

Changing Technology in Transportation: Automated Vehicles in Freight

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1. Introduction

The world of transportation is on the verge of undergoing an impactful transformation. Over the past decade, automotive computing technology has progressed far more rapidly than anticipated. Most major auto manufacturers integrated automated features such as adaptive cruise control, automated braking, self-parking, and lane departure warning into their new car models. Furthermore, numerous auto manufacturers and information technology companies have started to test their automated vehicles (AVs) on existing roads under certain conditions. A majority of the companies working on automated vehicle technology for passenger cars claim that highly automated vehicles will be ready to operate in the real world by the year 2021¹. However, it is important to recognize that there are different levels of automation with different technologies and functionalities. The implementation of different levels of automation for passenger cars and freight will vary. A better understanding of what technologies will be introduced, when they will be introduced, and what changes to laws/regulations, as well as the physical transportation infrastructure, will be required prior to the wide range deployment of AVs.

AVs have a vast potential to improve safety, reduce the cost of congestion, increase road capacity, and decrease the energy consumption and pollution. Recognizing their potential, the National Highway Traffic Safety Administration (NHTSA) released “Federal Automated Vehicles Policy” to accelerate the development, testing, and deployment of highly automated vehicles. In “Federal Automated Vehicles Policy,” NHTSA has adopted the Society of Automotive Engineers (SAE) International definitions for levels of automation². The SAE defines six levels of driving automation that spans from no automation to full automation (Figure 1).

For the automation levels 0, 1 and 2, the human driver conducts the driving task, so even though there might be some automated assistance systems functioning; the responsibility is on the human driver. Those automation levels are already commercially available and do not require any infrastructure changes or government actions. However, there is a key distinction between Levels 0-2 and 3-5 where automated systems are responsible for both conducting the driving task and monitoring the environment. U.S. Department of

¹ Muoio, D. (2016, October 17). *19 companies racing to put self-driving cars on the road by 2021*. Retrieved from Business Insider: <http://www.businessinsider.com/companies-making-driverless-cars-by-2020-2016-10/#tesla-is-aiming-to-have-its-driverless-technology-ready-by-2018-1>

² National Highway Traffic Safety Administration. (2016). *Federal Automated Vehicles Policy: Accelerating the Next Revolution in Roadway Safety*. Washington, D.C.: U.S. Department of Transportation.

Transportation draws a distinction between those two sets of automation levels and uses the term “highly automated vehicle” (HAV) for Level 3-5 vehicles³.

Figure 1. SAE Levels of Automation

SAE LEVEL	Name	Narrative Definition	Execution of Steering and Acceleration/Deceleration	Monitoring of Driving Environment	Fallback Performance of Dynamic Driving Task	System Capability (Driving Modes)
Human driver monitors the driving environment						
0	No Automation	the full-time performance by the <i>human driver</i> of all aspects of the <i>dynamic driving task</i> , even when enhanced by warning or intervention systems	Human driver	Human driver	Human driver	n/a
1	Driver Assistance	the <i>driving mode</i> -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 <i>human driver</i> perform all	Human driver and system	Human driver	Human driver	Some driving modes
2	Partial Automation	the <i>driving mode</i> -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 <i>human driver</i> perform all remaining aspects of the	System	Human driver	Human driver	Some driving modes
Automated driving system monitors the driving environment						
3	Conditional Automation	the <i>driving mode</i> -specific performance by an <i>automated driving system</i> of all aspects of the <i>dynamic driving task</i> with the expectation that the <i>human driver</i> will respond appropriately to a <i>request to intervene</i>	System	System	Human driver	Some driving modes
4	High Automation	the <i>driving mode</i> -specific performance by an automated driving system of all aspects of the <i>dynamic driving task</i> , even if a <i>human driver</i> does not respond appropriately to a <i>request to intervene</i>	System	System	System	Some driving modes
5	Full Automation	the full-time performance by an <i>automated driving system</i> of all aspects of the <i>dynamic driving task</i> under all roadway and environmental conditions that can be managed by a <i>human driver</i>	System	System	System	All driving modes

Source: Copyright © 2014 SAE International

³ National Highway Traffic Safety Administration. (2016). Federal Automated Vehicles Policy: Accelerating the Next Revolution in Roadway Safety. Washington, D.C.: U.S. Department of Transportation.

There is a general uncertainty about the level of automation that the companies are working on and that will be available by 2021. The general discussion around automated vehicles (mentioned in various sources as autonomous vehicles or driverless cars interchangeably) created the premise and public perception of fully automated SAE Level 5 vehicles being fully commercially available in 2021. However, currently all auto manufacturing companies are working on automated vehicles and agree that commercial availability of Level 3 and Level 4 vehicles will come first even as limited editions of level 5 vehicles are demonstrated .

In Level 3 vehicles, the automated system both monitors and drives the vehicle under certain conditions, but a human driver must be ready to take control when the automated system requires. Even though most major auto and truck manufacturing companies such as Ford, Tesla, GM, Volvo, Mercedes Benz, and BMW are expecting to introduce vehicles with substantial Level 4 technologies around 2021, the human machine interface (HMI) development needed for these and higher levels of automation still presents some significant challenges. The main concern is the human driver reengagement when the system requires it. When the system is automated, the human driver will be able to engage in other tasks and become distracted so his/her response might be late when the system requests it. Instant changes in the driving conditions like the changes in weather or accidents may require fast human driver reengagement. Some Auto manufacturing companies note that this safety challenge may lead the industry to limit some automation technology until they are confident they can directly move on to fully independent Level 4/5 vehicles.

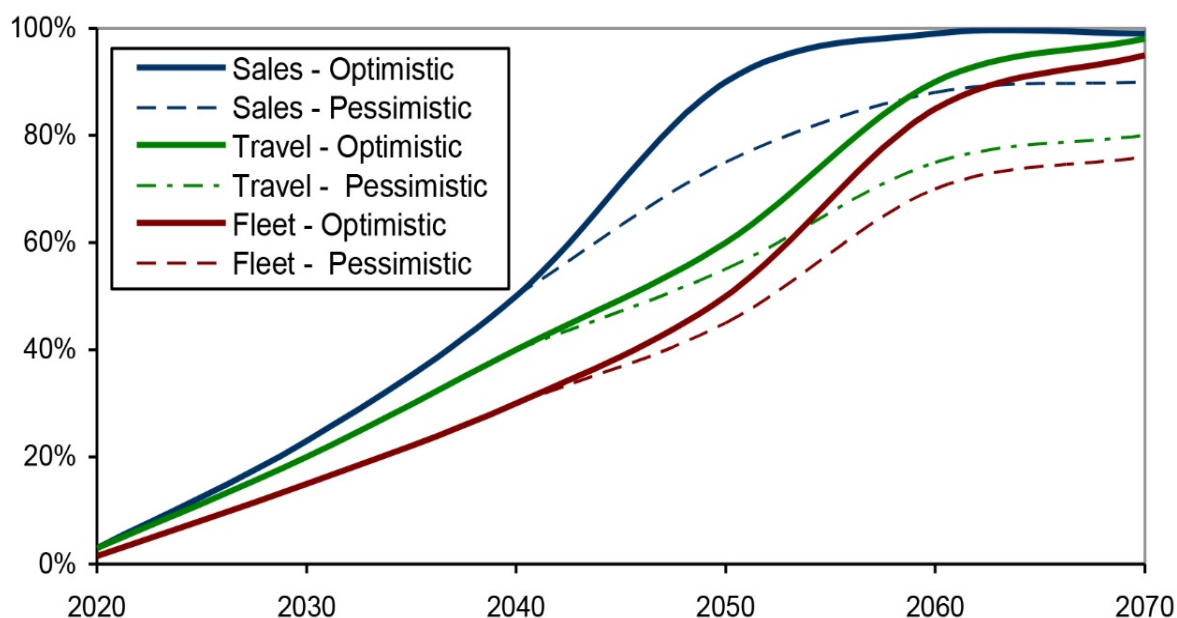
The forecasts of AV deployment and market penetration necessary to realize widespread benefits vary considerably. Most of the auto manufacturers working on AVs aim to routinely include Level 3 and aspects of level 4 vehicles by 2020. Based on an analogy with the evolution of previous automobile technologies such as air bags and hybrid vehicles, a 2013 study forecasts that the share of automated vehicles will reach 50% only around 2040s (Figure 2)⁴. Current estimates for introduction are now about 5 years earlier but the estimates for market penetration and fleet incorporation have not really changed. While the pace of technological development has been rapid, the highly automated vehicles expected to be introduced by 2019-2020¹ will be on limited routes under limited conditions. There are some lower level AVs available on the commercial market today (such as Tesla's Autopilot), and there are some higher level AVs in testing or limited pilots (by many major automakers as well as technology firms like Google, Tesla and Uber). However, experts disagree on when AVs will reach market-ready maturity.⁵ Aspects of fully automated vehicles will reach mass-market levels much

⁴ Tsugawa, S. (2013, October 13). *Final Report on Automated Truck Platoon within Energy ITS Project*. Retrieved February 10, 2017, from ORFE: http://orfe.princeton.edu/~alaink/SmartDrivingCars/ITFVHA13/ITFVHA13_JP_Energy_ITS_Tsugawa.pdf

⁵ ENO States and Automated Vehicle Policy, May 2017

sooner. For example, The Insurance Institute for Highway Safety estimates that features such as autobrake will be in 80% of registered vehicles by 2033 even though automakers have proposed a goal of 2022. Other aspects of higher level of automations will reach market earlier and later.

Figure 2. Anticipated Fully Automated Vehicle Percentage in traffic by years⁶



KPMG interviewed vehicle manufacturers and found that most expected fully autonomous vehicles would not appear until after 2025. The report argued that only 4% of passenger vehicles would be equipped with SAE level 4 or 5 technology in 2025. This production share was forecast to ramp up to 25% in 2030, though the share of fleet with this technology will be much lower as the new technology gradually enters the vehicle stock. PwC expects that fully autonomous long-range driving at highway speeds will emerge between 2020 and 2025, but that this technology will come with manual override until at least 2025 or 2030. By 2030, vehicles are expected to be sold without steering wheels and so would be legally operated fully autonomously.⁷

BMW, chip giant Intel and tech company Mobileye say they intend to deliver an autonomous vehicle by 2021. Ford plans to sell a personal-use self-driving car by the mid-2020s and expects autonomous vehicles to make up 20 percent of its sales by 2030. Volvo plans to test limited self-driving XC90 SUVs with real customers in Gothenburg,

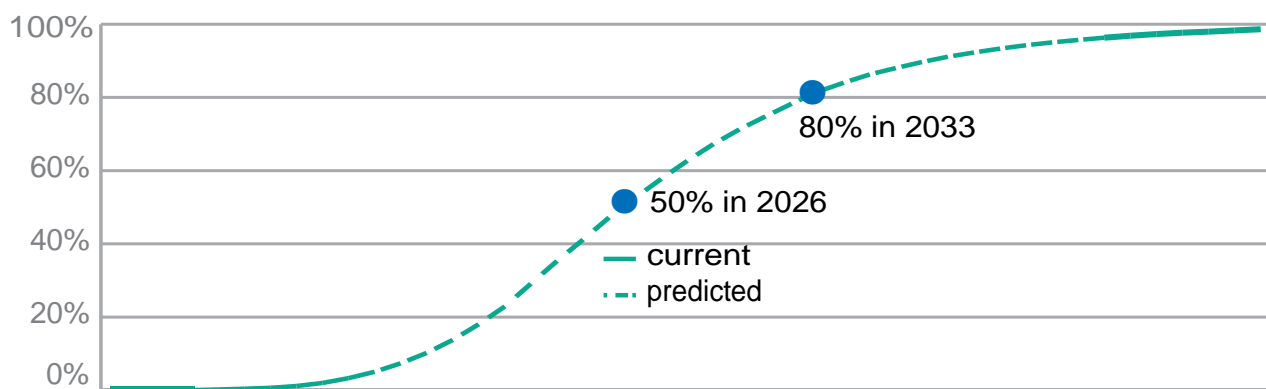
⁶ SOURCE: Reprinted from Final Report on Automated Truck Platoon within Energy ITS Project by Sadayuki Tsugawa

⁷ MANAGING THE TRANSITION TO DRIVERLESS ROAD FREIGHT TRANSPORT — OECD/ITF 2017; KPMG, “Connected and autonomous vehicles – the UK economic opportunity,” March 2015; PwC, “Connected car study 2015, racing ahead with autonomous cars and digital innovation,” report by Strategy&., April 2015

Sweden, as part of its Drive Me project beginning next year (2018). Audi, Infiniti, Mercedes-Benz, Nissan and Toyota also have projects in the works. How much autonomy these vehicles will achieve is unclear.

Elon Musk, Tesla's chief executive, said in October that the company is equipping its three models with the hardware "needed for a full self-driving capability at a safety level substantially greater than that of a human driver." Tesla says it will roll out the new features via over-the-air updates as the underlying software is validated. Musk says his goal is to take a Tesla cross-country in a "fully autonomous mode" demonstration by 2018.⁸

Predicted penetration of autobrake into vehicle fleet



IIHS Special Status Report Newsletter, Vol 51, No. *, November 10, 2016. "Special Issue: Autonomous Vehicles

Thus, Level 5 vehicles able to perform all driving tasks under all conditions without a human driver are still considered to be in research phase with some prototypes produced and introduced into limited use. More extensive demonstration projects will continue in the next 5 years. As is the case with the lower levels of automation, first and last mile, complex urban traffic, and difficult weather conditions require more research and testing. The testing period of different scenarios and standardization of infrastructure will take time and effort. Google Driverless Car is arguably the most well-known project, which was designed to be driverless from the ground up. Google has been working on its driverless car project since 2009, and while having driven more than 2 million miles in autonomous mode⁹, adverse weather like rain, snow and even poor light still present serious challenges and limitations for the technology. Renault¹⁰ announced in June 2017 that two autonomous taxis will be deployed in 2018 in Rouen, Normandy, France and a shuttle van will run between a train station and a university campus near Paris. Therefore, it is not easy to predict a definite timeframe for fully automated

⁸ IIHS Special Status Report Newsletter, Vol 51, No. *, November 10, 2016. "Special Issue: Autonomous Vehicles

⁹ Waymo. (2016). *On the road*. Retrieved March 23, 2017, from Waymo: <https://waymo.com/ontheroad/>

¹⁰ Associated Press, June 7, 2017. "Autonomous cars (no Human Backup) May hit road in 2018." (Dephi and Renault).

Level 5 vehicles for both passenger cars and freight yet. Even the most optimistic predictions do not foresee commercial introduction any time soon, and it will be at least 20 years before we see dominant market market penetration. However, the development of AV technology is progressing far more rapidly than expected and has a potential to alter transportation systems, so it is crucial to keep being informed about the current state of the technology and follow the direction it is moving towards.

Driving without any human control or supervision requires more technological development even if it is only in limited circumstances. Several years of development and testing will be needed for regulators and users to gain confidence that Level 4 vehicles are ready to operate under the specified conditions and be introduced and widely accepted in the market. The most difficult aspects of higher-level automation, such as driving in complex urban environments will take a longer time to be finished and made highly reliable. The difficulties in making the advanced technology easy to use and highly reliable was emphasized by J.D. Power's 2017 Initial Quality Study which found semiautonomous features the only category with increased problems led by complaints related to semi-adaptive cruise control which doubled to 34%. "The largest increases in problems are for cruise control (primarily adaptive cruise); lane departure warning; collision avoidance/alert systems; and blind spot warning. These features comprise some of the building blocks of autonomous vehicles, and an increasing number of consumer-reported problems sounds warning bells for automakers and suppliers. Consumers will need to be convinced that these systems are foolproof before they will give up driving control to autonomous vehicles."¹¹ .Recent estimates of commercial Introduction of fully autonomous taxis reaching 20% market share by 2025 ***"assume that current technological limitations and problems some autonomous vehicles have in show such as difficulty reading signs and lane markings will be resolved by 2025."***¹²

The rate of introduction of more advanced technologies into trucks is more complicated as the presence of full time professional drivers and connected technologies such as platooning make lower levels of technologies more productive. This is further compounded by the cost of new automation hardware and software on each truck that ranges from \$13,000 per truck for Level 3 up to \$30,000 per truck for level 5, which will substantially affect company costs¹³. The automated system of Level 4 vehicles can conduct the driving task without human control or supervision but only in certain circumstances where road and weather conditions are ideal. For now, the demonstration projects are being done in limited routes and controlled environments under good weather

¹¹ J.D. Power, 2017 U.S. Initial Quality Study. Released June 22, 2017. <http://www.jdpower.com/press-releases/2017-us-initial-quality-study-iqs>

¹² Wall Street Journal, "Report on the Future of Transportation", June 21, 2017, page R2

¹³Short, J and Murray, D., (American Transportation Research Institute), Identifying Autonomous Vehicle Technology Impacts on the Trucking Industry. November 2016. Arlington, VA. www.atrionline.org

conditions. For example, the recent, highly publicized demonstration test of a truck from Uber Technologies' Otto Subsidiary with some Level 4 technology that took place on Interstate 25 in Colorado in October 2016, had the Colorado Department of Transportation preparing the route and made sure that the roadway was swept of debris and that there were not any abandoned vehicles on the side of the road¹⁴.

2. *The Benefits of Widespread Implementation of AVs with Passenger Cars*

While the earliest widespread implementation of AV technology will likely be in trucking and freight, much of the research focus has been on the environmental, safety and planning benefits from passenger vehicles though, ultimately, the same benefits will ultimately accrue for trucks and freight.

Safety

The most important benefit of AVs is safety. In 2015 alone, 35,092 people died on U.S. roadways, and 94 percent of the crashes can be tied to human error (Table 1)¹⁵. AV technology, using collision avoidance systems and eliminating human error, can dramatically reduce the number of crashes. IIHS studies suggest that if 90 percent of cars on U.S. roadways were fully automated, 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 year¹⁶. Another study estimates that the AVs may reduce crash and injury rates by 50 percent at 10 percent market penetration rate, and 90 percent at 90 percent market penetration rate¹⁷. Even in lower levels of automation and market penetration, function-specific automation such as dynamic brake support and lane departure-warning systems will lead to substantial reduction in crashes. The IIHS estimates that If all interstate miles were logged by autonomous vehicles and none of them crashed, the maximum overall benefit would be 17 percent fewer crash deaths and 9 percent fewer crash injuries — equal to the percentage of people who died and were injured in crashes on these roads in 2014.¹⁸

¹⁴ Hawes, C. (2016, November 1). *Here's How Colorado's Transportation Chief Organized Otto's Self-Driving Truck Beer Run*. Retrieved November 10, 2016, from Trucks: <https://www.trucks.com/2016/11/01/otto-self-driving-trucks-autonomous-delivery/>

¹⁵ Singh, S. (2015). *Critical reasons for crashes investigated in the National Motor Vehicle Crash Causation Survey*. (Traffic Safety Facts Crash Stats. Report No. DOT HS 812 115). Washington, DC: National Highway Traffic Safety Administration.

¹⁶ Thompson, C. *The 3 biggest ways self-driving cars will improve our lives*. Accessed December 10, 2016. <http://www.businessinsider.com/advantages-of-driverless-cars-2016-6/#roads-will-be-safer-1>

¹⁷ Fagnant, D. J., & Kockelman, K. M. (2013). *Preparing a Nation for Autonomous Vehicles: Opportunities, Barriers and Policy Recommendations*. Washington D.C.: Eno Center for Transportation.

¹⁸ IIHS Special Status Report Newsletter, Vol 51, No. *, November 10, 2016. "Special Issue: Autonomous Vehicles"

Table 1. Critical reasons for crashes, National Motor Vehicle Crash Causation Survey

Critical Reason Attributed to	Estimated	
	Number	Percentage*± 95% conf. limits
Drivers	2,046,000	94% ±2.2%
Vehicles	44,000	2% ±0.7%
Environment	52,000	2% ±1.3%
Unknown Critical Reasons	47,000	2% ±1.4%
Total	2,189,000	100%

* Percentages based on unrounded estimated frequencies

SOURCE: Reprinted from National Highway Traffic Safety Administration Traffic Safety Facts Crash Stats. Report No. DOT HS 812 115

Fuel Savings

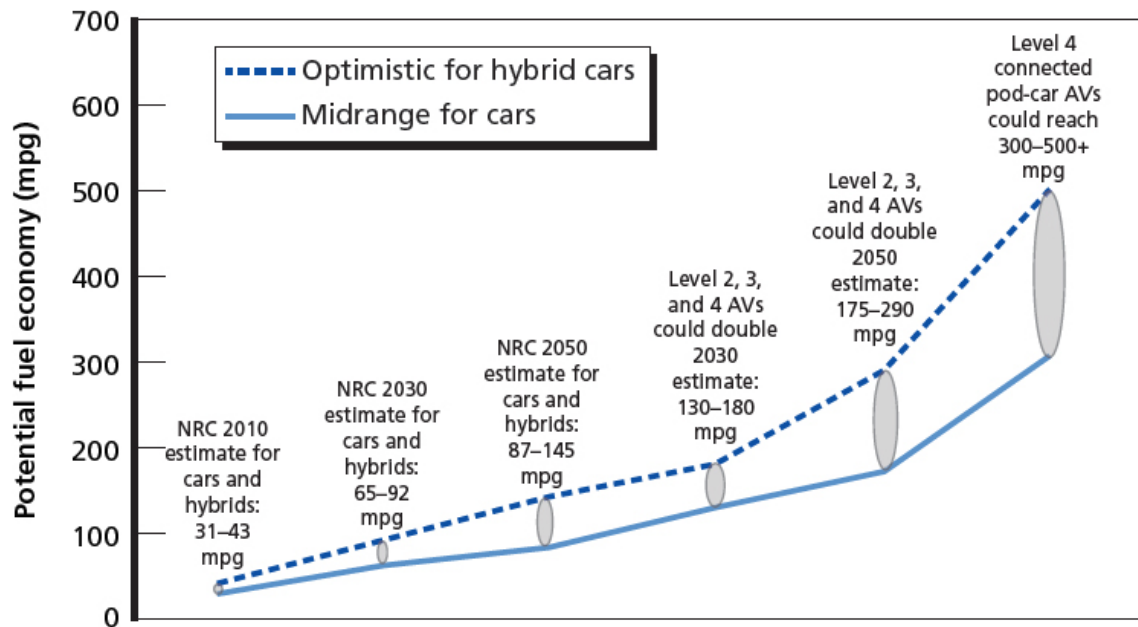
AV technology can also reduce fuel consumption and pollution as unnecessary acceleration and deceleration will be avoided. Just using cruise control in a car of today can easily result in a 15-30 percent fuel economy vs. manual operation by accelerating and decelerating more smoothly than a human driver can¹⁹. This savings is separate from the impacts of using Electric Vehicles where the emissions savings depend on how the electricity is produced and the effectiveness of the battery.²⁰ If the number of crashes reduces significantly, it may also be possible to lighten the cars, which would lead to even less fuel consumption per vehicle. RAND Corporation in its *Autonomous Vehicle Technology* report presented the ranges of potential fuel economy improvements for conventional cars, hybrid cars, and autonomous cars using data from National Research Council (NRC), and stated that automated vehicles could double 2030 and 2050 estimates for conventional cars and hybrids (Figure 3).

There is a well-established synergy between Electric Vehicles and Automated Vehicles given the extensive computerization needed for both. EV and hybrid vehicles are being more widely adopted and will represent significant market share. Tesla recently included more automated features in its newer vehicles. This will likely accelerate adoption of both.

¹⁹ Shanker, et al. (2013). *Autonomous Cars: Self-Driving the New Auto Industry Paradigm*. New York: Morgan Stanley & Co.

²⁰ Holland, S, et al, ENVIRONMENTAL BENEFITS FROM DRIVING ELECTRIC VEHICLES?, Working Paper 21291 <http://www.nber.org/papers/w21291> NATIONAL BUREAU OF ECONOMIC RESEARCH, June 2015

Figure 3. Range of Potential Fuel Economy Improvements for Conventional, Hybrid, and Autonomous Cars



SOURCE: Reprinted from *Autonomous Vehicle Technology: A guide for Policymakers* by RAND Corporation

Increased road capacity and land use changes

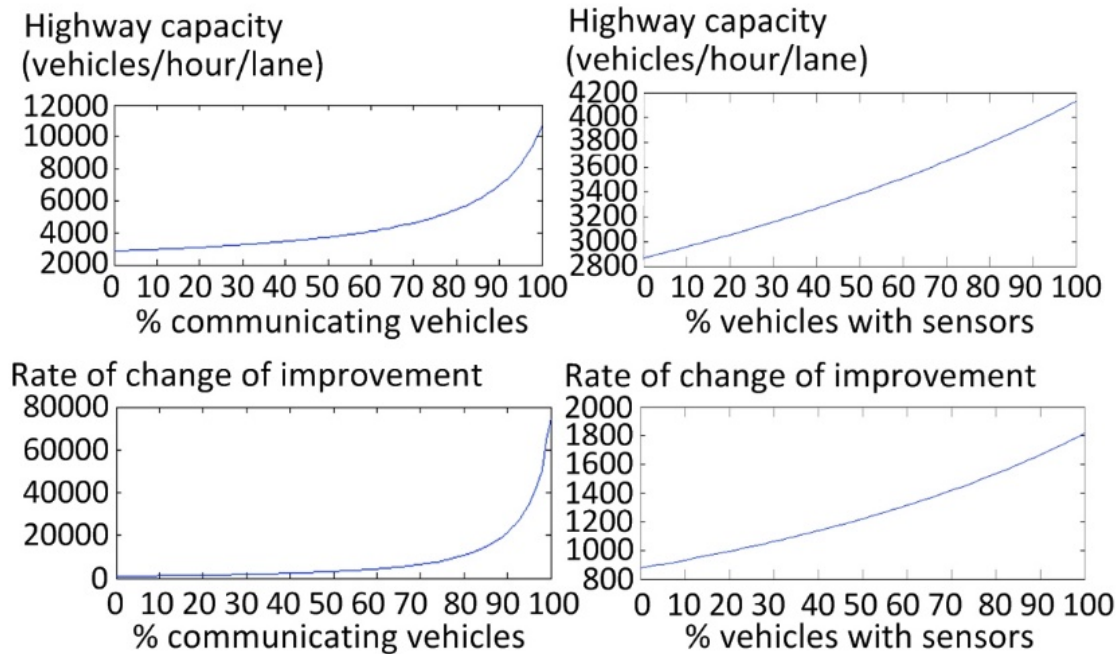
As AV technology can reduce following distances, estimates suggest that the road capacity can be doubled or even tripled when AV are present at significant levels²¹. Improvement in highway capacity, especially with trucking, depends on both the percentage of automated vehicles in traffic and any changes in vehicle occupancy rates. AVs that use sensors are expected to improve highway capacity linearly, and in case of utilizing vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication to continually monitor the speed, direction, and acceleration of other vehicles and surrounding information, AVs would improve the highway capacity very rapidly after the market penetration for passenger cars goes beyond 40% (Figure 4)²². Realizing any increase in Road Capacity will depend on achieving substantial market penetration as shown in Figure 4 below. The period for V2V and V2I implementation is long – at least 10 to 15 years. So based on the current levels of technology the capacity benefits can be way off.

²¹ Anderson, et al. (2016). *Autonomous Vehicle Technology: A guide for Policymakers*. Santa Monica: RAND Corporation.

²² Tientrakool, P., Ho, Y. C., & Maxemchuk, N. F. (2011). *Highway Capacity Benefits from Using Vehicle-to-Vehicle Communication and Sensors for Collision Avoidance*. 2011 IEEE Vehicular Technology Conference (VTC Fall) (pp. 1-5). San Francisco, CA: IEEE.

Increases in road capacity will, in theory, lead to changes in land use due to changes in parking areas for passenger cars as well as for trucks.

Figure 4. Rate of change of improvement in capacity at speed 100 km/h by the percentage of market penetration

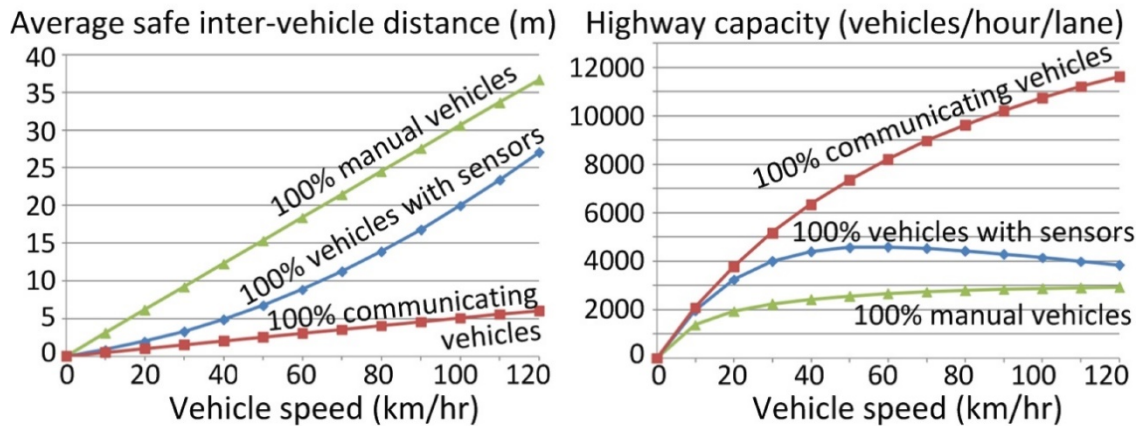


SOURCE: Reprinted from Highway Capacity Benefits from Using Vehicle-to-Vehicle Communication and Sensors for Collision Avoidance by Tientrakool et al.

Figure 5 from the same study shows that at a speed of 100 km/h, when all vehicles are equipped with sensors the highway capacity would be 1.4 times the capacity of manual vehicle traffic and when all vehicles have V2V ability with communicating devices, the highway capacity would be 3.7 times the capacity of manual vehicle traffic due to shorter safe inter-vehicle distance (Figure 5)²³.

²³ Tientrakool, P., Ho, Y. C., & Maxemchuk, N. F. (2011). *Highway Capacity Benefits from Using Vehicle-to-Vehicle Communication and Sensors for Collision Avoidance*. 2011 IEEE Vehicular Technology Conference (VTC Fall) (pp. 1-5). San Francisco, CA: IEEE.

Figure 5. Average safe inter-vehicle distance and estimated highway capacity according to vehicle types



SOURCE: Reprinted from Highway Capacity Benefits from Using Vehicle-to-Vehicle Communication and Sensors for Collision Avoidance by Tientrakool et al.

Level 3 or higher AVs, by enabling the human driver to undertake other activities like reading or making phone calls while the automated system conducts the driving task, will reduce the cost of congestion. As a result, there might also be an increase in the willingness to travel longer distances to and from work.

On the other hand, in metropolitan areas, the ability of fully automated vehicles to drive and park themselves would eliminate nearby parking need in commercial and work areas, enable new development on the parking lots and buildings, and increase urban density. At Level 4 and 5, AVs could drop its passenger and drive away to parking areas by itself. This may also lead to a decrease in the rate of car ownership.

In the long run, fully automated vehicles will also improve mobility for people with disabilities and elderly. Broadening transportation options accessible to underserved communities will contribute to a more inclusive society providing benefits like independence, reduction in social isolation and access to essential services²⁴.

At this point, it is impossible to predict exactly the impacts of Autonomous passenger vehicles on road capacity and land use. However, it is clear that such impacts will appear gradually over the next 10 or more years as AVs increase to significant levels as a percentage of the overall automobile fleet in a region.

²⁴ Alessandrini, et al. (2015). *Automated Vehicles and the Rethinking of Mobility and Cities*. Transportation Research Procedia, 145-160.

Tracking changes in the development and implementation of AV technology and its implementation is critically important for IDOT and municipalities to address those impacts and changes.

3. *The Benefits of Widespread Implementation of AVs with Trucking and Freight*

While automation technology is being developed and tested rapidly with passenger cars, the implementation in trucking has also developed quickly. Implementation of lower levels of automation has outpaced that of passenger cars – especially in Europe and Asia. Development of AV technology is very important and will certainly have major impacts on freight industry as current levels of automation can be safely applied to interstate routes with relatively uncomplicated driving conditions. Freight is expected to be an early adopter of AV technology because of substantial reductions in fuel costs, increased efficiency in scheduling and bundling shipments and likely increased flexibility in other costs through increased hours of operations. The higher vehicle cost will be offset by lower fuel costs, shipping efficiencies, and greater labor productivity, so the acceptance and adoption rate will probably be higher than cars even in the early stages of commercial introduction when the price of AV technology is higher due to limited production²⁵.

Platooning

Platooning is one of the most promising functions of automated vehicle technology for freight. The term “platooning” means the vehicles use radar and V2V communications to form and maintain a close-headway formation between them, keeping the control both longitudinally and laterally. Platooned vehicles can travel close together at highway speeds, mitigating traffic congestion, improving fuel economy, and increasing capacity by vehicle throughput. Early generation platooning technology requires the drivers to be responsible for steering, implying Level 1 automation. Platooning testing is proceeding for Level 2 automation where both the longitudinal and lateral control is managed by the automated system.

In Europe, truck platooning efforts began in late the 1990s with a project called Chauffeur, followed by Chauffeur II, and in 2000s by the SAfe Road TRains for the Environment (SARTRE) project²⁶. In 2016, an experiment featured six convoys of truck “platoons” from a diverse group of European trucking brands, originating from various factories in Sweden and Germany, and arriving in Rotterdam. During the 2000s, Japan also began a major program to examine truck platooning under the Energy ITS program. In U.S.,

²⁵ Guerra, E. (2015). *Planning for Cars That Drive Themselves: Metropolitan Planning Organizations, Regional Transportation Plans, and Autonomous Vehicles*. Journal of Planning Education and Research, 1-15.

²⁶ Shladover, S. (2012, December). *Recent International Activity in Cooperative Vehicle–Highway Automation Systems*. Retrieved from U.S. Department of Transportation Federal Highway Administration: <https://www.fhwa.dot.gov/advancedresearch/pubs/12033/004.cfm>

during this period similar research was sponsored by USDOT and US Army to confirm the technical feasibility and the fuel economy benefits²⁷. In Singapore, The Ministry of Transport (MOT) and PSA Corporation signed agreements with Scania and Toyota to design, develop and test-bed an autonomous truck platooning system for Singapore's port. The truck platooning trials will take place in two phases over a three-year period from January 2017 to December 2019, in which trucks will transport containers from one port terminal to another²⁸.

Most major truck manufacturers have already started and will continue platooning test in cooperation with government agencies all over the world and claim that the trucks equipped with the technology for platooning will come on the market by 2020. Trucks equipped with radar and V2V systems may form, join or leave a platoon on the highway and do not require changes in signage, striping, and lane markings, but does require changes to spacing requirements. However, even though the technology will permit cutting in by other vehicles, long line of platooning trucks may create some difficulties for the operation of other vehicles in traffic. For the states, following-too-closely (FTC) statutes, which might create an impediment to the platooning operations, should be reviewed and amended, and other regulations as needed to ease the operations in traffic such as designated lanes might be considered.

Safety

As for cars, the most important benefit of AV technology in freight is safety. In 2014, there were 3,903 fatalities resulting from large truck-involved crashes²⁹. 17 percent of those fatalities were the occupants of large trucks, 73 percent were the occupants of other vehicles and 10 percent were non-occupants (Figure 5)³⁰. Speeding, reckless driving, improper lane change and inattention are unsafe driving violations. The automated systems are programmed to drive safely and not to violate any laws, and thus decrease the number of "unsafe driving events" and the number of crashes. NHTSA estimates that after 20 years of their

²⁷ ATA Technology and Maintenance Council. (2015). *Automated Driving and Platooning Issues and Opportunities*. Arlington, VA: ATA Technology and Maintenance Council.

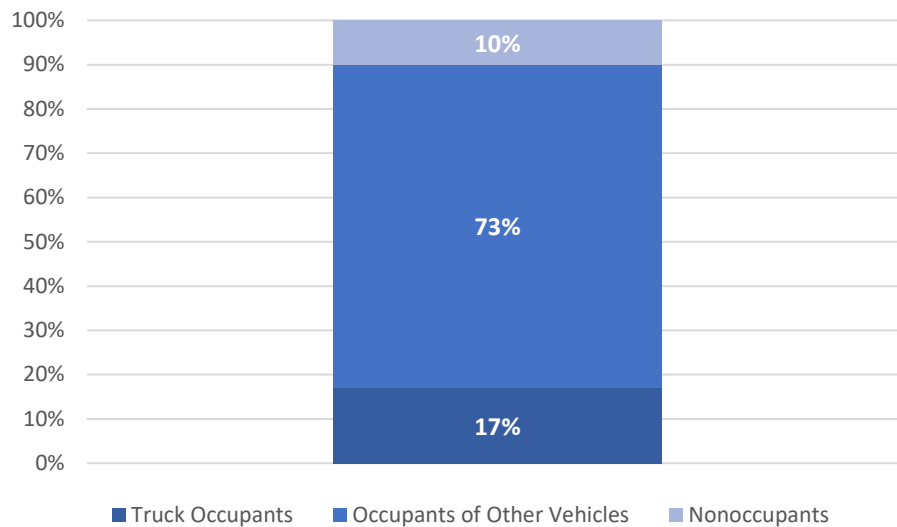
²⁸ Singapore Ministry of Transport. (2017, January 9). *Singapore to start truck platooning trials*. Retrieved from Singapore Ministry of Transport: <https://www.mot.gov.sg/News-Centre/News/2017/Singapore-to-start-truck-platooning-trials/>

²⁹ Short, J., & Murray, D. (2016). *Identifying Autonomous Vehicle Technology Impacts on the Trucking Industry*. Arlington, VA: American Transportation Research Institute.

³⁰ National Highway Traffic Safety Administration. (2016, March). *Quick Facts 2014*. Retrieved from CrashStats: <https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812234>

adoption, V2V and V2I technologies could eliminate or mitigate the severity of up to 80 percent of non-impaired crashes, including crashes at intersections or while changing lanes³¹.

Figure 6. Percent of Fatalities in Crashes Involving Large Trucks by Person Type



NOTE: Data from NHTSA's Quick Facts 2014 Report, Retrieved February 10, 2017, from <https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812234>

Energy and Fuel Savings

Automated vehicle technologies have the potential to operate vehicles not only more safely but also more efficiently than humans. Even with lower level automated systems, potentially V2V, and V2I communications, freight vehicles will be able to travel safely in sync at close distances. A platoon of closely spaced automated freight vehicles will improve travel time and fuel economy by enabling higher effective speeds and lowering air resistance³². The potential for substantial fuel savings has accelerated the testing and implementation of platooning in Europe and Asia over the last 5 years and equivalent demonstration

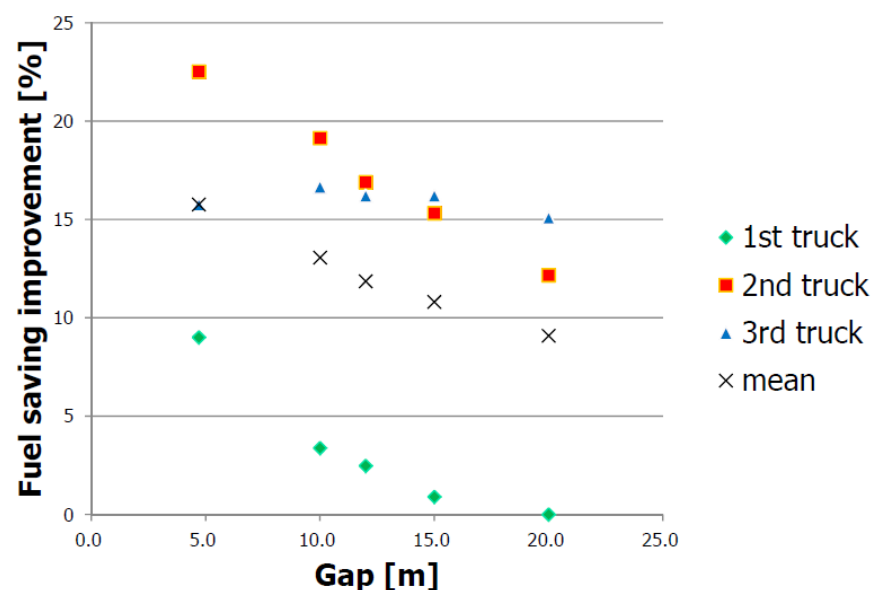
³¹ National Highway Traffic Safety Administration. (2016, December 13). *U.S. DOT Advances Deployment of Connected Vehicle Technology to Prevent Hundreds of Thousands of Crashes*. Retrieved from U.S. Department of Transportation: <https://www.transportation.gov/briefing-room/us-dot-advances-deployment-connected-vehicle-technology-prevent-hundreds-thousands>

³² Scribner, M. (2016). *Authorizing Automated Vehicle Platooning: A Guide for State Legislators*. Washington, D.C.: Competitive Enterprise Institute.

projects have occurred in Nevada, and other states and further tests are being developed now in other States.

In Japan, as a part of the project “Energy ITS,” the fuel consumption of platooning trucks were measured on a test track under the conditions that the velocity was constant at 80 km/h, the gap was between 4 meters and 20 meters. The measurements showed that the energy saving at a 10 meter gap was on average 13% and at a 4.7 meter gap it was 18% when the trucks were empty (Figure 6). When the trucks are ordinarily loaded and drive at 80 km/h, the average fuel saving estimated to be 8% at a 10 m gap, and 15% at a 4 m gap³³.

Figure 7. Fuel Saving Improvements in Platooning



SOURCE: Reprinted from Final Report on Automated Truck Platoon within Energy ITS Project by Sadayuki Tsugawa

Land Use

Truck parking is an increasing problem in Illinois with Over 75% of drivers report problems finding safe parking each week and 58% parking inappropriately 3-4 times per week.³⁴ Because of CV and AV

³³ Tsugawa, S. (2013, October 13). *Final Report on Automated Truck Platoon within Energy ITS Project*. Retrieved February 10, 2017, from ORFE: http://orfe.princeton.edu/~alaink/SmartDrivingCars/ITFVHA13/ITFVHA13_JP_Energy_ITS_Tsugawa.pdf

³⁴ Oberhart, E and Perry, E., The Missing Piece: Truck Parking Solutions for Chicagoland, Presented at Transport Chicago, June 2017. Poster Session. CPCS Transcom

applications in freight, the parking requirement and rest area demand for trucks could go down, though further study is needed to understand and quantify the effect. The parking requirement may go down as the applications lead to less active driving, thereby relaxing driver rest time requirements. This may release large parcels of land that could potentially be used for other purposes or allow other parcels to be repurposed for truck parking. In addition, the introduction of CV/AV applications will also affect the consideration of firms when they select their sites for warehousing. The change in warehousing locations can change the truck volumes on roads. Nevertheless, this consideration is external to planning and may be difficult to estimate. This will necessitate the involvement of private party stakeholders of freight such as trucking companies, third party logistics providers and large shippers in the planning process³⁵.

Increased Shipping Flexibility and Productivity

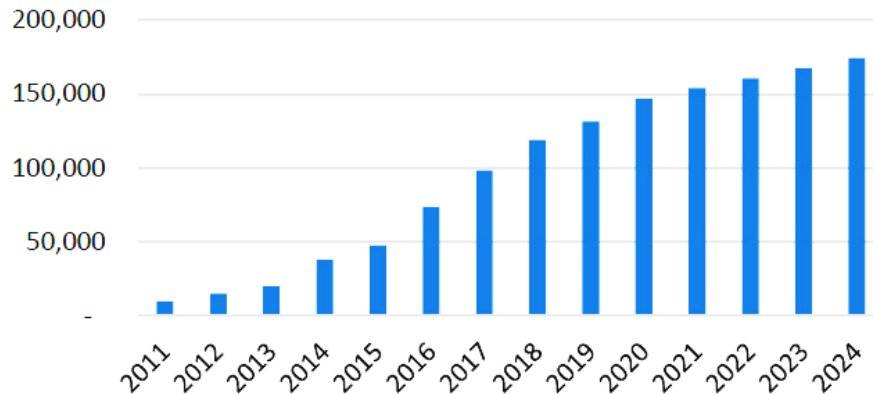
One of the most pressing issues of the freight industry is the severe shortage of drivers. The American Trucking Association predicts that by 2024 the driver shortage will increase from 48,000 available jobs to 175,000 (Figure 7)³⁶. American Transportation Research Institute's 2014 study of driver demographics also found that the number of U.S. truck drivers between the ages of 25 and 34 has dropped nearly 50 percent over the past two decades³⁷. Initially, it is expected that AVs with lower levels of automation such as in platooned trucks will simply increase the flexibility and productivity of existing drivers because the drivers will still be needed to take over control as needed, to oversee lateral movement and to also handle paperwork and loading and unloading. Only fully automated trucks (SAE Level 5) would produce any significant reduction in the need for drivers, and this level of automation is not likely to be commercially available for quite some time – with experts estimating 15 – 20 years before widespread and safe commercial implementation.

³⁵ Oberhart and Perry, op cit.

³⁶ Costello, B., & Suarez, R. (2015). *Truck Driver Shortage Analysis 2015*. American Trucking Associations. Accessed December 12, 2016. <http://www.trucking.org/ATA Docs/News and Information/Reports Trends and Statistics/10 6 15 ATAs Driver Shortage Report 2015.pdf>

³⁷ Short, J. (2014). *Analysis of Truck Driver Age Demographics across Two Decades*. American Transportation Research Institute. Arlington, VA.

Figure 8. Truck Driver Shortage Forecast



SOURCE: Reprinted from ATA Truck Driver Shortage Analysis, Retrieved December 12, 2016 from <http://www.trucking.org/ATA Docs/News and Information/Reports Trends and Statistics/10 6 15 ATAs Driver Shortage Report 2015.pdf>

On the other hand, as lower levels of automation start becoming available being a truck driver might become more attractive since it may relieve stress and monotony of driving for long hours and enable drivers to do other things and will require relatively small changes or increases in training. The ability to rest while driving could enable drivers to be more productive and be at home more often. Automated trucks may make the truck driver career more attractive to younger, tech-savvy populations.

As with the development of any new technology, there is still great uncertainty when more advanced levels of technology become reliable and safe enough for widespread commercial introduction. As technology is developed that will reduce or eliminate the amount of time a driver needs to be focused on road conditions, it could allow drivers to rest during long distance routes to increase productivity of freight operations and thus support changes to Hours-of-Service (HOS) rules (e.g. The regulations that govern the time that a truck driver can work and drive). If the drivers could use smartphones and embedded telematics while the automated system conducts the driving task, they would be able to identify parking locations, and in the case of HOS regulation changes, the need for truck parking spaces would also be decreased.

Increased road capacity

Congested roadways cost freight industry billions of dollars annually³⁸. On the highway, when there are few cars the travel speed is high. However, as the number of cars increases, sharp braking responses create

³⁸ Torrey IV, W. F. (2016). *Cost of Congestion to the Trucking Industry*. American Transportation Research Institute.

“stop and go” traffic, resulting in congestion and adversely affecting vehicle throughput especially during rush hours. AV technology has the potential to operate more efficiently by avoiding unnecessary acceleration and deceleration and being able to safely travel in sync at close distances by platooning. V2V and V2I technology will further enable trucks to communicate with traffic lights and other infrastructure components mitigate “stop and go” traffic and increase vehicle throughput. On the other hand, HOS changes that might take place due to automation would enable trucks to travel more in less-congested times. Reduced congestion, increased productivity, more dynamic route planning, available time for the driver to tackle with administrative tasks and customer service will provide significant economic benefits for the freight industry.

Reduced congestion will be effective sooner on highways, as the levels of automation will be introduced more quickly in the controlled environment of highways travelling long distances. Level 4 and 5 automated trucks might bring about big changes in fleet and delivery management, but lower levels will not need any changes in the short term.

4. Government responsibilities

AV technology has considerable promise for improving social welfare and requires careful policymaking at both the state and the federal level to maximize its promise. The division of responsibility between Federal and State authorities is clear; the Federal Government is responsible for regulating motor vehicles and motor vehicle equipment, and States are responsible for regulating the human driver and most other aspects of motor vehicle operation.

a. The Federal role

The regulatory responsibility of Department of Transportation (DOT) and Federal Government for motor vehicle operations would remain largely unchanged for highly automated vehicles and focus only on the vehicle technology. Responsibilities of National Highway Traffic Safety Administration (NHTSA) include setting Federal Motor Vehicle Safety Standards (FMVSS) for new motor vehicles and equipment, enforcing compliance with FMVSS, investigating and managing the recall and remedy of non-compliances, and issuing guidance for vehicle and equipment manufacturers to follow³⁹.

Arlington, VA.

³⁹ National Highway Traffic Safety Administration. (2016). *Federal Automated Vehicles Policy: Accelerating the Next Revolution in Roadway Safety*. Washington, D.C.: U.S. Department of Transportation.

NHTSA has released “Federal Automated Vehicles Policy” in September 2016 to accelerate the development, testing, and deployment of highly automated vehicles. Under the current conditions, manufacturers are responsible for self-certifying their vehicles that they comply with all FMVSS standards, and manufacturers and other entities designing HAV systems are expected to follow the Guidance as they design, test, and deploy HAVs, and submit a safety assessment letter which will cover operational capabilities and conditions such as geographic condition, roadway type, speed, weather condition, human machine interface, system safety, data recording and sharing, and crashworthiness⁴⁰. As the level of automation increases, DOT’s responsibility to regulate the safety of equipment could involve “licensing” of the automated system that will conduct a part of all of the driving task, describing the operation domains –roadway types, geographic area, speed range, weather condition, etc.- in which the automated system is designed to properly operate.

Some AV systems use complementary sensor technologies such as V2V and V2I capabilities to improve system performance. The inclusion of V2V and V2I capabilities could enhance the safety and performance of AV systems and improve traffic conditions since all the vehicles having the same system would be aware of each other and could choose routes accordingly to avoid congestion. NHTSA, believing that V2V has the potential to revolutionize motor vehicle safety, recently proposed to issue a new Federal Motor Vehicle Safety Standard No. 150 to require all light vehicles to have the capability of V2V communications by 2023. For the time being, NHTSA just requires the vehicle to have V2V capabilities but does not require states to have physical or network infrastructure to make use of the V2V or V2I technology.

Safety and liability issues

Most experts agree that the industry has not yet perfected the hardware, guidance systems and software to make vehicles that can reliably and safely drive themselves (e.g. SAE level 4 and 5). Recent demonstration projects in California, Arizona and Pennsylvania showed the need for additional development to insure that AVs can operated safely under reasonably anticipated real-world conditions. The demonstration projects involving freight pose different issues as the trucks still have skilled, professional drivers able to take over from AV technology currently employed. States will, at this point, rely on Federal regulation and oversight to insure that the software and sensor technology are sufficient to meet the legal and ethical challenges and uncertainties of real-world commercial introduction.

⁴⁰ National Highway Traffic Safety Administration. (2016). Federal Automated Vehicles Policy: Accelerating the Next Revolution in Roadway Safety. Washington, D.C.: U.S. Department of Transportation.

b. The State role

The steps that need to be taken by States to encourage the development and deployment of the new technology might be collected under three headings: 1) Changes to the Physical Transportation Infrastructure of IL; 2) Permitting and enforcement changes including coordination among levels of government within Illinois and coordination with other states; 3) Legal and legislative changes.

Illinois has no legal or regulatory impediments to demonstration projects, as the existing laws do not deliberately require a motor vehicle to have a driver. Without the need for immediate legislative or regulatory changes, Illinois could easily accommodate AV demonstration projects with only administrative oversight setting research and data collection goals. Demonstration projects should allow other aspects of AV operations such as licensing, registering, vehicle insurance and liability, and some regulations like “following-too-closely” statutes and regional coordination of oversize and overweight permits to be addressed.

As the new technology is deployed and put into commercial operation, eventually the State might need to make changes to the physical infrastructure and “permitting”.

The current state of AV technology does not require major such changes to the physical transportation infrastructure in the near future; however, IDOT will need to coordinate with other state agencies on permitting, enforcement and legislative changes.

Infrastructure issues

To ensure safety and gain confidence in the new technology, the demonstration projects will continue to take place in diverse environments and weather conditions. Handling various kinds of interactions safely with other vehicles, trucks, bicyclists, and pedestrians in adverse weather and road conditions are essential. Both the State and the industry will need to design the demonstration projects to ensure controlled and safe real-world experience opportunities for AVs.

In order to function safely, AVs need a predictable environment. Well-maintained lanes, readable and proper signage, and constant flow of updated information on road conditions, work zones and accidents would enable AVs to function better. The states will need to be in touch with the AV technology companies to identify the needs in the face of this emerging and rapidly advancing technology and define a path to handle possible infrastructure modifications needed.

For V2I capabilities, certain infrastructure investment will be required from governmental agencies. However, auto-manufacturing companies see information from V2V and V2I communications useful to support their automated systems but believe that their vehicles should comprehend the world on their own. There are different technological approaches to automated vehicles technology, and the state of the technology is still premature to make any investment decisions.

The consistency of standards among the states and within states is important for the development and operation of AVs. Working together with other states and with local jurisdictions for the standardization of laws and policies as well as road infrastructure would support the efforts and ensure safety. Standardization of policies and creating consistency of signage, physical infrastructure, DRSC networks and updates between states are the responsibility of the States whereas the Federal government will just be responsible for mandating technology on vehicles just like CAFE standards. In *Federal Automated Vehicles Policy*, NHTSA notes that State policies need not be uniform but be consistent enough not to impede the development and operations of AVs. IDOT will have a leading role in licensing and permits (including coordinating permitting for OS/OW, weigh stations, tolling) and maintaining necessary infrastructure, and will be coordinating with other state agencies and localities to work through legal and regulatory changes. Initial challenge is creating a framework for demonstration projects especially ones that can last for long periods and cover relatively large areas. Iowa has suggested that the 2020+ time frame to introduce V2I information improvements to facilitate vehicle automation in Freight via DRSC networks such as Hazard alerting, travel condition data feeds and other real time information will be beneficial.⁴¹

Legal and liability issues

States' responsibilities for motor vehicle operation include licensing human drivers and registering motor vehicles; enacting and enforcing traffic laws and regulations; conducting safety inspections and regulating motor vehicle insurance and liability. For AV operations, the States will need to review their current laws and regulations such as State vehicle codes and following distance requirements and make necessary changes to eliminate impediments to the safe testing, deployment, and operation of AVs.

5. Recommended State Actions

⁴¹ Iowa Department of Transportation, Automated Vehicle Technologies Project – Final Vision Document. March 2017

For the next five years, several recommended actions are listed below:

I. Form an AV Task Force with industry

To guide the demonstration and later the commercial introduction phases, IDOT should form an AV Task Force together with other government agencies, industry representatives, academic institutions, and other public and private stakeholders such as Illinois Trucking Association and Society of Automotive Engineers. The Task Force will be responsible for tracking and staying aware of the development of technology, how industry and technology needs change and thus what changes government needs to make to adapt, and will act as an advisory board to identify best practices, guide testing, evaluate current laws and regulations, and work on policy recommendations. For a technology that is rapidly advancing and with so many unknowns broad representation of the various public and private stakeholders would guarantee to balance multiple objectives and ensuring public safety while avoiding unnecessary impediments.

A major responsibility of this Task force will be to establish and expedite approval procedures for demonstration projects and provide both oversight and needed coordination between State agencies and local governments as well as the industry so that the demonstration projects proceed smoothly and safely and that the data produced is useful and used.

Specific tasks will include:

a. Establish Testing Approval process

Testing Approval process should be developed to set parameters and establish minimum approval criteria. Each manufacturer or AV technology company should submit an application to the agency. The application should identify each vehicle that will be used on roadways for testing purposes by vehicle type, automation level, year and model. The application should also include a self-certification of testing and compliance to NHTSA's Vehicle Performance Guidance for the technology in the test vehicles under controlled conditions that stimulate the real-world conditions⁴².

b. Identification and preparation of demonstration routes

For the time being, most demonstration projects are done in limited routes and controlled environments under good weather conditions. For different levels of automation, different challenges

⁴² NHTSA. (2016). *Federal Automated Vehicles Policy: Accelerating the Next Revolution in Roadway Safety*. Washington, D.C.: U.S. Department of Transportation.

such as severe weather conditions or unexpected obstructions would be incorporated into test protocols to evaluate the efficiency and safety of AV operations. For each testing, demonstration routes should be identified, and notification process and signage, as well as temporary improvements to infrastructure, should be handled in accordance with the needs of the AV technology that would be tested.

c. Defining Test Oversight and Data Collection Measures

To document and measure the progress of testing and to follow system failures or crashes, IDOT should collect fundamental data from all companies testing their AVs. In addition to the testing data, which will cover the number of miles and hours traveled and the size of the testing fleet, companies should also be required to report the crashes and document the number of times human drivers had to intervene. Additionally, testing vehicles should be subject to a special insurance policy. In some states, \$5M in insurance is required for AV testing operations as a safety measure and a barrier to entry.

d. Building Coalition with neighboring States

Working together with other states for the standardization of laws and policies as well as road infrastructure would support the efforts and ensure safety. Freight automation will be effective on interstate highways; therefore, collaboration in research and testing efforts is essential. The coalition might also be helpful for seeking joint funding opportunities for large-scale transportation research and implementation projects.

II. Form an Internal Government Committee

IDOT should also create an internal government committee that includes representatives from the governor's office, the Illinois Department of Motor Vehicles, the Illinois State law enforcement agency, the Illinois Division of Traffic Safety, Illinois Department of Innovation & Technology, Illinois Department of Insurance, and Illinois State Toll Highway Authority. As also stated in the Modal State Policy section of the NHTSA's Federal Automated Vehicle Policy, the committee should examine its laws and regulations in the areas of (1) licensing and registration; (2) driver education; (3) insurance and liability; (4) enforcement of

traffic laws and regulations; and (5) administration of motor vehicle inspections⁴³. The most urgent tasks that need to be explored in the early stages of automation are:

a. Review and revision of state laws

State law and the Federal Motor Carrier Safety Regulations (FMCSRs) do not address the automated driving environment and might conflict with automated truck operations. Before the commercial introduction of the highly automated vehicles (Level 3 and above), state laws pertaining to commercial vehicles should be reviewed and revised as appropriate.

b. Necessary changes to “following-too-close” statutes

Following-too-close (FTC) statutes are also an impediment for both automated vehicles and platooning operations. Automated vehicle platooning, as mentioned above, is one of the most promising functions of AV technology. Platooned vehicles will be able to travel close together at highways improving fuel economy and increasing vehicle throughput. As the platooning technology is too close to be perfected and introduced to the commercial market, FTC statutes should have the priority for review and revision.

Similarly, Oversize/Overweight permits might be reviewed and if needed be revised accordingly.

c. Identification of research needs for any infrastructure modifications needed to accommodate AVs in future

To accommodate AVs operations in future, research needs will have to be identified by the Task Force to keep an eye on the direction the technology is advancing in terms of the infrastructure modifications that would be needed. For example, in the current state of the technology, some believe that road markings will need to incorporate sensors in order to be detected in snow or limited visibility conditions. Even though some AV technology companies claim that their vehicles will not need any infrastructure modification other than improving road striping and signage, the benefits V2I communications will probably make them a part of AVs soon as they can provide valuable information for AVs about the road ahead such as lane closures, obstacles or construction site. Incorporating V2V and V2I communication technologies will make AVs safer, faster and more efficient.

⁴³ NHTSA. (2016). Federal Automated Vehicles Policy: Accelerating the Next Revolution in Roadway Safety. Washington, D.C.: U.S. Department of Transportation.

After 5 years, if the technology is going to develop in the pace and direction expected today, the next steps for governmental authorities would be focusing on funding strategies to improve infrastructure and V2I systems, designating lanes to AVs on major arteries to improve benefits, and creating a structure for constant information flow to mapping companies:

a. Funding strategies to maintain and improve infrastructure

HAV operations require high-quality roadways. Road striping and signage will need to be maintained in the condition required for the operation of the automated technology. V2I capabilities, which would need infrastructure investments, will also enhance the safety and performance of HAV systems. Necessary funding strategies should be developed in the demonstration phase and be developed with the commercial introduction to enable a smooth transition to AV operations providing infrastructure improvements.

b. Designating lanes

Automated vehicles in freight will benefit the most from higher effective speeds, improved travel time and fuel economy if they are separated from human drivers. Special use lanes such as High Occupancy Vehicle (HOV) and High Occupancy Toll (HOT) lanes are common traffic control measures utilized by transportation agencies. Dedicated lanes can also be employed for AVs to aid their integration to today's human-dominated traffic and improve their performance.

c. Creating a structure for constant information flow to mapping companies

AV technology operates best in predictable environments and will rely on mapping in addition to sensors, radar and lidar systems. Mapping companies need a constant flow of reliable information about road traffic, road closures, work zones, accidents, etc. to aggregate and communicate it to the vehicles. Governments should create a structure for this vital information flow and form collaborations with mapping companies.

Performance, prices and consumer acceptance will affect the market integration of highly automated vehicles. Over time, as the portion of new vehicles with automated driving capabilities increases and as potential users gain confidence in technology, the portion of AV fleets will increase over a few decades after commercial

introduction. As the technology improves and in the light of the demonstration and commercial introduction phases, there might be some changes needed to be done to the physical environment and the infrastructure for operational ease. At the current state of the technology, it is likely that virtual weigh stations would be needed for the safety and supervision of automated truck operations, and Level 4 platooning might decrease the number of truck drivers per fleet creating a need for staging areas similar to intermodal yards.

The state of technology enables us to predict some possibilities and challenges ahead; nevertheless, it is early to start making permanent decisions or changes for higher levels of automation. The possibilities and challenges will become clearer as testing phase continues and the technology develops; therefore, the most important role that awaits IDOT at this stage is that of a collaborator. Forming strong relations with the industry, being a partner in testing and collaborating with neighboring states will enable the agency to get a better understanding of the technology and make necessary changes on time.
