Truck Platooning: Future of the Freight Industry

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ABSTRACT
This paper presents a state-of-the-practice of truck platooning technology, including policy, regulatory, and technological challenges and opportunities, and an envisioned timeframe for the implementation of the technology. Several demonstration projects on truck platooning conducted in the past have been highlighted, including the demonstration of a truck platooning system on September 14-15, 2017 on I-66 in Virginia, near Centerville. The I-66 demonstration was the most robust demonstration of truck platooning system considering that it was done on a highway in real traffic conditions, one of the busiest and most congested in the nation. Technological advances in automated vehicle technology, including truck platooning, are moving at a rapid pace. However, legislative and regulatory barriers need to be overcome for the widespread application and acceptance of this technology. Also, partnership among various stakeholders is crucial for the success of this technology.

Keywords: automated vehicles, automation level, connected vehicles, demonstration, highway, policy, regulation, safety, technology, truck platooning

WHAT IS TRUCK PLATOONING?
As the name implies "Truck Platooning" is the formation of a platoon of trucks on highways following each other at established close distances by communicating with each other through smart automated vehicle technologies, with capabilities to brake and stop as the situation and road conditions warrant. The truck in the front acts a platoon leader and the trucks behind react and adapt to the movements of the platoon leader. The benefits of truck platooning include reduced fuel consumption and carbon-di-oxide emissions, improved safety, efficient use of roads, and faster delivery of goods. Truck platooning is considered as the future of the freight industry.

BACKGROUND
The idea of automated vehicles was conceived more than 70 years ago when, in 1939, General Motors (GM) envisioned a world in 1960 comprised of intelligent highway systems and self-driving cars at Futurama Exhibit at New York's World Fair. The research and development efforts on automated vehicles started in 1950's, continue to date, and will continue in the foreseeable future. The U.S. Department of Transportation (DOT) started its Automated Highway System Program in 1992 leading to Demo '97 in San Diego, which showcased automated cars, trucks, and buses in a freeway environment to get the word out that automated driving was not just a talk and buzzword, rather it was reality of the future. In 2004, the U.S. Defense Advanced Research

Projects Agency (DARPA) announced a competition inviting qualified teams to drive a 150-mile route in Mojave Desert with their fully automated vehicles. In 2007, DARPA followed it up with an urban challenge where both cars and large trucks competed in a street environment. The announcement in 2010 by Google that it has logged 170,000 miles of driving with its fleet of self-driving cars was the beginning of a race among vehicle manufacturers and suppliers to be in the race and ahead in the race, and this accelerated the transition of research to practice (ATA Technology and Maintenance Council Future Truck Program, 2015).

The concept of automated driving of trucks and truck platooning has been experimented and demonstrated since 1990's. It was realized from the beginning that truck platooning technology can address many issues related to fuel economy, traffic congestion, and traffic safety. In Europe, the technology was focused in a program Chauffeur, which continued with a follow-on program Chauffeur II. In 2000, these programs were followed up with other programs, namely HAVE-IT, STARTRE and Konvoi. Also, during 2000's, the Japanese government started examining the truck platooning technology under its Energy ITS program. This was the same time period when U.S. DOT and California DOT sponsored research programs on truck platooning for civilian purposes and the U.S. Army for military purposes (ATA Technology and Maintenance Council Future Truck Program, 2015).

The truck platooning is tied to the level of vehicle automation available today, which is generally Level 1, as classified by the Society of Automotive Engineers (SAE). In Level 1 vehicle automation, an advanced driver assistance system (ADAS) on the vehicle can, if needed, assist the human driver with either steering or braking/accelerating, but not both together. As a benchmark to different levels of automation, Level 0 means that all the driving functions are performed by the human driver. In Level 2 automation, ADAS can assist the human driver with both steering and braking/accelerating at the same time. In vehicle automation, beyond Level 2, advanced driver assistance system (ADAS) transitions to automated driving system (ADS). In the next stage of automation, Level 3, the ADS can perform all the driving functions by itself under right circumstances, but still a human driver is needed who can take back control of the vehicle and perform all the driving functions if directed by the ADS. In Level 4 automation, the ADS can perform all the driving functions and monitor the driving environment by itself in certain circumstances. The ultimate level of vehicle automation, Level 5, completely eliminates the human involvement in driving functions in all the circumstances and humans are just passengers in the automated vehicle. According to National Highway Traffic Safety Administration (NHTSA), the time period of 2016 to 2025 will witness partially automated vehicles including lane keeping assistance, adaptive cruise control, traffic jam assistance, and self-park assistance. Fully automated vehicles can be expected in years beyond 2025 (National Highway Traffic Safety Administration, 2018).

EUROPEAN EXPERIENCE

In 2017, the European Automobile Manufacturers Association (ACEA) presented an EU roadmap for truck platooning (European Automobile Manufacturers Association, 2017). According to this roadmap, the technology for mono-brand truck platooning is already available where trucks of the same brand (make/model) can be platooned together. The roadmap projects that by 2023,

multi-brand truck platooning would be possible with SAE Level 2 automation. The roadmap further projects that beyond 2023, the automation level of trucks could reach to an extent where the drivers of the trailing trucks can sleep, followed by fully automated trucks where the drivers of both the leading and trailing trucks in the platoon can sleep. Some of the recommendations included in this plan include the following (European Automobile Manufacturers Association, 2017):

- Further develop, test, and verify platooning technology.
- Develop standards relevant to platooning technology.
- Upgrade highway infrastructure.
- Develop a supportive regulatory framework.
- Perform collaborative research projects and showcase activities.
- Acquire more experience with platooning in real-traffic conditions.
- Develop cooperation among stakeholders, including operators of the highway infrastructure, logistics operators, insurance companies and policymakers.
- Generate political support for the introduction and application of truck platooning technology.

The roadmap acknowledges that the market introduction of this technology will require permission to drive platoons on motorways across the European Union, without needing any specific exemptions. The same is true in the United States that the success of this technology depends upon permission to drive truck platoons across the state borderlines.

U.S. FEDERAL POLICIES

Government policies are critical to the success and widespread application of truck platooning technology. Both the federal and most state governments are aware of the policy and legislative challenges associated with automated vehicles and truck platooning. In May 2013, the NHTSA issued a "Preliminary Statement of Policy Concerning Automated Vehicles" (National Highway Traffic Safety Administration, 2013). This policy statement did not recommend that states authorize the operation of self-driving vehicles for purposes other than testing. According to NHTSA, there were a number of technological and human performance issues that needed to be addressed before the public use of self-driving vehicles.

In 2016, NHTSA issued the initial version of the Federal Automated Vehicles Policy titled "*Accelerating the Next Revolution in Roadway Safety*" (U.S. Department of Transportation, 2016). This document provided vehicle performance guidance for highly automated vehicles (HAV's). It outlined the best practices for the safe pre-deployment design, and development and testing of HAV's prior to their commercial sale or operation on public roads. The document also offered a Model State Policy where it confirmed that States retain their traditional responsibilities for vehicle licensing and registration, traffic laws and enforcement, and motor vehicle insurance and liability regimes. NHTSA retained its responsibilities for setting Federal Motor Vehicle Safety Standards (FMVSS) and enforcing compliance with the FMVSS.

Automated Driving Systems 2.0 titled "*A Vision for Safety*," issued in September 2017, replaced the Federal Automated Vehicles Policy of 2016. This updated policy was focused on making the DOT regulatory processes more in pace with private sector innovation (U.S. Department of Transportation, 2017). In this update, NHTSA maintained its role of providing vehicle performance guidance (termed as "Voluntary Guidance"), and setting and enforcing FMVSS. As part of voluntary guidance, the agency identified 12 specific items that entities involved with manufacturing, designing, supplying, testing, selling, operating, or deploying ADS should consider. This included items such as object and event detection and response, human-machine interface, vehicle cybersecurity, and data recording. NHSTA again delineated federal and state roles, and went on to clarify that the states should not codify the federal voluntary guidance into their state statutes as a legal requirement for any phases of development, testing, or deployment of ADSs. This would help avoid any real or perceived conflicts between federal and state regulations and authority.

The policy Automated Driving Systems 2.0 provided more than 10 best practices to state legislators and state highway safety officials. For examples, one of the recommendations was to provide a "technology-neutral environment" where any entity can be authorized to test and deploy ADS technology in the state as long as they meet the federal and state law prerequisites for such testing and deployment, and this authorization is not limited to only vehicle manufacturers. Another recommendation was that before states grant permission for entities to test ADS on public roads, they should involve law enforcement agencies in the process in order to ensure greater public safety. Also, they should suspend permission to test if the entity fails to comply with the state insurance or driver requirements.

The NHTSA policies described above have primarily focused on higher levels of automation (Level 3, Level 4, Level 5) where the vehicles can drive by themselves for a limited or extended period of time with or without the engagement of human drivers. The truck platooning technology, which is currently being explored at Level 1 and Level 2 automation is generally not affected by these NHTSA policies. Furthermore, interstate motor carrier operations and commercial motor vehicle (CMV) drivers fall under the jurisdiction of Federal Motor Carrier safety Administration (FMCSA), not of NHTSA. The Federal Motor Carrier Safety Regulations (FMCSRs) currently require the presence of a trained commercial driver behind the wheel at all times, regardless of any automated driving technologies available on the CMV.

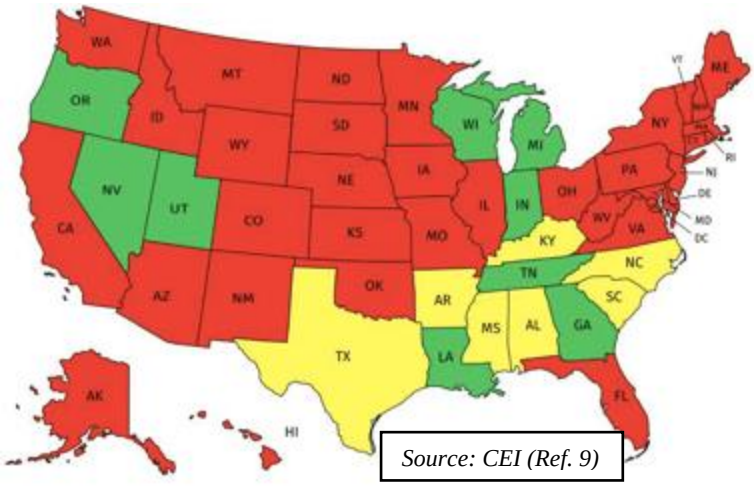
The latest version of the DOT policy on automated vehicles is Automated Vehicles 3.0 titled "*Preparing for the Future of Transportation,*" which was released in September 2018 (U.S. Department of Transportation, 2018). This is the first policy document of the DOT that is multi-modal in nature and includes all the modal administrations, including Federal Highway Administration (FHWA), FMCSA, Federal Aviation Administration (FAA), Federal Rail Administration (FRA), Federal Transit Administration (FTA), Maritime Administration (MARAD), NHTSA, and Pipeline Hazardous Materials Safety Administration (PHMSA). There are specific policy positions from four modal administrations: NHTSA, FMCSA, FHWA, and FTA, which, so far, were primarily from NHTSA. This policy document does not replace Automated Driving Systems 2.0, rather builds upon it. For example, additional items have been added to Best Practices for

State Legislators and State Highway safety Officials. One such additional item is a recommendation to engage U.S. DOT for legislative technical assistance. Other recommendation is to assess state roadway readiness level for automated vehicles. It is generally acknowledged that greater uniformity and quality of road markings, signage, and good pavement condition would be beneficial to both human drivers and automated vehicles.

The FMCSA, which has jurisdiction over truck platooning, particularly when it comes to interstate movements, has the following policy positions: 1) FMCSA retains its authority to take enforcement action if an automated system inhibits safe operation, 2) In the future, FMCSA regulations will no longer assume that the CMV driver is always a human or that a human is necessarily present onboard a commercial vehicle during its operation, 3) If FMCSA determines that state or local legal requirements may interfere with the application of FMCSRs, the agency has preemptive authority (U.S. Department of Transportation, 2018).

U.S. STATE POLICIES

Several state governments have authorized the testing of automated vehicles on public roads in their states. These include California, Florida, Michigan, Nevada, Virginia, and the District of Columbia. Other states are considering enabling legislation to allow the testing of automated vehicles. California is one of the early states that has issued detailed regulations regarding the testing of automated vehicles, including requirements for certificates of self-insurance and reporting any instances where the automation has failed. Most states have regulated the minimum following distances between vehicles, which can impact truck platooning operations.



Source: CEI (Ref. 9)

In a recent study by Competitive Enterprise Institute (CEI), the existing statutes of all the states have been reviewed from the standpoint of their following-too-closely (FTC) rules. Currently, there are 9 states which have relaxed FTC rules for truck platooning without unnecessary restrictions (green in the map) and there are 7 states which have conditionally relaxed FTC rules for truck platooning (yellow in the map). However, there are still 34 states that have not taken any action on relaxing FTC rules (red in the map). The study has made specific recommendations on amendments to state statutes that would relax FTC rules and make truck platooning practical in those states (Scribner, 2018).

In addition to FTC rule, a state law which is problematic for truck platooning is the “hand on the wheel” law, which requires that at least one hand of the driver must be at the steering wheel all the time. At this stage, New York is the only state which has this regulation in place. According to New York State Statute Article 33 § 1226 “No person shall operate a motor vehicle without

having at least one hand or, in the case of a physically handicapped person, at least one prosthetic device or aid on the steering mechanism at all times when the motor vehicle is in motion" (Windover, et al., 2018). During the 2015-2016 legislative session of the New York State, efforts were made to amend this law with a language "at all times when the motor vehicle is in motion, unless driving technology is engaged to perform the steering function" but did not succeed and the law remains in place. However, at this stage of Level 1 and Level 2 truck platooning, this is not of much concern since at these automation levels, the driver is always at the wheels. In the long-term, this needs to be resolved for automation levels at Level 3 and above. Even with this hands on the wheel law, New York State enacted a law in 2017 authorizing demonstration and testing of motor vehicles equipped with automated vehicle technology.

DEMONSTRATIONS

Several demonstrations of truck platooning have been conducted during the recent years, both in controlled settings and on public roads. The first demonstration of truck platooning in the United States was conducted on November 20, 2015 on I-80 in Tooele County, outside Salt Lake City. This demonstration used a two-truck platooning system and was in collaboration with Peloton Technology and the Utah Department of Transportation. The two trucks in the platoon were within 40 ft. of each other and capable of simultaneously braking, accelerating and reacting to road hazards up to 800 feet away. The collision mitigation system was capable of reacting to a slowing vehicle ahead of the platoon without driver input (Peloton, 2018).

On a project, jointly sponsored by FHWA and the Texas Department of Transportation, the Texas Transportation Institute (TTI) conducted a proof-of-concept demonstration of a two-truck platooning system on a runway at their RELLIS facility on July 22, 2016. Various scenarios that were demonstrated included platoon formation, platoon abandoning, changing gap between the trucks, and changing lane (Kuhn et al., 2017). On another project, jointly sponsored by the FHWA and the California Department of Transportation (Caltrans), Partners for Advanced Transportation Technology (PATH) conducted truck platooning demonstrations, with Volvo trucks, in San Jose, CA in June 2016 and at the Port of Los Angeles in March 2017. These public demonstrations in controlled settings ultimately led to the demonstration of this truck platooning system on September 14-15, 2017 on I-66 in Virginia, near Centerville.

The I-66 demonstration was the most robust demonstration of truck platooning system considering that it was done on a highway in real traffic conditions, one of the busiest and most congested in the nation. This demonstration involved a platoon of three Volvo trucks and stretched over 8 miles of busy highway traffic. The gap between the trucks was 45 to 50 ft., at 55 mph, about 0.6 seconds apart. The Virginia State Police actively participated in this effort (AASHTO, 2017).

Source: AASHTO (Ref. 13)

The most recent demonstration of truck platooning was on June 27, 2018 on N.C. 540 (Triangle Expressway), which was done through collaboration of Volvo Trucks North America, FedEx, and the North Carolina Turnpike Authority (NCTA). The platoon consisted of three tractors, each pulling 28-ft. twin trailers (MarketWatch, 2018). The platoon traveled at speeds of up to 62 mph, with a time gap of 1.5 seconds. The demonstration included planned and unplanned vehicle cut-ins.

TECHNOLOGY

Dedicated Short-Range Communication (DSRC) and Cooperative Adaptive Cruise Control (CACC) are at the core of current truck platooning technology. In a platoon, the connected trucks communicate with each other via DSRC, which is a radio communication at 5.9 GHz transmission. The DSRC enables vehicle-to-vehicle communication, commonly referred to as V2V. The DSRC also enables vehicle-to-infrastructure (V2I) communication, where vehicles can collect information from and send information to physical infrastructure equipped with sensors, including highways, bridges, and traffic signals. The CACC technology is augmenting the existing adaptive cruise control (ACC) technology with V2V communication. ACC is currently available in most recent vehicles reasonably equipped. The integration of ACC and V2V technologies in CACC helps control the gap between trucks in a platoon. Other components of the truck platooning technology include millimeter-wave radar, infrared laser radar, and cameras to detect objects and lane markings, a computer to run the system control software, and an interface to the throttle and brake systems (longitudinal control) and an interface to the steering control system (lateral control).

Further enhancements to the truck platooning technology in the near future include incorporating technologies such as Light Detection and Ranging (LiDAR). This technology provides high-resolution and real-time 3D information needed to support ADAS. LiDAR sensors provide horizontal and vertical field of views of as much as 360 degrees and, with their effectiveness in a variety of environmental conditions, can help avoid difficult blind spots and overhead obstructions (Velodyne, 2018). One of the concerns in truck platooning is that for drivers in the follower trucks blindly following the lead truck and its driver, at a close spacing, without a view of the road ahead could be stressful. This can be alleviated if all the trucks in the platoon have a good size computer screen displaying the road ahead.

The development of truck platooning technology needs the involvement of a variety of stakeholders including vehicle manufacturers, fleet owners and operators, drivers, and public agencies. Currently, there are a number of providers of the truck platooning technology and others will emerge as the technology matures. Peloton Technology is one of the providers of the highway platooning technology. They have collaborated with Volvo, Peterbilt Motors, and others in the demonstration of highway platooning technology. Currently, Peloton Technology provides necessary hardware, software, and cloud-based communication (using Long Term Evolution or "LTE" modem) for truck platooning. The technology incorporates real-time information on weather, traffic, and other conditions. At this stage, the technology uses V2V communication, but not V2I. Peterbilt Motors has been involved in Truck Platooning Technology for some time,

particularly in Europe, however, their technology is not widespread at this stage. They are looking into even retrofitting their existing trucks with this technology. Highway Pilot of Freightliner (parent company Daimler) is a highly automated driving system than can be used in truck platooning. The technology has been demonstrated on concept Freightliner Cascadia trucks. Navistar International is another truck manufacturing company that has demonstrated truck platooning technology on its trucks and has an interest in the technology.

SUMMARY AND CONCLUSIONS

The idea of automated vehicles which was conceived more than 70 years ago is coming to fruition today. Truck platooning, which builds upon automated vehicle technology, is currently being tested and validated on real highway infrastructure at SAE Level 1 and Level 2 of vehicle automation. With the current pace of technological advancements and easing of regulatory framework, it is envisioned that truck platoons with Level 1 and Level 2 automation will be on highways performing their intended function by 2025. The introduction of truck platoons on real highways will help improve public confidence in the technology and serve as a catalyst in further automation and deployment of the technology. Truck platoons with Level 3 automation can be expected on highways by 2030 and with Level 4 and Level 5 automation by 2040.

The need for collaboration, cooperation, and partnership among various stakeholders, like other innovative technologies, is crucial in the widespread acceptance and application of truck platooning technology. Even the current U.S. DOT policy on automated vehicles is based on the concept of active involvement and partnership of all the stakeholders. It provides voluntary guidance and best practices on vehicle performance which entities involved with manufacturing, designing, supplying, testing, selling, operating, or deploying advanced driving systems should consider. These voluntary guidelines include items such as object and event detection and response, human-machine interface, vehicle cybersecurity, and data recording. The U.S. DOT, rightfully, maintains its responsibility and authority of setting and enforcing Federal Motor Vehicle Safety Standards. The U.S. DOT also offers guidance, best practices, and legislative technical assistance to state legislators and state highway safety officials that would help expedite the deployment of truck platooning technology.

Other partners in advancing truck platooning technology include OEM (original equipment manufacturer) and technology providers, which may be separate entities or the same, motor carriers, law reinforcement agencies, universities, and research institutions. The readiness level of highway infrastructure is equally important in advancing truck platooning technology. Greater uniformity and quality of road markings, signage, and good pavement condition would be needed for automated vehicle technology, including truck platooning. Thus, architects, engineers, designers, and builders of the highway infrastructure should be part of the partnership. A new generation workforce would be needed in this era of vehicle automation.

DISCLAIMER

In this paper, the author has analyzed various Federal and state policies on automated vehicles and truck platooning. However, any opinions expressed in the paper are solely of the author, and do not necessarily represent the position of any government institution.

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