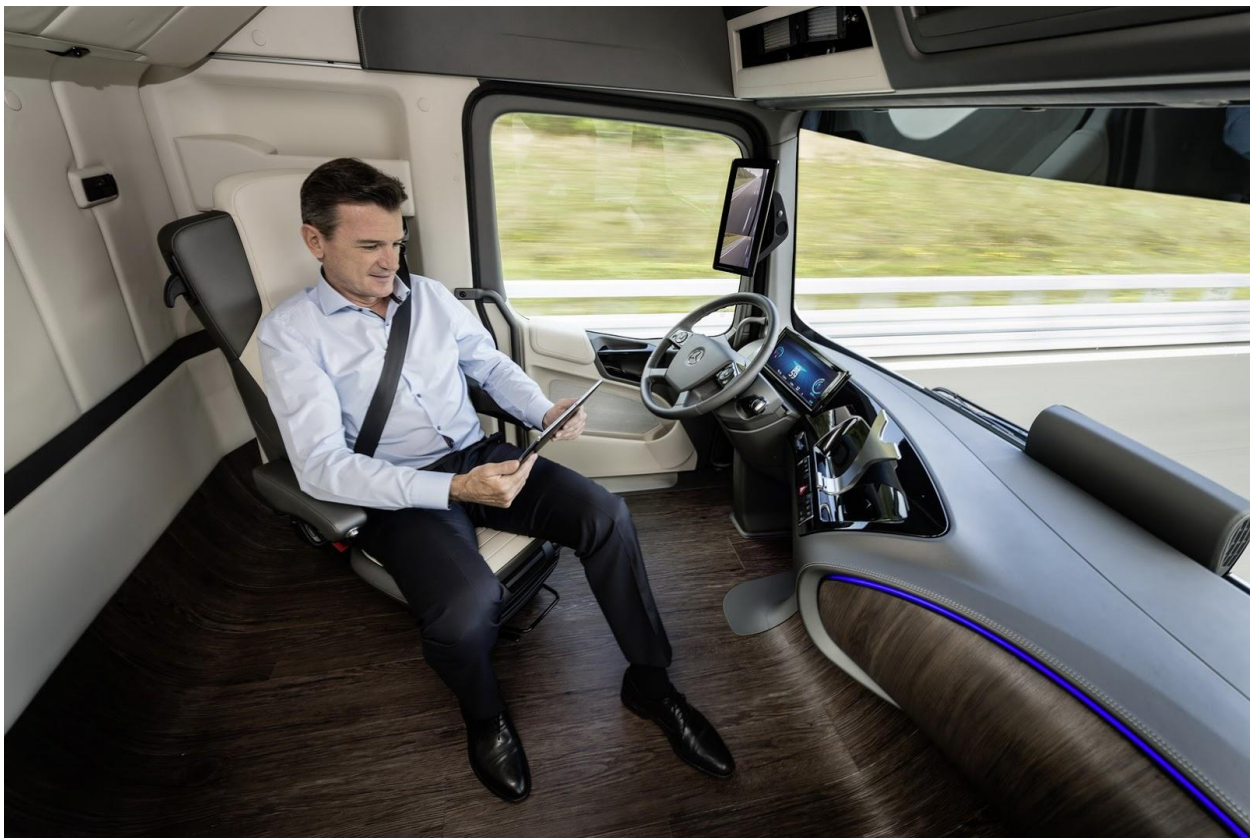


Autonomous Truck and Its Implication on the Trucking Industry



A press photo from Freightliner's Inspiration truck showcasing the autonomous future of trucks

Xiang Li

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Foreword

With technology growing fast in the automotive sector, the topics of autonomous vehicles have been discussed more and more. With many consumer cars already come with some basic level of driver assistance technologies, the future of fully autonomous driving is closer to us than many people realize. Many of the same concepts and technologies are also being developed for the commercial Class 8 vehicles. Autonomous Trucks (AT) can provide boost in both safety and productivity for the trucking industry. Trucking industry is a highly competitive market with thin profit margin. The promise of increasing both safety and efficiency while reducing expense provides the huge economic incentives to adopt this technology, and due to the nature of trucker's long distance driving on highways, autonomous technology is easier to implement and provides greater economic benefit in commercial vehicles than personal vehicles. Thus, I believe the vehicle automation revolution will be pushed forward by the commercial vehicles, then become more prevalent in personal vehicles.

Landscape of the Trucking Industry

Industry at a Glance

America's economy is built upon trucking industry. Trucking sector's performance is directly related to the nation's economy performance. During good times, consumer spending increases while leads to industrial, retail and trade activity to rise. Manufacturing industry relies on cheap, reliable transportation to deliver their goods to consumers. In 2011, 9.2 billion tons of freight were transported by trucks, representing 67.0% of total domestic tonnage shipped.¹

Average numbers from 2011 to 2016, long-distance freight trucking industry has a total annual revenue of \$182.3bn and \$13.7bn in profit, netting a 7.5% of profit margin. Its annual growth during the five-year period from 2011 to 2016 is 2.1%, and total amount of wages paid is \$48.0bn.² There are no major players in the industry. Out of the 360,032 businesses, 90% of them are owner-operators.³ Annual wages round up to about \$48bn, roughly 26% of total revenue.⁴

There are four major forms of carrier within the trucking industry, they are private carrier, common carrier, contract carrier and independent carrier⁵. Private carrier focuses on transporting the company's own goods and products, an example would be Walmart. Common

¹ "Reports, Trends & Statistics." *American Trucking Associations*. American Trucking Associations, n.d. Web. 08 Dec. 2016.
<http://www.trucking.org/News_and_Information_Reports_Industry_Data.aspx>.

² Rivera, Edward. *Long-Distance Freight Trucking in the US*. Rep. Vol. 48412. N.p.: IBISWorld, 2016. Print.

³ Ibid

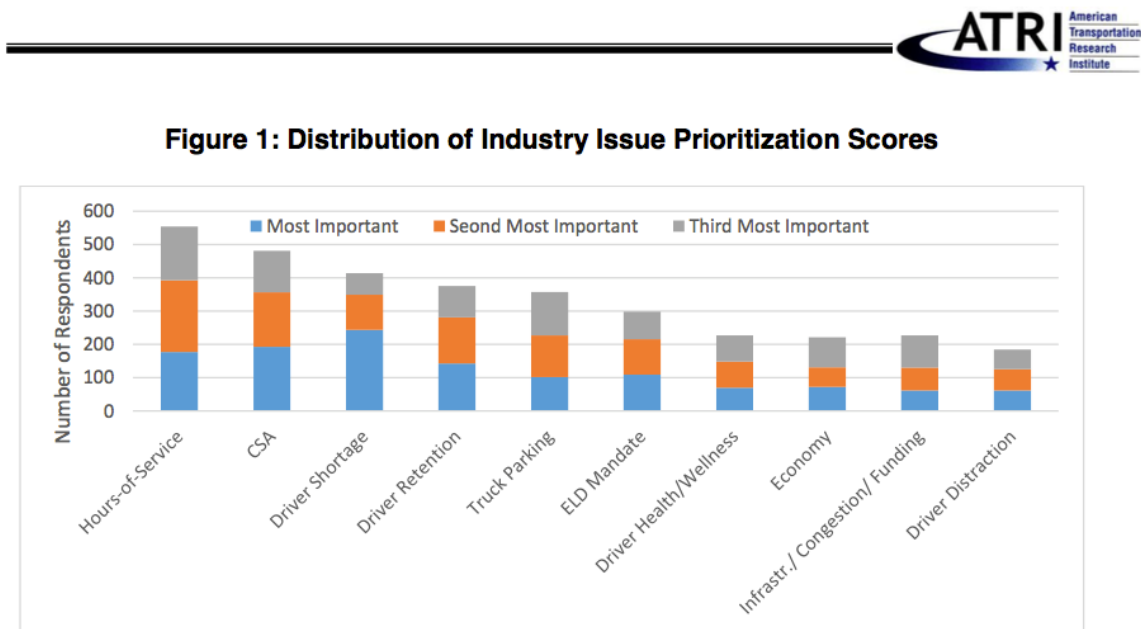
⁴ Ibid

⁵ "Difference Between Private, Common, Contract and Independent Carriers | MCT Transportation." *MCT Transportation*. MCT Transportation, LLC, 12 Apr. 2016. Web. 28 Nov. 2016.

carrier would work with different clients to transport their products, and represents the largest segment of the carrier industry at 61.9%. It then subdivides into truckload (accounting for 37.4% of market) and less than truckload (LTL) segments (accounting for 24.5% of market). An example of a common carrier is Estes. A contract carrier transports products for particular customers or market segments, such as a carrier specialized in temperature controlled delivery. As opposed to fleets mentioned above, an independent carrier is usually the owner and operator of a truck.

Trucking Industry's Current Top Issues

Currently there are many companies working and developing next generation autonomous software and hardware for class 8 trucks. To understand why the companies are spending millions on the development of this new technology, it is important to understand



what kind of problems autonomous driving trucks can solve for the industry, and the economic benefit it could bring to the table for the sector.

The above chart is a research done by American Transportation Research Institute(ATRI) that listed out 10 most critical issues the trucking industry in 2015. ATRI first identifies leading issues with key trucking shareholder groups. Then motor carriers and commercial drivers were surveyed thru the 50 State Trucking Associations, generating 1,388 complete responses. Respondents are asked to select their top three choices from the aforementioned list, and subsequently rank their top three issues.

The top issue of the industry is, and has been for the past two years, Hour of service regulations. HOS is issued and governed by Federal Motor Carrier Safety Administration (FMCSA). These regulations dictate how many hours a truck driver can operate legally and how long they have to rest in between driving duty. The details of the hour of service rules are listed below. To ensure both compliance and operational efficiencies, companies that carry or ship freight must design routes, schedules and entire supply chains to fit within the constraints of the HOS rules.⁶ It is clear that Hour of Service rules have significant impact on commercial vehicle safety. However just like any other regulations, a moderate regulation is necessary to ensure the wellness for everyone involved, but poorly designed regulation could cause more problems than it could solve. The highly controversial 34 Hour Restart enacted on July 1, 2013 and its impact on trucking industry's efficiency proved how a poorly designed government regulation could cause adverse effect to the trucking industry. The 34 Hour Restart rule was

⁶ Short, Jeffrey. "Assessing the Impacts of the 34-Hour Restart Provisions." (2013).

suspended by the effort of congress and American Trucking Association in December of 2014.

"We have known since the beginning that the federal government did not properly evaluate the potential impacts of the changes it made in July 2013," said ATA President and CEO Bill Graves.

"Now, thanks to the hard work of Senator Collins and many others, we have a common sense solution. Suspending these restrictions until all the proper research can be done is a reasonable step.⁷

HOURS-OF-SERVICE RULES	
PROPERTY-CARRYING DRIVERS	PASSENGER-CARRYING DRIVERS
11-Hour Driving Limit May drive a maximum of 11 hours after 10 consecutive hours off duty.	10-Hour Driving Limit May drive a maximum of 10 hours after 8 consecutive hours off duty.
14-Hour Limit May not drive beyond the 14th consecutive hour after coming on duty, following 10 consecutive hours off duty. Off-duty time does not extend the 14-hour period.	15-Hour Limit May not drive after having been on duty for 15 hours, following 8 consecutive hours off duty. Off-duty time is not included in the 15-hour period.
Rest Breaks May drive only if 8 hours or less have passed since end of driver's last off-duty or sleeper berth period of at least 30 minutes. Does not apply to drivers using either of the short-haul exceptions in 395.1(e). [49 CFR 397.5 mandatory "in attendance" time may be included in break if no other duties performed]	60/70-Hour Limit May not drive after 60/70 hours on duty in 7/8 consecutive days.

⁷ "FMCSA Officially Suspends 34-hour Restart under HOS Rule." *Bulk Transporter*. Bulk Transporter, 23 Jan. 2015. Web. 29 Nov. 2016.

<p>60/70-Hour Limit May not drive after 60/70 hours on duty in 7/8 consecutive days. A driver may restart a 7/8 consecutive day period after taking 34 or more consecutive hours off duty. Must include two periods from 1 a.m. to 5 a.m. home terminal time, and may only be used once per week, of 1-8 hours, measured from the beginning of the previous restart.</p>	<p>Sleeper Berth Provision Drivers using a sleeper berth must take at least 8 hours in the sleeper berth, and may split the sleeper berth time into two periods provided neither is less than 2 hours.</p>
<p>Sleeper Berth Provision Drivers using the sleeper berth provision must take at least 8 consecutive hours in the sleeper berth, plus a separate 2 consecutive hours either in the sleeper berth, off duty, or any combination of the two.</p>	

Incentives for Different Parties

Both the private sectors and public sectors are putting a lot of efforts in realizing the autonomous future of transportation. Many of the benefits of HAVs apply to both non-commercial and commercial vehicles, but some of them are more specific to commercial vehicles. Trucking and commercial transport will likely see a faster adoption of self-driving vehicles than the consumer market because there is a better business case, Friedmar Rumpel, a director in the automotive practice of global consulting firm AlixPartners, told Trucks.com.⁸ And as such, this paper will discuss the incentives for both private sector and public sector to invest

⁸ Hirsch, Jerry. "Uber Acquires Otto Self-Driving Truck Startup, Signs Volvo Deal | Trucks.com." *Trucks.com*. Trucks.com, 07 Sept. 2016. Web. 03 Dec. 2016.

in the development of autonomous vehicles.

Private Sector

For the private sectors, applying automated technologies towards commercial trucks can potentially bring massive economic rewards. The per-hour cost to operate a truck is now at \$68.50. Any incentives that minimizes time delays and congestions related impacts will likely provide a very solid ROI for stakeholders. With about 500,000 trucking companies registered with the U.S. DOT, the competition is stiff and the margins are low.⁹ Automation could address many of the inefficiencies in the industry and bring ROI to fleet managers and owner operators alike.

One of the two key industry problems are driver shortage and driver retention. “The ability to find enough qualified drivers is one of our industry’s biggest challenges,” ATA President Bill Graves said. “This latest report plainly lays out the problem — as well as some possible solutions — to the driver shortage.”¹⁰ In a recent report, ATA found that 45 percent of driver hires are done to replace retirees, while 33% are hired for industry growth.¹¹ More specifically, the industry is facing an aging workforce, with 26% of the drivers being 55 and older, and is having hard time getting younger generations to join the rapidly aging workforce.¹²

⁹ Bevy, David, et al. "Heavy truck cooperative adaptive cruise control: Evaluation, testing, and stakeholder engagement for near term deployment: Phase one final report." (2015).

¹⁰ “Driver Shortage Worsened This Year, ATA Says.” Transport Topics. October 6, 2015. Available online: <http://www.ttnews.com/articles/basetemplate.aspx?storyid=39635&t=Driver-Shortage-Worsened-This-Year-ATA-Says>

¹¹ Ibid

¹² Short, Jeffery. Analysis of Truck Driver Age Demographics Across Two Decades. American Transportation Research Institute. Arlington, VA. December 2014.

In a new report from the American Trucking Associations, the current driver shortage is now estimated to be 48,000, a number that is projected to increase to 175,000 by 2024.¹³

Many drivers are expected to cover 125,000 miles per annum. That breaks down to around 2,500 a week or 500 miles a day.¹⁴ Miles upon of miles of driving on the highway is a daunting and monotonous task, causing fatigue to the driver both mentally and physically. In addition, a driver could drive no more than 11 hours a day, and must take a 10-hour break to satisfy Hours of Service requirement.

HAV will also address another top concern in the trucking industry: driver distraction. It first arrived on the ATRI's Top Ten list in 2014, there is an increased concern about the rising use of technology in vehicles by drivers and its safety implication. It is not uncommon to see truck drivers on the phone, texting or using apps while operating their vehicles these days. By implementing vehicle automation, drivers are relieved of the responsibility to pay attention to the surrounding environment and the computer will take care of the long, tedious stretch of highway driving and operate much safer than human drivers. Now with the vehicle responsible for driving safely, truck drivers will be able work on logistics tasks such as route planning, connecting with clients, looking for new shipments and reporting to the fleet manager or just simply rest while the truck is assuming full control on the highway. By making the job less

¹³ "Driver Shortage Worsened This Year, ATA Says." Transport Topics. October 6, 2015. Available online: <http://www.ttnews.com/articles/basetemplate.aspx?storyid=39635&t=Driver-Shortage-Worsened-This-Year-ATA-Says>

¹⁴ Evans, Kim. "8 Facts About the Truck Driver Way of Life." *8 Facts About the Truck Driver Way of Life*. Jobs.com, n.d. Web. 02 Dec. 2016.

physically exhausting and stressful, working as a truck driver could appeal to a broader and different audience, and potentially require a very different skillset.

Solving driver shortage and reduce accidents are both very tangible things the industry could benefit from, but I believe the most important benefit HAV could bring to the table is its ability to increase productivity of the fleet while reducing cost-per-mile(CPM) for carriers.

Where drivers are restricted by law from driving more than 11 hours per day without taking an 8-hour break, a driverless truck can drive nearly 24 hours per day.¹⁵ That alone can almost double trucking industry's capacity and therefore reduce shipping cost. Even partial automation will generate considerable amount of labor savings, further reducing the cost of shipping. Driver pay was the highest share of carrier's total CPM at 31 percent in 2015, and that's without including driver benefits and additional bonus incentives.¹⁶ In addition, there will be fuel efficiency gains. The optimal cruising speed from a fuel efficiency standpoint is around 45 miles per hour, whereas truckers who are paid by the mile drive much faster. Further fuel efficiencies will be had as the self-driving fleets adopt platooning technologies.¹⁷ Since transportation cost accounts for a significant amount cost in the goods we buy, all the economic benefits from trucking automation will be eventually passed down to consumers in terms of lower price for goods.

¹⁵ Petersen, Ryan. "The Driverless Truck Is Coming, and It's Going to Automate Millions Of jobs." *TechCrunch*. N.p., 25 Apr. 2016. Web. 08 Dec. 2016.

¹⁶ Torrey, Ford, and Dan Murray. "An Analysis of the Operational Costs of Trucking: 2016 Update." *American Transportation Research Institute*. N.p., Sept. 2016. Web. 11 Dec. 2016.

¹⁷ Petersen, Ryan. "The Driverless Truck Is Coming, and It's Going to Automate Millions Of jobs." *TechCrunch*. N.p., 25 Apr. 2016. Web. 08 Dec. 2016.

Public Sector

The public sector has a long-standing interest in reducing highway accident numbers and make the public roadway safer for everyone. 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.¹⁸ In 2014 there were 3,903 fatalities that resulted from large truck-involved crashes; 657 of those fatalities were occupants of large trucks.¹⁹ An important promise of HAVs is to address and mitigate that overwhelming majority of crashes. Whether through technology that corrects for human mistakes, or through technology that takes over the full driving responsibility, automated driving innovations could dramatically decrease the number of crashes tied to human choices and behavior. HAVs also hold a learning advantage over humans. While a human driver may repeat the same mistakes as millions before them, an HAV can benefit from the data and experience drawn from thousands of other vehicles on the road.

Government legislators need to study closely at the development of these technologies and make sure that the regulations are sufficiently protecting the public safety while not restricting technology developments. National Highway Transportation Safety Administration (NHTSA) has been following the development of automated technologies in the private sectors,

¹⁸ "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

¹⁹ "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>

and recently issued Federal Automated Vehicles Policy and acknowledged the manufacturers and other entities significant progress in developing automated vehicle technology and its “ambitious approach to accelerate the HAV revolution.” Federal Automated Vehicles Policy is aimed to provide guidance for manufactures on best practices for “the safe pre-development design, development and testing of HAVs prior to commercial sale or operation on public roads”, as well as laying out the basis to create a “consistent national framework rather than a patchwork of incompatible laws (across different states)” for state governments.²⁰ Federal Automated Vehicle Policy also acknowledged the benefits of HAV goes beyond safety:

“Innovations have the potential to transform personal mobility and open doors to people and communities—people with disabilities, aging populations, communities where car ownership is prohibitively expensive, or those who prefer not to drive or own a car—that today have limited or impractical options. Cities will reconsider how space is utilized and how public transit is provided. Infrastructure capacity could be increased without pouring a single new truck load of concrete. HAVs may also have the potential to save energy and reduce air pollution from transportation through efficiency and by supporting vehicle electrification.”²¹

²⁰ United States. Department of Transportation. National Highway Traffic Safety Administration. *Federal Automated Vehicles Policy: Accelerating the next Revolution in Road Safety*. N.p.: n.p., 2016. Print.

²¹ Ibid

In addition, HAV technology will essentially render many of the current trucking regulations such as ELD mandate, Hour of Service (HOS) and CSA program obsolete, if not completely irrelevant. With Level 2 automation, a lot of the minor longitude and latitude correction will be handled by the computer and effectively reducing driver workload and driver drowsiness, allowing them to operate safely for longer.²² With Level 3 automation and above, the responsibility of driving will be largely handed over to the truck while the driver assumes a supervisory role, allowing the truck to be driven continuously while the driver rest in the sleeper berth. Electronic Logging Device (ELD) is used to electronically record a driver's Record of Duty Status (RODS), which replaces the paper logbook some drivers currently use to record their compliance with Hours of Service (HOS) requirements.²³ If HOS regulation were to be changed, ELD mandate would also need to be amended accordingly.

Technology

SAE Level of Automation

There are six different levels of automation level, as defined by New SAE International Standard J3016 listed as below. Most of the trucks operated on the road today are at Level 0, (driver assuming full control of the vehicle). There are about 100,000 ACC, or Level 1 equipped

²² O'Kane, Sean. "This Is What It's like to Ride in Daimler's Self-driving Semi Truck." *The Verge*. The Verge, 12 May 2015. Web. 05 Dec. 2016.

²³ "The ELD Mandate: A Trucking Industry 101." *ELD Facts*. OMNITRACS LLC, n.d. Web. 07 Dec. 2016.

Class 8 trucks on the road today. There is a shift in liability going from Level 2 to Level 3 automation. From Level 3 and above, while the vehicle is under automated control, the driver is not liable if the vehicle got into an accident. Currently, there are no Class 8 trucks with Level 3 and above automated system available commercially.

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 remaining aspects of the <i>dynamic driving task</i>	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 <i>dynamic driving task</i>	System	Human driver	Human driver	Some driving modes
Automated driving system (“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 dynamic driving task 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

AV Hardware

Automated vehicle relies on a few key hardware for the computer onboard to perceive the world and drive properly. This section is directly quoted from ATRI's *Identifying Autonomous Vehicle Technology Impacts on the Trucking Industry*, which summarized some common hardwares used for this application and the way they work.²⁴

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.²⁵ 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°).

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 equipment has hindered adoption.²⁶ Google reports that its autonomous vehicle

²⁴ Short, Jeffery, and Dan Murray. *Identifying Autonomous Vehicle Technology Impacts on the Trucking Industry*. Rep. N.p.: n.p., 2016. *American Transportation Research Institute*. Web. 1 Dec. 2016.

²⁵ "Safer, More Efficient Commercial Trucks." Accessed October 25, 2016.
<http://www.freightlinerinspiration.com/technology/>

²⁶ "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/>

uses a roof-mounted LIDAR where “64 lasers spin at about 900 rpm to give a 360 degree view.”²⁷ 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.²⁸ In an autonomous truck, the same functions may exist through the video camera but would be automatic.²⁹

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.³⁰ 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

²⁷ “Google's Autonomous Vehicle. Accessed November 14, 2016.

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

²⁸ “Mobileye 5-Series.” Accessed November 14, 2016

<http://www.mobileye.com/products/mobileye-5-series/>

²⁹ “Safer, More Efficient Commercial Trucks.” Accessed October 25, 2016.

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

³⁰ 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

safety systems or enable new communication-based safety applications.”³¹ 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.³²

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.³³ 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

³¹ 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.

³² “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

³³ “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

from within several meters to several centimeters. Such accuracy, if employed in real time, could help maintain a travel lane when markings are missing.³⁴

Security

Vehicles that are connected to each other, to infrastructure, or to the Internet are increasingly open to cyberattack. David Strickland, former head of NHTSA, has noted (2013):³⁵

With this evolution comes increased challenges, primarily in the area of system reliability and cybersecurity—the latter growing more critical as vehicles are increasingly more connected to a wide variety of products . . . Whether the entry point into the vehicle is the Internet, aftermarket devices, USB ports, or mobile phones, these new portals bring new challenges.

On the evening of July 14, 2016, a terrorist attack happened in Nice, France where Mohamed Lahouaiej-Bouhlel drove a cargo truck into a crowd of people celebrating Bastille Day and killing 85 people. The attack ended after an exchange of gunfire, and Lahouaiej-Bouhlel was killed by the police. As vehicles become more computerized and more connected, automated vehicles will become easy targets for malicious attackers to carry out crimes, or even acts of

³⁴ Short, Jeffery, and Dan Murray. *Identifying Autonomous Vehicle Technology Impacts on the Trucking Industry*. Rep. N.p.: n.p., 2016. *American Transportation Research Institute*. Web. 1 Dec. 2016.

³⁵ Anderson, James M., et al. *Autonomous vehicle technology: A guide for policymakers*. Rand Corporation, 2014.

terrorism. The consequence of a terrorist attack with a fleet of large commercial vehicles can be devastating.

As such, preventing attackers from accessing and modifying software of the onboard computers should be one of the top priorities of manufacturers, and focus on a developing a system to safeguard all forms of communications from the outside world into a vehicle such as Wi-Fi, LTE, DSRC, or wired connections used for software updates, etc. Newer vehicles on the road are incorporating up to 100 ECUs and approaching the limit of wiring harness, prompting manufactures to come up with more centralized computer controls, reducing total number of ECUs while increasing the number of functions and complexity of the software. A holistic approach to vehicle security is required.³⁶ However, auto manufacturers source ECUs from multiple different suppliers, meaning no one player is in complete control of a vehicle's source code.³⁷ Argus executive Yoni Heilbron spoke with TechChurch about automotive cybersecurity.

"The best mental model for understanding how automotive cybersecurity solutions work is to envision them as having several layers of defense," Heilbronn said. "Multiple solutions focused on different parts of the connected car ecosystem must be integrated in order to provide comprehensive, end-to-end protection; a single product alone is not adequate."³⁸

³⁶ Brown, David A., Geoffery Cooper, Ian Gilvarry, Anand Rajan, Alan Tatourian, Claire Vishik, and David Wheeler. *Automotive Security Best Practices*. Working paper. N.p.: Intel Security, n.d. Web. 10 Dec. 2016.

³⁷ Toews, Rob. "The Biggest Threat Facing Connected Autonomous Vehicles Is cybersecurity." *TechCrunch*. N.p., 25 Aug. 2016. Web. 10 Dec. 2016.

³⁸ Ibid

According to Yoni, starting from the base of the system, each individual ECU (ie. car's brakes and steering ECU) can incorporate defensive software to reinforce them against attacks. Moving up a level, a software solution monitoring the vehicle CANBUS to detect anomaly in the vehicle network that might indicate a sophisticated attack can be put in place.³⁹ Next level up, security measures should be implemented at units that are connected to the outside world, such as Wi-Fi/LTE/DSRC communication module. This is a critical step in the overall security hierarchy, since it bridges the vehicle's internal network with the external world.⁴⁰ Lastly, cloud security service can detect and correct threats before they reach the vehicle.

Apart from software security concern, there is also concern on vandals or criminals using jammers to carry out interference signals to disrupt sensors and wireless communications on an AV. These attacks include but are not limited to Wireless Denial of Service (WDoS) to interrupt Basic Safety Message (BSM) transmission⁴¹, sending false Lidar returns to confuse a vehicle using three-dimensional mapping to navigate through its environment⁴², Differential

³⁹ "Symantec Anomaly Detection for Automotive." *Anomaly Detection for Automotive / Symantec*. Symantec Corporation, n.d. Web. 10 Dec. 2016.
<<https://www.symantec.com/products/threat-protection/endpoint-family/anomaly-detection-for-automotive>>.

⁴⁰ Toews, Rob. "The Biggest Threat Facing Connected Autonomous Vehicles Is cybersecurity." *TechCrunch*. N.p., 25 Aug. 2016. Web. 10 Dec. 2016.

⁴¹ Serageldin, Ahmed, Hani Alturkostani, and Axel Krings. "On the reliability of DSRC safety applications: a case of jamming." *2013 International Conference on Connected Vehicles and Expo (ICCVE)*. IEEE, 2013.

⁴² Anderson, James M., et al. *Autonomous vehicle technology: A guide for policymakers*. Rand Corporation, 2014.

Global Positioning System (DGPS) jamming that prevents vehicle from getting an accurate geographic location reading.

Like any technology, AVs will experience failures and breaches. As a last resort, manufactures should implement a failsafe mechanism that can detect failures and breaches and act safely —switching to a tightly controlled and simple safety system or refusing to engage at all⁴³, reverting all controls back to the driver.

Stefan Savage, a computer science professor at the University of California, San Diego, said at the Enigma security conference in San Francisco that carmakers don't know exactly the software is inside the vehicles they sell.⁴⁴ The way the auto industry work caused this, since car builders source components from third parties at the lowest cost, and these components' software are all hidden from the manufacturers of a vehicle. "There is nobody in the world that owns all the code in a vehicle," said Savage. "That's a big problem."⁴⁵

Upstart autonomous car builders such as Tesla and Google are designing their vehicle architecture from scratch as opposed to established car companies, and this give them an advantage to design a platform with cybersecurity in mind. However, even Tesla and Google are relying heavily on third party supplied parts, meaning they might not have total control of the codes in their vehicles.⁴⁶ Moving the focus back onto trucks, a group of University of Michigan researchers found that developing attacks for commercial trucks easier than with consumer

⁴³ Anderson, James M., et al. *Autonomous vehicle technology: A guide for policymakers*. Rand Corporation, 2014.

⁴⁴ Simonite, Tom. "Your Future Self-Driving Car Will Be Way More Hackable." *MIT Technology Review*. N.p., 16 Mar. 2016. Web. 10 Dec. 2016.

⁴⁵ Ibid

⁴⁶ Ibid

cars due to the standard internal SAE J1939 network used in most industrial diesel vehicles from cement mixers to tractor trailer to school buses.⁴⁷ And due to the wide adoption of telematics technology for fleet management and its Internet connected nature, it provides a potential entry point for hackers to remotely access the vehicles J1939 network.

Key Businesses in the Industry

Private companies working in auto tech are on pace to attract record levels of deals and funding in 2016, with autonomous driving startups leading the charge. As expectations around self-driving vehicles have risen, major corporations have ramped up their own initiatives as well.⁴⁸ Companies ranging from small startups to large corporations are racing to deploy technology onto public roads. There are simply too many companies currently working on autonomous vehicles to list, here we will discuss only a few companies that are focused on automation in commercial trucks.

OTTO

Ottomotto LLC (OTTO, now owned by Uber) was founded by a group of former Googlers in self-driving car and mapping divisions in 2015, and is developing kits that can be used to

⁴⁷ Greenberg, Andy. "Hackers Hijack a Big Rig Truck's Accelerator and Brakes." *Wired*. Conde Nast, 02 Aug. 2016. Web. 10 Dec. 2016.

⁴⁸ "33 Corporations Working On Autonomous Vehicles." *CB Insights - Blog*. CB Insights, 11 Aug. 2016. Web. 06 Dec. 2016.

retrofit existing big rigs into autonomous trucks.⁴⁹ Otto demonstrated in October 2016 an origin to destination delivery in Colorado using its aftermarket L4 autonomous system during a 120-mile delivery.⁵⁰ 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.⁵¹ While being asked by Bloomberg Technology's Alex Webb regarding concerns on the technology's threat to replace truckers' jobs, Lior Ron, the president and co-founder of Uber's Otto unit said "driver will become a co-pilot while driving the truck manually on city streets, and the system driving all the cumbersome miles on the highway where driver remains in the cabin, safer, making more money and getting back home sooner to the family." ⁵² "Even in the future as we start doing more (than highway driving), we still think a driver is needed in terms of supervising the vehicle."

⁴⁹ Hirsch, Jerry. "Uber Acquires Otto Self-Driving Truck Startup, Signs Volvo Deal | Trucks.com." *Trucks.com*. Trucks.com, 07 Sept. 2016. Web. 03 Dec. 2016.

⁵⁰ "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/>

⁵¹ "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>

⁵² Newcomer, Eric, and Alex Webb. "Uber Self-Driving Truck Packed With Budweiser Makes First Delivery in Colorado." *Bloomberg.com*. Bloomberg, 25 Oct. 2016. Web. 03 Dec. 2016.

Peloton Technology

Another startup company based in Mountain View California, Peloton Technology's focus is on Driver Assistive Truck Platooning (DATP). Established in 2011, the company has been developing a system built upon the current Adaptive Cruise Control (ACC) technology that is currently available on many new consumer cars and commercial trucks alike. There are approximately 100,000 ACC-equipped Class 8 trucks are on the road now. In DATP, two or more trucks are exchanging data, with one or more trucks closely following the leader. The technology basis includes radar (for longitudinal sensing), V2V communications (for low latency exchange of vehicle performance parameters between vehicles), satellite positioning (sufficient to discriminate in-lane communications from out-of-lane communications), actuation (for vehicle longitudinal control), and human-machine interfaces (with distinct modes for leading or following)⁵³. Compared to Otto's vision, Peloton Technology's DATP technology is a lower level automation system (Level 2 Automation), but the company has publicly stated it will be the first company to offer a commercial platooning system for use by the truck fleets in 2017.⁵⁴

Freightliner

Freightliner and Daimler hosted a debut event at Hoover Dam to announce their Inspiration truck, and according to their press release, "it is the first self-driving commercial

⁵³ Bevy, David, et al. "Heavy truck cooperative adaptive cruise control: Evaluation, testing, and stakeholder engagement for near term deployment: Phase one final report." (2015).

⁵⁴ Reiskin, Jonathan S. "Panelists Say Driverless Trucks Decades Away; Platooning Pairs Coming in 2017." *Transport Topics Online | Trucking, Freight Transportation and Logistics News*. N.p., 6 Oct. 2016. Web. 03 Dec. 2016.

truck in the world to receive a full license to operate on public roads in 2015.”⁵⁵ Freightliner claims the Inspiration truck as a Level 3 autonomous vehicle, however, from some of the ride-along videos online it is clear that with the highway pilot automation engaged, the truck driver seems to be uneasy while the truck came to a slight curve and hovered his hands right above the wheel, ready to take control at any second.⁵⁶ This instance shows that the system does not meet SAE’s Level 3 automation standard since the system is not fully aware of the driving environment (see chart above) and the driver is still responsible for being aware of the surroundings. Thus, the system should be categorized as a Level 2 automated system rather than Level 3. Just like in the non-commercial passenger car space, the established auto manufacturers (in this case, Daimler) use a more conservative approach to vehicle automation, intending it to be an evolutionary step after the current adaptive cruise control technology instead of the more radical but riskier approach Silicon Valley’s technology startups tend to adopt. Daimler Trucks North America president and CEO Martin Daum said it will “enhance” the driver’s capabilities. It is clear the company view its automation system as an advanced driver assistance system to improve safety, increase driver comfort and productivity rather than replacing drivers altogether. Nevada’s long, straight, hypnosis-inducing roads allowed the company to test driver drowsiness. “The steering wheel twisted back and forth as the Highway Pilot system guided the truck between the boundaries of our lane, fighting the wind and the truck’s momentum. All that correction would normally be done by the driver, and on long

⁵⁵ Freightliner. *Freightliner Inspiration Truck Unveiled at Hoover Dam. Freightliner Inspiration*. Freightliner, 5 May 2015. Web. 5 Dec. 2016.

⁵⁶ O’Kane, Sean. “This Is What It’s like to Ride in Daimler’s Self-driving Semi Truck.” *The Verge*. The Verge, 12 May 2015. Web. 05 Dec. 2016.

drives that take up nearly half a day, all those little corrections add up.”⁵⁷ Dr. Wolfgang Bernhard said "we measured brain activity with [and] without autonomous function. It clearly shows that driver drowsiness decreases by about 25 percent when the truck is operating in autonomous mode." Both Bernhard and Daum both spoke about how automating part of the whole process will let drivers make longer runs. At one point, Daum even said that it's up to Daimler to prove to regulators "that driver fatigue is decreased, so guys who use support systems can have longer hours of service."⁵⁸

Societal Impact

Perception of the autonomous trucks

“Of the 7.1 million people employed throughout the economy in jobs related to trucking activity, 3.4 million were truck drivers in 2014. There are over 10 million CDL (Commercial Driver's License) holders in the U.S., but most are not current drivers and not all are truck drivers. There are between 2.5 million and 3 million trucks on the road today that require a driver to have some sort of CDL. Of those trucks, 1.6 million are tractor-trailers. Of those tractor-trailers, no more than 800,000 are used in OTR (i.e., non-local) operations.”⁵⁹ Since the

⁵⁷ O'Kane, Sean. "This Is What It's like to Ride in Daimler's Self-driving Semi Truck." *The Verge*. The Verge, 12 May 2015. Web. 05 Dec. 2016.

⁵⁸ Ibid

⁵⁹ Costello, Bob, and Rod Suarez. *Truck Driver Shortage Analysis*. Publication. N.p.: American Trucking Association, 2015. Web. 8 Dec. 2016.

automation we talk in this paper is focused on highway driving only, those 800,000 or so drivers are the one that will be directly affected by this technology.

It is not surprising that most truck drivers are rather bitter and doubtful of the future of automation. This attitude can be seen on truckers' Internet forum discussions⁶⁰. There is a big disconnect between Silicon Valley and the old-school trucking industry. As far as most truckers can tell, the danger of losing their jobs to robots is still a long, long way off, while one venture investor in autonomous vehicle technology estimated "three years, at most" before such commercial trucks hit the road.⁶¹ This disconnect reveals different beliefs of how the trucking industry will evolve. Most of the trucking companies are surviving on thin margins and has little for splashing out on new technology. Most companies are not showing positive attitude toward fleet automation. This reluctance to adopt evolutionary new technology will open up opportunities for newcomers to the field, giving them steep cost advantages and enable them to grow rapidly.⁶² Today's trucking companies will very likely get replaced by the newcomers who adopt the latest technologies.

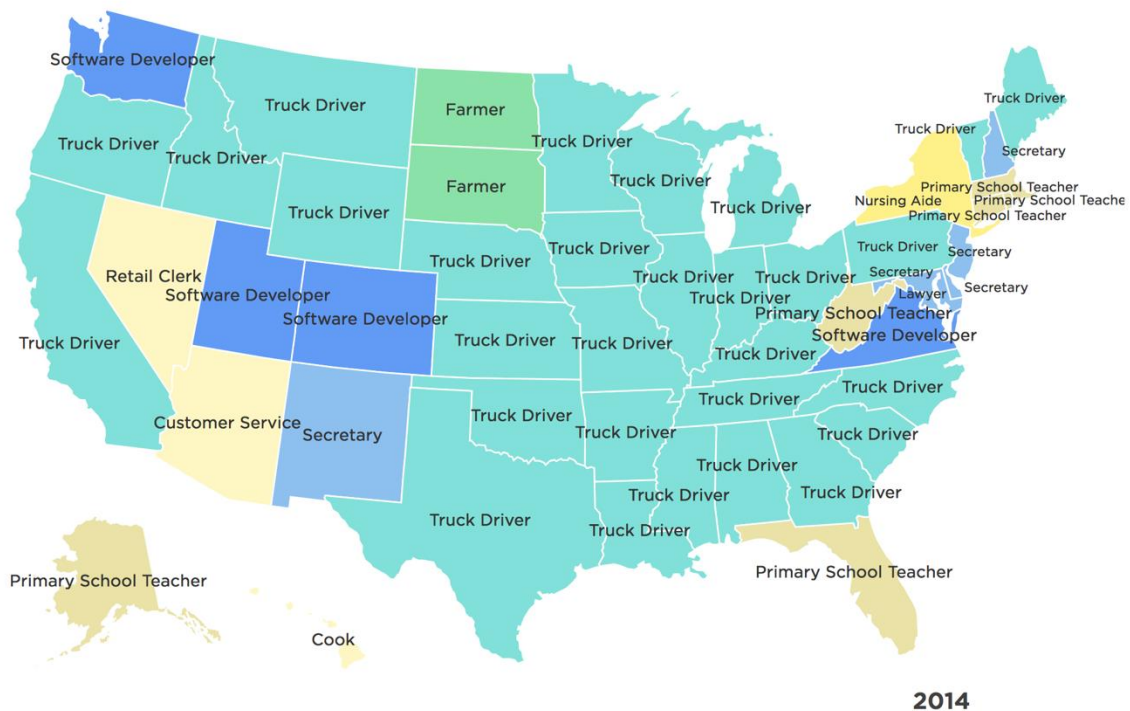
⁶⁰ Examples can be found [here](#) and [here](#)

⁶¹ Coren, Michael J. "Truckers Think Automation Won't Take Their Jobs for 40 Years. Silicon Valley Strongly Disagrees." *Quartz*. N.p., 07 Dec. 2016. Web. 08 Dec. 2016.
<<http://qz.com/854117/truckers-think-automation-wont-take-their-jobs-for-40-years-silicon-valley-strongly-disagrees/>>.

⁶² Ibid

Jobs

Truck driver is the most common job in 29 states, according to NPR's analysis of U.S. Census data (see most common jobs in the map below). Due to the nature of driving a truck, it is immune to globalization, as in a worker from China cannot drive a truck in Ohio.⁶³ As such, driving a truck is considered one of the last good jobs providing middle class income for Americans without college educations. Truck drivers are well-paid, and have an average annual income of \$40,000 a year.⁶⁴ Private fleet drivers (such as Walmart truck drivers) are even paid approximately 60 percent more than for-hire drivers.⁶⁵ There is a strong demand for new truck



Source: NPR

⁶³ Bui, Quoc Trung. "Map: The Most Common* Job In Every State." *NPR*. NPR, 5 Feb. 2015. Web. 11 Dec. 2016.

⁶⁴ Gillespie, Patrick. "Truck Drivers Wanted. Pay: \$73,000." *CNNMoney*. Cable News Network, 9 Oct. 2015. Web. 11 Dec. 2016.

⁶⁵ Torrey, Ford, and Dan Murray. "An Analysis of the Operational Costs of Trucking: 2016 Update." *American Transportation Research Institute*. N.p., Sept. 2016. Web. 11 Dec. 2016.

drivers in the industry right now. The industry needs to hire 89,000 new drivers per year, with 33% of the new hiring contributed by industry growth.⁶⁶ Due to the increasing demand for truckers while driver shortage remains one of the biggest challenge in the industry, driver pay is expected to increase steadily over the next few years at the current rate of 8% or faster.⁶⁷

However, this will change when soon Level 3 and Level 4 automation becomes commercially available to the trucking industry. The economic benefits of embracing automation and getting rid of drivers are just too good to pass up. Driver pay accounts for 31% of a carrier's cost-per-mile expenses, and that does not include driver benefits and bonus incentives. Along with other benefits of automation such as safety, ability to operate 24/7, automation makes it hard for human drivers to compete with computers. It is unnerving for many in the industry to see the excitement of executives at major trucking companies towards the autonomous future.⁶⁸

"Everyone wearing a suit, sitting in the corporate headquarters looks at the numbers and thinks that automated commercial vehicles seem to be the wave of the future. Drivers on the other hand are less than sold on the idea. There is a general feeling amongst truck drivers – those who know the business best –

⁶⁶ Costello, Bob, and Rod Suarez. *Truck Driver Shortage Analysis*. Publication. N.p.: American Trucking Association, 2015. Web. 8 Dec. 2016.

⁶⁷ Torrey, Ford, and Dan Murray. "An Analysis of the Operational Costs of Trucking: 2016 Update." *American Transportation Research Institute*. N.p., Sept. 2016. Web. 11 Dec. 2016.

⁶⁸ Barradas, Samuel. "ATA: Self-Driving Trucks Are "Close To Inevitable"." *TruckersReport.com*. N.p., 01 Aug. 2013. Web. 11 Dec. 2016.

that there are just too many things that drivers do other than holding a steering wheel that an automated truck would not be able to do.”⁶⁹

In the near future, a driver will still need to supervise the truck’s operation, fuel the vehicle, take care of off-the-highway driving, loading/unloading, pre-trip inspection. However, it is inevitable that automation will start to bite into truckers’ paychecks, and sooner or later they will no longer be needed and become jobless. The future of complete automation is perhaps another two decades away from us, but it is a future truck drivers and our society as a whole will need to be prepared for.

Conclusion

Along with burger flippers, cashiers, factory workers, truck drivers are going to be out of work in the coming decades. The income from those eliminated jobs will be paid to fewer knowledge workers such as programmers and engineers, while most of the wealth will transfer to the few with access to capitals. This is similar in nature to the Industrial Revolution in the 19th century in it will create widespread social disruption and unrest. Many are calling for a Universal Basic Income and “Technological Socialism”.⁷⁰ The progress of the human society, however should not slow down because of the fear of change. The automated driving

⁶⁹ Barradas, Samuel. "ATA: Self-Driving Trucks Are "Close To Inevitable"." *TruckersReport.com*. N.p., 01 Aug. 2013. Web. 11 Dec. 2016.

⁷⁰ Diamandis, Peter. "Why the Cost of Living Is Poised to Plummet in the Next 20 Years." *Singularity HUB*. N.p., 18 July 2016. Web. 11 Dec. 2016.

technology itself is maturing rapidly and is almost ready to be commercialized. However, in order for it to have a smooth and safe transition into everyday operation, there are many things that need to be addressed first, such as legislation, software security, infrastructure update/improvements, and driver training.

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