relatively small number of people and companies receiving the majority of the benefits. Governments will likely realize indirect benefits over a longer period, while the private sector likely will realize the returns on investments more quickly.[66] As a result, some State and local governments might choose to wait until infrastructure is in poor condition and needs replacement before installing ITS infrastructure. Government investment delays will also prolong the potential benefits.

Widespread autonomous vehicle adoption will also potentially reduce State and local government revenues by reducing the number of traffic violations; parking fees; and taxes on fuel, taxi drivers, and other revenue-generating elements of the driver and privately owned vehicle-based system. In 2014, Los Angeles city generated approximately $161 million from parking violations.[67] In 2009, impounds in California brought in more than $40 million in revenue for local governments and towing companies.[68]

Changes in Mobility and Urbanization

Fully autonomous vehicles that allow commuters to take their hands off the wheel, and network-connected vehicles in which commuters can use wireless Internet during travel, could result in urban sprawl, widespread movement to suburbs, or both.

People may be willing to travel farther if autonomous vehicles allow them to work, sleep, or accomplish other tasks during their commute, which could reverse current urbanization trends. Urbanization is motivated in part by the desire to be closer to work. According to a 2015 report by the National Association of Realtors, approximately 20 percent of respondents purchased a home because it was convenient to their job.[69] Urbanization has many benefits, including improved access to education and health services, economic efficiencies, and job growth. However, there are likely to be negative consequences if populations extend beyond traditional urban boundaries.[70] To meet demands, State and local governments might need to increase public expenditures on infrastructure such as sewer collection systems, water distribution lines, and power lines.[71]

Autonomous vehicles could lead to more productivity or new social engagement for populations that face barriers to driving, including people with disabilities and older adults.

According to a 2015 survey by the Kessler Foundation, more than 25 percent of those with disabilities report a lack of transportation.[72] As of 2017, there are approximately 50 million U.S. residents over the age of 65, and this

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[65] Desouza, Kena; Fedorschak, Kevin. (2015). "Autonomous Vehicles Will Have Tremendous Impacts on Government Revenue." http://www.brookings.edu/blogs/techtank/posts/2015/07/07-autonomous-vehicle-revenue. Accessed April 8, 2016.
[66] Monitor 360 interview with subject matter expert. (2016).
[67] Alpert Reyes, Emily. (2014). "Group wants to revamp how L.A. collects parking ticket revenue." *Los Angeles Times*. http://www.latimes.com/local/cityhall/la-me-parking-fine-cap-20140613-story.html. Accessed March 27, 2017.
[68] *PBS News Hour*. (2011). "California to Stop Towing, Impounding Vehicles of Unlicensed Drivers." http://www.pbs.org/newshour/rundown/california-impounding-practices-change-for-unlicensed-drivers/. Accessed March 27, 2017.
[69] Riggs, Amanda. (2016). "How Commuting Costs Factor into Home Buying." http://economistsoutlook.blogs.realtor.org/2016/02/02/how-commuting-costs-factor-into-home-buying/. Accessed April 8, 2016.
[70] Wirth, Anthony; Rasmussen, Marc. (2015). "US Urbanization Trends: Investment Implications for Commercial Real Estate." *CBRE Global Investors*. www.cbreglobalinvestors.com/research/publications/documents/special%20reports/us%20urbanization%20trends_JAN%202015.pdf. Accessed December 22, 2016.
[71] Siedentop, Stefan; Fina, Stefan. "Urban Sprawl Beyond Growth: the Effect of Demographic Change on Infrastructure Costs." *Cairn*. http://www.cairn.info/article.php?ID_ARTICLE=FLUX_079_0090. Accessed April 12, 2016.
[72] Kessler Foundation. (2015). "2015 National Employment & Disability Survey: Executive Summary." http://kesslerfoundation.org/sites/default/files/filepicker/5/KFSurvey2015_ExecutiveSummary.pdf. p. 2. Accessed May 22, 2017

number is predicted to grow to almost 90 million by 2050.[73] Autonomous vehicles will help keep this population mobile as age and physical conditions potentially create driving barriers.[74]

Different segments of the population will possibly adopt autonomous vehicles at different rates, potentially resulting in regional, demographic, or other divides.

Although autonomous vehicle adoption is likely in urban and suburban communities, a similar adoption of the technology in rural areas is less uncertain.[75] McKinsey and Company's 2016 analysis observes that, "cities provide sufficient scale for new mobility business models, [while] by contrast, in rural areas, where low density creates a barrier to scale, private car usage will remain the preferred means of transport." [76] The culture of private vehicle ownership and driving might also be stronger in rural populations.[77] If autonomous vehicle implementation is limited to urban and suburban areas, which become dependent on ITS, rural regions that lack the appropriate infrastructure could face barriers to societal and economic integration, further deepening regional divides.

Changes to Physical Infrastructure Systems

A significant reduction in the number of vehicles within urban areas could lead to a decline in parking lots—a change that would not only affect physical infrastructure and aesthetics of cities but could also inspire economic growth.

In some U.S. cities, parking garages and lots occupy one-third of city space.[78] Estimates show that the total surface area of parking lots in the United States comprises a combined area larger than Puerto Rico, a significant amount of underused real estate.[79] Economic benefits could accrue if autonomous vehicles decrease the amount of space needed for parking lots, or allow parking lots to be moved farther from population centers. Boston's Seaport District, for example, once a 1,000 acre "decrepit no man's land of parking lots," has transformed into the city's waterfront "Innovation District," attracting new biotechnology pharmaceutical and energy companies.[80] Parking lots could also be repurposed for apartments and condominiums, something that would be especially useful for cities where housing is limited because of space limitations.

Adoption of autonomous vehicles in urban areas could change the ways that buildings will need, or have the opportunity to, integrate with their surrounding environment and vice versa.

Access features ubiquitous in many buildings could become outdated, affecting the design and operation of buildings and other facilities in the Healthcare and Public Health, Emergency Services, Commercial Facilities, and other infrastructure sectors. The constant flow of data among vehicles and infrastructure will likely be significant and might require communications infrastructure in urban areas to be updated to handle the additional data.[81] The benefits of autonomous vehicles can be optimized only if the flow of data is continuous.[82]

Many of the possible positive implications will not provide significant benefit until a threshold of sufficient smart technology infrastructure is implemented, delaying the need for significant investment. Early planning will be

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[73] U.S. Census Bureau. (2017). "An Aging Nation." https://www.census.gov/library/visualizations/2017/comm/cb17-ff08_older_americans.html. Accessed May 22, 2017.
[74] Lawrence, Erik. (2014). "When Should Elderly People Stop Driving?" http://www.usatoday.com/story/news/nation/2014/01/20/when-should-elderly-people-stop-driving/4659103/. Accessed April 8, 2016.
[75] McKinsey & Company. (2016). "Automotive Revolution – Perspective Towards 2030." *Advanced Industries*. https://www.mckinsey.de/files/automotive_revolution_perspective_towards_2030.pdf. pp. 9 and 10. Accessed December 27, 2016.
[76] Ibid.
[77] *Victoria Transport Policy Institute*; Litman, Todd. (2016). "Autonomous Vehicle Implementation Predictions." http://www.vtpi.org/avip.pdf. p. 17. Accessed December 22, 2016.
[78] Dizikes, Peter. (2012). "Lots of trouble: In a new book, an MIT urban planner rethinks the mundane, ubiquitous parking lot," http://news.mit.edu/2012/parking-lot-redesign-0313. Accessed April 8, 2016.
[79] Ibid.
[80] Baker, Mathew; Vogel, Chris; and Doyle, Patrick. (2012). "The Rise of the Seaport." http://www.bostonmagazine.com/2012/07/rise-seaport-district-boston/. Accessed April 8, 2016.
[81] Monitor 360 interview with subject matter expert. (2016).
[82] Ibid.

important for decision makers to make smart and timely investment prioritization decisions. A compounding effect could occur in which incremental infrastructure development could lead to more rapid development.

CONCLUSION

Although autonomous vehicles will offer many benefits to society, many concerns exist with the technology. For example, already vehicles are vulnerable to cyber attacks. Because of reliance on an increasing number of connected systems, autonomous vehicle vulnerabilities and consequences are likely to increase until cybersecurity becomes better integrated into vehicle design and development. Also, a number of legal and regulatory gaps exist involving accident liability and safety standards. These gaps could increase the production cost of autonomous vehicles and slow the adoption rate, thus dampening the benefits that autonomous vehicle technologies offer. Additionally, concerns exist that fully autonomous vehicles will have a major effect on the economy, potentially costing millions of bus, taxi, and truck drivers their jobs. Autonomous vehicles could be extremely beneficial for society, but risky. Addressing these risks quickly and effectively will help maximize the benefits offered by vehicle automation.

APPENDIX A. NARRATIVE ANALYSIS

As part of this net assessment, Monitor 360, in support of OCIA, conducted a narrative analysis where thousands of online traditional media and social media sources were collected and analyzed using a combined qualitative and quantitative approach to identify and understand the narratives (strongly held beliefs and assumptions) surrounding a topic. Narratives are useful to understand because, while beliefs can be irrationally optimistic or pessimistic, they still drive decisions. For example, men and women who are afraid of flying, despite it being a statistically safer alternative to other modes of transportation, either spend more money and lose time when travelling, or do not travel at all. If enough people hold a belief, it can drive government and business decision makers to sub-optimal choices. Decision makers who understand the narratives surrounding autonomous vehicles will better understand the forces driving autonomous vehicle development, as well as the impediments to adoption.

The narrative analysis for autonomous vehicles includes three quantitative or qualitative metrics: Narrative Overview (the key narratives regarding a topic), Narrative Importance (the relative importance of each narrative), and Narrative Relationship (the relative importance of each narrative to different stakeholders).

Narrative Overview

The Narrative Overview for autonomous vehicles reveals 11 narratives (see table 3) spanning policy, economic, and sociocultural themes, and reflect both the optimism and concern surrounding autonomous vehicles. These narratives represent the dominant themes in what the engaged public (e.g., thought leaders, corporate leaders, journalists, policymakers, technologists, consumers, and others) are writing about, reading, and discussing online. They convey a combination of fact and belief about autonomous vehicles. Fact-based and belief-based themes in the online discourse both contribute to the analysis. Although the importance of facts can be self-evident, beliefs are often an important driver of actions—in this case, actions related to the adoption, risks, and benefits of autonomous vehicles.

TABLE 3—NARRATIVES AND CATEGORIES

CATEGORY	NARRATIVE TITLE
Supportive narratives about autonomous vehicles	Transforming Our Way of Life
	Expanding Interconnectedness
	Car Sharing Is the Future
	V2V–V2I Improves Safety
	The End of Human Road Hazards
	Holding the Industry Back
Oppositional narratives about autonomous vehicles	Vulnerable to Hacking
	Disruptive Market Force
	Unlikely to Take Off
Neutral narratives about autonomous vehicles	Government Investing in the Future
	Many Speed Bumps Along the Way

The Narrative Overview reveals widespread public recognition of the benefits from autonomous vehicles. These benefits include, but are not limited to, improved road safety, economic growth, decreased urban congestion, and increased productivity. Narratives that support the emerging transformation of the U.S. transportation system might influence and sustain autonomous vehicles and provide insight into why and how people are likely to use autonomous vehicles in the future.

Oppositional and neutral narratives cite numerous risks and obstacles to autonomous vehicle adoption including cybersecurity vulnerabilities, market disruption, and high costs, emphasizing a need for caution and significant regulation. These narratives describe impediments to adoption, providing decision makers areas that might need to be addressed before significant investment occurs in autonomous vehicles and ITS.

Table 4 provides descriptions of the 11 autonomous vehicle narratives identified in the Narrative Overview. These narratives about autonomous vehicles do not necessarily reflect the views of OCIA or Monitor 360.

The supportive narratives can be generally divided into two groups. The first argues that autonomous vehicles will make people's lives easier. *Transforming Our Way of Life, Expanding Interconnectedness,* and *Car Sharing Is the Future*, are all based on the idea that autonomous vehicles will enhance our lives. *Transforming Our Way of Life* and *Car Sharing Is the Future* focus on a paradigm shift in which the benefits of owning a vehicle, as opposed to renting a vehicle as needed, will become negligible. Car sharing tools such as ZipCar and Car2Go, and ride sharing apps like Uber and Lyft, are already reducing the need to own a vehicle, especially for urbanites, and autonomous vehicles will likely increase the push away from individual vehicle ownership. *Expanding Interconnectedness* focuses on how autonomous vehicles will improve productivity. Riders will be able to send emails, hold conference calls, read books or magazines, and perform other tasks rather than focus on driving. This capability will increase as vehicles continue to become more connected to the Internet with Bluetooth and Wi-Fi built in.

The second general category of positive narrative argues that autonomous vehicles will increase safety. Autonomous vehicles and their supporting technologies, such as V2V and V2I communications will reduce the likelihood of crashes.

TABLE 4—NARRATIVE DESCRIPTIONS[83]

NARRATIVE TITLE	NARRATIVE DESCRIPTION IN THE VOICE OF THOSE WHO EXPRESS IT
Transforming Our Way of Life	The inevitable adoption of autonomous vehicle technology will lead to profound changes in U.S. culture, society, and environment. From expanding the reach of urban areas, to creating new markets and changing consumption patterns, to opening up mobility to previously immobile populations, the opportunities of this new technology are seemingly unlimited. Moreover, automating transport will increase convenience for commuters and make parking obsolete, freeing up vast areas of space dedicated to parking structures. The public and private sectors need to take an integrated look at how this technology will change the way of life in the United States.
Expanding Interconnectedness	Software being introduced to vehicles promises to alleviate the countless hours commuters spend stuck behind the wheel. Moreover, features such as wireless Internet will allow drivers to stream music and data, work, shop, and do much more. Real-time traffic updates will be communicated using V2V and V2I technology and will divert vehicles real time reducing congestion. This new technology promises to bridge the divide between mobile connectivity and transportation, ushering in a new era of productivity.

[83] The narrative descriptions are expressed in the voice of those who drive and express each narrative. The narratives are derived from research conducted through Narrative Analysis, which drew on nearly 2,000 articles and blog posts in the network reviewed by the Monitor 360 analysts from January 2015 to January 2016. Appendix A provides a summary of the top 100 news sources and top 100 blog sources for the nearly 2,000 pieces of content that produced the narratives.

Car Sharing Is the Future	Autonomous vehicles will fundamentally alter the transportation paradigm. The current model, underpinned by vehicle ownership, delegates security to the abilities of each driver and incurs high ownership and insurance costs for consumers. In a world of driverless vehicles, car sharing will provide on-demand options for mobility. In addition to clear safety gains, car sharing will reduce costs for families, lessen congestion in urban areas, minimize environmental impact, and make parking easier. A future where car sharing eclipses car ownership presents innumerable upsides. Therefore, adopting this revolutionary new paradigm for transportation is a universal imperative.
V2V and V2I Communication Improve Safety	V2V and V2I communication are a key to a crash-free future. Enabling vehicles to "talk" to each other and the traffic infrastructure around them improves decision-making. This talk improves the situational awareness of drivers and vehicles and provides real-time warnings of obstructions or hazards nearby. V2V communication is beneficial for autonomous vehicles, improving their capability to detect other driverless vehicles' intentions and thereby reducing the risk of collision. Implementing V2V and V2I capabilities must be the top priority for policymakers and auto manufacturers to advance transportation safety and prevent millions of fatalities.
The End of Human Road Hazards	Autonomous vehicles represent a major opportunity to curb a leading cause of death in the United States: motor vehicle crashes. Human error is the cause of most crashes, and by taking that out of the equation, driverless vehicles and their extensive safety technology could revolutionize passenger safety. Relying on sensors and intelligent computers that react to the road, fine-tuned navigation systems, and other technologies that outstrip human abilities, driverless vehicles may soon make motor vehicle crashes history. A need exists to continue developing this groundbreaking technology.
Holding the Industry Back	Government bureaucrats across the country are pumping the brakes on driverless vehicles. Their supposed guidelines dramatically hinder efforts to test and develop this innovative technology, despite the undeniable benefits it brings. Politicians claim to represent the people, but their shortsighted and regressive policies only cater to lobbyists and special interests. If government blocks driverless cars, the industry will move to other states or countries with more favorable policies. Policymakers have a choice: get on board the autonomous revolution or watch it go elsewhere; obstructionism is unacceptable—particularly when stakes are so high.
Vulnerable to Hacking	Although smart cars sound beneficial to how people live their lives, the risks associated with these new technologies are reason for concern. Tests conducted on several cars, including high-end vehicles made by Tesla and Jeep, have found numerous vulnerabilities easily exploitable by hackers. Wireless entry, for instance, allows hackers to remotely control navigation systems or steering, and even hijack communication with other cars. Connected vehicles present a genuine and imminent threat to consumers. The government must get serious and regulate security for this budding industry before a major catastrophe occurs.
Disruptive Market Force	The adoption of autonomous vehicles will have massive harmful ripple effects on the economy. The reduction in accidents and car ownership will drastically disrupt the auto insurance and services industry, with fewer people needing insurance and new parts. Driverless vehicles will also drastically alter commercial trucking and shipping services—benefiting companies that depend on transportation at the expense of the taxi, bus, and truck drivers whose jobs will become obsolete. Tax revenue may also be affected because of fewer traffic and parking violations. Industry leaders and policymakers must adjust their business models to stay relevant and mitigate the consequences of this future.

Unlikely to Take Off	Although autonomous vehicles may sound impressive, widespread adoption is unlikely. Most projections fail to account for the varying needs of rural and urban populations, as well as the cultural barriers at play. Though urban dwellers may support driverless cars for evident commuting advantages, the benefits and implementation for rural areas are murkier. Moreover, extensive adoption would require a cultural shift because personal mobility is tied with perceptions of personal freedom, and many will resist the notion of giving up driving altogether.
Government Investing in the Future	Although infrastructure in the United States is not always prioritized, the Government has realized that autonomous vehicles are worth investing in. The Government is demonstrating its commitment to working with the private sector to hasten development and implementation of this new technology through its investments, including a $4 billion plan put out by the U.S. Department of Transportation. The national outlook toward infrastructure needs overhauling. The Government's interest in autonomous vehicles is a clear indication that it sees Transportation Systems Sector innovation as a key component of renewing U.S. infrastructure.
Many Speed Bumps Along the Way	As with many breakthroughs and innovations, driverless cars are much farther away than is thought. Although autonomous vehicles are the future, the barriers remain high, and the timelines are too ambitious. From the absence of necessary enabling infrastructure and regulation, to the lack of ethics of artificial intelligence, to uncertain interoperability of autonomous vehicle components, the barriers to implementation are significant. Instead of overhauling the auto industry all at once, companies need to integrate smart technology in steps, starting with vehicle-to-vehicle and vehicle-to-infrastructure capabilities in the short term. Manufacturers and legislators should be realistic and focus on incrementally rolling out elements of this technology over time.

Narrative Importance

Analysis of the Narrative Overview also enables the calculation of a foundational quantitative metric, called Narrative Importance. This metric measures the prominence of each narrative during the period of the dataset. Narrative Importance is calculated based on the volume of the discourse online about and related to autonomous vehicles, the social sharing of the views and the underlying data that comprise the narratives, and the consistency of the beliefs expressed in each narrative.

The Narrative Importance score, shown in figure 1, measures the importance of a narrative within the Narrative Overview. The balance of narratives, shown in figure 2, compares the relative effect of groups of narratives (in this case, the broader grouping of positive, negative, and neutral narratives).

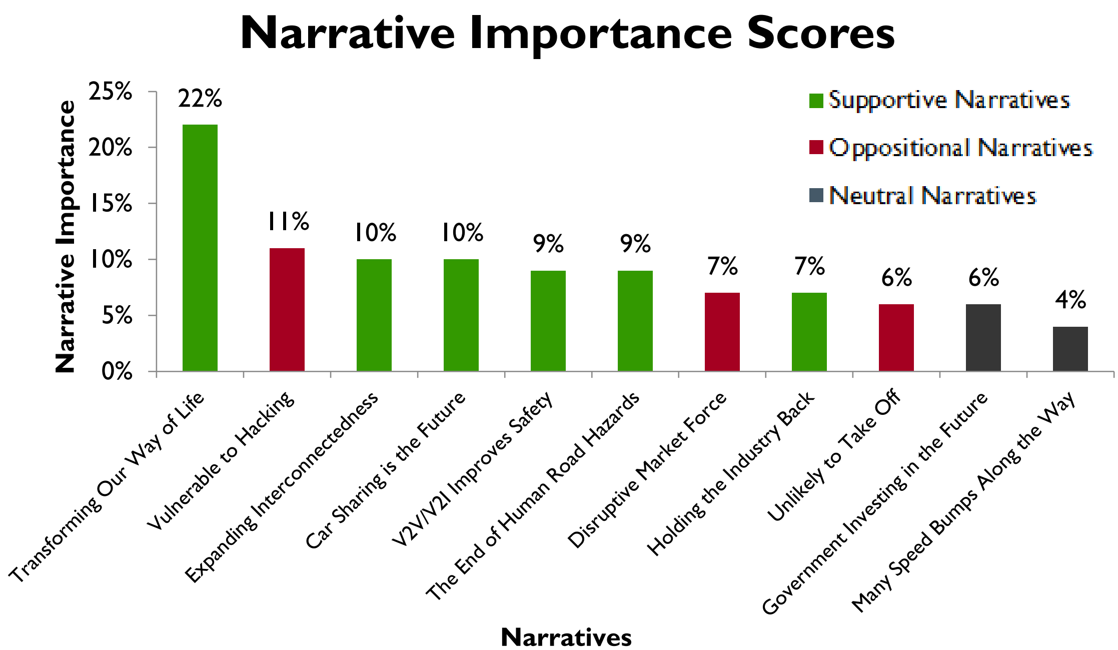

FIGURE 1—NARRATIVE IMPORTANCE SCORES[84]

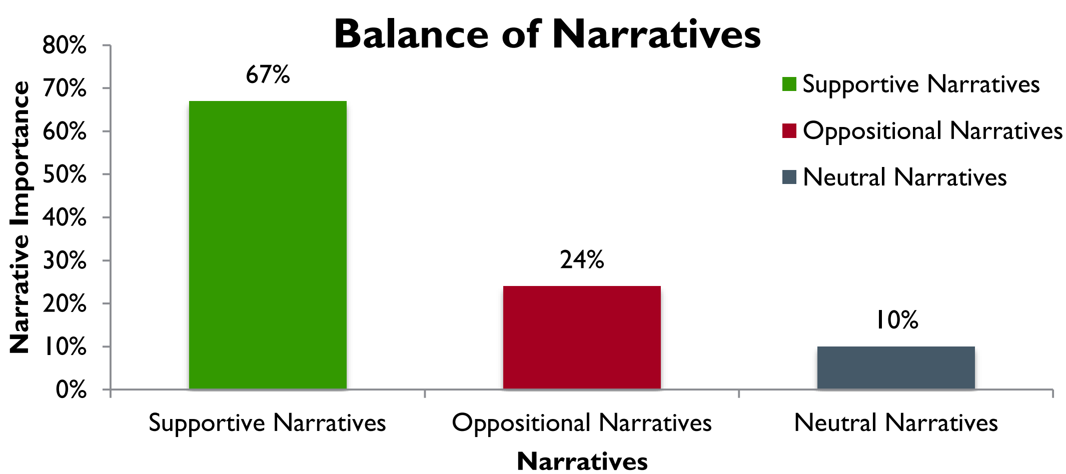

FIGURE 2—BALANCE OF NARRATIVES

As figures 1 and 2 show, no single narrative dominates the conversation, but two-thirds of the narratives are supportive, with an additional 10 percent of the narratives neutral. This positive outlook suggests that much of the public will be receptive to autonomous vehicles as they become available, assuming they are priced similarly to standard vehicles. Additionally, *Transforming our Way of Life* has the highest Narrative Importance score, which provides some insight into why people will adopt, and how people will use, autonomous vehicles. This narrative encompasses several ideas, but includes reduced needs for public parking in urban and suburban environments. Cities would therefore be able to use their space differently, potentially repurposing or knocking down parking structures, or adding lanes to busy streets when street parking is no longer necessary, but also would decrease city revenues from reduced parking. Understanding that convenience is a primary reason people will adopt autonomous vehicles, and that convenience will likely result in these consequences, will help cities plan for a future where autonomous vehicles become pervasive in the United States.

[84] Scores may not add up to 100 percent because of rounding.

Narrative Relationship Analysis

The Narrative Relationship measures the association of each stakeholder category with each narrative, with a higher percentage indicating a stakeholder group is strongly associated with a narrative. The Narrative Relationship analysis (see table 5), identified five categories of stakeholders: insurance companies, automakers and the automotive industry, technology-sector companies, government, and academia. Table 5 shows the Narrative Relationship of the relevant stakeholder categories in each of the narratives in the autonomous vehicle Narrative Overview.

TABLE 5—NARRATIVE RELATIONSHIP ANALYSIS

NARRATIVE	INSURANCE	AUTO	TECH	GOV'T	ACADEMIA
Transforming Our Way of Life	5%	28%	34%	5%	20%
Expanding Interconnectedness	N/A	67%	17%	N/A	9%
Car Sharing Is the Future	21%	72%	62%	8%	25%
V2V and V2I Communication Improves Safety	1%	27%	34%	15%	24%
The End of Human Road Hazards	4%	43%	34%	17%	43%
Holding the Industry Back	3%	74%	39%	30%	13%
Vulnerable to Hacking	2%	87%	N/A	20%	43%
Disruptive Market Force	65%	63%	19%	3%	16%
Unlikely To Take Off	16%	73%	N/A	11%	9%
Government Investing in the Future	34%	19%	12%	47%	10%
Many Speed Bumps Along the Way	8%	55%	33%	20%	32%

*Shaded boxes represent the most prominent audience(s) associated with each narrative. N/A indicates that no meaningful narrative was associated with this stakeholder group.

The insurance industry appears to be most associated with oppositional narratives, especially the *Disruptive Market Force* narrative. This is understandable because several uncertainties exist with respect to insurance and autonomous vehicles. First, who is liable in a collision involving an autonomous vehicle? Will the driver or the car manufacturer be responsible? Second, uncertainty exists regarding the overall car insurance market. As fully autonomous vehicles replace non- and semiautonomous vehicles, and car ownership decreases overall, will there still be a market for automobile insurance?

Interestingly, the technology industry is associated almost entirely with positive narratives, and is not significantly associated in any of the oppositional narratives. Its only association in a nonsupportive narrative is in *Many Speed Bumps Along the Way*, which highlights that although autonomous vehicle adoption is inevitable, it will most likely face a number of challenges and setbacks.

The automotive industry is engaged in almost every narrative. However, it is associated with Vulnerable to Hacking because of the high-profile incidents of hacks that mention specific automakers, but not because the stakeholder group itself is promoting this narrative.

SOURCES FROM NARRATIVE ANALYSIS PROCESS

The dataset collected and analyzed for the Intelligent Transportation Systems Narrative Analysis drew from more than 600 different traditional media sources and more than 200 blog sources. Collectively they produced a Narrative Analysis network drawing on more than 135,000 articles. The names of the top 100 traditional media publication sources and top 100 blog sources (ranked by source prominence) are provided in table 6.

TABLE 6—TOP 100 TRADITIONAL MEDIA PUBLICATION SOURCES

TOP 1–34 NEWS SOURCES		TOP 35–68 NEWS SOURCES		TOP 69–100 NEWS SOURCES	
1	Boston Globe	35	Washington Post	69	BusinessPundit
2	CBS News	36	Chicago Tribune	70	CleanTechnica
3	Christian Science Monitor	37	NBCNews.com	71	Communications Daily
4	CNN Money	38	Railway-technology.com	72	Defense Transportation Journal
5	MSNBC Newsweek	39	San Francisco Chronicle	73	FD (Fair Disclosure) Wire
6	Boston.com	40	BusinessWeek	74	FierceWirelessTech
7	Business Wire	41	Computerworld	75	Government Publications & Documents
8	CFO	42	Los Angeles Times	76	Health Aim
9	Denver Post	43	SiliconValley.com	77	Hot Hardware
10	Industrial Equipment News	44	The White House	78	Inside Cyber Security
11	Mother Jones	45	Fast Company	79	Insurance Networking News
12	National Journal	46	Huffington Post	80	International New York Times
13	PR Newswire	47	Wards Auto.com	81	Mechanical Engineering
14	Risk Management Magazine	48	EE Times	82	National Public Radio (NPR)
15	Search-Autoparts.com	49	Industry Week	83	NBC News
16	Street Insider	50	Mashable	84	Next Big Future
17	Tech Republic	51	RCR Wireless News	85	Philadelphia Business Journal (Philadelphia, PA)
18	The Washington Post	52	TheStreet.com	86	Rural Telecommunications
19	Time	53	Business Insider	87	TechSpot
20	WCVB.com	54	Politico	88	The Independent Review
21	Wharton	55	CNET News	89	The Journal of Marketing
22	FOXNews.com	56	ZDNet	90	Miami Herald
23	Wired News	57	CNBC	91	USA Today
24	CIO Magazine	58	Seeking Alpha	92	Consumer Electronics Daily
25	Harvard Business Review	59	Yahoo! Finance	93	Consumerist

TOP 1–34 NEWS SOURCES		TOP 35–68 NEWS SOURCES		TOP 69–100 NEWS SOURCES	
26	Mass Transit Magazine	60	Fleet Owner	94	Engadget HD
27	NetworkWorld	61	PRWeb	95	Network World
28	NPR	62	Reuters	96	The Detroit News (Michigan)
29	Roll Call Online	63	Bloomberg	97	AUTOMOTIVE DESIGN & PRODUCTION
30	The Hill	64	24/7 Wall St.	98	CQ Congressional Testimony
31	The New York Times	65	Assembly	99	Automotive News
32	Yahoo! Autos	66	AutoWeek	100	US Official News
33	Forbes.com	67	Aviation Week & Space Technology		
34	Fortune	68	Benzinga		

TABLE 7—TOP 100 BLOG PUBLICATION SOURCES

TOP 1–34 BLOG SOURCES		TOP 35–68 BLOG SOURCES		TOP 69–100 BLOG SOURCES	
1	Hacker News	35	The Ingenuity of the Commons	69	AnyVan
2	PBS NewsHour	36	IFExpress	70	DATAVERSITY
3	ArchDaily	37	NBC News Business	71	Direct2Dell
4	Tech	38	The Guardian Nigeria	72	GM Authority
5	CNET News	39	Ars Technica	73	AMERICAN.COM -- A Magazine of Ideas, Online
6	WIRED	40	Memeburn	74	Game Revolution - Everything You Care About
7	Kia BUZZ : Kia's official corporate blog	41	Autoblog Green	75	NEXT Network
8	Pacific Standard. Smart Journalism. Real Solutions.	42	belhabib.com	76	Security Intelligence
9	CB Insights - Blog	43	The State of Security	77	Software Monetization
10	it+management Resources | ZDNet	44	IndustryWeek	78	Technical.ly Philly
11	Autoblog	45	Silicon Florist	79	VentureBeat
12	Welcome to Linda Ikeji's Blog	46	Social Media Week	80	HybridCars.com
13	Inc.com	47	BMW BLOG	81	Insurance Journal
14	Nerdist	48	The Truth About Cars	82	MoneyWatch - CBSNews.com

	TOP 1–34 BLOG SOURCES		TOP 35–68 BLOG SOURCES		TOP 69–100 BLOG SOURCES
15	INQUIRER.net	49	platform	83	Network World
16	Transport Evolved	50	bizmology.hoovers.com	84	TechnoBuffalo
17	The Next Web	51	Daily Dot	85	AndroidHeadlines.com |
18	MediaPost | Online Spin	52	Government Technology News	86	CloudTweaks.com
19	Web Strategy by Jeremiah Owyang | Digital Business	53	Live Trading News	87	CTOvision.com
20	ZDNet | Between the Lines RSS	54	WebUrbanist	88	Green Car Congress
21	GeekWire	55	M2M Now - News and expert opinions on the M2M industry, machine to machine magazine	89	Inside EVs
22	Tech in Asia	56	Technology Personalized	90	John Day's Automotive Electronics
23	Security Bloggers Network	57	Identity Week	91	RushLane
24	Automotive News Breaking News Feed	58	The Inquisitr News	92	Techweez
25	WIRED	59	The Security Ledger	93	BLOUIN BEAT: Business
26	Bosch ConnectedWorld Blog	60	InformationWeek:	94	Disruption
27	MakeUseOf	61	Videos from CNET	95	Gemalto blog
28	Gizmag Emerging Technology Magazine	62	Blog of the NC State Alumni Association	96	Luxury Daily
29	Nextgov—All Content	63	Policy@Intel	97	Tuvie
30	ZDNet | Social Business RSS	64	Transport Evolved: Cleaner, Greener, Safer, and Smarter	98	Playpen
31	The Motor Report	65	healthsystemcio.com	99	Self Storage Blog: The Storage Facilitator
32	Economy Class & Beyond	66	Beyond PLM (Product Lifecycle Management) Blog		
33	Government Industry	67	Legal Theory Blog		
34	News at Florida International University	68	Motor Trend		

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