

Identifying Autonomous Vehicle Technology Impacts on the Trucking Industry

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LIST OF ACRONYMS

ATRI – American Transportation Research Institute
AT – Autonomous Truck
AV – Autonomous Vehicle
BASICs – Behavior Analysis and Safety Improvement Categories
CMV – Commercial Motor Vehicle
CSA – Compliance, Safety, Accountability
DARPA – Defense Advanced Research Project Agency
DGPS – Differential Global Positioning System
DSRC – Dedicated Short-Range Communications
ELD – Electronic Logging Device
FCC – Federal Communications Commission
FMCSA – Federal Motor Carrier Safety Administration
FMCSR – Federal Motor Carrier Safety Regulations
FMVSS – Federal Motor Vehicle Safety Standards
GPS – Global Positioning System
HAV – Highly Automated Vehicle
HAT – Highly Automated Truck
HM – Hazardous Materials
HOS – Hours-of-Service
LTE – Long-Term Evolution
NHTSA – National Highway Traffic Safety Administration
OEM – Original Equipment Manufacturer
R&D – Research and Development
RAC - Research Advisory Committee
RIA – Regulatory Impact Analysis
ROI – Return on Investment
SAE – Society of Automotive Engineers
SMS – Safety Management System
USDOT – U.S. Department of Transportation
V2I – Vehicle-to-Infrastructure
V2P – Vehicle-to-Pedestrian
V2V – Vehicle-to-Vehicle
V2X – Vehicle-to-Everything
VMT – Vehicle Miles Traveled
WLAN – Wireless Local Area Network

INTRODUCTION

Autonomous vehicle technologies have the potential to dramatically impact nearly all aspects of the trucking industry. A fully autonomous truck will have the ability to identify, interact with and safely react to all aspects of the driving environment without a driver in control of the wheel – in theory, this includes but is not limited to weather conditions, road types and unexpected events such as work zones and traffic accidents. It may be decades, however, before such a vehicle is commercially available.

Autonomous truck (AT) technology is advancing rapidly, and as these advancements enter the marketplace, the responsibilities of truck drivers could dramatically shift. It is clear, however, that driver tasks will not be the only area where adaptation is essential – operations may become more productive, freight may move faster, and federal regulations could be dramatically altered to accommodate a new driving environment. How individual carriers respond to the advent of the autonomous truck may determine their successes or setbacks in this new environment.

RESEARCH OBJECTIVES

In 2016 the American Transportation Research Institute’s (ATRI) Research Advisory Committee¹ (RAC) ranked “Analysis of Autonomous Truck Impacts” as its top research priority. Citing the institutional complexities of AT deployment and the rapid technological advances taking place in this field, the RAC asserted that industry stakeholders would benefit from an understanding of how this emerging technology would impact today’s most critical trucking issues.

This report has two main objectives in response to the RAC’s mandate. The first is to offer background on the current state of autonomous vehicle (AV) technologies. The second and more central goal of the report is to outline the impacts of AT deployment on the topics found within ATRI’s 2015 Top Industry Issues.² To accomplish this, the report explores the role of each top industry issue across several levels of truck automation, offering a discussion of impacts to drivers, companies and operations in general. Additional issues related to AT impacts on the industry are also discussed.

While it is clear that trucking companies and commercial drivers will operate differently in an automated environment, the degree to which this new technology will mitigate (or intensify) some of the industry’s most pressing issues is not fully understood. This report takes a first step at highlighting a variety of potential changes and challenges, and intends to help prepare the industry for a new trucking environment.

¹ The American Transportation Research Institute (ATRI) Research Advisory Committee (RAC) is comprised of industry stakeholders representing motor carriers, trucking industry suppliers, labor and driver groups, law enforcement, federal government, and academics. The RAC is charged with annually recommending a research agenda for the Institute.

² American Transportation Research Institute (ATRI). *Critical Issues in the Trucking Industry – 2015*. Arlington, VA. October, 2015.

AUTONOMOUS VEHICLE BACKGROUND

While vehicles including trucks have traditionally been operated manually, research and development has been conducted for nearly a century on automating aspects of vehicle control.³ Over the past 15 years, this technology has advanced rapidly, bolstered in part by Defense Advanced Research Project Agency (DARPA) initiatives in the U.S. that encouraged university research through autonomous vehicle competitions.⁴ These research and development (R&D) activities demonstrated that vehicle automation was possible by developing systems with existing technology components.

Today there are at least 33 vehicle manufacturers and technology companies that have R&D underway focused on autonomous vehicle technology.⁵ There has been broad deployment of automated features and significant demonstrations and pilot tests of automated vehicle operations.

It is important to recognize that the different levels of “autonomy” come with different technologies, functionalities and expectations. To better define and categorize autonomous systems, both the National Highway Traffic Safety Administration (NHTSA) and the Society of Automotive Engineers (SAE) have developed automation scales. SAE’s six level scale can be found in Appendix A and NHTSA’s five-level scale is listed in Appendix B.^{6,7} This report will refer to SAE’s six-level scale using the “layman’s” description of each level provided by NHTSA in its September 2016 Federal Automated Vehicles Policy report (see Table 1).⁸

³“History of Autonomous Cars.” Accessed November 14, 2016.

https://en.wikipedia.org/wiki/History_of_autonomous_cars.

⁴ Thompson, C. “These Images Show How Far Self-driving Cars Have Come in a Few Short Years.” October 22, 2015. Accessed October 10, 2016. <http://www.businessinsider.com/the-first-self-driving-cars-that-competed-in-darpa-grand-challenge-2015-10/#the-red-teams-car-made-it-further-than-any-other-vehicle-during-the-2004-competition-1>.

⁵ “33 Corporations Working On Autonomous Vehicles.” August 11, 2016. Accessed November 14, 2016.

<https://www.cbinsights.com/blog/autonomous-driverless-vehicles-corporations-list/>

⁶ “U.S. Department of Transportation Releases Policy on Automated Vehicle Development.” May 30, 2013. Accessed November 11, 2016. <http://www.nhtsa.gov/About-NHTSA/Press-Releases/U.S.-Department-of-Transportation-Releases-Policy-on-Automated-Vehicle-Development>

⁷ SAE International. “Automated Driving: Levels of Driving Automation are defined in New SAE International Standard J3016.” [Brochure]. Accessed November 14, 2016. http://www.sae.org/misc/pdfs/automated_driving.pdf

⁸ National Highway Traffic Safety Administration (NHTSA). *Federal Automated Vehicles Policy: Accelerating the Next Revolution in Roadway Safety*. Washington, DC. 2016.

Table 1: Autonomous Vehicle Scale⁹

At SAE Level 0 (L0) No Automation: the human driver does everything.
At SAE Level 1 (L1) Driver Assistance: an automated system on the vehicle can sometimes assist the human driver conduct some parts of the driving task.
At SAE Level 2 (L2) Partial Automation: an automated system on the vehicle can actually conduct some parts of the driving task, while the human continues to monitor the driving environment and performs the rest of the driving task.
At SAE Level 3 (L3) Conditional Automation: an automated system can both actually conduct some parts of the driving task and monitor the driving environment in some instances, but the human driver must be ready to take back control when the automated system requests.
At SAE Level 4 (L4) High Automation: an automated system can conduct the driving task and monitor the driving environment, and the human need not take back control, but the automated system can operate only in certain environments and under certain conditions.
At SAE Level 5 (L5) Full Automation: the automated system can perform all driving tasks, under all conditions that a human driver could perform them.

Large trucks have traditionally been in the L0 group. Safety and convenience technologies such as electronic stability control and adaptive cruise control bring a vehicle into L1 where specific functions are automated but the human driver remains responsible for operating the vehicle. If there are more than one of these automation technologies working independently, the vehicle is still L1. When two or more L1 systems work together (collision mitigation systems for example) the vehicle falls into the L2 category. L3, L4 and L5 are the more advanced stages of automation on the SAE scale.

An example of an L3 vehicle is the Freightliner Inspiration Truck, which can operate autonomously with close driver oversight.¹⁰ This truck has the ability to drive and monitor the driving environment in specific conditions, though the driver must be ready to take control of the vehicle. The driver therefore must be present in the driver’s seat, awake and alert, with hands near the wheel.

L4 is significantly more automated, allowing the driver to leave the driver’s seat and give full control of the vehicle to the automated system. What separates L4 from a fully autonomous, driverless vehicle is that L4 systems can only operate in certain environments and conditions. For instance, it may be that an L4 vehicle would only be authorized to travel on certain highways that are certified for L4 use, and the driver would need to operate the vehicle on all other roads. Additionally, weather conditions may play a role in safe operation of the vehicle. Using L4, the driver would benefit from

⁹ Ibid.

¹⁰ “Freightliner Inspiration Truck Unveiled at Hoover Dam.” May 5, 2016. Accessed November 12, 2016. <http://www.freightlinerinspiration.com/newsroom/press/inspiration-truck-unveiled/>

not having to be in the driver's seat when the autonomous system is fully engaged – a benefit that, as will be discussed extensively in this report, could have many positive implications for productivity and driver health and wellness. Ottomotto LLC (OTTO, now owned by Uber) demonstrated in October 2016 an origin to destination delivery in Colorado using its aftermarket L4 autonomous system during a 120-mile delivery.¹¹ During this demonstration, the driver entered an interstate highway and placed the vehicle in autonomous mode, and then entered the truck's sleeper berth area where he remained for the duration of the interstate travel. While this was a well-planned event and was monitored by a police cruiser, it demonstrated that L4 technology works and could be available to motor carriers in the near future.¹²

An L5 vehicle allows for full driving automation on any roadway. A driver is not required for an L5 truck to move from an origin to a destination, but that does not mean a driver would not be on-board or necessary. As will be described later in this report, even in a highly automated environment, commercial drivers are responsible for a number of critical freight movement tasks beyond maneuvering the vehicle. It is also important to note that while an L5 truck might not have a driver, there would be some level of oversight regarding origin, destination and route performance from a company employee – one scenario might be a “driver” overseeing several trucks from a remote location.

Technologies That Enable Automation

Vehicle automation is predicated on a variety of technologies that allow for different levels of functionality and capability. The following section describes the technologies most commonly associated with autonomous vehicles.

Radar utilizes several specific radio frequencies to provide continuous monitoring of distance (and to some degree object size) by measuring the time it takes the radio waves to travel to an object and back. In a trucking application, radar sensors are installed on the front bumper area of the vehicle, utilizing both long- and short-range radar.¹³ The long-range radar has been utilized to focus farther down the road (820', 18°), and the short-range radar has a closer and wider field of view (230', 130°).¹⁴

LIDAR is a concept similar to radar that uses lasers (instead of radio waves) to collect information about the surrounding environment. While LIDAR has distinct advantages over radar, the “size, weight, cost and power consumption” of the

¹¹ “Uber's Self-Driving Truck Makes Its First Delivery: 50,000 Beers.” Accessed October 25, 2016.

<https://www.wired.com/2016/10/ubers-self-driving-truck-makes-first-delivery-50000-beers/>

¹² “Uber Self-Driving Truck Packed With Budweiser Makes First Delivery in Colorado.” Accessed October 25, 2016.

<https://www.bloomberg.com/news/articles/2016-10-25/uber-self-driving-truck-packed-with-budweiser-makes-first-delivery-in-colorado>

¹³ “Safer, More Efficient Commercial Trucks.” Accessed October 25, 2016.

<http://www.freightlinerinspiration.com/technology/>

¹⁴ Ibid.

equipment has hindered adoption.¹⁵ Google reports that its autonomous vehicle uses a roof-mounted LIDAR where “64 lasers spin at about 900 rpm to give a 360 degree view.”¹⁶ The cost of this technology is reported as \$75,000.¹⁷ In a trucking environment the 360° view would be challenging with a similar configuration due in part to the trailer and the additional height requirements for a rooftop mount.

Video Camera Systems are utilized to read signs, roadway striping, and other features of the surrounding transportation infrastructure and environment. Current video camera applications aid truck drivers in maintaining lanes and warning of a possible collision with both vehicles and pedestrians.¹⁸ In an autonomous truck, the same functions may exist through the video camera but would be automatic.¹⁹

Figure 1: Location of Technologies that Enable Automation



¹⁵ “Laser Breakthrough Could Speed the Rise of Self-Driving Cars.” Accessed November 14, 2016.

<https://www.wired.com/2015/09/laser-breakthrough-speed-rise-self-driving-cars/>

¹⁶ “Google’s Autonomous Vehicle. Accessed November 14, 2016.

<http://googlesautonomousvehicle.weebly.com/technology-and-costs.html>

¹⁷ Ibid.

¹⁸ “Mobileye 5-Series.” Accessed November 14, 2016 <http://www.mobileye.com/products/mobileye-5-series/>

¹⁹ “Safer, More Efficient Commercial Trucks.” Accessed October 25, 2016.

<http://www.freightlinerinspiration.com/technology/>

5.9 DSRC (Dedicated Short-Range Communications) is a specific range of the 75 MHz spectrum that was set aside by the Federal Communications Commission (FCC) in 1999 for use in intelligent transportation systems.²⁰ This range has been tested extensively in safety applications to assess whether DSRC when “paired with accurate vehicle positioning can improve upon autonomous vehicle-based safety systems or enable new communication-based safety applications.”²¹ Since 5.9 DSRC only has a range of up to 1,000 meters, embedded DSRC transceivers are needed approximately every quarter mile to ensure continuous connectivity. While the DSRC range is short, the 5.9 GHz frequency permits very fast data transmission rates.²²

4G/5G LTE (Long-Term Evolution) is a high-speed wireless communications platform that is most commonly used by smartphones. The next generation of this terrestrial platform is often called 5G LTE. The 5G platform is expected to be “10-100 times faster than today’s average 4G LTE connections,” and could enable cellular communications to support collision avoidance and truck platooning.²³ While capable of operating over a much longer range than 5.9 DSRC, 4G wireless communications have a slower rate of data transfer.

Differential Global Positioning System (DGPS) builds upon Global Positioning System (GPS) by adding ground-based correction stations that act as a third reference point between the vehicle and a GPS satellite. This increases accuracy from within several meters to several centimeters. Such accuracy, if employed in real time, could help maintain a travel lane when markings are missing.

At the present time, combinations of these technologies have been used to produce autonomous systems. The Freightliner L3 vehicle discussed earlier utilizes radar and video camera systems.²⁴ OTTO uses those same categories of technology, but adds three LIDAR units and detailed mapping information, bringing the system up to L4.²⁵

It is possible that L3-L5 technologies will be improved and enabled through connected vehicle technologies (e.g. 5.9 DSRC), often referred to as V2X or vehicle-to-everything. Based on wireless local area network (WLAN) technology, V2X communicates directly

²⁰ Federal Communications Commission. *FCC Allocates Spectrum in 5.9 GHz Range for Intelligent Transportation Systems Uses*. [Press release]. October 21, 1999. Accessed October 15, 2016

https://transition.fcc.gov/Bureaus/Engineering_Technology/News_Releases/1999/nret9006.html

²¹ Carter, A. A., & Chang, J. *Using Dedicated Short Range Communications for Vehicle Safety Applications – The Next Generation of Collision Avoidance*. NHTSA Paper Number 09-0330.

²² “Dedicated Short Range Communications (DSRC).” April 2013. Accessed November 05, 2016.

https://web.archive.org/web/20130216162616/http://www.standards.its.dot.gov/Documents/advisories/dsrc_advisory.htm

²³ “AT&T Unveils 5G Roadmap Including Trials In 2016.” February 12, 2016. Accessed October 25, 2016.

http://about.att.com/story/unveils_5g_roadmap_including_trials.html

²⁴ “Safer, More Efficient Commercial Trucks.” Accessed October 25, 2016.

<http://www.freightlinerinspiration.com/technology/>

²⁵ “Uber’s Self-Driving Truck Makes Its First Delivery: 50,000 Beers.” Accessed October 25, 2016.

<https://www.wired.com/2016/10/ubers-self-driving-truck-makes-first-delivery-50000-beers/>

between vehicles or infrastructure when two V2X devices come within each other's range. Table 2 below contains a list of common categories of V2X.

Table 2: V2X Categories²⁶

V2X Technology	Functionality
Vehicle-to-Infrastructure (V2I)	Enables vehicles to communicate with and gain awareness of infrastructure such as traffic signals.
Vehicle-to-Vehicle (V2V)	Enables vehicles to communicate with and gain awareness of other vehicles.
Vehicle-to-Pedestrian(V2P)	Enables vehicles to communicate with and gain awareness of pedestrians, bicyclists and others.

These technologies might allow vehicles to monitor and react to surroundings faster and with better precision than a human driver. As an example, V2I may allow a vehicle to anticipate traffic signal changes or operate at variable speeds as a vehicle transverses different roadways. V2V may allow a vehicle to instantly know and react to another vehicle that is ahead and suddenly braking, or might see a vehicle around an urban street corner as long as the signal is not blocked.

Projections, Timelines and Costs

Autonomous Vehicle Research and Development (R&D) Investment

The level of R&D investment in autonomous vehicle technology will likely drive the speed at which L3-L5 vehicles enter and replace the existing U.S. vehicle fleet.

The public sector has clearly fostered some of the early advancements in autonomous vehicle technology, particularly through research funding for in-vehicle technology and V2X research. In January 2016, the U.S. Department of Transportation (USDOT) made a commitment to autonomous vehicle research with the announcement of “a 10-year, nearly \$4 billion investment to accelerate the development and adoption of safe vehicle automation through real-world pilot projects.”²⁷ The intent of this investment is to support the ongoing work of the private sector. Additionally, investment in V2X research will help enable full automation of vehicles.

That said, private sector investment in autonomous vehicles has been substantial, going back to early onboard safety systems, and is currently being driven by the car, truck and technology industries. Due to the competitive nature of these efforts, investment levels

²⁶ “Connected Vehicles: Vehicle-to-Pedestrian Communications.” Accessed November 09, 2016. http://www.its.dot.gov/factsheets/pdf/cv_v2pcomms.pdf

²⁷ “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.” January 14, 2016. Accessed August 10, 2016. <https://www.transportation.gov/briefing-room/secretary-foxx-unveils-president-obama’s-fy17-budget-proposal-nearly-4-billion>

and research discoveries are not often publicly shared; the public must rely on press releases of autonomous vehicle breakthroughs or demonstrations. It is known however that as of 2016, automobile manufacturers were testing autonomous technology as well as companies such as Alphabet (a holding company developed by Google).²⁸ Major automobile manufacturers such as Ford and General Motors are both investing internally in autonomous vehicle R&D and are purchasing technology companies that will help advance AV efforts.²⁹

In 2016 NHTSA released its Federal Automated Vehicles Policy which offered guidance on vehicles it refers to as “Highly Automated Vehicles” or HAVs.³⁰ The report states that:

“Under current law, manufacturers bear the responsibility to self-certify that all of the vehicles they manufacture for use on public roadways comply with all applicable Federal Motor Vehicle Safety Standards (FMVSS). Therefore, if a vehicle is compliant within the existing FMVSS regulatory framework and maintains a conventional vehicle design, there is currently no specific federal legal barrier to an HAV being offered for sale.”³¹

In the report Highly Automated Trucks (HATs) are not mentioned specifically by NHTSA. It can be assumed though that if the report had discussed HAT applications, NHTSA would indicate that truck original equipment manufacturers (OEMs) and their suppliers would hold the primary responsibility of providing a safe vehicle that meets minimum standards.

The deployment of autonomous trucks to trucking companies offers several challenges for truck OEMs, including some that have been well researched and potentially already solved pre-deployment. The following table contains the key items that trucking companies will rely on truck OEMs for guidance.³²

²⁸ “33 Corporations Working On Autonomous Vehicles.” 2016, August 1, 2016. Accessed November 14, 2016. <https://www.cbinsights.com/blog/autonomous-driverless-vehicles-corporations-list/>

²⁹ Naughton, K., & Hull, D. “Ford Plans Leap from Driver’s Seat with Autonomous Car by 2021.” August 16, 2016. Accessed August 30, 2016. <https://www.bloomberg.com/news/articles/2016-08-16/ford-aims-to-offer-fully-autonomous-ride-sharing-vehicle-by-2021>

³⁰ National Highway Traffic Safety Administration (NHTSA). *Federal Automated Vehicles Policy: Accelerating the Next Revolution in Roadway Safety*. Washington, DC. 2016.

³¹ Ibid.

³² Ibid.

Table 3: Key Areas of Responsibility for Truck OEMs

Topic	Issue Description
Cyber Security	Carriers must be confident that their autonomous truck systems will not be hijacked for the purpose of theft, destruction of property, or any other reason. Thus systems must have a level of security that cannot be breached. Additionally, if a truck is hacked, there must be limitations on what can be accomplished by the hacker.
Maintenance	Autonomous system hardware and software will have to be properly maintained to ensure safety. While OEMs may provide this service or may partner with third parties for this service, education and training also needs to be available for drivers, equipment managers, and mechanics employed by the carrier.
Training/ Human-Machine Interface	Drivers will need training on how to operate an autonomous vehicle. This is particularly true for drivers who will be operating the first vehicles that are on the market.
Safety	While the safety benefits of autonomous technologies are widely discussed, significant safety testing and demonstrations in all situations must be conducted and made publicly available. Some level of benchmarking across OEMs may be beneficial.
Operational Design Domain ³³	Where and in what conditions an AT can operate must be clear. Simple geo-fences could limit autonomous operations to specific roadways. Likewise, real-time weather information could limit autonomous operations to favorable conditions.
Malfunction	There must be procedures (fall-backs) in place to ensure that potentially catastrophic events do not occur.

Autonomous Truck Projections and Timelines

As discussed earlier, Freightliner introduced an autonomous truck proof-of-concept in 2015, which demonstrated L3 automation – allowing the truck driver to conduct other tasks while at the wheel. OTTO has since demonstrated a system that converts a standard truck into an L4 autonomous truck, thus allowing a driver to be away from the steering wheel in certain driving conditions. While the availability of autonomous trucks is limited today, there are predictions that AT technology will be widely adopted in the future.

IHS Automotive states that “autonomous truck sales could reach 60,000 annually by 2035 [or] 15 percent of sales for trucks in the big Class 8 weight segment.”³⁴ There are

³³ Ibid

³⁴ Bukszpan, D. “Could autonomous trucks be the next weapon for terrorists?” July 21, 2016. Accessed November 14, 2016. <http://www.cnbc.com/2016/07/21/could-autonomous-trucks-be-the-next-weapon-for-terrorists.html>

currently 3.46 million Class 8 trucks in the U.S.;³⁵ if hypothetically 60,000 autonomous trucks were added annually starting today (instead of 20 years from now), it would be more than five years before autonomous trucks made up 10 percent of the total fleet. Thus, the IHS prediction does not see rapid adoption in the shorter term.³⁶

The cost of trucks with autonomous systems will be greater than a standard truck. Since there are no commercially available systems at the time of publication, estimates are relied on for this report. For the OTTO retrofit and the Freightliner Inspiration, a figure of \$30,000 per truck automated systems cost has been published.^{37 38} One report looked at costs incrementally, and estimated that additional costs per truck for hardware and software would be as follows:³⁹

- L3: \$13,100 added to truck price
- L4: \$19,000 added to truck price
- L5: \$23,400 added to truck price

These costs are mainly related to software, and do not include inspection, maintenance or updates. As these technologies become more widely adopted, prices are likely to decrease. At the moment due to numerous unknowns related to software investment needs and industry regulations, an accurate return-on-investment (ROI) analysis is not possible.

Public Sector Deployment Impediments and Catalysts

Based on safety benefits alone, deployment of autonomous technologies ostensibly carries significant societal benefits. The public sector, therefore, is keenly interested in understanding AT impediments and fostering the deployment of these technologies.

One weak link however is the infrastructure needed to support AVs. Roadway infrastructure conditions, which are generally outside of the control of the private sector, play an important role in the facilitation of AT technologies. For example, lane markings must be visible to video camera systems. Signage must be correct, visible and appropriate. Pavement quality may also cause issues. Sufficient infrastructure requires public sector investment, however. Typically revenue for infrastructure is sourced

³⁵ American Trucking Associations. American Trucking Trends 2016. Arlington, VA. 2016.

³⁶ It is important to note also that in 2015 Class 8 vehicle sales in the U.S. were nearly 250,000; some years are much lower with 2009 only experiencing sales of approximately 95,000 vehicle. (American Trucking Trends 2016) Additionally, the 60,000 estimate for 2035 is only 15% of sales – thus the vast majority of vehicles exiting the U.S. fleet will still be traditional vehicles two decades from now. Thus, the current estimates indicate that it will be several decades before the majority of the U.S. Class 8 fleet is autonomous. OEMs are not likely the only large-scale providers of autonomous trucks, however. Companies such as OTTO intend to sell aftermarket technology that will be installed by a third party on existing vehicles.

³⁷ “2015 Freightliner Inspiration Truck.” Accessed November 14, 2016. <http://www.topspeed.com/trucks/truck-reviews/daimler/2015-freightliner-inspiration-truck-ar169226.html#main>

³⁸ “\$30K Retrofit Turns Dumb Semis Into Self-Driving Robots.” May 17, 2016. Accessed November 14, 2016. <https://www.wired.com/2016/05/otto-retrofit-autonomous-self-driving-trucks/>

³⁹ Roland Berger. *Automated Trucks: The next big disruptor in the automotive industry?* Chicago. March 2016.

through mechanisms such as the Federal motor fuels taxes – that said, current political forces are recalcitrant to raise new funds.

The legal and regulatory landscape related to autonomous vehicles is another major challenge for the public sector. In most states drivers are primarily held liable for at-fault accidents and for moving violations. If a vehicle has no driver, many questions can be raised related to both civil and criminal violations. This topic will be discussed in more detail later in this report. Likewise, specific state and federal regulations that govern the trucking industry may not apply in the AT environment, and some will require modifications to remain relevant. Additionally, new policies and legislation will be necessary to expand AT activities. In Nevada, state law now provides business licenses for manufacturers and software developers to test autonomous technologies on public roadways, thus helping foster advances in this type of technology.⁴⁰ Alternatively, many state laws articulate the continuous role and responsibility of the vehicle driver – often flying in the face of AV objectives.

Finally, from a trucking industry perspective, the role of the federal government in leading the deployment of autonomous technologies is essential. The industry relies on an interstate highway system that facilitates the free flow of goods between the states. As AT technology is commercialized, it is critical that the state and local laws do not create disparities that limit commerce and obstruct the successful adoption of these potentially safety- and productivity-boosting technologies. Thus it is critical that the federal government take a clear leadership role in autonomous technology deployment and, if necessary, exercise federal preemption. Table 4 lists some of the issues that face autonomous truck deployment.

⁴⁰ “Autonomous Vehicles.” Accessed November 14, 2016. <http://www.dmvnv.com/autonomous.htm>

Table 4: Government Impediments to AT Deployment

Autonomous Truck Issue	Government Impediment	Solution
Autonomous Truck Operational Environment	AT operations require high-quality roadways. Deficient infrastructure, such as potholes and poor lane markings can impede autonomous technology.	Increase infrastructure funding to improve and maintain infrastructure.
Liability for AT-Involved Accidents	Liability across a variety of state laws has not been addressed.	Legal system will, over time, set legal precedent. State liability laws related to vehicle crashes will likely change significantly.
State and Federal Trucking Regulations	State law and the Federal Motor Carrier Safety Regulations (FMCSRs) do not sufficiently address the autonomous environment. Many rules within the FMCSRs currently conflict with or do not address autonomous trucks. For the trucking industry, federal leadership and possibly federal preemption is critical in providing a seamless national transportation system that benefits from autonomous technology.	Major overhaul of state laws pertaining to commercial vehicles as well as the FMCSRs.
Traffic Laws	Following too close is a moving violation. The congestion mitigation aspect of autonomous vehicle technology requires close vehicle proximity during movement. For truck platooning, close proximity is also required to realize fuel savings.	Changes in state law will be required.

IMPACT OF AUTONOMOUS TRUCKS ON THE TRUCKING INDUSTRY'S TOP ISSUES

ATRI annually conducts a survey of motor carrier executives and commercial drivers to identify the industry's top issues. In 2015 the industry ranked the following as their top issues:⁴¹

1. Hours-of-Service
2. Compliance, Safety, Accountability
3. Driver Shortage
4. Driver Retention
5. Truck Parking
6. Electronic Logging Device Mandate
7. Driver Health/Wellness
8. Economy
9. Infrastructure/Congestion/Funding
10. Driver Distraction

To fully assess how autonomous vehicles will impact the industry's most pressing issues, the following section reviews the impact of ATs and AVs on the trucking industry.

⁴¹ American Transportation Research Institute (ATRI). *Critical Issues in the Trucking Industry – 2015*. Arlington, VA. 2015.

Issue 1: Hours-of-Service (HOS)

The HOS regulations govern the time that a truck driver can work and drive. Under normal circumstances a driver may be on-duty for up to 14 consecutive hours, drive up to 11 of those hours, and must rest at least 10 hours before regaining a new 14-hour on-duty window. There are also rules that require rest breaks, and limit cumulative weekly on-duty time totals.

HOS is regularly ranked at the top of the list of industry issues. Industry concerns include the numerous and volatile changes to the rule over the past 15 years including a recent 30-minute rest break provision, the inability to pause the 14-hour window once a driver has begun work, and uncertainty related to a specific provision known as the “34-hour restart.” There has been legal action related to the HOS rules for more than a decade, and it is likely that conflict regarding the rule will continue in the courts, in Congress and on the regulatory level.

The HOS regulations are collectively designed to ensure safe driving and reduce fatigue by limiting drive and on-duty time. These boundaries on work-time, by their very nature, limit productivity levels. Many drivers and carriers, however, believe that some of the limitations do not offer enough flexibility. An example of this is found in the 14-hour rule. Under normal circumstances, a driver’s 14-hour on-duty period cannot be stopped mid-way for any reason. For instance, the driver could sleep for five hours after logging on-duty and those hours would not be counted as rest time, even though they resulted in a more rested driver. Typically the only way to commence a new 14-hour on-duty window is to be off-duty for 10 consecutive hours and to be at least 14 hours under the weekly 60/70 hour on-duty limit.

The current rules were developed to ensure adequate off-duty time for drivers of L0-L2 configured vehicles which require the full attention of the driver. By allowing drivers opportunities to rest while the vehicle is moving, automated driving systems could support changes to the HOS rules that allow for increased flexibility and better rest for drivers. Simply put, automated systems could allow rest and productivity to occur simultaneously.

Before such benefits could be realized, however, guidance on how current HOS regulations relate to autonomous driving is needed. Additionally, legislation and regulations that pertain directly to autonomous truck operations may also be required.

The following discussion explores issues and solutions related to the current HOS rules when applied to the top three levels of automation:

L3 Conditional Automation: Commercial motor vehicle (CMV) drivers engaged in an L3 automated driving environment may have fewer physical and mental commitments to driving a truck. The driver must, however, remain at the wheel and be ready to take control of the vehicle when necessary. For that reason it is

not likely that use of L3 automation could justify modifications to the HOS rules. Additionally, time spent at the wheel while the L3 system is engaged will likely be considered drive time since the driver must remain alert and ready to take control of the truck.

L4 High Automation: Within the L4 category the automated system is capable of driving a vehicle on specific roadways under certain conditions without any input from the driver. This level of automation allows the driver to conduct other work (i.e. logistics or administrative functions) or to rest. In a scenario where a vehicle is controlled by the automated system for several hours or more on a long stretch of interstate highway, the driver may be able to sleep in the sleeper berth. Depending on interpretation, there is the potential for increased rest and large productivity gains with modifications to the existing regulations. Additionally, L4 automation could address fatigue to such a degree that additional flexibility within the HOS regulations would be warranted. The key areas of the HOS that have a nexus to L4 High Automation are discussed below:

30-Minute Rest Break: If a driver rests or even sleeps for at least 30-minutes in a sleeper berth while the automated system is in full control of the truck, it could be reasoned that stopping the truck to rest for 30 additional minutes should not be required under current rules. Thus, drivers using L4 have the potential to obtain the required rest without having to stop. This has additional benefits as the driver may still receive per-mileage pay while resting (as the vehicle will be moving), and it does not require the driver to spend time driving off-route to find a parking location.

14-Hour On-Duty Limit: A driver can currently begin an on-duty period of up to 14 hours after completing 10 consecutive hours off-duty. There are two questions that can be raised in the L4 environment regarding these off- and on-duty requirements. The first is whether a driver can log off-duty while the vehicle is in “self-driving” mode, particularly if he or she is resting and has no responsibilities during a full 10-hour stretch of automated driving. Such a scenario could potentially (in certain operations) eliminate the need to rest for 10 full hours while stationary. This would clearly generate productivity and quality of life benefits. Second is whether the regulations could be modified to pause the 14-hour rule for periods of rest that are less than 10 hours. This will be discussed further in the sleeper berth provision section below.

11-Hour Daily Drive Time Limit: Under current regulations, 11 hours of driving time are allowed within the daily 14-hour window. It can be argued that any periods where the L4 automated system is in control of the vehicle should not be counted against the 11-hour cumulative driving time limit. This could extend the available driving hours for L4 drivers versus

those of standard vehicles, resulting in productivity gains for L4 drivers and their motor carriers.

Sleeper Berth Provision: Under the sleeper berth provision, rest periods can be split into: 1) one period of eight consecutive hours in a sleeper berth which does not count against the 14-hour daily on-duty time limit; and; 2) one period of two consecutive hours of off-duty or sleeper berth time that does count against the 14-hour limit. Upon completion of the two rest periods, a new 14-hour period is available.⁴² This rule is often used by team drivers to keep the vehicle moving while one driver rests.⁴³

It could be argued that under current HOS regulations an L4 autonomous system is considered a “team driver.” This designation could allow the human driver to take eight consecutive hours in the sleeper berth while the vehicle is moving in an automated mode, and two additional hours either off-duty or in the sleeper berth. If eight consecutive hours in the sleeper berth is achievable on a given route, far less time would be required at a truck stop or rest area between 14-hour periods.

A driver could also take two hours off-duty while the vehicle is moving autonomously, thus requiring only eight hours (instead of 10) in the sleeper berth at a truck stop – resulting in additional productivity benefits.

The industry could also seek more flexibility in the sleeper berth provision for L4 operations. For example, a 5/5 or 6/4 split where the driver is in the sleeper berth during both rest periods may be just as appropriate and restful as the current 8/2 split, particularly since far less over-the-road driving will be done by the driver.

60/70-Hour Limit: The weekly on-duty time limits are meant to address accumulated fatigue over a seven- or eight-day period. The typical over-the-road driver is allowed 70 hours of on-duty time within an eight-day period. As drivers shift their interstate miles to automated systems, daily drive time would decrease while on-duty time, which counts toward the 70 hours, remained the same. This would be the case even if the driver was sleeping. Thus, the weekly limitations may appear too restrictive when automated systems are in use.

L5 Full Automation: The HOS rules as presently written would serve no safety function in a scenario where a driver does not operate on public roadways, and particularly where there is no human on-board the vehicle.

⁴² Federal Motor Carrier Safety Administration (FMCSA). *Interstate Truck Driver's Guide to Hours of Service*. Washington, D.C. March, 2015. Accessed November 14, 2016.

https://www.fmcsa.dot.gov/sites/fmcsa.dot.gov/files/docs/Drivers_Guide_to_HOS_2015_508.pdf

⁴³ Ibid.

Issue 2: Compliance, Safety, Accountability (CSA)

Compliance, Safety, Accountability (CSA) is a Federal Motor Carrier Safety Administration (FMCSA) initiative that aims to improve trucking industry safety through the use of a scoring system. FMCSA uses its Safety Management System (SMS) to monitor and manage data from individual companies relating to seven safety areas known as BASICS.⁴⁴

Of the seven BASICS, there is significant stakeholder concern with the Crash Indicator BASIC. According to FMCSA, the Crash Indicator BASIC measures “histories or patterns of high crash involvement, including frequency and severity,” and is “based on information from State-reported crashes.”⁴⁵ The key issue is that all preventable and non-preventable crashes are reported as part of the scoring. This has the potential to harm carriers and drivers that are not at-fault in a crash.⁴⁶

The following is an analysis of the nexus between CSA BASICS and autonomous vehicles.

Basic 1 - Unsafe Driving: Speeding, reckless driving, improper lane change, and inattention are examples of violations that impact the Unsafe Driving BASIC.⁴⁷ Unsafe driving violations have always been the fault of the driver. It is likely that the number of “unsafe driving” events will decline for L4 and L5 fleets, raising questions about comparing AT and non-AT fleets in the same peer group within CSA. There will also be challenges related to whether equipment malfunctions in L4 or L5 driving modes should be assessed to the driver, carrier or OEM. It could be the case that violations are not assigned to anyone in some instances. State or Federal law will ultimately dictate how AT violations are addressed.

Though unsafe driving violations will likely not disappear, autonomous technology can be programmed to not violate traffic laws. Therefore, to the extent that drivers shift over to autonomous driving, there will be fewer unsafe driving violations and raw scores would likely improve for carriers that use automated technologies. Due to this potential safety benefit, it is critical that the BASIC methodology focus on raw scores instead of percentile scores.⁴⁸

⁴⁴ The Behavior Analysis and Safety Improvement Categories or BASICS include: 1) Unsafe Driving, 2) Hours-of-Service, 3) Driver Fitness, 4) Controlled Substances/Alcohol, 5) Vehicle Maintenance, 6) Hazardous Materials (HM) Compliance, and 7) Crash Indicator.

⁴⁵ “Safety Measurement System.” Accessed October 20, 2016.

<https://csa.fmcsa.dot.gov/about/basics.aspx>

⁴⁶ Boris, Caroline and Dan Murray. *Assessing the Impact of Non-Preventable Crashes on CSA Scores*. American Transportation Research Institute. Arlington, VA. November 2015.

⁴⁷ Ibid.

⁴⁸ FMCSA has released a notice of proposed rulemaking (NPRM) to address the issue of percentile scoring; the problem will persist, however, if a regulatory change is not implemented. More information can be found at the following location: “Safety Fitness Determinations.” Accessed November 14, 2016.

<https://www.regulations.gov/docket?D=FMCSA-2015-0001> Docket ID: FMCSA-2015-0001

BASIC 2 - Hours-of-Service (HOS) Compliance: The HOS BASIC focuses not only on compliance with HOS regulations, but also with driving a truck when ill or tired regardless of accumulated hours.⁴⁹ As discussed in the previous section, the HOS rules could change dramatically within the L4 and L5 environment. Thus, there is the chance that compliance could become less of an issue and raw scores could improve among carriers that utilize autonomous vehicles.

BASIC 3 - Driver Fitness; BASIC 4 - Controlled Substances: The Driver Fitness BASIC has scoring penalties for drivers who are “unfit due to lack of training, experience or medical qualifications,” and the Controlled Substances BASIC focuses on “drivers who are impaired due to alcohol, illegal drugs, and misuse of prescription or over-the-counter medications.”⁵⁰ It is possible that requirements within these BASICS could change, though it is unlikely. A driver who is onboard an L4 vehicle will be required to take over the vehicle in certain situations and must therefore be trained, qualified and sober. If there are no situations where an L5 will be operated by a driver, however, then anyone onboard the vehicle is simply a passenger, and therefore driver requirements (including the two aforementioned BASICS) are not relevant.

BASIC 5 - Vehicle Maintenance: The Vehicle Maintenance BASIC addresses “failure to properly maintain a CMV and/or properly prevent shifting loads,” with violation examples that include “brakes, lights, and other mechanical defects, failure to make required repairs, and improper load securement.”⁵¹ Autonomous truck technology will likely expand the requirements and expectations of this list (such as radar, LIDAR and video camera) as well as software that will ensure safe operations. As autonomous trucks become commercially available, truck drivers will need enhanced training on system maintenance, and enforcement will need additional skills in order to properly input SMS data in support of this BASIC. Additionally, trucking companies will require mechanics and technicians to have similar skillsets for maintenance and repair of the hardware and software that is employed in autonomous truck systems.

BASIC 6 - Hazardous Materials (HM) Compliance: Hazmat operations have stricter rules and guidelines than do other sectors of the industry. The HM BASIC addresses violations such as “release of HM from package, no shipping papers (carrier), and no placards/markings when required.”⁵² It is likely that the HM BASIC will not change in an AT environment.

BASIC 7 - Crash Indicator: It is anticipated that fewer crashes will occur as trucks and automobiles are automated. Any decrease in truck-involved crashes will lead to a decrease in raw crash scores. As with the Unsafe Driving BASIC,

⁴⁹ “Safety Measurement System.” Accessed October 20, 2016. <https://csa.fmcsa.dot.gov/about/basics.aspx>

⁵⁰ Ibid.

⁵¹ Ibid.

⁵² Ibid.

due to the likelihood of a decrease in crashes using AT, a focus on raw scores instead of percentile scores would be appropriate to reduce peer grouping conflicts between AT and non-AT fleets. Since this BASIC does not currently consider fault, a crash due to a malfunction of an autonomous system will impact the score.

Issue 3: Driver Shortage

As the economy strengthened in the years after the Great Recession, a severe shortage of drivers in the trucking industry once again emerged. The American Trucking Associations predicts that by 2024 the driver shortage will increase from a recent 48,000 available driving jobs to 175,000.⁵³ There is additional evidence pointing toward a persistent driver shortage in the coming decades found in ATRI's 2014 study of driver demographics.⁵⁴ This research found that the number of U.S. truck drivers between the ages of 25 and 34 has dropped by nearly 50 percent over the past two decades. In some instances, the void created by these new drivers has been filled by older drivers, particularly those who are 55 years or older. The trucking industry therefore faces an increasing shortfall of qualified drivers while, at the same time, the industry's driver base is aging.

Significant differences exist in use of and reliance on technology across younger and older individuals, resulting in an opportunity to utilize more sophisticated AT technologies as a way to incentivize younger individuals to become a truck driver.⁵⁵ This "Age/Technology" continuum will be an important discussion item in any formal approach to incorporate AT systems into fleets.

It is thought by some that AT technology will solve the driver shortage issue, and several news articles have insinuated that autonomous trucks will eliminate the need for many drivers.⁵⁶ To move freight without a driver, however, would require an L5 truck that can move from an origin to a destination entirely without the aid of a human, and under ideal conditions. For long-haul, irregular route operations in the U.S., the L5 AT technology would need to include the ability to operate in most weather conditions and on all roadway types. A vehicle with this level of functionality, along with adequate infrastructure, is not likely to be commercially available for quite some time.

Alternatively, truck driving as a career may become more attractive as L3 and L4 trucks are commercially available. L3 automation may relieve some of the stress and monotony of driving long hours, and L4 could allow drivers to work on tasks such as logistics while the vehicle is moving. Additionally, the ability to rest while driving in the L4 environment could enable drivers to be at home more often rather than parked at distant locations, and to use equipment and their own labor more productively. Any gains in productivity could likewise decrease the number of trucks and drivers needed to move the nation's freight, which could act to mitigate the driver shortage problem.

⁵³"Truck Driver Shortage Analysis 2015." Accessed October 15, 2016. http://www.trucking.org/ATA_Docs/News_and_Information/Reports_Trends_and_Statistics/10_6_15_ATAs_Driver_Shortage_Report_2015.pdf

⁵⁴ Short, Jeffrey. *Analysis of Truck Driver Age Demographics across Two Decades*. American Transportation Research Institute. Arlington, VA. 2014.

⁵⁵ Ramasubbu, S. "From Gen X to Y and Z: Technology and the Generation Gap." June 24, 2015. Accessed November 14, 2016. http://www.huffingtonpost.com/suren-ramasubbu/from-gen-x-to-y-and-z-tec_b_7645410.html

⁵⁶ Solon, O. "Self-driving trucks: What's the future for America's 3.5 million truckers?" June 17, 2016. Accessed November 08, 2016. <https://www.theguardian.com/technology/2016/jun/17/self-driving-trucks-impact-on-drivers-jobs-us>; and Roberts, D. "1.8 million American truck drivers could lose their jobs to robots. What then?" August 3, 2016. Accessed October 14, 2016. <http://www.vox.com/2016/8/3/12342764/autonomous-trucks-employment>

It is important to note, however, that even in a highly automated environment, there are a number of critical freight movement tasks that will still be required of commercial drivers, including:

- Shipper/Client Relationship
 - Represent trucking company during interactions with shippers/clients.
 - Interact with shipper regarding delivery time and delivery location within a facility.
- Equipment Management
 - Ensure that truck has fuel and is clean.
 - Ensure the truck, trailer and components are in working order.
 - This includes daily vehicle inspection required by the FMCSRs.
- Route Management
 - Plan routes to/from origins and destinations.
 - Identify (and avoid if possible) traffic congestion and traffic incidents.
 - Identify and modify trip due to weather-related issues.
- Cargo Management
 - Load and unload cargo at origin/destination facilities.
 - Organize type and amount of cargo/bills of lading.
 - For certain freight types additional work is required:
 - Flatbed operations require cargo securement tasks.
 - Hazmat operations require additional tasks, training and endorsements.
- Regulations
 - Ensure that all laws, both state and federal, are followed.
 - Maintain CDL and meet driver medical exam requirements.

Issue 4: Driver Retention

Related to the Driver Shortage, retaining qualified safe drivers is a challenge for many motor carriers who face competition from other fleets (which may offer better pay or income-earning opportunities, more home time, etc.) or from other industries outside of trucking (which may pay more and provide the opportunity to be at home rather than long stretches on the road). Combined, these two forces (often referred to as “churn”) result in driver turnover rates that are approaching 100 percent annually across the industry.⁵⁷

One of the strategies that fleets pursue to retain their drivers is to utilize newer model equipment with the latest technologies designed to increase safety and reduce the fatigue and stress associated with driving tasks.⁵⁸ AT technology offers the potential to harness this retention strategy through trucks that not only reduce the monotony of long hours of driving but also get drivers home sooner (with associated changes to HOS rules as described earlier).

Additionally, L3 and L4 technologies may make the driver career path more attractive by greatly expanding productivity, particularly to younger, tech-savvy populations. Carriers with AT systems may also be able to attract drivers away from carriers that do not utilize AT.

⁵⁷ “Truck Driver Shortage Analysis.” Accessed October 15, 2016. <http://www.trucking.org/ATA Docs/News and Information/Reports Trends and Statistics/10 6 15 ATAs Driver Shortage Report 2015.pdf>

⁵⁸ Smith, P. (2006, April). Improving Driver Retention. Accessed November 14, 2016. <http://www.truckinginfo.com/article/list/tag/driver-retention.aspx>

Issue 5: Truck Parking

As noted earlier, drivers must rest for 10 hours between on-duty periods and many rely on private and public parking facilities as a place to log off-duty hours. It is well documented, however, that in many areas of the U.S. there is insufficient truck parking.⁵⁹ The industry has long advocated for several solutions to this issue, including the development of new truck parking facilities and real-time parking information systems as well as parking reservation systems.

L3 technologies, which allow for hands-free driving, could facilitate dynamic route planning. Through the use of smartphones and embedded telematics, a driver would be able to identify ideal parking locations, determine if space is or will be available, and even plan for alternative parking if the selected location was not available upon arrival. Due to the dangers (and legal limitations) of smartphone use while driving, this is not possible with today's standard vehicles. New rules allowing for the expanded use of smartphone devices while engaged in L3 driving would be necessary.

The use of L4 technology in conjunction with HOS changes discussed earlier could significantly decrease the need for truck parking spaces. Simply put, if rest periods can be taken while the truck is moving, there is no need to stop. Truck parking locations will still be utilized, particularly for the services provided at private truck stops (food, fuel, emergency maintenance), for vehicle inspection and for pre-delivery staging. Breaks of 30 minutes would likely disappear for authorized AT users, and 10-hour breaks will likely become less common, resulting in additional truck parking capacity for those who do need to park their vehicles.

L5 technology could ostensibly eliminate all HOS regulations and therefore result in significantly fewer stops than L4 trucks. If the L5 vehicle had no driver in the truck, there would be no need to park other than for pre-delivery staging, though stops for fuel and maintenance would be necessary. In either case, it is almost certain that L4 and L5 trucks will be redesigned to support radically different driver needs, amenities and services.

⁵⁹ Federal Highway Administration (FHWA). *Jason's Law Truck Parking Survey Results and Comparative Analysis*. Washington D.C. August, 2015.

Issue 6: Electronic Logging Device Mandate

The Electronic Logging Device (ELD) mandate will be effective in December 2017 and will require that drivers' hours on-duty and driving are recorded using electronic devices.⁶⁰ This concerns some in the industry who currently use paper logs and will have to invest in the technology, and will also have to train drivers and office staff on the use of these devices.

While approved L4 and L5 technology will likely warrant changes in the HOS regulations, a customized ELD will still likely be required for trucks that utilize a truck driver. If through the use of L5 technology no person is on-board a vehicle there is of course no need for an ELD.

⁶⁰ "Electronic Logging Devices." Federal Motor Carrier Safety Administration. Accessed November 14, 2016. <https://www.fmcsa.dot.gov/hours-service/elds/electronic-logging-devices>

Issue 7: Driver Health and Wellness

Driving a truck is a sedentary occupation, particularly in the long-haul sector. Much like a typical office occupation, there are long periods of time spent sitting in one place. Unlike office work, however, up to eight hours of sitting might occur before a driver stops a vehicle and is able to stand and move around. While standing and stretching routinely can help an office worker mitigate the impacts of sedentary work, this is not an option for long-haul truck drivers.⁶¹

For these same drivers, the work day often ends at a truck stop. More than 63 percent of respondents to the top industry issues survey believed that the lack of healthy food options and exercise facilities at truck stops contributes to driver health issues.⁶²

L3 technology is likely to have little impact on driver health and wellness, though there is the potential that drivers could relieve the stress and/or monotony of some highway driving by utilizing hands-free driving.

However, L4 and L5 vehicles will allow drivers to move within the vehicle. Though there are seatbelt laws, the ability for a driver to stand briefly or move from the seat to the sleeper berth will prevent long sedentary time periods. Additionally, if adjustments to the HOS are allowed there could be less time spent at truck stops and more home time for drivers. This could improve a driver's emotional health, eating habits and the activity level of drivers. Again, to facilitate such changes in truck driver activities, a thorough analysis of regulatory changes must be conducted, addressing such things as seat belt usage, standing or exercising in moving vehicles and "distracted driving" laws.

⁶¹ "Standing Up for Your Health." American Osteopathic Association. Accessed November 14, 2016. <http://www.osteopathic.org/osteopathic-health/about-your-health/health-conditions-library/general-health/Pages/sedentary-lifestyle.aspx>

⁶² American Transportation Research Institute (ATRI). *Critical Issues in the Trucking Industry – 2015*. Arlington, VA. October 2015.

Issue 8: The Economy

The health of the U.S. and global economies are critical factors in a trucking company's success, and thus the topic is typically on the top ten list of industry issues. Demand for consumer and industrial goods drives the demand for trucking services, and also the prices charged by motor carriers. As economies soften, so does the ability of motor carriers to charge favorable rates.

There are several potential relationships between the broader economy and autonomous vehicles. First, technology evolution is more likely to advance faster in a more robust economy given the higher tolerance for riskier investment in research and development.

At the microeconomic level, autonomous trucks (particularly L4 and L5 vehicles) have the potential to significantly change the operations of individual firms. This might include the following:

- Increased productivity due to HOS changes
 - Fewer drivers needed to move the same amount of freight
 - Fewer trucks needed to move the same amount of freight
- Expanded driver responsibility
 - More dynamic route planning
 - Administrative tasks
 - Increased customer service responsibility through email and cell phone communications
- Changes due to technology
 - Potential for increased equipment cost (especially for early adopters)
 - Changes in maintenance practices/skills
- Decreased insurance costs with fewer at-fault crashes

If early adopters are able to gain a competitive advantage, other companies will follow their lead.

Issue 9: Infrastructure, Congestion and Highway Funding

The Infrastructure, Congestion and Highway Funding issue is focused on the Nation's roadway network, which is essential to, and in substantial part funded by, the trucking industry.⁶³

As an overview, the infrastructure component is concerned with the condition, quality and capacity of freight-significant roadways. Many in the industry feel that U.S. infrastructure falls far short of what is acceptable. The capacity problem in particular leads to traffic congestion, particularly during morning and afternoon rush hours when commuters clog the highways. Congested roadways cost the trucking industry billions of dollars annually in wasted time and resources.⁶⁴ The capacity/congestion problem could be addressed through tax increases that fund highway investment. At the Federal level it has been politically challenging to increase fuel taxes – the federal fuel tax rate has not increased in more than 20 years. Many states, however, have successfully increased funding. The potential impacts of AT, and autonomous vehicles in general, is discussed below.

Infrastructure. Today's autonomous vehicle technology operates best on high quality infrastructure. Proper road striping, signage, geometries and pavement conditions all help facilitate autonomous vehicle use. Additionally, vehicle-to-infrastructure (V2I) technology will enable vehicles to communicate with traffic lights and other aspects of the infrastructure. Thus, while automated vehicles will not improve the infrastructure, the technology used by AV might necessitate infrastructure investment.

Congestion. Autonomous vehicle technologies have the potential to operate vehicles more efficiently than human drivers. The technology is focused only on the task of getting from point A to point B safely and efficiently, with no distractions. With the AT systems and potentially V2X communications, vehicles will be able to safely travel in sync and at close distances, thus mitigating highway congestion issues related to inefficient “stop and go” traffic that often occurs on urban roadways during peak travel periods. Specific to trucking, HOS changes in concert with ATs could move more trucks to less-congested time periods (than rush hours). All of this could generate benefits that range in the billions of dollars annually, particularly in the form of fuel and time savings.

A report by RAND does identify several aspects of autonomous vehicles that may counteract the benefits to congestion.⁶⁵ First, the report suggests that the tolerance for long commutes may increase as automobile drivers are able to

⁶³ The trucking industry paid \$39.9 billion in federal and state highway user taxes in 2014 according to: American Trucking Associations. *American Trucking Trends 2016*. Arlington, VA. 2016.

⁶⁴ Torrey, W. Ford, IV. *Cost of Congestion to the Trucking Industry*. American Transportation Research Institute. Arlington, VA. April 2016.

⁶⁵ Anderson, James, N. Karla, K. Stanley, P. Sorenson, C. Samaras and O. Oluwatola. *Autonomous Vehicle Technology: A Guide for Policymakers*. RAND Corporation. 2016.

focus on activities other than driving. The additional vehicle miles traveled (VMT) have the potential to impact trucking in outer suburbs and even rural areas. Additionally, RAND suggests that since parking is an issue within central business districts (it is expensive and is not an ideal land use where land availability is limited), fully autonomous L5 automobiles might drop passengers off and then drive without passengers to parking locations many miles away. This too would increase VMT and possibly create off-peak congestion where there was none previously. Finally, automobile usage and mobility could actually increase as persons not able to operate a motor vehicle, including those who are “blind, disabled, or those too young to drive” could now do so.⁶⁶ In summary, there may be a greater interest in AVs operating in dramatic new ways, with the end result being more vehicles on the road leading to increased congestion.

Highway Funding. On the surface, highway funding will be primarily influenced by factors not related to autonomous vehicles. The areas that might impact increases or decreases in funding (based on current collection methods) are vehicle registration fees (as a percentage of sales price), fuel consumption, VMT levels and alternative power sources. There may be some degree of fuel economy improvement related to autonomous vehicles, generating from closer headways, more stable acceleration and braking, and higher average speeds. With lower fuel consumption per mile there are lower fuel tax revenues per mile. VMT per vehicle, however, may increase as a result of autonomous vehicle adoption, and thus revenues may actually increase. Finally, there is some association between autonomous vehicles and electric vehicles (Tesla being the main company combining the two technologies). If electric vehicles become more prevalent, revenues will decrease unless vehicle electricity or VMT are taxed.

⁶⁶ Anderson, James, N. Karla, K. Stanley, P. Sorenson, C. Samaras and O. Oluwatola. *Autonomous Vehicle Technology: A Guide for Policymakers*. RAND Corporation. Pg XV. 2016.

Issue 10: Driver Distraction

With the advent of texting and smartphones, distracted driving has become a significant public safety problem. NHTSA statistics show that seven percent of all vehicle crashes are caused by distracted driving.⁶⁷

L3 through L5 vehicles could mitigate distracted driving. If a driver must use a device, the option to turn the controls of the vehicle over to the automated system could prevent a distracted driving situation. Fully autonomous L4 and L5 vehicles, when engaged in autonomous driving, by their very nature have the potential to eliminate the distracted driving problem. When there is no driver, there is no opportunity for driver distraction. Other non-autonomous vehicles, however, will still pose a threat if there is a distracted driver behind the wheel.

⁶⁷ "Critical Reasons for Crashes Investigated in the National Motor Vehicle Crash Causation Survey." February 2015. Accessed November 05, 2016. <https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812115>
DOT HS 812 115

ADDITIONAL TRUCK SAFETY AND OPERATIONAL CONSIDERATIONS

Beyond the Top Industry Issues, there are several other key areas where the trucking industry may be impacted by autonomous trucks and cars.

Crash Costs, Severity and Responsibility

Vehicle crashes result in approximately 30,000 fatalities each year in the U.S. and have additional costs associated with property damage and personal injury, for a total cost of \$836 billion annually.^{68 69} Research has shown that the majority of motor vehicle crashes in the U.S. are the result of human error. In 2015, NHTSA estimates that 94 percent of crashes can be attributed to the driver.⁷⁰ In 2014 there were 3,903 fatalities that resulted from large truck-involved crashes; 657 of those fatalities were occupants of large trucks.⁷¹

The cost of crashes to the industry and drivers is therefore significant – yet there is potential that crashes and their associated costs will decrease through the use of autonomous vehicles. Technologies that assist driver's awareness and ability to operate safely have been shown to improve roadway safety. A recent study attributed technologies such as electronic stability control and forward collision warning systems to the continual steady decline of fatal crash rates.⁷² Given the benefit of motor vehicle safety technologies, if 90 percent of cars on American roads were fully autonomous, it has been suggested that the number of accidents per year could fall from 6 million to 1.3 million, and fatalities could decrease from 33,000 to 11,300 per year.⁷³ Fully autonomous cars also have the potential to eliminate impaired driving fatalities, which make up more than a third of motorist fatalities.⁷⁴ While these statistics do not specifically cite truck automation, it is likely that truck-car crashes would decrease as a result of car automation. Additionally, the safety benefits overall are estimated at \$642 billion in savings due to the reduction of both fatal and non-fatal crashes.⁷⁵

⁶⁸ NHTSA. *The Economic and Societal Impact Of Motor Vehicle Crashes, 2010 (Revised)*. US DOT, Washington D.C. 2015. "When quality of life valuations are considered, the total value of societal harm from motor vehicle crashes in 2010 was \$836 billion."

⁶⁹ "Distraction Driving 2014." April, 2016. Accessed November 05, 2016.

<https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812260>
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⁷⁰ "Critical Reasons for Crashes Investigated in the National Motor Vehicle Crash Causation Survey." February 2015. Accessed November 05, 2016. <https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812115>

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⁷¹ "Large Truck Bus Facts 2014." Federal Motor Carrier Safety Administration. Accessed November 11, 2016.

<https://www.fmcsa.dot.gov/sites/fmcsa.dot.gov/files/docs/Large-Truck-and-Bus-Crash-Facts-2014%28April%202016%29.pdf>

⁷² Anderson, James, N. Karla, K. Stanley, P. Sorenson, C. Samaras and O. Oluwatola. *Autonomous Vehicle Technology: A Guide for Policymakers*. RAND Corporation. 2016.

⁷³ Thompson, C. "The 3 biggest ways self-driving cars will improve our lives." Accessed November 11, 2016.

<http://www.businessinsider.com/advantages-of-driverless-cars-2016-6/#roads-will-be-safer-1>

⁷⁴ Anderson, James, N. Karla, K. Stanley, P. Sorenson, C. Samaras and O. Oluwatola. *Autonomous Vehicle Technology: A Guide for Policymakers*. RAND Corporation. 2016.

⁷⁵ Ozlmeck, A. "The Massive Economic Benefits of Self-Driving Cars." Accessed November 14, 2016.

<http://www.forbes.com/sites/modeledbehavior/2014/11/08/the-massive-economic-benefits-of-self-driving-cars/#6724673e68d9>

There will still, however, be vehicle crashes with all levels of autonomous vehicles, and both cost and responsibility will be assigned to a party as a result.

In terms of litigation targets, a self-driving truck will have an owner, associated manufacturers (both the primary OEM and the makers of vehicle parts and software), insurers, and may have an occupant. If a self-driving truck is the cause of a crash while in driverless mode, new applications of tort law will likely arise, and may apply to multiple entities.

Traditional negligence laws, which are created and adjudicated primarily at the state level, hold that “drivers are liable for injuries that they cause in violation of [the] duty of reasonable care.”⁷⁶ As Anderson et al point out however, it would not be intuitive to assign crash blame for the aforementioned self-driving mode to an occupant of the vehicle. This is particularly true if the self-driving system used is commercially available and widely used. In a situation where the self-driving system’s decision results in a crash, the blame essentially goes to decisions made by software.

Several states use a no-fault system which generally relies on insurance instead of litigation for addressing losses that result from vehicle crashes. Anderson et al suggest that this system may be more appropriate for autonomous vehicles, though this would require significant changes in state law across the U.S.

The literature suggests also that it is possible that crash responsibility could shift to manufacturers from the driver when a vehicle crash is caused by a driverless system.⁷⁷ If this is the case, the potential liability associated with developing autonomous technology could hinder or stop development.⁷⁸ Likewise, if motor carriers that utilize autonomous truck technologies or insurers that write policies on autonomous trucks have more of a liability burden than with traditional trucks, adoption may be limited. It is even conceivable that far in the future when autonomous systems are ubiquitous, a driver that has, but does not use an autonomous system, is liable for an additional degree of negligence when causing a crash.

There are countless other scenarios where responsibility will be determined by the legal system. Potential future scenarios where liability could be debated include:

- A driver engages the driverless system in weather conditions that are not ideal (for use of the autonomous technologies).
- A self-driving vehicle suddenly stops for a nonexistent hazard due to a system glitch, causing a crash.
- A self-driving vehicle is hacked, resulting in a crash.

⁷⁶ Anderson, James, N. Karla, K. Stanley, P. Sorenson, C. Samaras and O. Oluwatola. *Autonomous Vehicle Technology: A Guide for Policymakers*. RAND Corporation. 2016.

⁷⁷ Ibid.

⁷⁸ Marchant, Gary, and R. Lindor. *The Coming Collision between Autonomous Vehicles and the Liability System*. Santa Clara Law Review, Vol. 52, 2012, pp. 1321–1340. 2012.

- A company is sued for additional negligence simply because they do not utilize “safer” self-driving technologies.

There are varying laws in 50 states that govern crash responsibility. Legal standards in each of the states will likely evolve as crashes occur and litigation takes place. At this time, however, there is no clear path that will be taken regarding crash responsibility and autonomous vehicles.

Inspection, Repair and Maintenance of Autonomous Technology

The technologies that enable autonomous truck systems, such as LIDAR, radar and video, must function properly and safely. Additionally, system failure could be catastrophic, particularly in L5 systems where it is possible that no human is present to take control of the vehicle.

Section 396 of the FMCSRs (which specifically covers inspection, maintenance and repair) states that “every motor carrier and intermodal equipment provider must systematically inspect, repair, and maintain, or cause to be systematically inspected, repaired, and maintained, all motor vehicles and intermodal equipment subject to its control.”⁷⁹ This includes daily inspections (driver vehicle inspection reporting) and a more comprehensive annual inspection (which must be conducted by an inspector that meets specific qualifications outlined in the FMCSRs). FMCSA and authorized law enforcement may also conduct roadside inspection of vehicles.

Minimum standards for the components of a commercial vehicle are described in Section 393 of the FMCSRs – Parts and Accessories Necessary for Safe Operation. This section requires that “parts and accessories shall be in safe and proper operating condition at all times.”⁸⁰ Inspection requirements are found in Section 396. FMCSRs as currently written do not specifically address specifications, inspection, repair and maintenance of autonomous truck systems. Requiring new AT maintenance certifications could have a dramatic impact on the already huge shortage of truck and engine mechanics and technicians.⁸¹

Within the public sector, NHTSA states in its September 2016 AV policy publication that it “will continue to exercise its available regulatory authority over [highly automated vehicles] using its existing regulatory tools: interpretations, exemptions, notice-and-comment rulemaking, and defects and enforcement authority.”⁸² It is also assumed that FMCSA, in following its current regulations related to commercial vehicles and vehicle parts utilized in interstate commerce, will facilitate changes to the FMCSRs that address the entrance of autonomous truck systems into the industry. It is assumed also that these FMCSA rules would go beyond the limitations of NHTSA, and focus on actions

⁷⁹ 49 C.F.R., § 396.

⁸⁰ 49 C.F.R., § 393.

⁸¹ Kilcarr, S. “Is the technician shortage becoming a catastrophe?” March 1, 2016. Accessed November 13, 2016. <http://fleetowner.com/fleet-management/technician-shortage-becoming-catastrophe>

⁸² National Highway Traffic Safety Administration (NHTSA). *Federal Automated Vehicles Policy: Accelerating the Next Revolution in Roadway Safety*. US Department of Transportation, Washington D.C. Page 7. September, 2016.

that fleets and drivers must take to maintain a properly functioning autonomous truck system. Thus, changes to Sections 396 and 393 of the FMCSRs could be expected. It is anticipated that state agencies overseeing vehicles registered for intrastate use will develop rules as well.

Law enforcement will certainly need new tools and training to be able to determine if a carrier meets the standards set forth by state and federal regulations.

To meet new regulatory requirements, it is likely that multiple personnel within any one fleet will require training as well. For drivers this could require training to identify technical issues associated with “taking control back” from ATs. As noted, mechanics will need to understand both hardware and software repair and maintenance – including integration of disparate systems and components. Original equipment manufacturers (OEMs) will be essential in “train-the-trainer” programs for the autonomous truck systems.

Cyber Security (Hacking) and Terrorism

Researchers have demonstrated that it is possible for a hacker to access a motor vehicle’s electronics systems for malicious purposes. A team of computer science researchers, for instance, was able to remotely gain access to a car’s electronics system and take control of systems, resulting in the falsification of instrument readings (e.g. speedometer) and a shutdown of the engine while moving.⁸³ In another instance, researchers were able to remotely control a vehicle by exploiting a bug in the vehicle’s software – this resulted in a widespread recall of the vehicle.⁸⁴ Researchers have even demonstrated methods for LIDAR systems to “detect” obstacles that are not actually present; in the demonstration this caused a driverless car to abruptly stop and swerve.⁸⁵

As vehicles are more accessible over the internet, and more reliant upon software and computer systems, greater threats to hacking arise. These threats could be simply disruptive or could lead to accidents that cause significant injury, loss of life and property damage. There is even the potential to use a hacked vehicle to commit acts of terrorism.⁸⁶ Motor carriers are not experts in cyber security, and few will be able to quickly detect and defeat a breach of an autonomous truck system. Security measures therefore will be the responsibility of the manufacturer, and any vulnerabilities that arise will have to be addressed by the manufacturer. That said, trucking companies should be prepared to report any irregularities that are discovered.

⁸³ Koscher, Karl, Stephen Checkoway, et al. *Experimental Security Analysis of a Modern Automobile*. 2010 IEEE Symposium on Security and Privacy. 2010. Accessed November 1, 2016. <http://www.autosec.org/pubs/cars-oakland2010.pdf>

⁸⁴ Greenberg, A. “Hackers Remotely Kill a Jeep on the Highway - With Me In It.” July 2015. Accessed November 14, 2016. <https://www.wired.com/2015/07/hackers-remotely-kill-jeep-highway/>

⁸⁵ Gershgorn, D. “Hackers can Trick Driverless Cars with a Handheld Laser.” September 8, 2015. Accessed November 11, 2016. <http://www.popsci.com/hackers-can-trick-lidar-used-in-autonomous-cars-with-laser-pointer>

⁸⁶ Bukszpan, D. “Could autonomous trucks be the next weapon for terrorists?” July 21, 2016. Accessed November 14, 2016. <http://www.cnn.com/2016/07/21/could-autonomous-trucks-be-the-next-weapon-for-terrorists.html>

General Impact on FMCSRs and State Regulations

The laws that govern the trucking industry have been discussed throughout this report. At the federal level many of the key sections within the FMCSRs will likely see necessary changes with the widespread adoption of L4 and L5 autonomous trucks:

- Section 395: Hours of Service of Drivers
- Section 396: Inspection, Repair, and Maintenance
- Section 393: Parts and Accessories Necessary for Safe Operation
- Section 391: Qualification of Drivers
- Section 390: Federal Motor Carrier Safety Regulations; General
- Section 383: Commercial Driver's License Standards; Requirements and Penalties

FMCSA is granted general authority to regulate the trucking industry through the Motor Carrier Safety Improvement Act of 1999, and Congress may instruct the agency directly to take certain action.

To take AT-related regulatory action without Congressional direction FMCSA must follow a rulemaking process. This process may take several years or more, and requires that FMCSA inform the public and other government entities of regulatory plans and the purposes of those plans. As part of this process, rules and supporting information may be published within the Federal Register. These documents often include:

1. Unified Agenda, which consists of an annual "Regulatory Plan" and "Agenda of Regulatory and Deregulatory Actions"
2. Advance Notice of Proposed Rulemaking
3. Notice of Proposed Rulemaking
4. Final Rule

Throughout this process there are public comment periods, and additional information may be required for rules that could have a significant financial impact. In such situations, a Regulatory Impact Analysis (RIA) of the proposed rules would be required whereby the agency would identify and quantify costs and benefits.

Though trucking is often thought of as an interstate-focused industry, there are numerous intrastate exemptions and regulatory impacts that will need to be addressed as well.

CONCLUSION

Autonomous truck technology is on a course that will fundamentally change the trucking industry. Shifts of this magnitude do not come often – and may prove to be as momentous as the building of the Interstate System and deregulation.

The technology to demonstrate L3-L5 operations exists today, though motor carriers do not currently have access to AT systems. That will change in the coming years as systems are further developed and commercialized. Individual motor carriers, and the trucking industry as a whole, can use that time for planning an approach to this technology, both in terms of regulatory and operational changes.

For carriers there are still many unknowns, particularly the return-on-investment (ROI). On the investment side of the ROI equation there is only a sense of what the current “demonstration” systems cost. There is a fair amount of speculation as well. The technology is in a pre-deployment stage of development, and with no clear price points it is difficult to assess value to ATs. The industry understands that whatever the initial price is, per-unit technology costs do tend to decrease with widespread adoption.

On the benefit side the two critical positives are productivity and safety. With changes to the FMCSRs, particularly though an adaptation of the hours-of-service for AT users, there is the potential that individual over-the-road drivers will be able to operate in what is essentially a team environment. The systems will operate the vehicle during interstate travel while the driver rests, and the driver will take over on secondary roadways. The elimination of human error-related crashes also has the potential to save the industry billions of dollars annually.

The bigger picture of what this technology means for the industry quantitatively will emerge in the coming years. Until that time, this report offers a sense of how AT will impact the industry’s most critical issues. The potential benefits of AT on these issues are condensed in the following table:

Table 10: List of Top Trucking Industry Issues and AT Benefits

Top Issues	Key Autonomous Truck Benefit
Hours-of-Service	Allows for driver rest and productivity to occur simultaneously.
Compliance, Safety, Accountability	Will decrease raw SMS scores, though percentile scoring needs to change.
Driver Shortage	Driving more attractive with higher productivity, less time away from home, and additional logistics tasks; fewer driver may be needed.
Driver Retention	Companies with autonomous technology may attract and retain drivers.
Truck Parking	If "productive rest" is taken in the cab during operations, less time will be required away from home at truck parking facilities and fewer facilities will be needed.
Electronic Logging Device Mandate	Modifications will be necessary depending on level of autonomy.
Driver Health and Wellness	Driver could be less sedentary; injuries could be reduced.
The Economy	Carriers that use AT may see productivity and cost benefits.
Infrastructure / Congestion / Funding	Urban congestion could be mitigated through widespread use of autonomous vehicles (including cars).
Driver Distraction	Drivers will not be distracted from driving if vehicle in autonomous mode.

APPENDIX A

Summary of SAE Internationals Levels of Driving Automation for On-Road Vehicles⁸⁷

SAE Level	Name	Narrative Definition
Human driver monitors the driving environment		
0	No Automation	the full-time performance by the human driver of all aspects of the dynamic driving task, even when enhanced by warning or intervention systems
1	Driver Assistance	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
2	Partial Automation	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
Automated driving system (“system”) monitors the driving environment		
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
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 request to intervene
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

Source: SAE International and J3016

⁸⁷ SAE International. “Automated Driving Levels of Driving Automation are Defined in New SAE International Standard J3016.” Accessed November 14, 2016. http://www.sae.org/misc/pdfs/automated_driving.pdf

APPENDIX B

NHTSA Level	Name	Definition
0	No Automation	The driver is in total control of the primary vehicle controls (steering, brake, motive power) at all times.
1	Function Specific Automation	Automation at Level 1 involves one or more specific control functions.
2	Combined Function Automation	Automation at Level 2 involves at least two of the control functions designed to work together to alleviate the driver having to do the control.
3	Limited Self-Driving Automation	Allows vehicle to take full control of all safety-critical functions from driver in certain traffic and environmental conditions. Driver must be able to take occasional control of vehicle but with suitable amount of time for transition.
4	Full Self-Driving Automation	Vehicle is capable of performing all safety-critical functions and monitoring conditions of road for a complete trip.



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