Driver Assistive Truck Platooning: Considerations for Florida State Agencies

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List of Acronyms

ADB:	Air Disc Brakes
ATA:	American Trucking Association
AV:	Automated Vehicle
CV:	Connected Vehicle
DATP:	Driver Assistive Truck Platooning
DDT:	Dynamic Driving Task
DHSMV:	Department of Highway Safety and Motor Vehicles
EPTC:	European Truck Platooning Challenge
FCAM:	Forward Collision Avoidance and Mitigation
FDOT:	Florida Department of Transportation
FHP:	Florida Highway Patrol
FMCSA:	Federal Motor Carrier Safety Administration
FTE:	Florida Turnpike Enterprise
HAV:	Highly Automated Vehicle
HOS:	Hours of Service
ISO:	International Standards Organization
MPO:	Metropolitan Planning Organization
NACFE:	North American Council on Freight Efficiency
NCHRP:	National Cooperative Highway Research Program
NHTSA:	National Highway Traffic Safety Administration
ODD:	Operational Design Domain
OEDR:	Obstacle and Event Detection and Response
OEM:	Original Equipment Manufacturer
SAE:	Society of Automotive Engineers
TMC:	Technology and Maintenance Council
TTI:	Texas Transportation Institute

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Executive Summary

Introduction

Florida House Bill 7027 (2016-81) states "The Department of Transportation, in consultation with the Department of Highway Safety and Motor Vehicles, shall study the use and safe operation of driver-assistive truck platooning technology, as defined in s. 316.003, Florida Statutes, for the purpose of developing a pilot project to test vehicles that are equipped to operate using driver-assistive truck platooning technology." Florida Statute 316.003 defines Driver Assistive Truck Platooning (DATP) as: "vehicle automation and safety technology that integrates sensor array, wireless vehicle-to-vehicle communications, active safety systems, and specialized software to link safety systems and synchronize acceleration and braking between two vehicles while leaving each vehicle's steering control and systems command in the control of the vehicle's driver in compliance with the National Highway Traffic Safety Administration rules regarding vehicle-to-vehicle communications."

Current Florida statute (316.0895) prohibits truck drivers from following closer than 300 feet based on an assessment that following at shorter distances is unsafe given the nature of truck braking systems and reaction times for human drivers. DATP technology now being commercialized is designed to safely achieve shorter following distances, which would reduce fuel use due to aerodynamic drafting effects. Significant fuel economy benefits from platooning (on the order of 7% improvement for the truck pair) have been documented through extensive test track evaluations, motivating major trucking fleets to work toward platooning deployment. If current law is revised to allow shorter following distances while trucks platoon, Florida will see enhanced safety and reduced environmental impacts (emissions and energy use) from trucking operations while maintaining its standing as a tech-forward state. At the same time, the cost of goods movement will be reduced for freight carriers, with savings potentially passed on to consumers.

Ten states (Arizona, Arkansas, Georgia, Michigan, Nevada, North Carolina, Ohio, South Carolina, Tennessee, and Texas) currently allow commercial truck platooning on their highways. Additional states are expected to join this group in 2018.

In response to the legislative mandate quoted above, FDOT issued a Task Work Order to the University of Florida in January of 2017 to conduct this study. DATP has the potential to lower the cost of freight transport and the footprint of trucks on the road. But important questions must be addressed:

a. Will DATP trucks be more likely to crash, or increase the severity of a crash?
b. Will DATP trucks impede other traffic, particularly at interchanges?
c. Will DATP trucks damage infrastructure due to intensified loading or aerodynamic effects?
d. What administrative processes to allow DATP operations would best serve State interests?

Therefore, this study addresses the implications of DATP across four core dimensions that fall under the purview of Florida state agencies:

- Safe operation (DHSMV/ Florida Highway Patrol (FHP))
- Unimpeded traffic operations (FDOT)
- Infrastructure integrity (FDOT)

- Administrative Processes (FDOT)

The study approach centered on a thorough literature review relating to automated vehicles generally and DATP specifically. The findings of the literature review were then applied to key questions and issues raised by the Florida DATP Working Group (consisting of representatives from FDOT, DHSMV, and FHP). Key findings are summarized for each major section.

Driver Assistive Truck Platooning: The Basics

Truck platooning is not new to the engineering community. Initial tests of close following truck platooning on public roads occurred in the late 1990s in Germany, and publicly sponsored platooning research and development occurred during the ensuing years, funded by governments in Germany and Japan, the state of California, and the Federal Highway Administration. DAF Trucks, Daimler Trucks, IVECO, MAN Truck & Bus, Scania, and Volvo Group participated in the European Truck Platooning Challenge in 2016. Commercially oriented platooning pilot projects are now underway in the U.S., Germany, Japan, Sweden, and the United Kingdom.

Platooning depends fundamentally on three technologies: "connected braking," Forward Collision Avoidance and Mitigation (FCAM), and disc brakes.

Connected braking is enabled by secure vehicle-to-vehicle (V2V) communications between a leader truck and follower truck, so that braking (and acceleration) of the follower truck is synchronized with that of the leader truck, providing automated longitudinal control of the follower truck. Communications occur via 5.9 GHz Dedicated Short Range Communications (DSRC), which has been allocated for traffic safety use. Vehicle-to-Infrastructure communications is not required.

Working in conjunction with connected braking is the radar-based FCAM system, which enhances the driver/vehicle reaction in an emergency braking event. FCAM systems build upon Adaptive Cruise Control (ACC), which uses radar to adjust the speed to match that of preceding vehicles and has been in use by truckers (and in passenger cars) for several years (ACC is currently in widespread use in hundreds of thousands of cars and trucks). In order to have the latest version FCAM systems on tractors, tractors must have Electronic Stability Control (which includes Roll Stability Control) and Anti-Lock Braking Systems. Additionally, commercially available FCAM systems for trucks also include lane departure warning systems for added safety. An NTSB study noted that early adopter Conway Trucking (now XPO/Conway), with over 30 months with FCAM systems operating on 12,600 tractors, experienced a 71% reduction in rear-end collisions along with a 63% reduction in unsafe following behavior. Since 2015, FCAM systems have been mandated on all new heavy trucks in Europe.

The third leg of the DATP stool is disc brakes. Most trucks on the road today are equipped with drum brakes. Disc brakes have superior performance to drum brakes and are now widely available on new trucks. Disc brakes have shorter stopping distances, automated brake adjustment, and greater predictability /reliability due to reduced overheating and associated wear effects. However, due to a higher cost, disc brakes can be found on less than 15% of heavy trucks.

It is estimated that the combination of FCAM and disc brakes exists on well under 10% of trucks now on the road in the U.S. With the fuel economy benefits of DATP being highly compelling to the trucking industry, purchases of DATP-equipped vehicles by truck fleets will increase the numbers of trucks equipped with these best-in-class safety systems, resulting in DATP trucks being safer than most other trucks on the road. Note that FCAM systems (active at all times) and disc brakes provide a continuous safety benefit, whether or not trucks are platooning.

First generation DATP systems now being commercialized will predominantly consist of two trucks operating at a separation distance of approximately 40-70 feet (steady-state following distances of non-platooning trucks were found to average 170 feet in a 2016 USDOT study). The driver in the leader truck drives normally, controlling throttle, brakes, and steering. The driver in the follower truck allows the system to control throttle and brakes while he or she retains responsibility for steering and monitoring/responding to the driving environment. The systems are designed to safely handle emergency braking of the leader truck (due to a traffic disturbance ahead) as well as opening up the inter-vehicle space to accommodate another vehicle cutting in between the two trucks.

DATP is an SAE Level 1 system where the human drivers continue to play essential roles in the driving task. Importantly, DATP is a connected vehicle system and should not be confused with the "highly automated," "autonomous," or "self-driving" trucks now being developed in other segments of the trucking industry.

Is DATP commercially feasible? An FHWA-funded study conducted by Auburn University (Auburn, 2015; Bevly, 2017) concluded that "based on fuel economy improvements observed in testing, a strong business case exists for introducing this technology." Further, that "DATP operations are highly likely to be feasible for a substantial portion of trucking operations, and key fleets clearly see this value."

Based on published information, DATP will likely come to the U.S. trucking market via Freightliner Trucks and Peloton Technology, Inc. working with other truck-makers. Freightliner is the market leader in Class 8 trucks. Peloton Technology is a Silicon Valley startup founded in 2012 focusing on connected and automated vehicle technology in the freight sector. Peloton has announced plans to have their first production DATP systems in use by customers in 2018; truck-maker Navistar plans to make the Peloton system available in their vehicles in 2018 as well. Peloton's "Platooning Plan" submitted in early 2017 to the State of Michigan has provided the most detailed information on pre-commercial DATP systems, serving as an important reference point for this study.

At this early stage in market development, no formal DATP industry standards or recommended practices have been published. However, the Automated Driving and Platooning Information Report, published by the American Trucking Association Technology and Maintenance Council in 2015, has been referenced by some system developers. The report has served as a useful reference for the recommendations of this UF study.

DATP Literature Review Findings

DATP Regulations

As an SAE Level 1 system, existing Federal regulations have no bearing on DATP operations. State DATP regulatory issues center on following distance laws. A "reasonable and prudent" rule requires a vehicle operator to follow the vehicle in front while allowing for sufficient space to stop in an emergency. It is the most common following distance rule for cars and is sometimes combined with other types of rules. DATP operations can be allowed under this language, depending on interpretations by authorities in specific states. Distance rules, which are fairly common, specify the precise safe following distance generally by codifying a fixed distance interval. Additionally, regulations in some states contain language requiring platooning vehicles to allow road users to pass other vehicles safely and enter and exit the roadway.

Of the ten states that now allow commercial deployment of DATP (including Georgia and South Carolina), some allow for platooning operations "carte blanche" while others require a "platooning plan" or a notification. Currently no permits are required in states with platooning commercial allowance laws.

Across states allowing platooning, self-certification of safe operations and practices is the norm. For example, the state of Tennessee requests information via an on-line "Vehicle Platooning Operations Request." The information requested addresses technology systems, safety validation, operational design domain, platoon formation method, and platoon dissolution method.

For DATP operations, there may be calls to set a new minimum following distance specifically for platooning. However, just as the original minimum following distances were set based on an assessment of the abilities of human-only operation, the proper following distance for DATP depends on the system abilities. The determination of a safe gap distance can be made only by the system developer, based on their choices of sensors, communication protocols, and many other factors.

DATP Safety Measures and Risk Assessment

The safety case for DATP is multi-dimensional. To gain the confidence of trucking industry customers, state regulators, and the general public, a set of layered best safety practices are being implemented by DATP developers:

a. System Design: a "functional safety" design approach based on established standards for the automotive / commercial vehicle industry is the starting point, as well as fail-operational measures so that platooning is gracefully dissolved if, for example, V2V communications is disrupted.
b. Safety Equipment: the base equipment package consists of Air Disc Brakes and Electronic Stability Control (on tractors), FCAM (which includes Lane Departure Warning systems on systems being marketed today), V2V communications, Anti-lock Braking Systems required on tractors and trailers, health monitoring of all critical functions, and fail-safe protocols.
c. Safe Operations: while operating, the system estimates vehicle weight and other key parameters to set an inter-vehicle gap within safety tolerances, accounting for any uncertainty. Furthermore, since DATP is designed for use only on

limited-access highways, at least one DATP vendor (Peloton Technology) will use vehicle-to-cloud communications and geo-fencing to prevent use on other types of roads, as well as the ability to ensure that DATP operations only occur at or below the posted speed limit by adjusting the threshold automatically as speed limits change.

d. Driver Involvement: DATP drivers trained in both leader and follower roles; drivers engaged in the driving task, reacting early to potential cut-ins and taking other steps as needed.
e. Driver Teaming: truck-to-truck video and/or audio, enabling drivers to maximize situational awareness by teaming.
f. Additional best practices at the freight carrier level include maintaining brakes at a high level of performance (following Tier 1 braking supplier-recommended maintenance and replacements protocols) plus comprehensive industry-provided driver training on use of DATP (both as leader and follower). Drivers can recognize situations in which platooning may not be advised (due to traffic, weather, etc.) and make the decision as to whether to platoon when these conditions are present.
g. Platoon Operations Center to monitor safety-relevant conditions and adjust platooning parameters as needed.

Like any other vehicle on the road, heavy trucks can be involved in collisions. In a two-truck platoon, the front truck colliding with a vehicle ahead is not different from a non-platooning truck colliding with a vehicle ahead; this is a risk in today's world and not an issue specific to platooning. However, there are two collision scenarios that arise specifically with DATP operations:

a) rear truck colliding with the front truck when the front truck initiates emergency braking to avoid colliding with a vehicle ahead
b) rear truck colliding with a cut-in vehicle if the cut-in vehicle brakes significantly while in between platooning trucks

Successfully addressing these two crash scenarios relies on the system detecting the threat quickly and reliably and activating brakes on the rear truck to avoid a collision with the vehicle ahead.

For the truck-to-truck scenario, the FCAM system will monitor traffic ahead and issue a warning to the driver when a threat is first detected. If braking is then required (manual or automatic), information on the forward truck's braking sent via V2V communications causes the rear truck to also initiate braking in less than two tenths of a second. The response is optimized via the concept of "intelligent ordering," in which the rear truck braking's is as good or better than the front truck's, based on estimates of vehicle weights and braking performance.

For the cut-in scenario, the attentive rear truck driver plays an important role in addition to the technology. The rear driver's responsibility includes watching for traffic that may be seeking to change lanes and thus create a cut-in situation. The rear driver may choose to pre-emptively halt platooning to allow the intervening vehicle space to perform their desired maneuver. Alternately, if the situation develops more quickly, the rear driver is expected to detect the impending cut-in as the intervening vehicle approaches the lane boundary and initiate a braking response before the system registers an in-lane intruder vehicle. The combination of early driver-initiated braking followed by system emergency braking provides an optimum safety response.

With regard to truck safety inspections, the Level I North American Safety Inspection protocol used by State Police currently covers proper maintenance and function of brakes for the tractor-trailer combination. Because DATP builds upon proper brake operation, current inspection protocols are sufficient for DATP. Given the safety best practices described above, DATP vehicles can be expected to operate well above minimum standards.

In addition to equipment, the Peloton Network Operations Center enforces operational aspects of the safety approach: platooning can occur only on multi-lane, divided, controlled-access highways and on pre-approved road segments on those highways; weather and traffic conditions must be appropriate; and the truck in the platoon with the best estimated braking capability is placed in the rear position.

DATP Traffic Interactions

Traffic must not be impeded by DATP trucks in merging and de-merging at freeway interchanges. This is addressed by proper share-the-road behavior on the part of truck drivers in today's world, and the same applies to DATP operations. Both the Daimler and Peloton approaches accommodate any need to open up the inter-vehicle gap for traffic situations so that other vehicles may safely merge or change lanes. When traffic is merging, the leader truck driver assesses the situation, keeping in mind the overall length of the two truck platoon, and the driver judges whether to brake for merging traffic or to maintain speed so that merging traffic can come in behind the platoon. In some cases this will be preferable to two trucks in today's traffic whereby a "lead" driver has only limited awareness of truck traffic immediately behind.

While limited evaluation of platooning traffic effects have been conducted via simulation and observed in field demonstrations in the U.S. and Europe, no detailed public road data have been published to date. Qualitative observations from the days-long 2016 European Truck Platooning Challenge indicated that passenger car traffic was not disrupted. Simulation/modeling studies indicate the DATP operations at low market penetration would have a marginal, if any, negative effect on light to medium traffic. At high market penetration, simulation studies have shown that platooning would improve flow in heavier traffic, since platooning trucks take up less road space than trucks traveling alone, while other studies found significant negative effects in congested traffic at interchanges (a situation in which platoons would likely dissolve, as the fuel economy benefits are minimal a lower speeds). Traffic interactions during the recent Florida Platooning Pilot operational demonstration, which included interchanges, bridges, toll plazas, Service Plazas, etc., did not raise concerns.

DATP Interactions with Bridge Structures

Truck weights and spacings are a key component in bridge design. Physics dictate that legally loaded trucks operating at very close following distances will create stresses on today's bridges that could shorten the structure's lifespan. But at what following distance does this have an appreciable effect? A 2017 FDOT analysis found that well less than 1% of bridges on interstate and turnpike mainlines could be subject to stresses exceeding bridge design specifications with trucks platooning at a 30-foot spacing. First generation platooning systems are expected to operate at spacings over 30 feet.

It would be straightforward for the State to notify system providers and fleets regarding any locations/areas where platooning should be restricted, due to specific infrastructure elements or other factors. Data provided by the State can be used by platooning system providers and fleet users to update geofencing and driver usage of platooning.

DATP Pilot Findings

Based on responses to a Request for Information published earlier in the year, FDOT, FTE, and FHP coordinated with Peloton Technology, Inc. to conduct a DATP Pilot on the Florida Turnpike during December 18-19, 2017. Peloton Technology provided written and video documentation of the system safety approach for highway driving, providing a sufficient basis to proceed with on-highway pilot operations.

Two routes were run multiple times. The "Long Route" was a 295 mile round trip from FTE Headquarters at Turkey Lake to Route 706 (near Jupiter). The "Short Route," used for demonstrations to public officials and fleet representatives, was a 16 mile round trip from FTE Headquarters at Turkey Lake to Route 50 (near Oakland). Several days of testing preceded the Pilot Days on December 18-19, such that a total distance of 1,215 miles were driven, platooning in low to moderate traffic conditions during daylight as well as dusk. Data, photo and video documentation was generated for later analysis.

As agreed with state officials prior to the pilot, Peloton provided data generated by the DATP systems during the runs. This data revealed that, while no system-initiated hard braking events occurred, the DATP system successfully handled a "cut-off" by another vehicle in front of the forward truck by automatically activating braking. Additionally, in a small number of cases, the rear truck driver detected impending cut-ins between the two platooning trucks and manually initiated braking to accommodate the merging traffic.

FHP experienced Peloton DATP system operations and observed no clear safety concerns during the three-day pilot phase. During this time, six members of the FHP rode inside commercial DATP-equipped motor vehicles engaged as both the lead and rear commercial motor vehicle at separation distances averaging 66 feet. Each commercial motor vehicle was a truck tractor semi-trailer combination which operated on the Turnpike (limited-access facility) primarily during clear daylight conditions, with some minor fog conditions interspersed during one morning.

Additionally, FHP had its aircraft pilot observe the long run demonstration. From the pilot's perspective it was clear the CMV's were travelling close together and within the 300 foot allowable distance; there were no observed traffic related problem during the testing. Similarly, state traffic officials observing operations in the Pilot did not observe any instances of the platoon interfering with traffic or inconveniencing other motorists. Pilot participants observed platoon drivers accommodating merges and lane changes for other traffic. The FTE Traffic Management Center monitored the 1,215 miles of testing and recorded no impacts to daily operations.

Conclusions and Recommendations

The DATP Pilot plus the University of Florida DATP Study have given state officials a degree of confidence that platooning can be done safely without disruption to surrounding traffic. Based on discussions with DATP vendors and early-adoption fleets, only a small number of DATP-equipped vehicles are expected to be deployed on Florida highways during the first year after DATP following distances are allowed. This gives the State the opportunity to evaluate the approach to DATP deployment and coordinate with manufacturers and trucking fleets to develop best legislative and operational approaches as the technology continues to mature, in addition to defining optimum approaches to communicating with the public. Florida has the opportunity to take a leadership position in creating an approach that accelerates early deployment.

Table 8 in the main report addresses key parameters summarizing study findings in terms of the roles of State agencies and the private sector.

Safe Operation and Enforcement

Responsibility for safe operations of trucks on the roads today lies with the vehicle operator. Based on the above discussion and the in-depth findings in this study, the same paradigm can be extended to DATP operations.

Because DATP builds upon proper brake operation, current inspection protocols are sufficient for DATP. Given the safety best practices described above, DATP vehicles can be expected to operate well above minimum standards. This approach can be evaluated during the initial phase of deployment.

Because FHP troopers and other law enforcement agencies may pull over trucks as a normal part of their duties in enforcing the 300-foot minimum following distance for non-DATP trucks, some means is valuable for enforcement officers to understand the DATP status of trucks. Options considered for this were a decal indicating the tractor is DATP-capable, an active indicator showing when platooning is underway, and various electronic means including methods that would provide information to existing systems on law enforcement vehicles. During discussions of the Florida DATP Working Group, only a state-issued decal was considered practical for initial deployment of DATP. While other approaches are straightforward technically, there are numerous practical hurdles. The decal protocol is seen as a simple approach for the early phase of DATP deployment; the effectiveness of this approach will be evaluated after the initial phase of DATP operations.

Recommendations

- Enforcement personnel on the road can be informed that tractors are DATP-capable via a state-issued decal (issued based on the recommended permitting process). This is seen as a simple initial approach for the early phase of DATP deployment, in which relatively few DATP-equipped trucks are expected to be operating in Florida.
- Evaluate the effectiveness of the DATP decal approach during the first phase of DATP deployment.
- Enforcement operations would benefit from evaluating the degree to which "copycat" behavior (non-DATP vehicles closely following behind a platoon) is occurring, if at all. This can be augmented by discussions with early deployment

fleets. If this appears to be an issue, develop training and methods for troopers to detect and respond to such instances.

Planning

Potential planning measures could include capacity change considerations with higher truck platooning penetration. Although capacity increases can be theorized for rural highways, these are typical road segments in which there is spare capacity. To the degree platooning is deemed appropriate on urban or suburban highways, a net benefit may occur.

MPO policies could address the creation of "truck platooning opportunity corridors. However, based on the literature and discussions with stakeholders, DATP operations would not require dedicated lanes.

Recommendations

- Planning processes would benefit by adapting travel demand models to include DATP operations to support future planning studies.
- Traffic simulations incorporating DATP behavior would be useful to understand the potential effects of extensive DATP operations.
- It will take time after initial DATP deployment to gain a sense for operating parameters (inter-vehicle gaps preferred by fleets, for instance) and adoption rates. Therefore, any assessments of the need for dedicated lanes and/or environmental impacts should be deferred for the time being.

Traffic Operations/Interactions

Operations activities do not require any specific actions at the outset of DATP deployment. DATP, being initially limited via legislation to two trucks, is expected to be a benign presence on the road in general. Surrounding traffic will find it preferable to pass two closely spaced trucks rather than two trucks with today's typical spacing. Traffic interactions during the 1,215-mile DATP Pilot did not raise concerns.

Regarding merging and diverging, the trucker road etiquette for merging traffic that has long been in place also encompasses two-truck DATP operations.

Driver judgment regarding when to platoon appears to be a better approach than road segmentation or placing restrictions upon DATP use based on traffic / interchange density.

Recommendations

- Allow DATP operations on any limited access, multi-lane, divided highway, with decisions to platoon on a particular road segment based on driver and system assessment of conditions (traffic, topography, work zones, weather), plus any guidance from road authorities.
- Allow DATP operations on any lane currently allowable for trucks. Based on an assessment of the immediate traffic situation and consistent with existing state guidance and practices, allow drivers to choose which lane is best.
- As DATP operations begin to proliferate in certain corridors, this provides an opportunity to evaluate any occurrences of traffic disruptions (near interchanges or other areas), as well as assess any detrimental behavior of other traffic near the platoon.

- Given that no data have been published to date of DATP operations on public roads, as DATP comes into use in Florida and across the nation empirical data should be collected to understand any impacts more thoroughly.
- If any restrictions need to be applied, the State should develop an approach to notifying platooning operators of such areas and what operating parameters should be observed by platoons.
- Platoons of greater than two trucks may be beneficial to both the public and private sector in certain situations, such as roads that are dominated by truck drayage services near seaports. This could be a unique innovation opportunity for the State and should be examined.

Infrastructure

Within Florida, no bridges would be of concern with legally loaded two-truck platoons operating at 60-foot spacing, and less than 1% of bridges would be of concern at 30-foot spacing. First generation DATP systems are expected to operate at spacings over 30 feet.

Recommendations

- Identify structures that should be geo-fenced as restricted platooning zones, if any.
- Devise a process to notify DATP permit holders of any locations for which platooning should be restricted, due to specific infrastructure elements or other factors. Platoons would be required to cease platooning when traversing these locations.
- Conduct modeling, simulation, and empirical studies to gain a more complete understanding of bridge effects from various DATP configurations and following distances.

Administrative Processes

Changes in licensing, registration, and titling processes for DATP are not required. With regard to licensing, DATP drivers are fully engaged in the driving task and report that use of DATP is quickly learned and not significantly different from regular driving.

Of the states that now allow commercial deployment of DATP, the “notification form” approach that Tennessee has established may be a good model for Florida, as it provides opportunity for a two-way process with applicants. Based on an applicant submitting a notification form, state agencies can receive key information specified by the state (such as approaches to system safety design and validation), seek further information if needed, and disallow an entity from proceeding if they determine there are concerns.

Note however that in discussions during the preparation of this study, DATP developers and fleet industry comments have stressed the importance of keeping the requirements and mechanism for issuing permits relatively simple so as to not create a state-specific burden on industry.

Recommendations

If Florida statue is modified to allow DATP operations, the research team recommends to implement a process to issue DATP-specific permits on a per-vehicle basis.

In the permit application process, fleets (possibly working jointly with DATP suppliers) could be required to provide information such as the following (based on results of the DATP Study, manufacturer's recommendations, and discussions with stakeholders):

- Fleet name and contact information
- Supplier of DATP system and contact information (fleets may rely on the supplier to provide some of the information below)
- Truck VIN
- Type of trailers to be pulled plus configuration (single, tandem)
- Routes and general timeframes for DATP operations
- Operational Design Domain of system (includes number of vehicles in platoon, minimum inter-vehicle gap used)
- Equipment Description (self-certify):
    - Tractor: disc brakes on all tractor axles, forward collision avoidance and mitigation system, plus any other equipment applicant notes as further enhancing safety
    - Trailers: ABS-equipped
- Description of Safety Validation Procedure
- Description of operational practices to enhance safety while platooning (examples specific to Peloton: intelligent ordering, role of Network Operations Center)
- Description of operational practices to accommodate nearby traffic while platooning

As part of the process to approve an Application, FDOT may request a demonstration of system capability on a closed-course track.

Related recommendations are:

- DATP-capable trucks affix a state-issued decal(s) to the vehicle at locations specified by DHSMV and FDOT. Input from freight carriers would be useful in defining these locations.
- Equipped vehicles carry documents showing the tractor is equipped with the platooning and supporting safety systems
- Drivers carry a document showing they have completed an industry-provided DATP training.
- Hauling of placarded hazardous materials using DATP would not be allowed.
- Seek input on implementation of these recommendations from stakeholders including the Florida Trucking Association, leading fleets exploring platooning, and others as appropriate.

State Liability

For DATP, having engaged drivers in both trucks serves to keep the liability questions very similar to those for regular driving. State liability relates to well-marked and -maintained infrastructure, as is the case now.

Summary

This study has brought to light the extensive body of literature regarding truck platooning in general. Much of this literature is focused on research and simulations. The literature review provided a solid basis for planning the DATP Pilot in December 2017. The Pilot provided state officials with real world experience with traffic and safety relevant interactions on public roads, leading to confidence that deployment of DATP could go forward based on a permitting process focusing strongly on industry best safety practices.

In the initial phase of DATP deployment, ongoing evaluation of DATP operations could be useful. Because DATP is likely to be operating across multiple states, FDOT and DHSMV can work with other states to monitor traffic and safety measures of truck platooning and further evaluate system effects.

I. Introduction

This study was initiated by Florida DOT in compliance with Florida House Bill 7027 (2016-81), which states:

> The Department of Transportation, in consultation with the Department of Highway Safety and Motor Vehicles, shall study the use and safe operation of driver-assistive truck platooning technology, as defined in s. 316.003, Florida Statutes, for the purpose of developing a pilot project to test vehicles that are equipped to operate using driver-assistive truck platooning technology.

Florida Statute 316.003 defines Driver Assistive Truck Platooning (DATP) as:

> vehicle automation and safety technology that integrates sensor array, wireless vehicle-to-vehicle communications, active safety systems, and specialized software to link safety systems and synchronize acceleration and braking between two vehicles while leaving each vehicle's steering control and systems command in the control of the vehicle's driver in compliance with the National Highway Traffic Safety Administration rules regarding vehicle-to-vehicle communications.

I.A. Project Objectives

The objective of this Task Work Order is to provide research required to assist the Florida Department of Transportation (FDOT) and Florida's Turnpike Enterprises (FTE) in the development of an analysis of DATP in Florida and guidelines for implementation. Specifically, the Task Work Order provides coordination and communication, research, investigation, and reporting on DATP in support of legislative requirements. The intent of the DATP research is to address issues related to DATP from a State Government perspective and to identify the need for further analysis through a pilot project.

The intent of this study is to focus on those issues that are relevant to creating Florida DATP policies. A significant amount of work has been done over the past few years regarding the underlying technologies associated with DATP and its benefits to the trucking industry. This study will reference that prior work but is not intended to repeat those prior analyses.

The core questions focus on the methods and measures that are required for:

- informed planning and policy decisions regarding DATP
- studying DATP effects on transportation infrastructure
- studying use and safe operation of DATP, particularly in terms of how DATP may impact the traveling public

Research and analysis under this Task Order was organized as follows:

Task 1 – Information Gathering Services (Literature Review)
Task 2 – DATP Task Team Meetings and Coordination
Task 3 – Identification and Exploration of Issues
Task 4 – Deployment Implication Analysis
Task 5 – Prepare and Administer RFI for Industry Feedback
Task 6 – Draft Final Report and Have Closeout Teleconference
Task 7 – Final Report

The Task 1 Literature Review surveyed academic papers, government reports, relevant regulatory activity, and information provided by industry to provide a comprehensive view of current activity and thinking regarding DATP.

Task 2 DATP Task Team meetings were held on an ongoing basis during this study.

Within Task 3, specific DATP operational parameters were identified and explored in the areas of:

a. Hardware/software minimum technical requirements
b. Safety of operations
c. Locational/temporal considerations
d. Driver/vehicle limitations
e. Driver/operator responsibilities
f. Data notifications and Reliability

These factors are addressed with respect to whether they fall within private sector or public sector / state agency responsibilities. For those within the purview of state agencies, further discussion and recommendations are provided.

The Task 4 Deployment Implication Analysis is based on the literature review (Task 1), responses to the DATP Pilot Request for Information, interviews with tech developers, and discussions with state stakeholders. The Analysis addresses:

a. Implications to Infrastructure
    a. Planning
    b. Operations
    c. Maintenance
    d. Design
    e. Permitting
b. Implications to Public Safety
    a. Public Safety Operations / Enforcement
    b. DATP Notification Techniques
    c. Roadside Inspections
c. Implications to Administrative Processes
    a. Permitting of DATP
    b. Registration/Titling
    c. Licensing
    d. Certification/Equipment Testing
    e. State Liability
    f. Legal Implications

A key source document were meeting notes from meetings of the Driver Assistive Truck Platooning Task Force held during May 2016 (Florida DOT, 2016). These meetings involved key in-state stakeholders, such as FDOT, Florida's Turnpike Enterprise, the Department of Highway Safety and Motor Vehicles (including Florida Highway Patrol), and subject matter experts. The issues raised in these meetings are directly addressed in this Study, in the Deployment Implications section. The key points and questions contained in these notes are provided in Appendix A.

The Request for Information (Task 5) is provided along with an analysis and commentary on responses received from industry.

This document is the Task 7 Final Report.

I.B. Document Organization

This document is organized as follows.

a. Section II provides results of the DATP Literature Review. This section thus provides the lion's share of the knowledge base upon which the study conclusions are based.
b. Section III provides a discussion of potential DATP effects on roadway structures. While this is an area that has not been studied specifically for DATP, the University of Florida has provided a preliminary analysis of key issues and potential approaches going forward.
c. Section IV presents the DATP Deployment Implication Analysis. This section draws upon the literature review to address specific DATP topic areas.
d. Section V describes the planning process for the DATP Pilot and results.
e. Section VI provides a summary and recommendations.
f. Section VII provides references.

The major sections open with Key Findings to summarize the section content.

The following appendices are provided:

Appendix A: 2016 FDOT DATP Task Force Meetings – Key Issues
Appendix B: DATP Pilot Request for Information
Appendix C: NCHRP Truck CV AV Report Critique

II. Task 1: Driver Assistive Truck Platooning Literature Review

II.A. Key Findings

DATP Evolution

- Truck platooning is not new to the engineering community. Germany ran initial tests of close following truck platooning on public roads in 1999, and publicly sponsored platooning R&D occurred during ensuing years funded by governments in Germany and Japan, the state of California, and the Federal Highway Administration.
- Commercial development of DATP began in 2012 and vehicle industry developers expect to launch commercial systems in 2018. In terms of technology maturity and cost, there are no barriers to commercialization of DATP. DATP builds upon radar-based driver assistance products, which have been in use by truckers for several years.
- Publicly funded deployment-oriented projects are underway in Germany, Sweden, the United Kingdom, Singapore, and in the U.S., assessing logistics factors, public acceptance, and traffic impacts.

Differentiation from Highly Automated Trucks

- In parallel with DATP, highly automated trucking systems are being developed in which computer control handles a large portion of the driving task (or all of it). These should not be confused with DATP, in which truck drivers remain responsible for steering and monitoring the driving environment while the automation handles the throttle and brakes.
- With a DATP truck driver playing a vital role in the driving task, the complex regulatory issues arising with Highly Automated Trucks do not come into play.

Market Factors

- Trucking is getting safer due to increasing uptake of FCAM and air disc brakes. The fuel savings achieved by DATP is expected to stimulate rapid uptake by truckers. Since DATP requires these underpinning technologies, DATP introduction promises to accelerate uptake of these safety systems.

Infrastructure and Connectivity Factors

- In terms of infrastructure support, no specialized road infrastructure is required for DATP deployment.
- DATP fundamentally requires low latency V2V connectivity to operate safely at short inter-vehicle spacings; V2I / I2V is not required.
- Although NHTSA is considering a V2V mandate for new passenger vehicles, which may be followed by a similar mandate for heavy trucks, there is no dependency between this NHTSA action on V2V and the commercial deployment of platooning. This is because the FCC spectrum use rules are in place to use the DSRC band for platooning.

Regulatory Aspects of DATP

- DATP regulatory issues center on following distance laws. These laws fall into four categories: "reasonable and prudent," distance, time, and "sufficient space to enter and occupy without danger." A "reasonable and prudent" rule requires a vehicle operator to follow the vehicle in front of it while allowing for sufficient space to stop in an emergency. It is the most common following distance rule for cars and is sometimes combined with other types of rules. DATP operations can be allowed under this language, depending on interpretations by state authorities. Distance rules, which are fairly common, specify the precise safe following distance generally by codifying a fixed distance interval. Time-based following distance rules specify the time interval between vehicles; this is the least common rule type. "Sufficient space to enter and occupy without danger" rules aims to allow other road users to pass other vehicles safely and enter and exit the roadway.
- Commercial DATP operations in some form is allowed in the states of Arizona, Arkansas, Georgia, Michigan, Nevada, North Carolina, Ohio, South Carolina, Tennessee, and Texas.
- State approaches to DATP favor self-certification so far, particularly in terms of "Platooning Plans" as pioneered by Michigan and now adopted by two other states (Arkansas and Tennessee).
- The European Truck Platooning Challenge in 2016 provided insights into platooning on public roads, with several three-truck platoons traveling across several countries. Detailed quantitative data was not collected as to safety or traffic factors, however.
- Following the Challenge, Germany has allowed platooning on several hundred miles of public road.
- DATP systems can adapt to different operational modes across jurisdictional boundaries via geo-location and software. Depending on the specifics, regulatory differences across different states may not present a problem.
- Requiring "platooning indicators" to indicate that trucks or platoon-capable and/or actively platooning is an active discussion topic in the state regulatory and enforcement community. While States that have allowed platooning to date have not included any such requirements, law enforcement personnel may benefit from knowing DATP status of pairs of trucks traveling closely together. A separate discussion relates to informing the public, where the need to do so is less clear.
- Regarding traffic interactions, language requiring operators of DATP trucks to "allow reasonable access for other vehicles to afford safe movement among lanes and/or to exit or enter the highway" has been put in place in other states.

Standards

- Standards development organizations are pursuing technical standards in areas important to the deployment of trucking CV and AV applications, including DATP. However, standards are not needed for DATP to be launched and for platooning trucks to become common on highways. In the trucking industry, there are many systems in wide usage that are not standardized. The impetus for standardization comes from the users (i.e., trucking fleets), if they believe their operations would improve as a result of standards.

DATP Safety

- Safety with regard to setting the inter-vehicle gap is dependent on several factors, but two key factors are a) reducing the likelihood of the front truck initiating hard braking and b) the performance of the rear truck braking as that interacts with the inter-vehicle gap setting. This is addressed via technology and operational approaches.
- Using V2V communications, DATP enables brake application on the front truck to be communicated to the rear truck, such that brake activation is synchronized. One DATP developer (Peloton Technology) provided a video showing a DATP system maintaining the inter-vehicle gap during "extreme braking" by the lead vehicle from highway speed down to a stop, on a closed test track.
- Operationally, at least one vendor (Peloton Technology) implements "intelligent ordering" of the platooning trucks, so that the vehicle with the lesser relative braking capability is placed in the front position.
- Regarding inter-vehicle gap settings, the Peloton system sets the target inter-vehicle distance between 36 and 80 feet based on rules of the Operational Design Domain, accounting for traffic and weather conditions, certainty of the real-time assessment of relative braking capabilities of the trucks, and other factors. Daimler Trucks has stated that their platooning system is designed for an inter-vehicle following distance of 50 feet.

DATP Requirements

- Freight carriers in the trucking industry have developed a thorough set of high-level DATP System Requirements from a user perspective. These requirements were published in 2015 by the American Trucking Association Technology and Maintenance Council.
- The requirements address areas including equipment factors, operations, safety, communications integrity, maintenance, training, and driver responsibilities.
- Based on a submission to Michigan DOT, Peloton Technology has implemented many of these DATP system requirements.

Managed Platooning

- The concept of a Platooning Service Provider (PSP) has emerged to support ad hoc formation of platoons. The PSP would help platoon partners find one another on the road, as well as certify that platoon partners can be trusted.
- The PSP can also play a role to authorize platooning based on safety parameters (weather, road conditions) and traffic densities and may adjust gap sizes based on conditions.
- The PSP can also inform drivers of how the trucks must be ordered based on their relative real-time braking abilities, so that the vehicle with the best braking is placed in the rear position.

Driver Considerations

- Industry studies, based on a relatively small set of truck drivers who have driven in platooning mode for a significant period, have concluded that the learning curve for platooning is shallow and stress will be modest if any.

- Drivers reported that platooning “did not increase anxiety levels, nor did they feel they were disengaged from driving the truck or unable to process and track road conditions around them.”
- Drivers also reported that passenger car cut-ins between platooning trucks were a “non-event” when it occurred, because the system was very quick in responding to an intruding vehicle.
- Drivers platooning on German motorways noted “copycat” behavior; i.e., other single trucks in the vicinity of the truck platoons driving more closely to a truck ahead than would normally be considered safe. Although no data was collected to quantify the frequency of this behavior, this is a highly important issue to monitor going forward.

Traffic Interactions

- As noted in the Regulatory section, a key concern for state agencies is ensuring that non-platooning traffic maintain the ability to change lanes and enter/exit the facility. Of course, whether DATP operations are occurring or not this can be challenging on today’s roads with high truck densities. A USDOT study found that cut-ins between trucks by passenger vehicles are uncommon with inter-vehicle distances under 100 feet; passenger car drivers operating near platoons at much shorter separations are therefore more likely to change lanes ahead of or behind the two truck DATP platoon.
- A Dutch study using traffic simulation software to investigate impacts of widespread truck platooning found a large negative effect for near congested or congested traffic flow. However, since platooning benefits occur at free-flow speeds, operating a platoon in low speed congested traffic has no benefit. This study also found “no substantial concerns in allowing truck platoon sizes of two or three trucks, or allowing gap settings between trucks in the range of 0.3-0.7 seconds in regard to the traffic flow,” specifically with regard to traffic interactions. (Calvert, 2017)
- A Texas Transportation Institute Platoon Feasibility Study confirmed freeway capacity increases from platooning under certain conditions. In their simulation results, “peak volume of 3000 vph did not show any pronounced increase in vehicle throughput regardless of market penetration because the traffic volume did not exceed normal freeway capacity. However, there is a pronounced increase in vehicle throughput over time for the peak volume of 10,000 vph.” The increases were consistent when the market penetration of two-truck platoons were over 30 percent. (TTI, 2017)

II.B. Approach to Literature Review

The team conducted a comprehensive literature search on DATP issues and projects in order to assist in the identification of issues critical to the Florida DOT and DHSMV. The literature review aimed to take full advantage of previous DATP-related studies globally. It also included activities of other state agencies addressing DATP, plus statements from vehicle manufacturers, tech developers, fleet operators, and others within the trucking industry. Based on the knowledge gained, the analysis focused specifically on issues within the purview of the FDOT and DHSMV mission and vision.

II.C. Brief Background on Automated Vehicle Developments

Given the extensive media coverage of automated vehicles, misinformation and misperceptions abound. This section is intended to provide a brief status of pertinent AV topics, and clarify the specific aspects of AV activity that are relevant to this DATP study.

II.C.i. Terminology and Levels of Automation

Proper terminology is important. While terms such as “autonomous,” “self-driving,” and “driverless” vehicles are used in media and marketing materials, NHTSA and the Society of Automotive Engineers (SAE) have agreed upon “automated” as the most meaningful and versatile term. This is codified in the SAE J3016 standard addressing automated driving (Society of Automotive Engineers, 2016).

It is important to distinguish the role of automated driving from the crash avoidance systems that are now available for personal and commercial vehicles. Crash avoidance systems assist the driver when “something is wrong” while driving and take momentary action to avoid or mitigate a potential crash. Automation systems address the more general case of normal driving, taking over a task on behalf of the human driver. In practice, both the crash avoidance and the automation levels operate together. Whether automated driving comes to fruition or not, the market diffusion of crash avoidance systems is well underway for passenger and commercial vehicles, such that a steady decline in crash rates can be expected over the coming decades.

The SAE J3016 Recommended Practice also defines levels of automated driving, as shown in the Table 1 below. The table uses terms that are explained briefly here:

- ODD: Operational Design Domain, referring to situations in which an AV is designed to operate. This may be defined by road type, speed range, and many other factors.
- DDT: Dynamic Driving Task, refers to the set of basic actions and awareness needed to safely drive a vehicle on public roads.
- OEDR: Obstacle and Event Detection and Response, refers to effective handling of exceptional situations on the road.

Level	Name	Narrative definition	DDT		DDT fallback	ODD
			Sustained lateral and longitudinal vehicle motion control	OEDR		
Driver performs part or all of the *DDT*						
0	No Driving Automation	The performance by the *driver* of the entire *DDT*, even when enhanced by *active safety systems*.	*Driver*	*Driver*	*Driver*	n/a
1	Driver Assistance	The *sustained* and *ODD*-specific execution by a *driving automation system* of either the *lateral* or the *longitudinal vehicle motion control* subtask of the DDT (but not both simultaneously) with the expectation that the *driver* performs the remainder of the *DDT*.	*Driver* and *System*	*Driver*	*Driver*	Limited
2	Partial Driving Automation	The *sustained* and *ODD*-specific execution by a *driving automation system* of both the *lateral* and *longitudinal vehicle motion control* subtasks of the *DDT* with the expectation that the *driver* completes the *OEDR* subtask and *supervises* the *driving automation system*.	***System***	*Driver*	*Driver*	Limited
ADS (“*System*”) performs the entire *DDT* (while engaged)						
3	Conditional Driving Automation	The *sustained* and *ODD*-specific performance by an *ADS* of the entire DDT with the expectation that the *DDT fallback-ready user* is *receptive* to *ADS*-issued *requests to intervene*, as well as to *DDT performance-relevant system failures* in other *vehicle* systems, and will respond appropriately.	*System*	***System***	*Fallback-ready user (becomes the driver during fallback)*	Limited
4	High Driving Automation	The *sustained* and *ODD*-specific performance by an *ADS* of the entire *DDT* and *DDT fallback* without any expectation that a *user* will respond to a *request to intervene*.	*System*	*System*	***System***	Limited
5	Full Driving Automation	The *sustained* and unconditional (i.e., not *ODD*-specific) performance by an *ADS* of the entire *DDT* and *DDT fallback* without any expectation that a *user* will respond to a *request to intervene*.	*System*	*System*	*System*	**Unlimited**

Table 1: SAE Defined Levels of Automation: Surface Vehicle Recommended Practice J3016

The levels can be simplified by speaking in terms of the driver role relative to today's driving

- Level 0: driver fully in charge of the DDT (today's driving)
- Level 1: driver may be “feet off” if using Adaptive Cruise Control or “hands off” if a Lane Keeping Assist system is engaged
- Level 2 allows for both hands-off, feet-off driving; eyes must stay “on” the road
- Level 3: enables hands-off, feet-off, and eyes-off driving, “brain on” (driver is able to resume control within a reasonable transition time)
- Level 4: human driver has no responsibilities with limits on the ODD
- Level 5: human driver has no responsibilities with no limits on the ODD

Another important aspect of terminology is distinguishing between Independent Operation and Cooperative Operation.

- Independent AV systems use on-board systems to provide the information critical to driving (they may also be receiving GPS signals and connected to the cloud for other functions).
- Cooperative AV systems use on-board systems plus vehicle-to-vehicle communications (V2V) and/or vehicle-to-infrastructure (V2I) communications to provide information critical to driving.

II.C.ii. Technology Basis for Automated Driving

Automated driving relies on various combinations of on-board sensors (i.e., radar, stereo/mono camera, and LiDAR). For higher level automated driving systems, sensors are mounted to provide a near-360 degree view of the road scene.

Vehicle manufacturers see information flowing through V2V or V2I communications as useful to augment on-board systems; they will use this information when it is available. However, deployment of V2V/V2I is not necessary for automated vehicles to be introduced in a general sense. During the period in which V2X ("vehicle-to-anything") communications is gradually rolling out in vehicles and infrastructure, the vehicle industry will rely on on-board sensors for fundamental automated vehicle system operation.

Truck platooning is an exception, because this application depends on V2V communications between the linked pair of trucks (it does not depend on V2V communications with other nearby vehicles, however). Use of V2V communications for platooning, based on current best practices and FCC spectrum use rules, were included in the extensive requirements list in the TMC Information Report (see II.H.ix. Standardization and Interoperability).

II.C.iii. Cybersecurity

Detecting and protecting against potential cyber attacks is absolutely essential.
The EPTC Stakeholder Consultation process identified cybersecurity, hacking, and wireless communication security as areas of concern (Rijkswaterstaat, 2016).

The American Transportation Research Institute (ATRI) published a study on the impacts of autonomous vehicles on the trucking industry (Short and Murray, 2016). Regarding cybersecurity, this view was offered:

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

However, rather than being an issue specific to automated driving, it can be argued that this is just as much a concern with modern road vehicles in general. Significant advances in vehicle cybersecurity are expected in the coming years based on today's threats; these advances will benefit AV's as well.

Currently, many vehicles on the market are equipped with adaptive cruise control, emergency braking, and lane centering. Strong security measures must be employed to prevent hackers from theoretically controlling these systems from outside the vehicle. Therefore, cybersecurity is a "here and now" issue. Independently and through collaborative organizations such as Auto ISAC, vehicle manufacturers are actively working to define and implement adequate levels of security against attacks, as well as to ensure fail-operational modes when attacks are successful. The design principles being developed now will be applied and refined for automation (TMC, 2015) (Auto ISAC, 2017).

SAE published a Recommended Practice establishing a set of high-level guiding principles for cybersecurity as it relates to this domain (Society of Automotive Engineers, Cyber-security, 2016).

In contrast to the telematics and infotainment systems that have been the main portal for major hacking attacks to date, DATP-related V2V communications have been designed for security from the start. It is essential to maintain communications security for systems relying on V2V, such as truck platooning. In this regard, Peloton Technology notes that their software includes "vehicle-control and cybersecurity algorithms developed by Peloton, in consultation with Tier 1 automotive collision avoidance systems and wireless communication system suppliers, truck OEMs and automotive safety validation providers" (Peloton Plan 2017).

II.C.iv. Truck Automation Areas of Responsibility for Truck OEMs and Freight Carriers

The ATRI AV report (Short and Murray, 2016) noted several areas as being the manufacturer's responsibility as AV development progresses. Table 2 below is excerpted from this report.

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

Table 2: Key Areas of Responsibility for Truck OEMs (Short and Murray, 2016)

While the issues here are critically important for highly automated vehicles (HAVs), defined as using L3-L5 vehicle automation systems, there could be some relevance to Level 1 DATP systems, even though DATP vehicles have engaged drivers.

II.C.v. Infrastructure Considerations

Current AV systems under development do not rely on any particular infrastructure installed specifically for automation. No literature was identified stating a need for road infrastructure to support DATP. If fact, the business case for an automated truck which depended on infrastructure modifications would be weak, due to uncertainties regarding public sector funding and deployment pacing.

II.D. Automation Activities Specific to Trucking

Various applications of automated driving for trucks have been demonstrated across the globe since the 1990s. Until recently, the focus has mainly been on proof of concept for truck platooning due to the foreseen fuel economy and traffic flow benefits. Europeans began their efforts in this area with a project called Chauffeur and it continued with Chauffeur II; this work was followed in the 2000s by HAVE-IT, SARTRE, and Konvoi. During the 2000s, the Japanese government began a major program to examine truck platooning under the Energy ITS program. Also during this period similar research was sponsored by USDOT and the California Department of Transportation for civilian purposes and within the U.S. Army for military purposes. Overall, this research served to confirm the technical feasibility and in particular the fuel economy benefits of close-headway operations (TMC Information Report, 2015).

II.D.i. Advanced Driver Assistance Systems are the Platform for Platooning and Truck Automation

In the last several decades, suppliers have developed and OEMs have introduced many of the building blocks required for the automated truck in the form of Advanced Driver Assistance Systems (ADAS). ADAS include safety systems (collision avoidance systems, lane departure warning) as well as convenience systems (Adaptive Cruise Control). Electronic throttle control became commonplace starting in 1990, eliminating the mechanical linkage to the engine. Advanced automatic transmissions, electronic stability control, and electronic power steering are further examples of such "drive by wire" type developments. Radar-based Adaptive Cruise Control systems were first introduced in 2008 and over 100,000 trucks operate with ACC on the road today, almost all of them Class 8 vehicles.

Forward Collision Avoidance and Mitigation Systems

In North America, the trucking industry commonly refers to Automated Emergency Braking as Forward Collision Avoidance and Mitigation (FCAM). There are two suppliers of FCAM systems that are integrated by truck manufacturers:

a. The Bendix Wingman Fusion system fuses data from radar and camera sensors. Their product brochure notes "the radar locates objects – moving and stationary – within its detection range, which is about 22 degrees wide and 500 feet long. It is particularly good at detecting the distance, speed, and angle of objects even through difficult-to-see conditions like snow, rain, fog, or smoke…. [The camera's] viewing angle is wider than the radar (about 42 degrees) to better detect cut-ins." (Bendix, 2015)
b. The WABCO OnGuardACTIVE™ system, which uses radar only, "is capable of analyzing traffic up to 650 feet ahead, thus recognizing impending critical driving situations earlier." (Wabco, 2017)

NTSB has estimated that FCAM systems could reduce ~80% of rear-end crashes (NTSB, 2015). The NTSB study referenced an internal study performed by early adopter Conway Trucking (now XPO/Conway), which found that, in over 30 months with FCAM systems operating on 12,600 tractors, a 71% reduction in rear-end collisions occurred along with a 63% reduction in unsafe following behavior.

Similarly, heavy-duty truck fleets using Wabco's OnGuard collision mitigation system have reported "a 65 to 87% reduction in accidents, resulting in an up to 89% reduction in accident costs compared to vehicles without OnGuard, with a payback in just two years" (Roeth, 2016).

NHTSA has estimated $3.1B annual savings from full deployment of FCAM technology. Current systems are available from all major truck OEMs and are seen as effective, but there is room for improvement. A major study funded by NHTSA evaluated two existing FCAM systems (also featuring collision warnings and lane departure warning). The study, conducted by the Virginia Tech Transportation Institute, collected approximately 3 million miles of Class 8 truck data involving 150 Class 8 tractor-trailers from 7 fleets driving for about one year. About 85,000 hours of driving and 885,000 FCAM system activations were collected across all activation types. From this data 6,000 FCAM system activations were sampled. The trucks drove revenue-producing routes and were equipped with either of the commercially available FCAM systems. In addition to accurately detecting safety critical events and applying braking, false FCAM activations also occurred, in particular for stationary objects. Researchers noted that stationary object alerts "were often caused by overhead objects or objects in a curve." They suggested that test procedures for FCAM systems include scenarios with these infrastructure elements. Lane departure warning activations were mostly advisory and were generated during intentional lane departures without turn signal use (Grove et al., 2016).

Since 2015, automated emergency braking systems have been mandated on all heavy trucks in Europe, which has been estimated to save 5,000 lives per year. In the U.S., although passenger car OEMs have voluntarily pledged to NHTSA to make FCAM standard on all vehicles by 2022, no similar agreement has emerged for commercial vehicles.

At a practical level, early FCAM systems required maintenance to ensure the radar sensors were properly aligned, particularly after minor forward collisions. Current systems are more robust in adapting to misaligned sensors (Transport Topics, 2017).

Air Disc Brakes

Air Disc Brakes (ADB) provide improved braking performance. ADB benefits include (Bendix White Paper):

a. shorter stops (100 feet shorter than today's drum brakes from 70 mph)
b. better braking feel / improved side-to-side brake consistency
c. greater braking power
d. longer lining life (typically twice the lining life of drum brake applications)
e. sealed design (no periodic lubrication required)
f. sealed and integrated automatic brake adjustment
g. quick change of brake pads compared to drum brakes

Adoption Rates for Truck Advanced Driver Assistance Systems

These pre-automation on-board technologies are a key part of the foundation for vehicle automation. As the benefits of automated driving stimulate the trucking marketplace, adoption rates for these safety-focused systems will increase. For instance, DATP systems from at least one system provider (Peloton Technology) will require DATP vehicles to be equipped with both FCAM and ADB. DATP, by incorporating the building blocks of FCAM and ADB, can serve to improve truck safety by incentivizing adoption of foundational safety-enhancing technologies.

As of 2015, less than 20% of new Class 8 trucks sold in the U.S. were equipped with FCAM systems (U.S. Truck Safety Coalition, 2015). Payback from non-events is difficult to measure for fleets, and the current system upfront cost (between $2,000 and $3,000) is an impediment. However, during 2016 and 2017, most OEMs made FCAM standard on their highway trucks (OEMOffHighway.com, 2016; Transport Topics, 2017).

ADB provide improved braking performance but cost and weight factors have inhibited adoption; with rising volumes costs are expected to decrease (Bendix White Paper).

The NACFE Confidence Report on Platooning (Roeth, 2016) addresses the growing use of vehicle safety systems by noting that "the 'take rate' for safety systems on heavy-duty trucks today is already at the 30% rate on all new vehicles sold." With new truck sales strong in 2017 and expected to remain so in 2018, market penetration of FCAM is rising. Ryder, Penske, and UPS are examples of major truck fleets that purchase all new trucks with FCAM capability (Trucks.com, 2017).

II.D.ii. Current Commercial Truck Automation Activity

Most leading truck manufacturers are developing automated driving systems at various levels of automation. In fact, some experts contend that automated trucks will arrive sooner than automated passenger vehicles due to offering strong business propositions such as improving fuel economy, reduced frequency and severity of accidents, and more.

In May 2015, Freightliner announced that it had been granted licenses for road testing of trucks equipped with their Highway Pilot automated driving system (Level 3) in Nevada (Daimler, 2015). Their prototype truck provides Level 3 automated driving, but does not perform automated passing or merging/exiting maneuvers; these must be done by the driver. The driver can deactivate the Highway Pilot manually and is able to override the system at any time. If the vehicle is no longer able to handle the driving, the driver is prompted to retake control with enough time for the driver to gracefully re-engage driving.

In March 2017, Paccar and chipmaker Nvidia announced that they have built a concept self-driving truck capable of piloting itself through most driving conditions (US News, 2017). PACCAR makes Peterbilt, Kenworth, and DAF trucks.

Additionally, the Silicon Valley start-up community is addressing truck automation. Uber Advanced Technology Group, Embark, Starsky Robotics, Tesla, Waymo, and TU-Simple are focusing on highly automated driverless operations (Level 4) for highway driving (Bishop, 2017).

Amazon formed an internal think tank in 2016 to explore what role autonomous vehicle technology could have in optimizing the efficiency of its delivery and logistics chain (Wall Street Journal, April 2017). According to press reports, Amazon's interest includes automated driverless trucks, which could reduce a four-day truck drive across the U.S. to 36 hours without the hours-of-service restrictions that currently apply to truck drivers.

II.D.iii. Recent and Ongoing Public-Private Sector Projects

A variety of recent and ongoing public-private projects have complemented commercial activity. These are summarized here, starting with past projects and continuing to ongoing projects.

SARTRE

a. Schedule: 2009-2012
b. Partners: Volvo Cars, Volvo Trucks, research institutes
c. Objectives: demonstrate feasibility of platooning approach in which first vehicle (a professional driver in a truck) is followed by several HAV vehicles in tight platooning formation (cars following trucks). This was seen as an early deployment approach for automation, since the primary intelligence for driving stayed with a human driver. Business case and environmental impact analyses were conducted in addition to vehicle testing. Platooning was supported by 5.9 GHz DSRC in addition to on-board sensors.

d. Results: SARTRE developed a prototype Human-Machine Interface to support joining and leaving the platoon, plus a prototype vehicle-to-vehicle communication unit that allowed all vehicles within the platoon to communicate with each other. Fuel consumption benefits were simulated, tested on a private track, and tested on road. Empirical testing correlated well with simulated benefits and these in turn correlated generally with testing in other contemporary projects.
e. (Waibel, 2011)

COMPANION

a. Schedule: 2013-2016
b. Partners: Volkswagen Group Research, Stockholm's Royal Institute of Technology KTH, Oldenburger Institut für Informatik (OFFIS) in Germany, IDIADA Automotive Technology in Spain, Science & Technology in the Netherlands and the Spanish haulage company Transportes Cerezuela
c. Objectives:
    a. COMPANION is a research project concerned with the means required for the implementation of the platooning concept in daily transport operations. COMPANION was motivated on an emissions and fuel basis. With heavy-duty vehicles presently accounting for 17% of total CO2 emissions, the aim is to meet reduction goals set by the EU through closely spaced trucks under a V2V connected scheme.
    b. Testing of the full system on Spanish roads was conducted in 2016.
d. Results:
    a. The project evaluated the performance of the COMPANION system in a real environment along with the coordination of platoons; i.e., the platoon capabilities of the vehicles provided by the on-board units were integrated with the off-board platoon coordination system.
    b. Several driver trials with three vehicles in different EU countries where performed. These tests demonstrated the feasibility of international platoons as well as providing valuable information of the performance of the whole COMPANION system.
    c. Results from COMPANION are integrated into Section II.G. of this report.
e. (COMPANION, 2016)

European Truck Platooning Challenge

a. Schedule: 2015-2016
b. Partners: Dutch Rijkswaterstaat and other EU road operators, DAF Trucks, Daimler Trucks, IVECO, MAN Truck & Bus, Scania, and Volvo Group
c. Objectives:
    a. The Netherlands launched the European Truck Platooning Challenge during its 2016 presidency of the Council of the European Union in 2016. The aim was to accelerate deployment of platooning by stimulating public sector regulatory authorities across Europe to consider permitting and other regulatory steps needed for deployment, leading to a "borderless" environment for truck platooning.
    b. Backing came from leading EU umbrella bodies including CEDR (road authorities), EREG (European vehicle and driver registration authorities),

ACEA (vehicle manufacturers), CLEPA (automotive suppliers), IRU (freight haulers), and ESC (shippers).

d. Results:
    a. Tractor-trailer combinations were used in the Challenge. On a single day in April 2016, two- and three-truck platoons from six different truck makers arrived in Rotterdam, operating DATP Level 1 platooning on public roads from Sweden, Denmark, Germany, Belgium, and the Netherlands.
    b. Although not a research project as such, the EU Truck Platooning Challenge provided an opportunity to gain experience and accumulate knowledge around cross border truck platooning on public roads, with mixed traffic.
e. Stakeholder Consultation: After the event, 79 members of the EU Truck Platooning Challenge network took part in an online Stakeholder Consultation survey. This consultation had two goals in mind:
    a. To validate and build wide-ranging support for Vision Truck Platooning 2025.
    b. To identify as many challenges as possible and open questions on the road toward commercial deployment of truck platooning.
f. Results from the EPTC are highly relevant to DATP and this study; these results, including the stakeholder consultation, are integrated into sections II.C-G, section II.J, and sections IV.B-C.
g. (Rijkswaterstaat 2016)

Sweden 4 Platooning

a. Schedule: 2017-2019
b. Partners: Scania CV AB, Volvo Technology Corporation, SICS, Swedish ICT, Royal Institute of Technology, Schenker AB and the Swedish Transport Administration.
c. Objectives:
    a. increase knowledge of the needs and economic values for different platooning related services, such as mechanisms for the formation of a platoon
    b. create a standardized platooning application for inter-operability across different truck brands, addressing functional safety and driver-vehicle interface
    c. conduct a commercial pilot study with the CACC (only longitudinal control, i.e., DATP)
    d. demonstrate platooning with lateral and longitudinal control with vehicles from different manufacturers
d. (Vinnova, 2016)

FHWA Exploratory Advanced Research Project: Heavy Truck Cooperative Adaptive Cruise Control: Evaluation, Testing, and Stakeholder Engagement for Near-Term Deployment

a. Schedule: 2013-2017
b. Partners: Auburn University (lead), Peloton Technology, Peterbilt Trucks, Meritor-WABCO, American Transportation Research Institute
c. Objectives: perform the necessary technical work, evaluation, and industry engagement to identify the key questions that must be answered prior to market introduction of heavy truck DATP. Activities include business case analysis, performance testing, aerodynamics modeling, wireless communications evaluations,

platoon formation assessment, traffic modeling to assess on-road effects, and system demonstrations.

d. Note: Phase Two results were released in April 2017. These results are highly relevant to the Florida study and relevant aspects are integrated into sections II.G-H and IV.B.
e. (Auburn University, 2015) (Auburn University, 2017)

FHWA Exploratory Advanced Research Project: Partially Automated Three-Truck Platooning

a. Schedule: 2014-2017
b. Partners: Caltrans (lead), Volvo Group, Cambridge Systematics, LA Metro, Gateway Cities COG, Transport Canada, Peloton Technology
c. Objectives: Developing and evaluating CACC system performance on three Volvo Class-8 trucks (Level 1 automation, longitudinal control only) across driver-selectable time gaps of 1.5, 1.2, 0.9, 0.6 s; evaluating driver interfaces in a truck driving simulator; performing testing of platooning system reacting to third-party driver cut-ins; conducting system demonstrations.
d. Driver preferences for inter-vehicle gap distances were assessed during on-road driving trials. The trucks operated in mixed traffic on California freeways I-580 (suburban) and I-5 (rural) for approximately 3 hours. The experimental subjects were nine experienced long-haul truck drivers, driving both truck two and truck three at their choice of gap setting. A gap of 1.2 seconds (at 55 mph, 29.5m or 97 feet) was most preferred, but some drivers (most experienced group) preferred the shortest gap setting of 0.6 seconds (at 55 mph, 14.7m or 48 feet). The drivers had no preference regarding the truck two or three position.
e. (Shladover, 2016) (Shladover, 2017)

Texas DOT and Texas Transportation Institute Level 2 Truck Platooning

a. Schedule: three phases over 2015-2018
    a. Phase 1 (completed): feasibility planning study and proof-of-concept demonstration.
        i. Feasibility Study: the study focused on deployment of two or more platooning vehicles on specific corridors within Texas within 5 to 10 years. The TTI team documented lessons learned from past platooning projects; identified potential regulatory or legislative roadblocks to introducing platooning into commercial fleet operations; and explored potential implementation scenarios given the existing infrastructure and operational environment. The research team concluded that platooning technology is "ready for commercialization and that it provides value in specific roadway, fleet, and operating conditions." Specific areas of focus were:
            1. defining performance measures for evaluating different truck platooning system alternatives.
            2. identifying potential candidate locations where truck platooning may be beneficial.
            3. identifying organizational issues that need to be addressed prior to implementing truck platooning in Texas. This process involved a small number of interviews with in-state

stakeholders (including trucking (large fleets, owner-operators), truck drivers, platooning system suppliers, safety experts, state police, road agencies, tolling authorities. The discussions addressed topics such as "appropriate user types, training requirements and constraints, enforcement and traffic incident management procedures, control algorithm and technology needs, and roles and responsibilities of operators." The process and issues raised align strongly with items addressed by the Florida Driver Assistive Truck Platooning Task Force held during 2016 (Florida DOT, 2016).

i. Proof-of-Concept Demonstration: conducted in July 2016 on a closed course

b. Phase 2 (ongoing): Develop the concept of operations and requirements for the design and vehicle system; enhance system functionality and reliability; and develop the Phase 3 implementation plan and deployment guidance.
c. To demonstrate real-world viability, the TTI-led team will test the system in one or more field pilot demonstrations and/or in controlled, open-road scenarios. Researchers will assess the impact of platooning on TxDOT's infrastructure and operations by researching critical issues like geometric and traffic operations impacts, while providing necessary outreach and training related to truck platooning. Besides drafting a Phase 3 deployment plan, the team will also develop near-term guidance for TxDOT and other stakeholders to prepare Texas for deploying truck platooning on key facilities across the TxDOT freight network.
d. Phase 3 (planned): Deploy a commercial truck-platooning application in Texas.

b. Partners include Navistar Trucks; suppliers Bendix, Denso, and ZF-TRW, and U.S. Army TARDEC.
c. Uniquely to the U.S., this work focuses on Level 2 platooning, in contrast to DATP, which is Level 1 platooning.
d. (TTI, 2017) (Kuhn, et al., 2017)

Smart Columbus

a. Schedule: 2017-2020
b. Partners: the Smart Columbus project has many partners. Peloton Technology is the platooning partner.
c. Objectives: as winner of the USDOT Smart City Challenge, Columbus, Ohio will be implementing a variety of ITS measures, including Level 1 DATP. Platooning will occur for trucks entering/leaving the Rickenbacker Intermodal Hub within the City's Logistics District during highway portions of their trip.
d. (Smart Columbus, 2017)

U.S. Army Platooning R&D

a. The U.S. Army has conducted several demonstrations of increasingly capable truck platooning technology. Most are led by the Tank Automotive Research and Development Engineering Center (TARDEC) in Warren, MI. In 2014 the AMAS Program (Autonomous Mobility Applique System) demonstrated a 3-truck platoon at up to 25 mph, followed by a 7-truck platoon at up to 40mph. The AMAS program at TARDEC developed out of the Convoy Active Safety Technology system (CAST), which in turn had developed from the Autonomous Land Vehicle (ALV) project funded by DARPA in 1985 (Roeth, 2016).

b. July 2016: TARDEC conducted a demonstration of four-truck platooning on I-69 in Michigan. The Michigan Department of Transportation has equipped a section of the I-69 with infrastructure to transmit and receive DSRC signals, enabling Vehicle-to-Infrastructure (V2I) communications (information available does not describe the role of V2I in the demonstration, however) (Roeth, 2016).
c. September 2017: TARDEC plans to demonstrate cross-border inter-brand platooning on public highways with 4- to 5-truck platoons. The demo will occur on I-69 in Michigan,and cross into Canada. The trucks will be a combination of vehicles from the AMAS program plus Auburn University (based on FHWA EAR project work and Auburn-developed platooning software). The platoon will consist of Peterbilt and Freightliner vehicles. Most vehicles will operate at SAE Level 1 and one may operate at Level 2 or 3.
d. (U.S. Army, 2017)

Canada ecoTECHNOLOGY for Vehicles Program

a. This is a broad-based program sponsored by Transport Canada to test the performance of advanced heavy-duty vehicle technologies including connected and automated vehicles, emphasizing safety and environmental aspects. Transport Canada has hosted testing in Canada in support of the FHWA-Caltrans platooning project.
b. (Transport Canada, 2017)

Singapore Platooned Container Transport

a. Schedule: 2017-2020 (estimated)
b. Partners: Scania Trucks (lead), Toyota, Singapore Ministry of Transport, Port of Singapore Authority
c. Platoons will operate on public roads while transporting containers between port terminals in Singapore. Operations involve platoons of four trucks, with the following three trucks behind the lead truck driven in automated mode. They also plan to fully automate the processes for precise docking and undocking of cargo.
d. The truck platooning trials will take place in two phases. The first phase will focus on designing, testing, and refining the truck platooning technology to adapt to local conditions. These will be conducted by Scania and Toyota at their respective research centers in Sweden and Japan to leverage their existing development work. The second phase will consist of local trials and development of the technology in Singapore.
e. (Scania, 2017)

UK Highways England Three-Truck Platooning Trial

a. Schedule: 2017-2019
b. Partners: Transport Research Laboratory (lead), DAF Trucks, Ricardo, DHL, TNO, Apollo Vehicle Safety, Millbrook Proving Ground, Costain
c. UK transportation agencies are sponsoring a test of truck platooning on public highways beginning in 2018, focused on driver experience, safety, and fuel efficiency. The two follower trucks will use automated throttle, braking, and steering (Level 2 operations).

d. DHL will use trucks from PACCAR-owned DAF Trucks in freight operations.
e. (Chan, 2017)

ARPA-E NEXTCAR: Enabling High-Efficiency Operation through Next-Generation Control Systems Development for Connected and Automated Class 8 Trucks

a. Schedule: 2017-2020 (estimated)
b. Partners: Purdue University (lead), Peloton Technology, Cummins, Inc., National Renewable Energy Laboratory
c. The U.S. Department of Energy's ARPA-E program selected a Purdue-led team to explore multiple approaches to co-optimizing vehicle dynamics and powertrains of Class 8 trucks to achieve up to 20% fuel savings compared to a MY2017 baseline. The project seeks to combine advancements in connectivity and automation to improve efficiency with minimal changes to Class 8 truck hardware. Platooning is one of five technology areas to be explored.
d. Fuel savings will be validated by simulations followed by on-road testing likely in the 2019-2020 period.
e. (ARPA-E, 2017)

II.E. Regulatory Aspects for Heavy Truck DATP and Higher Automation Systems

II.E.i. Regulatory Aspects for Truck Automation in General

Federal Government Role

The Federal government regulates specific performance, equipment and design features on new vehicles. Responsibility for operation of passenger vehicles is a State responsibility. Responsibility for operation of commercial vehicles also is a State responsibility, with specific aspects handled by the Federal Motor Carrier Safety Administration (FMCSA).

It is possible that NHTSA will issue Federal Motor Vehicle Safety Standards relating to AV. No definitive statements on this point have been made by the Agency. In the absence of FMVSS, at the federal level AV operation is legal, as vehicle regulations in the U.S. follow the principle of "anything not prohibited in permitted."

However, NHTSA's 2016 Federal Automated Vehicles Policy (NHTSA, 2016) provides some indication of the federal government stance. Most importantly, when it comes to "how" a vehicle is driven, NHTSA views an automated driving system as falling under their jurisdiction while human drivers remain under state jurisdiction. This means that, generally, vehicle and technology regulation can be left to NHTSA. NHTSA's updated Federal Automated Vehicles Policy (NHTSA FAVP 2.0, 2017) affirmed this policy.

At some point the role of the driver in actually driving will be diminished to the point that they can handle other administrative logistical matters and/or reduce their workload while the vehicle is performing the driving. This opens up the possibility for changes in Hours of Service regulations; however any serious consideration of changes is not expected in the next ten years (TMC Information Report, 2015).

With regard to the Federal role in highly automated truck inspections, the ATRI AV report (Short and Murray, 2016) noted:

> Section 396 of the Federal Motor Carrier Safety Regulations (FMCSRs), (which specifically covers inspection, maintenance and repair), states that "every motor carrier and intermodal equipment provider must systematically inspect, repair, and maintain, or cause to be systematically inspected, repaired, and maintained, all motor vehicles and intermodal equipment subject to its control." This includes daily inspections (driver vehicle inspection reporting) and a more comprehensive annual inspection (which must be conducted by an inspector that meets specific qualifications outlined in the FMCSRs). FMCSA and authorized law enforcement may also conduct roadside inspection of vehicles.
>
> Minimum standards for the components of a commercial vehicle are described in Section 393 of the FMCSRs – Parts and Accessories Necessary for Safe Operation. This section requires that "parts and accessories shall be in safe and proper operating condition at all times." Inspection requirements found in Section 396. FMCSRs as currently written do not specifically address specifications, inspection, repair and maintenance of autonomous truck systems. Requiring new AV truck maintenance certifications could have a dramatic impact on the already huge shortage of truck and engine mechanics and technicians. Thus, changes to Sections 396 and 393 of the FMCSRs could be expected. It is anticipated that state agencies overseeing vehicles registered for intrastate use will develop rules as well.

State-Level Approaches to Automated Trucks

The NCHRP Truck CV AV report (Fitzpatrick, 2016) emphasizes the need for a favorable policy environment, noting that "having the proper legal and regulatory framework in place is a high priority element for states, and of urgency for those states pursuing early adoptions of automated technologies." Further, that "States must … give priority to the communication and collaboration that is necessary for seamless deployment: coordination with other states in a region, communication to stakeholders including the traveling public, and with the state agencies needed to support deployment."

California draft regulation for Level 3, 4, 5 Deployment for Light Vehicles

The state of California has been a leader in one approach for defining specific regulations and administrative processes for highly automated light vehicles. All efforts are focused on light vehicles at this time but regulations for automated trucks are expected to be developed and released once the light vehicle regulations are finalized. It is highly likely that generic aspects of the light vehicle regulations will also be included in the automated truck deployment regulations.

California DMV has released a draft application for public operation of Level 3, 4, and 5 automated light vehicles (California DMV, 2017). Areas addressed include self-certification that the AV is designed to operate in the operational design specified and not be capable of automated operation outside of that domain; that the AV is designed to detect and respond to roadway situations in compliance with California Vehicle Code and local regulation; that best practice self-diagnostic capabilities are built into the design; and that the manufacturer has conducted test and validation methods and is satisfied that the autonomous vehicles are safe for deployment on public roads in California." The draft regulation also requires a data recorder to store AV-specific data.

Note that this DMV AV Application is an in-process document. Comments from industry and advocacy groups have raised questions and/or objected to several of the elements in this draft. It is beyond the scope of this study to examine the many pros and cons. However, the philosophy driving the DMV proposal has relevance to DATP regulations, most importantly that system providers / users are expected to self-certify compliance rather than the State playing any direct role in test and evaluation. Areas that could be applied to DATP include:

a. restricting operations to a defined operational design domain
b. requiring an event data recorder
c. requiring compliance with all applicable Federal regulations
d. self-diagnostic capabilities that meet current industry best practices for system health monitoring and cybersecurity

Florida AV Statutes

Florida's HB1207 legislation, passed in 2012, encouraged the safe development, testing, and operation of motor vehicles with autonomous technology on public roads of the state and found that the State does not prohibit nor specifically regulate the testing or operation of autonomous technology in motor vehicles on public roads. Florida's 2016 legislation expands the allowed operation of autonomous vehicles on public roads and eliminates requirements related to the testing of autonomous vehicles, and does not require the presence of a driver in the vehicle. Each is described in further detail below.

> HB1207 (2012)
> Defines "autonomous vehicle" and "autonomous technology." Declares legislative intent to encourage the safe development, testing and operation of motor vehicles with autonomous technology on public roads of the state and finds that the State does not prohibit or specifically regulate the testing or operation of autonomous technology in motor vehicles on public roads. Authorizes a person who possesses a valid driver's license to operate an autonomous vehicle, specifying that the person who causes the vehicle's autonomous technology to engage is the operator. Authorizes the operation of autonomous vehicles by certain persons for testing purposes under certain conditions and requires an instrument of insurance, surety bond or self-insurance prior to the testing of a vehicle. Directs the Department of Highway Safety and Motor Vehicles to prepare a report recommending additional legislative or regulatory action that may be required for the safe testing and operation of vehicles equipped with autonomous technology, to be submitted no later than Feb. 12, 2014. (myfloridahouse.gov, 2012)

> HB7027 (2016)
> Permits operation of autonomous vehicles on public roads by individuals with a valid driver license. This bill eliminates the requirement that the vehicle operation is being done for testing purposes and removes a number of provisions related to vehicle operation for testing purposes. Eliminates the requirement that a driver be present in the vehicle. Requires autonomous vehicles meet applicable federal safety standards and regulations. (myfloridahouse.gov, 2016)

It should be noted that, as DATP is a Level 1 system with the human driver alert and responsible for key aspects of vehicle operation, these AV laws do not apply to DATP. Florida statutes specific to DATP are found in the next subsection.

Texas Study: Connected and Automated Vehicles (CAV)

A study of CAV deployment policy focusing on Texas noted that while "taking no legislative action is a possible option, being proactive on shaping policy will help Texas reap the potential safety and operational benefits expected of CAVs to a greater extent and at a faster pace" (Kockelman, K. et al., 2016). The study recommended that TxDOT urge the legislature to address the following actions:

a. Setting standards for testing and development of CAVs
b. Legally defining the "operator" of a CAV
c. Establishing rules for intensive use of truck platooning
d. Addressing privacy and security questions stemming from CAV use
e. Answering liability questions that arise from CAV adoption
f. Advancing broader public goals in CAV innovation

II.E.ii. DATP-oriented regulation

As can be gleaned from the preceding discussion, some regulations addressing automation in general can apply to truck platooning systems. However, much of the focus on automated trucking centers on highly or fully automated driving, in contrast to DATP which automates operation of throttle and brakes only while the truck driver is fully aware of the road environment and remains responsible for steering. Thus, DATP is fundamentally no different than current systems in wide use, i.e., Adaptive Cruise Control.

Federal Regulations Potentially Relevant to DATP

The TTI Platooning Feasibility Study (Kuhn et al., 2017) listed several existing FMCSA regulations under 49 CFR Parts 300-399 that could be relevant to platooning, broadly defined. Items relevant to DATP include:

a. Part 381.4: Waivers, Exemptions, and Pilot Programs; details the requirements relating to getting temporary relief from regulations. A pilot program can be granted temporary relief from regulations for up to three years.
b. Part 393.3: Additional Equipment Requirements; additional equipment that decreases safety is prohibited, but other equipment—as long as it does not reduce safety—is not prohibited.
c. Part 393.28: Wiring Systems; "Electrical wiring shall be installed and maintained to
d. conform to SAE J1292." Any modifications to the wiring systems must conform to these standards.
e. Part 393.40: Required Brake Systems; this section provides, in specific detail, the exact ways brakes of differing varieties must operate. Any modifications that involve the brakes must not violate these requirements.
f. Part 393.51: Warning Signals; commercial motor vehicles must be equipped with warning signals that inform the driver when a brake system fails, and must meet certain requirements. Any modifications that involve the brakes must not violate these requirements.

g. Part 393.52: Brake Performance; describes the manner in which braking systems must perform. Any modifications that involve the brakes must not violate these requirements.
h. Part 396.3: Inspection, Repair, and Maintenance; establishes requirements for inspecting, repairing, and maintaining commercial vehicles. The requirements include any "parts and accessories which may affect safety of operation."

From a regulatory perspective, there are two areas unique to platooning:

- V2V Communications:
    - Platooning systems depend on V2V communications. A current NHTSA proposed rule-making would mandate broadcast of Basic Safety Messages using V2V radios in all new light vehicles, taking effect in the 2020 timeframe. It is not known whether this rule will be finalized, however. NHTSA announced some time ago that a decision regarding a similar rule for heavy trucks would be made following finalization of the light vehicle mandate. If so, the effective date of any new heavy truck V2V rule would likely be well after 2020.
    - A government mandated V2V communications system will likely include minimum requirements for hardware and messages, communications security, and possibly governance stipulations. Prior to such a mandate, and within the limits of FCC spectrum use rules, vehicles can use V2V for their own purposes and on their own terms, for applications such as truck platooning. Therefore, there is no dependency between NHTSA action on V2V and the commercial deployment of platooning.
- Following Distance:
    - State motor vehicle codes generally address truck following behavior. In some states, qualitative "reasonable and prudent"-type language is used; in other states a numeric minimum following distance is specified, ranging from 100 to 500 feet.
    - For platooning to have economic benefit, inter-vehicle gaps well less than 100 feet are needed. This requirement is in clear conflict numeric minimum following distances and potentially in conflict with "reasonable and prudent"-type standards, depending on how such qualitative standards are interpreted by state officials.
    - Information specific to DATP is provided in the following sections.

The TTI Platooning Feasibility Study (Kuhn et al., 2017) addresses V2V in a manner that may be misinterpreted. It notes that "since many aspects of the [connected vehicle] system are not yet ready for deployment, FHWA, NHTSA, and other federal agencies have not released final regulations for the system." This section of the study goes on to describe NHTSA's actions over recent years to implement a light vehicle (and eventually heavy vehicle) V2V mandate. However, as noted above, in the absence of any USDOT V2V mandate for heavy trucks, FCC rules apply for the allocated DSRC spectrum, and this spectrum is fully usable for platooning and other qualified purposes, even as more extensive definition of a fully inter-operable system is "not ready."

Overview of State Following Distance Approaches

Scribner (2017) addresses state Following Too Closely (FTC) laws relative to platooning. He provides a comprehensive overview of FTC laws and regulations and provides recommendations, as excerpted here:

> "State FTC rules vary by vehicle class and rule type. Most class-specific FTC rules are contained within a single statutory section. The three vehicle classes are cars (including light-duty trucks), heavy trucks, and caravans (sometimes called motorcades). The four FTC rule types are:
>
> - Reasonable and prudent;
> - Time;
> - Distance; and
> - Sufficient space to enter and occupy without danger.
>
> A 'reasonable and prudent' rule requires a vehicle operator to follow the vehicle in front of her while allowing for sufficient space to stop in an emergency. In application, this is a subjective standard that grants law enforcement a large degree of leeway. It is the most common FTC rule for cars and is sometimes combined with other types of rules.
>
> Time-based FTC rules specify the time interval between vehicles, such as by forbidding drivers from following less than 'at least two seconds behind the vehicle being followed.' This is the least common rule type and is limited to just two jurisdictions, Alaska and Utah.
>
> Distance rules specify the precise safe following distance either by codifying a fixed distance interval or, in the case of Alabama, a proportional distance interval requiring that "the driver of a vehicle shall leave a distance of at least 20 feet for each 10 miles per hour of speed between the vehicle that he or she is driving and the vehicle that he or she is following." This rule type is most common among the heavy truck and caravan vehicle classes.
>
> The 'sufficient space to enter and occupy without danger' rule, which is most common among the heavy truck and caravan vehicle classes, aims to allow other road users to pass other vehicles safely and enter and exit the roadway.
>
> A few U.S. jurisdictions lack explicit FTC rules, relying instead on broader reckless driving statutes. A number of jurisdictions do not fully define all vehicle classes, which means the "car" class becomes the default rule for all vehicles. Further, some jurisdictions distinguish between road types. A few jurisdictions have functionally identical rule types featuring different terminology, but these are rare exceptions.
>
> Exempting automated vehicle platoons from existing FTC rules is slightly more complicated in some jurisdictions, such as those in which FTC rules are spread through two or three class-specific statutory sections. For example, California's FTC rules are divided into three separate statutory sections for cars, heavy trucks, and caravans. In addition, two jurisdictions, Alaska and Massachusetts, codify their FTC rules within administrative, rather than statutory, codes."

A simplified view is provided in Figure 1. States with a qualitative standard are shown in blue-green, while states with a quantitative numeric minimum rule are show in orange (Peloton: Florida DATP Pilot Operational Phase, December 2017).

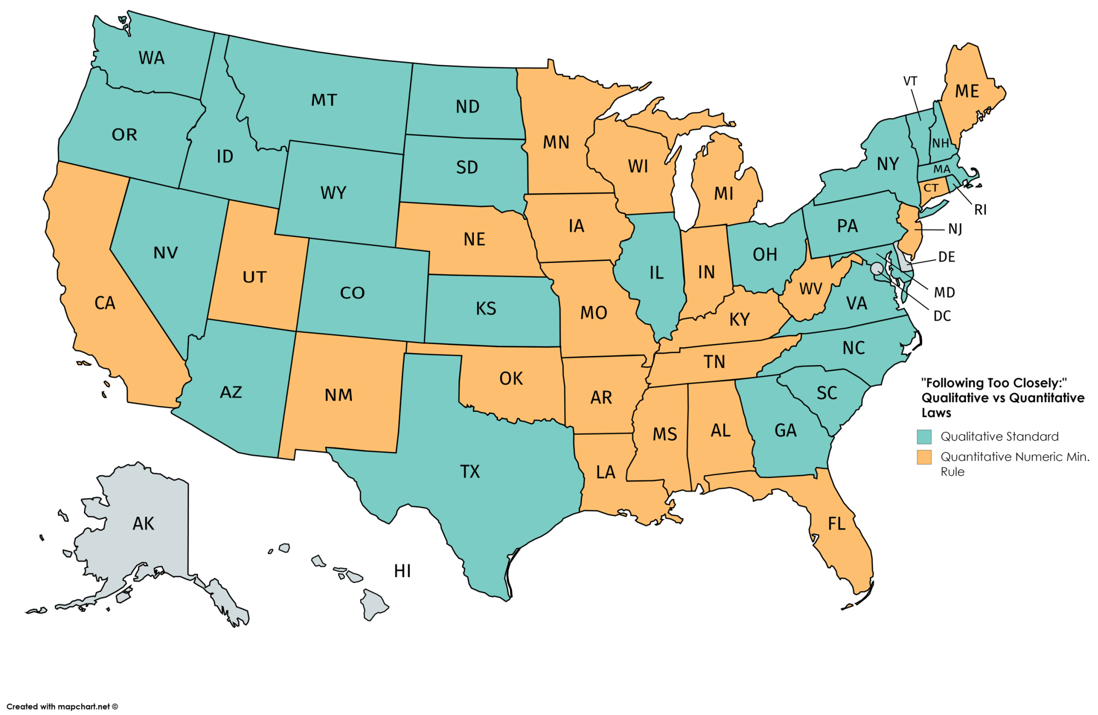

Figure 1: Qualitative Versus Quantitative Following Distance Rules in U.S. States (source: Peloton Technology)

Scribner's handbook provides a comprehensive national overview of FTC statutes and regulations and recommends specific changes for each jurisdiction, presenting two model amendments for each jurisdiction, as excerpted here:

> "The first, the 'strong amendment,' is self-executing and would preclude the state from promulgating any regulations restricting automated vehicle platoons. This is the most liberal, strongly pro-market method of authorizing automated vehicle platooning. The second, the 'weak amendment,' would require agency implementation and grant state motor vehicle authorities discretion in how they promulgate platooning FTC rules, while providing a statutory backstop aimed at preventing excessively burdensome regulation.
>
> From a pro-market perspective, the strong amendment offers the greatest protections against potential burdensome regulations. However, some legislatures may prefer to authorize platooning under a regulated rollout and thus prefer the weak amendment. In the latter case, lawmakers who opt for agency action will need to examine what additional agency resources may be required to carry out the weak amendment's administrative mandate."

Florida DATP Statutes

In 2016, the Florida legislature specifically focused on DATP study and evaluation, as follows (myfloridahouse.gov, 2016):

> Florida House Bill 7027 (2016-81) states: "The Department of Transportation, in consultation with the Department of Highway Safety and Motor Vehicles, shall study the use and safe operation of driver-assistive truck platooning technology, as defined in s. 316.003, Florida Statutes, for the purpose of developing a pilot project to test vehicles that are equipped to operate using driver-assistive truck platooning technology."
>
> Florida Statute 316.003 defines Driver Assistive Truck Platooning (DATP) as: "vehicle automation and safety technology that integrates sensor array, wireless vehicle-to-vehicle communications, active safety systems, and specialized software to link safety systems and synchronize acceleration and braking between two vehicles while leaving each vehicle's steering control and systems command in the control of the vehicle's driver in compliance with the National Highway Traffic Safety Administration rules regarding vehicle-to-vehicle communications."
>
> HB7061
> Defines autonomous technology and driver-assistive truck platooning technology. Requires a study on the use and safe operation of driver-assistive truck platooning technology and allows for a pilot project upon conclusion of the study.
>
> Within this bill, Section 9. Subsections (1) and (3) of section 316.303 of this bill was amended to address the use of video displays for autonomous and DATP vehicles, exempting them from a provision that such displays cannot be within the view of the driver.

It should be noted that the autonomous vehicle regulations covered in the previous section (II.E.i.) do not apply to DATP, since DATP is a Level 1 system with the human driver alert and responsible for key aspects of vehicle operation.

Michigan Motor Vehicle Code Act 300 of 1949 (revised December 2016)

The Michigan Vehicle Code was recently revised to define a platoon as "a group of individual motor vehicles that are traveling in a unified manner at electronically coordinated speeds" (Michigan Vehicle Code, 2016). The Act clarifies that vehicles in a platoon shall not be considered a "combination of vehicles," and that the lead vehicle in a platoon shall not be considered to draw the other vehicles. Therefore, the two tractor-trailer combinations operating as a platoon are not considered to be one "unit" for regulatory purposes; i.e., each tractor-trailer combination is a "combination vehicle" individually and the overall platoon is not itself considered a single "combination," which would otherwise invoke regulatory requirements intended for tractor-trailers.

The revision also considers that vehicles in a platoon are exempt from a requirement that vehicles must follow one another at a minimum distance of 500 feet. However, "when traveling upon a highway, the operator of a truck or truck tractor that is in a Platoon shall allow reasonable access for other vehicles to afford those vehicles safe movement among lanes to exit or enter the highway." Similarly, the operator of a truck or truck tractor in a platoon, "when traveling upon a highway outside of a business or residence district, when conditions permit, shall leave sufficient space between the vehicle and another truck or truck tractor so that an overtaking vehicle may enter and occupy the space without danger."

In addition to the above traffic requirements, a platoon is subject to the driver requirement that "an appropriately endorsed driver who holds a valid commercial driver license must be present behind the wheel of [any] commercial motor vehicle in a platoon."

Operation of platoons is allowed "if, after filing a plan for general Platoon operations with the Michigan Department of State Police (MSP) and the Michigan Department of Transportation (MDOT), the Plan is not rejected by either MSP or MDOT within 30 days after their receipt of the Plan."

Plan for General Platooning Operations Submitted by Peloton Technology Inc.

In March 2017, Peloton Technology filed a platooning plan to MSP and MDOT, which was accepted. Excerpts are provided here [note: the capitalization style is from Peloton's document):

> "Peloton Technology submits this Plan for General Platoon Operations to the Michigan Department of State Police and Department of Transportation in order to obtain allowance to operate Platoons via Peloton's Truck Platooning System in the State of Michigan. The System is a Level 1 driving automation system that electronically coordinates the speeds and inter-vehicular headway of pairs of Class 8 Trucks. The Driver of each Truck in a Platoon operated by the System retains continuous steering control and discretion to disengage the System via manual controls. In addition to connecting Trucks to each other, the System connects Trucks to a cloud-based Network Operations Center, which remotely issues and withdraws Safety Approval of Platoons to limit their operation to within a specified Operational Design Domain.
>
> The System consists of software and hardware developed by Peloton and integrated with commercial third-party technologies, including vehicle-to-vehicle (V2V) and vehicle-to-Internet cloud (V2C) communications devices and radar-based collision avoidance systems (CAS), in accordance with ISO 26262 (the functional safety standard for electrical and/or electronic systems in road vehicles) and with standards and best practices in emerging safety-relevant technical areas referenced in NHTSA's proposed Federal Automated Vehicles Policy, such as cybersecurity and human machine interface (HMI) design.
>
> For Platoon operations in the State of Michigan, Peloton proposes a five-step iterative Process to specify an Operational Design Domain for Trucks in Platoons based on a set of safety factors including, but not limited to, geography, roadway type, traffic, weather, time of day, following distance and speed, as well as feedback from roadway owners, operators and users. In addition, the operation of Platoons will be subject to Driver, Truck and Cargo minimum requirements and Carrier responsibilities."

Peloton's compliance with Michigan requirements for "reasonable access" for other vehicles is addressed as follows:

"*Driver supervision.* Consistent with Driver functions of monitoring the driving environment and intervening in vehicle motion control as appropriate during performance of the Dynamic Driving Task, the Peloton-approved Training that a Driver receives prior to operating a Truck in a Platoon instructs the Driver to monitor the driving environment for Cut-in Vehicles, and to act as appropriate to ensure that a Cut-in Vehicle is able to (a) enter and occupy the space between the Trucks safely, and/or (b) move safely between lanes to exit or enter the highway. A Driver may do so either by (a) acting to dissolve the Platoon, or (b) steering the Truck between lanes.

System-initiated dissolution. The System will automatically dissolve a Platoon when it detects a Cut-in Vehicle via radar or another sensor."

Peloton's "iterative process" for operation of platoons starts with a freight carrier request for a specific route, followed by a roadway inspection to evaluate whether the route has required multi-lane, divided, controlled-access properties. The Plan notes that "methods of Roadway inspection may be remote (e.g. via Internet-based mapping and visualization tools, sources of historical traffic and environmental data, discussions with Roadway owner, operator and users) and/or local (e.g. vehicle sensor data and observations from scout vehicles traveling the Roadway)."

Based on information gathered, Peloton notes that their evaluation may include "consultation with MDOT and MSP, comparisons of the proposed Roadway to other roadways already included in the Operational Design Domain (ODD), analysis of system feedback from operation of Platoons on those other roadways, and determination of any restrictions based on geography (i.e. which segment[s], if any, may be suitable for Platoons), roadway type, traffic, weather, time of day, following distance, speed and any other rules of the ODD to limit the operation of Platoons on the Roadway (Restrictions)."

2017 Tennessee Platooning Allowance Law

Following somewhat in Michigan's footsteps, vehicle platooning became permissible in Tennessee in early 2017 (TnDOT, 2017). The State notes that

> "those desiring to operate a platoon must provide notification to TDOT and the Tennessee Department of Safety. This must include a plan for the general operation of the platoon."

The Tennessee law permits platooning on all Tennessee roads. Two or more vehicles are considered a platoon.

By law, if the platoon includes commercial motor vehicles, an appropriately endorsed driver who holds a valid commercial driver license (CDL) must be present behind the wheel of each vehicle.

The state requests the following information via their on-line "Vehicle Platooning Operations Request":

a. Routes
b. Operational Time Frame
c. Number of Vehicles in Platoon and VIN Number
d. Number of overall vehicles equipped as part of activity

e. Unique vehicle markings (if any, or none)
f. Hazardous Materials (yes/no)
g. Detailed Plan for Platooning ("notification must include a detailed plan for general platoon operations for your company's proposal. This entry should address contributing technologies to be used, safety validation, operational design domain, platoon formation method, platoon dissolution method & fallback, and vehicle description.")

By submitting the form, the person submitting the request agrees to this statement:

> "I certify that the company vehicles and drivers will comply with state and federal rules and regulations and the driver-assist vehicle platooning equipment is installed properly and meets all USDOT safety standards."

Platooning Authorization in Other States

Since Michigan became the first state to authorize commercial deployment of truck platooning in December 2016, several other states have followed suit.

Like Michigan and Tennessee, North Carolina and Arkansas passed legislation which calls for technology providers to submit a "plan" to be reviewed and approved (either affirmatively or by not rejecting the plan within 30 days) by state departments of transportation and public safety prior to actual deployment.

In addition, Arizona, Georgia, Nevada, South Carolina and Texas have passed legislation which allows for deployment of truck platooning technology without submission of a plan.

Finally, the Ohio Department of Transportation and Department of Public Safety officials authorized platooning administratively by interpreting the state's existing statute governing following distance to allow for truck platooning. Ohio State Highway Patrol has issued guidance to its law enforcement officers stating that truck platooning is legal in the state, while still providing officers discretion in determining whether platooning trucks are operating in accordance with the statute, taking account of close-following distances enabled by the technology.

Summary of Current State DATP Allowance Regulations

Ten states now allow commercial platooning operations, as shown in Figure 2 (Peloton: Florida DATP Pilot Operational Phase, December 2017).

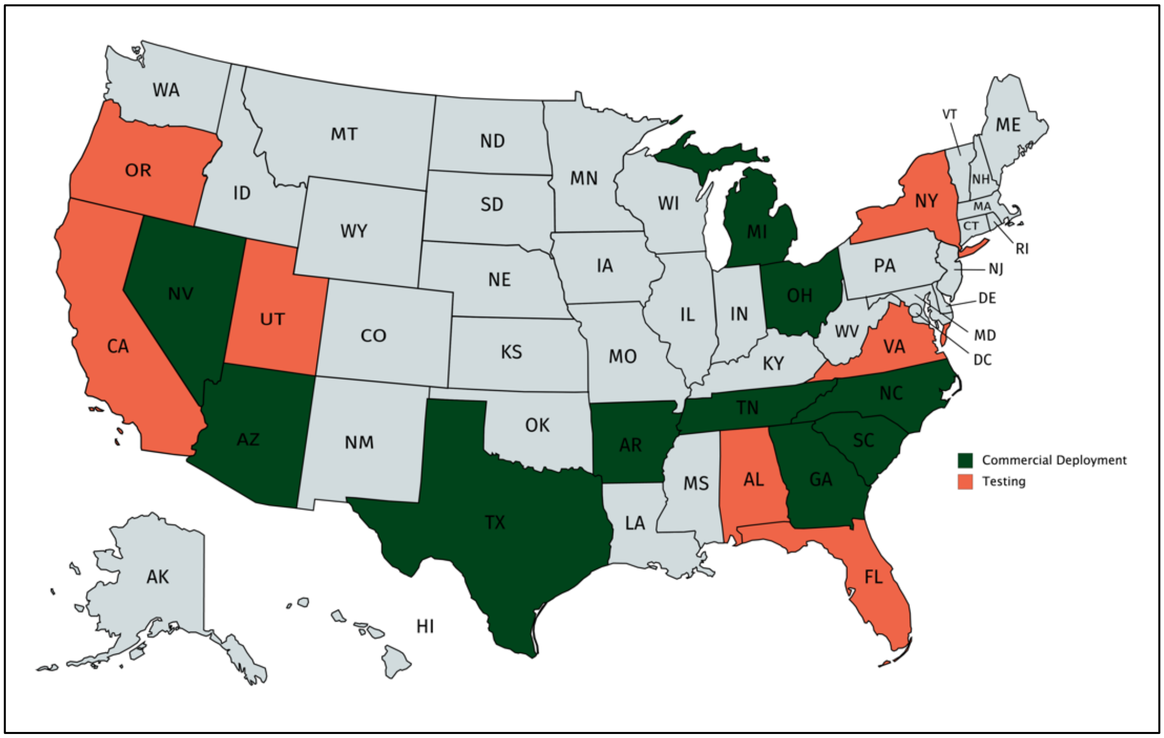

Figure 2: States Allowing Commercial DATP Operations (shown in green)
(source: Peloton Technology)

Regulatory Approach in the European Truck Platooning Challenge

The regulatory approach taken within the European Truck Platooning Challenge (EPTC) provides useful insights for introduction of DATP onto U.S. roadways. Five countries (Belgium, Denmark, Germany, Netherlands, and Sweden) participated.

The EPTC Lessons Learned document (Rijkswaterstaat, 2016) noted that three regulatory approaches were employed:

a. Self-reporting (Sweden and Denmark)
b. Prescriptive (Germany and Belgium)
c. Prescriptive and Code of Practice (the Netherlands)

The Lessons Learned document provides this elaboration:

> "Self-reporting
> Sweden took the self-reporting approach, asking the truck manufacturers to identify the risks they expected and their plans for mitigation. The basic principle here was that the truck manufacturer bears full responsibility for anything that may happen en route, whereby it will do anything it can to prevent accidents occurring. It is in their best interest to treat possible risks seriously. Moreover, Sweden is quite reluctant to impose requirements, as this would suggest that a road authority is in a position to indicate the safest course of action (responsibility devolves on the road authority). The Swedish government has launched a study into regulations for all

kinds of tests into automated operations tests, i.e. all vehicle types. The relevant agencies are drafting requirements for reporting/describing tests by manufacturers before they can actually start testing their products on public roads. This will replace the 'self-report' approach.

Denmark followed the Swedish approach, but treated the initiative as a one-off demonstration. The European Truck Platooning Challenge was their first experience in this area. For long-term tests the Danish approach would probably be more similar to Germany, Belgium and the Netherlands.

Code of Practice
The Netherlands road authority developed a Code of Practice as a guide for the platoon driver to evaluate the traffic situation. The Dutch philosophy says it is too early in the learning process for general rules governing all types of automated and connected vehicles, test conditions and purposes. One-fits-all rules would be too general and thereby obsolete in due course. The Code of Practice forms an appendix to the exemption. Although the Code of Practice has no basis in law, in the event of an accident, proof of disregard of content could be a factor in court."

The Lessons Learned document also noted that to some degree the Code of Practice "did not relate to expected risks of the truck platoons as such, but rather to expected risks due to media activity or the behavior of accompanying vehicles of the truck platoons."

For the Challenge, national authorities were required to approve modifications on the trucks and the following distances. Under European guidelines for truck weight and dimensions, the maximum length of each combination is 16.50 m. The following distance between vehicles is regulated nationally; in some countries this is expressed in meters or seconds, while in other cases regulators stipulate a "safe following distance." The European Truck Platooning Challenge allowed inter-vehicle distances that were shorter than those legally required in the various countries.

Because the participating vehicles were type approved, the testing and approval only covered the new technology: automatic braking and acceleration supported V2V communication. Each country conducted the approval in its own way. This led to different outcomes in following distance and additional safety measures, such as warning lights.

Truck manufacturers based in Germany who were fielding platoons in the EPTC needed to ask permission in the federal state where they were based, e.g., Baden-Württemberg and Bavaria. Generally, truck manufacturers can drive vehicle prototypes on public roads, but the issue of shorter following distance required special permission from the authorities.

Lane Restrictions

Regarding layout of motorways and position of the truck platoon on the road:

a. The German state of Schleswig-Holstein did not allow truck platooning on two-lane motorways.
b. The German state of Baden-Württemberg allowed truck platooning only on motorways with an emergency lane.
c. Belgium confined truck platooning to the right lane.
d. The Netherlands placed a general ban on overtaking.

Recognizability of Platooning Underway

Within the EPTC, some truck platoons were required to be recognizable by text markings and flashing lights. All German federal states involved required their truck manufacturers to place the message "Vorsicht Testfahrt! Geringer Abstand" (Attention Test Drive Low Distance) on the side and rear end of the truck. See Figure 3.

The German federal states also required flashing lights (as used in transportation of exceptional loads) to indicate platooning was underway.

Figure 3: Text Markings on European Truck Platooning Challenge Vehicle Trailers

Lessons Learned Regarding Platooning Rules and Restrictions

As is discussed in Section II.J.iii, some restrictions and rules placed on EPTC operations created traffic disruptions, particularly when speeds were slower or gaps were similar to non-platooned trucks. These were put into place from an abundance of caution. However, the discussion within the Lessons Learned report implies that any future regulations would approach these factors less conservatively (Rijkswaterstaat, 2016), as indicated by these excerpts:

> "Although the expected risks were justified, in general, the exact conditions for mitigation measures require evaluation, as on some occasions the requirements were seen to be counterproductive.
>
> One expected risk was the possible increased chance of accidents/ disturbance in traffic flow due to behavior of the truck platoon as a single vehicle entity. Truck platoons merging into the traffic flow introduce a new/ different factor. This applies to platoon drivers and other traffic. The truck drivers in a platoon feel part of a larger entity and act accordingly, taking into account the following and/or leading trucks. There seems to be a tendency to keep the platoon together as much as possible and when initiating or performing certain maneuvers, such as overtaking or changing lanes, the drivers need to realize that they are part of the platoon and so need more time and space than a single truck. Some requirements, as formulated in the exemptions (or accompanying code of practice), may lead to disturbances of the traffic flow, in particular in the vicinity of on- and off-ramps. For example, the stance on decoupling as a prescribed mitigation measure may need to be reconsidered, on the basis of experience during the Challenge. A less stringent approach may be more suitable for the variety of traffic flow conditions platoons may encounter.

> A further issue is the difference between the actual driving speed of single trucks and the speed limit for truck platoons imposed by the authorities in the exemptions. The truck platoons strictly complied with the speed limit resulting in platoons driving slower than other trucks whereby these overtook the platoons. A possible suggestion for the future would be to have platoons blend in as much as possible by minimizing the speed gap between them and other traffic and/or trucks.
>
> Two driver requirements were a) drivers should be employed by the truck brand, and b) the following trucks should have a co-driver. The reasoning behind these two requirements is unclear. They make it more difficult for transport companies to join Field Operational Tests. It also makes the pilots very expensive because of high labor costs."

The EPTC team did conclude that the stipulation requiring "experienced drivers who were familiar with the platooning system" is a reasonable requirement going forward into deployment.

Within the EPTC Stakeholder Consultation (Rijkswaterstaat, 2016), several legal/regulatory challenges were identified for attention going forward. Several of these addressed platooning at higher levels of automation (liability under full automation, hours of service, etc.). For DATP, issues noted were:

a. cross-border access across European motorways
b. harmonization of vehicle approval procedures across EU
c. vehicle following gap distance legislation harmonized across EU
d. insuring platoons: single or multiple underwriters
e. harmonization of platoon length legislation across EU

The specific approaches and restrictions on a country-by-country basis are provided in Table 3.

Table 3: National Approaches to the Exemptions Process in the European Truck Platooning Challenge					
Jurisdiction and Responsible Agency	**Approach**	**Assessment**	**Following Time Headway and Speed**	**Markings/ Lights**	**Other**
Belgium FOD Mobiliteit en Vervoer (central government), www.mobilit.fgov.be	Followed UK general Code of Practice for automated and connected vehicles.	The Netherlands and Belgium cooperated in assessment of prototypes that had not been previously approved by other EU member states.	1.0 - 1.2 sec 90 kph		
Denmark Vejdirektoratet (national road authority), www.vejdirektoratet.dk	Denmark relied on the EPTC Code of Practice. They distinguished between the character of the European Truck Platooning Challenge as a one-off demonstration, and truck platooning as a test. Volvo Trucks and Scania made specific applications for the demonstration platoon to drive through Denmark. These applications were similar to those submitted to the Swedish authorities. "In the context of the demonstration project Denmark was fully confident in the know-how from, and test reporting on, the C-ITS braking system by the truck manufacturers. As the authorities did not conduct their own tests on the braking system the truck manufacturers had full responsibility. For long-term testing exemptions the approach would probably be	Truck OEMs	.5 seconds		

	more similar to that in Germany, Belgium and the Netherlands." (Rijkswaterstaat, 2016), Denmark issued a permit for the specific platooning trucks for the specific date and route. The only exemption granted was permission to drive with a following time of 0.5 seconds.				
Germany: Bavaria and Baden-Württemberg Baden-Württemberg (B-W) (Traffic Ministry), www.mvi.badenwuerttemberg.de Bavaria (Interior Ministry, including traffic), www.stmi.bayern.de Germany: Schleswig-Holstein	TÜV Rheinland evaluation was similar to that in the Netherlands, including EMC and situations like platoon formation, normal platoon driving, cars getting between the platoon, shifting a truck from front to rear and breaking-up the platoon. TÜV Süd operated a different policy on EMC. Similar to Bavaria and Baden-Württemberg but less stringent.	Rules of the assessment are determined by a technical service (TS) like TÜV or DEKRA. TÜV Süd and TÜV Rheinland performed the evaluations.	Baden-Württemberg: 0.5 sec 80 kph Bavaria's permit did not state a following distance. The OEMs selected a following distance that they deemed safe, being no closer than 0.5 sec.	required special markings and a flashing light	2-lane direction motorways: only two trucks permitted in platoon; 3-lane motorways three trucks permitted in platoon (but not in all German Federal States) Vehicles required to have ACC and FCAM functions because these were listed in the application to the government. Before each journey, they were required to be checked for proper functioning
Netherlands RDW (Netherlands Vehicle Authority), www.rdw.nl	The Dutch Code of Practice aimed at emphasizing specific points without issuing them as requirements. One basic principle of the Code of Practice is that truck drivers are viewed as professionals, perfectly able to evaluate traffic situations by themselves. So, for example, the Netherlands did not require decoupling in situations like traffic jams or roadworks.		ranging from 0.7 sec to 1.3 sec 80 kph		

	The Netherlands distinguished between the character of the European Truck Platooning Challenge as a demonstration, and truck platooning as a test. "The ITS admittance procedure involves the gradual accrual of confidence, repetitively and step by step, based on wide ranging risk analysis. Prior to sanctioning practical road testing, the RDW methodically checks all applications around new technologies and functionalities, including testing at a closed site. RDW assessed all vehicles entering the Netherlands; for instance on the declared versus measured maximum automatic de-acceleration on a closed proving ground. " "The basis for determining the following distance included these criteria: a. Redundancy: is there a system that engages automatically and provides a safe new situation when the C-ACC no longer functions? A given system is fully redundant if it takes over the entire braking process from the driver. It is semi-redundant where the driver needs to assist the brake in realizing the full emergency delay; c. Reliable signals: this area is covered by EMC (electromagnetic compatibility). A vehicle with poor immunity and/or heavy emissions of EM radiation is vulnerable to interference of data signals around the control, which will reduce system reliability. RDW required EMC with this in mind."				

Sweden Trafikverket (national road authority), www.trafikverket.se Transportstyrelsen (road traffic authority), www.transportstyrelsden.se	Volvo Trucks and Scania made specific applications for the demonstration platoon to drive through Sweden.	Truck OEMs	0.5 seconds 80-90 kph		High capacity vehicles (32 meter vehicle combinations) could be used on certain stretches of roads while platooning (this is double the EU length limit)

Current DATP Regulations in Germany

Later in 2016, following the EPTC, the Daimler Trucks Highway Pilot Connect was approved for platoon driving within the federal state of Baden-Württemberg, for the complete A81 autobahn (about 180 miles) from Lake Constance to Würzburg (with the greater Stuttgart area excluded). Additional approval has been provided for the A52 in the greater Düsseldorf area (Daimler, 2016).

Other DATP Regulatory Factors

The NCHRP Truck CV AV study (Fitzpatrick et al., 2016) recommends the following: "standardize the requirements for indicators for platooning and other autonomous vehicle applications when operating in autonomous mode. This could be done either for the national highway network or on a larger scale." Based on discussions within the Florida DATP Working Group, this recommendation is premature; requiring or not requiring platooning indicators is an active area of debate subject to a wide range of pros and cons. The argument for an indicator when platooning is active centers on enforcement personnel to be able to distinguish platooning from tail-gating, as well as this information being valuable to other drivers near the platoon so they can make maneuvering decisions for merging and exiting the highway. For drivers, a counter-view is that drivers could be distracted by additional lighting information to process or could "take advantage" of the technology to enter a small gap, knowing the trucks will respond to make space; this also assumes other drivers know what platooning is in the first place. Another view is that DATP operations are not significantly different from regular truck operations in the view of other drivers. Indicators of platooning operations may confuse or alarm other drivers, particularly if they have misconceptions that the trucks are fully automated. At this time, no results of objective testing or evaluation concerning this question have been published. Currently none of the states that have authorized deployment of L1 truck platooning require the use of active platooning indicators, although some have called for signage particularly so that law enforcement can recognize trucks that are equipped for platooning.

II.E.iii. DATP Liability Considerations

The TTI Platooning Feasibility Study (Kuhn et al., 2017) examined liability issues for government agencies, via a literature review and expert interviews. They concluded that liability from platooning activities "is not likely to increase." Quoting the study report:

> "First, interviewees and the literature agree that government agencies receive sovereign immunity or protection from prosecution because the state is sovereign. This protection is only waived in very specific circumstances, such as when government actors are negligent in a specific manner. An example might be if the government is informed that a part of the CV system is malfunctioning (like a roadside unit), but fails to repair the equipment in a timely manner. If harm occurs as a result of the malfunction, the government could be found negligent and lose its sovereign immunity protections as a result of the notice and failure to act.
>
> A second reason governmental liability is unlikely to increase is the likelihood that the CV system, which platooning may or may not ultimately use, "does not create new or unbounded liability exposure for industry" (5). NHTSA argues that the CV

> system, (the development of which the federal government has funded, in which it has participated, and which state and local governments will likely implement) 'from a products liability standpoint… analytically, are quite similar to on-board safety warning systems found in today's motor vehicles.' The agency goes on to argue that it 'does not view V2V warning technologies as creating new or unbounded liability exposure for industry' and as a result, does not have 'a current need to develop or advocate the liability limiting agenda sought by industry in connection with potential deployment of V2V technologies.'"

The EPTC team addressed potential liability of road authorities as follows:

> "The EPTC brought together representatives of the participating national road authorities. The idea arose of setting a following distance per motorway junction, dependent on the distances between acceleration and deceleration lanes, the length of these lanes and the average traffic density. Some of the countries strongly argued against differing following distances per location. The argument was that in the event of an accident it would appear that the truck platoon had complied with the following distance as set, and the road authority would be responsible.
>
> There is a large grey area around the liability of road authorities. Road authorities have a duty of care for road users. Road users have the right to expect that the road is fit for purpose. The duty of care should cover all road users, even if these are autonomous cars. This field of knowledge is new territory. Although the legal experts assume that change will be minimal, case law should create greater clarity.
>
> This would be the situation when smart vehicles adapt to the roads and there are no changes in the current state of the infrastructure. The situation could change if, for example, road authorities created new standards for road markings, in support of lane departure warning systems. The system settings will be designed for the new road markings standards. If the road markings do not match these standards, for example because of damage caused by an accident, the road authority could be responsible."

II.E.iv. Summary of Regulatory Findings

Federal Level

Most Federal activity will apply to HAV, especially if state pre-emption is implemented; Federal regulations are not expected to impact DATP.

Although NHTSA is considering a V2V mandate for new passenger vehicles, which may be followed by a similar mandate for heavy trucks, there is no dependency between this NHTSA action on V2V and the commercial deployment of platooning. This is because the spectrum use rules are in place from the FCC to use the DSRC band for platooning.

State Level

Coordinated policies, regulations, and practices across the States are strongly encouraged by AV manufacturers and by AAMVA, NHTSA, and other national organizations. For the business community, it is also important to provide some degree of regulatory certainty so as to reduce the risk of launching automation-based services.

State approaches to Highly Automated Vehicles (Level 3 and above) point strongly toward self-certification so far, and this is also the case for Level 1 DATP in terms of the "Platooning Plan" approach pioneered by Michigan and now adopted by Arkansas, North Carolina, and Tennessee. In addition, Georgia, Nevada, South Carolina and Texas have passed legislation which allows for deployment of truck platooning technology without submission of a plan. Ohio DOT authorized platooning administratively by interpreting the State's existing statute governing following distance to allow for truck platooning.

Overall, ten states now explicitly allow commercial platooning operations.

It should also be noted that operational differences across different states are unlikely to be a problem, as DATP systems can adapt to different operational modes across jurisdictional boundaries via geo-location and software.

The question of "identifiers" of various sorts of AV capability has been raised; in particular, platooning indicators come up in regulatory discussions. As noted above, this is an active area of debate and clarification is needed; as an example, requirements for informing motorists may be very different from requirements supporting enforcement personnel.

Scriber puts forth two approaches to DATP regulation. The pro-market "strong amendment" would preclude the State from promulgating any regulations restricting automated vehicle platoons. Alternatively, the "weak amendment" would require agency implementation and grant state motor vehicle authorities "discretion in how they promulgate platooning Following Too Closely rules, while providing a statutory backstop aimed at preventing excessively burdensome regulation."

Regarding state agency liability relating to platooning, the TTI Platooning Feasibility Study concluded that liability from platooning activities "is not likely to increase."

Some factors gleaned from new and draft rules in California and Michigan, as discussed above, may be useful for consideration in Florida operations:

a. operators of platooning trucks shall allow reasonable access for other vehicles to afford safe movement among lanes and/or to exit or enter the highway
b. drivers shall hold an appropriately endorsed and valid commercial driver license
c. operations are restricted to a defined operational design domain
d. vehicles equipped with DATP systems shall comply with all applicable Federal regulations
e. vehicles equipped with DATP systems shall have self-diagnostic capabilities that meet current industry best practices for system health monitoring and cybersecurity
f. vehicles equipped with DATP shall have data recorders that can be used to investigate crashes; provisions should be put in place for the state to have access to the data

International Level

The European Truck Platooning Challenge was the most significant recent activity internationally. The nature of the platoons was very similar to DATP, and the factors considered and analyzed have high relevance to deployment considerations in Florida. This process resulted in significant learning to guide full deployment within the countries involved.

Germany and the Netherlands performed their own in-depth evaluations using the same laboratories having responsibility to certify type approval (a process not required by U.S. federal motor vehicle law). Alternatively, some countries (Sweden, Denmark) relied on a self-reporting and assessment process from the system providers.

Following the Challenge, Germany has allowed platooning on several hundred miles of public roads.

II.F. Standards for Heavy Truck DATP and Higher Automation Systems

The NCHRP CV AV Study offered the following recommendations regarding standards for AVs in general (Fitzpatrick, 2016):

a. Platooning solutions that are vendor-specific highlight the need for technical standards, ideally harmonized across the globe, for subjects such as data elements, messaging, and communications protocols. Standards development organizations are indeed pursuing technical standards in areas important to the deployment of trucking CV and AV applications.
b. Any rulemaking action the USDOT might take in the heavy trucking area for V2V will need to be evaluated for standards needs, just as has been done for the light-vehicle rulemaking.

Similarly, the EPTC Stakeholder Consultation identified standardized communication protocols as important to achieving multi-brand platooning (Rijkswaterstaat, 2016).

Standards bodies including the International Standards Organization and the Society of Automotive Engineers are in the early stages of a multi-year process to define some aspects of "Cooperative Adaptive Cruise Control" of which platooning is one form.

The SAE On-Road Automated Driving (ORAD) Committee Verification & Validation task force provides information and guidelines for verification and validation (V&V) of Automated Driving Systems (ADSs). The scope of this task force includes the V&V of all types of motor vehicles, including light-duty passenger, truck and multi-purpose vehicles, as well as medium- and heavy-duty, trucks, buses, freight and transit vehicles across AV Levels 3-5. Various test procedures, such as those performed on a test track, for verifying and validating ADS functions, are included. SAE J3018—Guidelines for Safe On-Road Testing of SAE Level 3, 4, and 5 Prototype Automated Driving Systems—provides general safety-relevant guidelines for performing tests of prototype ADSs equipped on test vehicles operated in mixed-traffic environments on public roads. This body of standards work does not address Level 1 DATP, however (SAE, 2015).

While standards will be useful in the long run, it is useful to point out that standards are not needed for DATP to be launched and for platooning trucks to become common on highways. In the vehicle standards world, initial launch generally comes in the form of proprietary systems from various competitors; as designs mature and to some degree converge, economic efficiencies result from standardization.

In the trucking industry, there are many systems in wide usage, such as Fleet Management Systems, that are not standardized. Nevertheless, these are successful in the marketplace. The impetus for standardization comes from the users, i.e. trucking fleets, if they believe their operations would improve as a result of standards. Thus, standards belong fully in the private sector; existence of or lack of standards does not impinge on state responsibilities.

II.G. Driver Assistive Truck Platooning: Current State of Development

II.G.i. DATP Definition

In the technical sense, there are different approaches to connected vehicle systems designed for close-following. Within the FHWA-funded Caltrans project on truck platooning, the project Concept of Operations (Nowakowski, 2015) provides an excellent overview:

> "There are important distinctions between CACC and automated truck platooning. First, with CACC, only truck speed control will be automated, using V2V communication to supplement forward sensors. The drivers will still be responsible for actively steering the vehicle, lane keeping, and monitoring roadway and traffic conditions. Second, while truck platooning systems have relied on a Constant Distance Gap control strategy, CACC has relied on a Constant-Time Gap control strategy, where the distance between vehicles is proportional to the speed. For these reasons, a series of trucks using CACC is referred to as a string, rather than a platoon."

DATP, the focus of this study, provides a specific implementation of truck platooning at Automation Level 1. The driver of both trucks remain fully responsible for steering and monitoring the road environment.

This study focuses on the Constant Distance Gap paradigm because this is the subject of all current commercial activity.

The TMC Information Report describes DATP as follows (TMC Information Report, 2015):

> "In the DATP application trucks are exchanging data, with one or more trucks closely following the leader in automated mode (the driver remains responsible for steering). V2V communications ensure that the degree of any braking initiated on the lead truck (prior to brake engagement and vehicle deceleration actually occurring due to brake system time lags) causes braking on the follower truck to be commanded at the same or greater deceleration level, virtually simultaneously. This is the key to enabling following distances shorter than a human driver can manage safely.
>
> DATP builds upon radar-based Adaptive Cruise Control systems and adds V2V communications so that the two trucks can "electronically couple": any braking or deceleration by the lead truck can instantaneously be initiated by following trucks. This enables inter-vehicle spacing to be greatly reduced, which improves aerodynamics and substantially reduces fuel use.
>
> DATP platooning systems should not decrease the overall level of safety to road

users. Ideally, due to the collision avoidance technologies underpinning the system, DATP will provide a net safety improvement."

The Florida statute relating to platooning aligns well with this definition, with the exception that DATP operation is limited to only a single follower truck.

II.G.ii. DATP Operational Design Domain

Automated driving systems at any level are described by an Operational Design Domain (ODD). Per SAE J3016, an ODD is made up of the "specific conditions under which a driving automation system is designed to function…. The ODD may include geographic, roadway, environmental, traffic, speed, and/or temporal limitations."

A full description of any DATP must include its ODD. Differences in operational factors due to differing legal frameworks across jurisdictions could also be included in the ODD.

A generic version of a DATP Operational Design Domain might include the following items; however, this is only a *representative* list and product offerings by individual companies will likely differ to some extent:

a. platoon length limited to specified number of trucks
b. platooning operates only on limited access highways
c. platooning only with functioning equipment on the tractor, such as air disc brakes on all axles, FCAM systems with a specific level of braking authority, Electronic Stability Control, Anti-Lock Braking
d. platooning only with trailers with functioning Anti-Lock Braking systems
e. Range of trailer types (van, tanker, flatbed, etc.) and configuration (single, tandem) to be pulled
f. platooning operates only above a minimum and below a maximum speed set by the system provider and/or fleet operator
g. platooning minimum/maximum following distances set by the system provider and/or fleet operator
h. platooning operations only within prescribed weather conditions
i. platooning operations only within prescribed traffic conditions
j. platooning operations only within prescribed road conditions
k. Description of operational practices to enhance safety while platooning is underway
l. Description of operational practices to accommodate nearby traffic while platooning.
m. Use of data from public infrastructure, if any

Role of Infrastructure-Provided Data in Platooning Operational Design Domain

While all platooning activities described in the literature rely only on V2V communications and on-board systems to accomplish critical control functions, data provided from the infrastructure could play a role. As noted in the TTI Platooning Feasibility Study (Kuhn et al., 2017):

> "The platoon controller reflects an operational environment in which platoon-related decisions are made within the vehicles themselves and potentially supplemented by external information. This approach was taken because vehicle-based decision-making would be sufficient to organize and coordinate vehicles effectively within a local platoon, but platoon-level speed recommendations and

advisories could come from an external entity (such as a traffic management center) that has visibility into the conditions of the entire road network."

Thus, information from the infrastructure (I2V) or road operators could theoretically be useful for higher level information on an advisory basis. However, literature regarding commercial activity does not indicate this is being implemented.

TTI Platooning Feasibility Study Approach to Platooning Operational Design Domain

The TTI Platooning Feasibility Study (Kuhn et al., 2017) defines platooning as follows for the purpose of the study (the researchers note that the parameters detailed here may be revised when implementing the experimental system in Phase 2). The parameters comprising the ODD are quite detailed, but it appears they have been defined primarily to guide downstream analysis rather than as input to a regulatory process. The study report does not describe particular analyses or methodologies used to arrive at these specifics.

> Platoon Operation
>
> "The Follower Vehicle (FV) will be equipped with automated longitudinal and lateral control after platooning is engaged. This FV will operate in automated ACC mode for longitudinal control with the driver controlling the steering (lateral motion) from the time a system is activated and a platoon formation request is sent until the system checks are acceptably completed and the platoon is formed (i.e., platooning is engaged). Once the platoon has engaged, the FV will then operate in (automated longitudinal) Cooperative Adaptive Cruise Control mode and use automated (lateral) steering control. It will remain operating in this mode until the FV driver or Lead Vehicle (LV) driver disengages the platooning system. Once in a platoon, the FV will maintain longitudinal control at a fixed preset, driver-selectable gap or headway. It is expected that this gap will range from 20 ft (6 m) to 100 ft (30 m) with less than a 1 ft margin of error and will be selectable by the driver.
>
> Once in a platoon, the two vehicles should function as a single unit. This means that whenever a lane change is required, the LV must identify a gap that is large enough for both vehicles in the platoon to fit. This process may require input from the driver of the FV or communication of information from sensors on the FV to the LV.
>
> The system shall be disengaged when the platoon encounters any one of the following operating situations:
>
> a. If the speed of the platoon of vehicles is not within the operating speed range (sustainable speed drops below 30 mph without stop-and-go system capability).
> b. If the driver overrides the system by:
>   a. Either driver manually disabling the system through a system switch.
>   b. The driver of the FV initiating a steering, brake, accelerator, or clutch input.
> c. If the platoon encounters unusual or unexpected driving conditions such as the following:
>   a. A maintenance or construction work zone.
>   b. Poor environmental conditions due to severe weather.
>   c. An emergency vehicle with its emergency warning lights activated.

d. A traffic incident."

Weather Conditions
"Platooning may only be permitted in a predefined set of weather conditions, with the system setting being adjusted based upon deviation from these weather conditions to maintain safety. However, the systems should be robust enough to monitor the environment to provide safe and reliable operation in normal driving conditions."

Vehicles Restricted From Platooning
"These select vehicles would not be permitted to participate in truck platooning:

a. Vehicles carrying hazardous materials.
b. Vehicles carrying fluids (e.g., tankers, concrete trucks).
c. Vehicles carrying pipes, lumber, or similar types of loose loads.
d. Automobile and boat transporter combinations (traditional and stinger-steered).
e. Truck and pole combinations.
f. B-Train combination.
g. Lowboy tractor/trailer combinations (loaded and unloaded).
h. Saddlemount or saddlemount with fullmount combinations.
i. Construction vehicles (e.g., mobile cranes, concrete mixers).
j. Recreational vehicles.

Lane Usage
"Truck platoons should primarily operate in the outside lane(s) depending on the total number of lanes present on the facility and should NOT travel for significant distances in the inside lane. The platoons may execute a lane change maneuver (as long as it is safe to do so) in order to overtake slower moving vehicles or to avoid vehicles entering the facility from a ramp; however, the driver shall disengage the platoon prior to leaving travel way."

Ideal Roadway Characteristics
"In the initial deployments of truck platooning concepts, platoons shall be permitted only on limited access, multilane facilities (or exclusive lane facilities) where the level of service (LOS) is C or better and the travel speeds consistently range between 55 mph and 75 mph. Once engaged, the platooning system must be capable of operating at speeds between 30 mph and 75 mph. Later deployments may include the ability for the systems to use stop-and-go ACC capability to allow the vehicles to come to a complete stop, and then automatically resume longitudinal control in congested traffic.

The following list provides the recommended ideal roadway characteristics under which truck platooning would be permitted in Texas:

a. The roadway should be classified as an interstate or divided multilane highway with at least 2 or more lanes in each direction with no median cross-over used by traffic.
b. The general operating speeds are in excess of 60 mph during the majority of the day.
c. At least 0.5-mile spacing (desirable) between ramps (entrance and exit

ramps).

d. The roadways should operate a LOS C or better (density < 26 pcpmpl) during times when truck platooning is permitted.
e. The roadway should be located on relatively level terrain with no sustained grades
f. The width of the primary travel lanes should be 11 ft or more throughout the entire section where truck platooning is to be deployed.
g. The roadway should have a continuous inside shoulder of at least 4 ft in width and an outside shoulder of at least 10 ft.
h. The pavements should be maintained in good state of repair with limited rutting, warping, and subsurface damage.
i. Radii for all horizontal curvature should be above usual minimum.
j. The roadway should be free of any horizontal obstructions that may block sight distance around horizontal curvatures. Horizontal curves should be designed with at least a 60 mph design speed.
k. The roadway should provide the recommended decision sight distance to safely execute a speed/path/direction change on rural roads.

Peloton Technology Approach to Platooning Operational Design Domain

In terms of commercial DATP systems, only Peloton Technology has published an ODD (Peloton Platooning Plan, 2017). Per Peloton, "The System's Internet cloud-based Network Operations Center (NOC) provides continuous remote management and supervision of Trucks in a Platoon. Trucks exchange data with the NOC via wireless vehicle-to-cloud (V2C) communications using cellular and WiFi networks." Peloton's concept for conducting operations only within the ODD centers on the NOC authorizing trucks to form a platoon based on satisfaction of a set of real-time safety requirements (Safety Approval). Key functions of the NOC are described by Peloton as follows:

> "The NOC stores the conditions, i.e. rules, governing the ODD of Trucks in a Platoon. Through its Safety Approval function, the NOC enforces compliance with the ODD by authorizing a Truck to form and continue to travel in a Platoon only when all rules of the ODD are met. Currently, the ODD is defined based on the following types of rules:
>
> 1. *Geographic*. The System can operate only in locations that have been previously included in the ODD. Geographic rules may be organized by road (e.g. a specific roadway), road segment (e.g. between two points on a roadway), terrain (e.g. road grade, curvature) or territory (e.g. a specific state). On-board GPS sensors supply a Truck's location data to the NOC, allowing for real-time enforcement of geographic rules (Geofencing).
>
> 2. *Roadway type*. The System authorizes operation of Platoons only on multi-lane, divided, controlled-access highways.
>
> 3. *Weather.* The System prevents operation of Platoons during weather conditions that are reasonably expected to degrade the safety performance of Platoons, based on analysis of weather data from Truck and exogenous sensors, including, but not limited to, traction control data and weather service data, and of System feedback from prior operation of Platoons. In addition, Peloton-approved training that a Driver receives prior to operating a Truck in a Platoon (Training) instructs the

Driver to exercise due care in selecting whether or not to travel in a Platoon even in weather conditions in which NOC is providing Safety Approval.

4. *Traffic.* The System prevents operation of Platoons in traffic conditions that are reasonably expected to degrade the safety performance, fuel efficiency benefits and/or Driver experience of Platoons, accounting for speed, traffic flow and the likelihood of a vehicle entering between Trucks in a Platoon, based on traffic data from Truck and exogenous sensors, including, but not limited to, vehicle speed and radar sensor data and traffic service data. In addition, as with respect to weather conditions, Peloton-approved Training instructs the Driver to exercise due care in selecting whether or not to travel in a Platoon even in traffic conditions in which the NOC is providing Safety Approval.

6. *Ordering.* The System designates the Truck in a Platoon with the lesser relative braking capability, i.e. longer estimated stopping distance, as the Lead Truck.

7. *Headway Setting*. The System sets the target Headway Setting between Trucks in a Platoon, i.e. the following distance from the front end of the Follow Truck to the rear end of the Lead Truck, at a point between 36 and 80 feet based on rules of the ODD, accounting for traffic and weather conditions, certainty of the real-time assessment of relative braking capabilities of the Trucks, and other factors.

8. *Speed.* The System authorizes operation of Platoons at or below posted speed limits for Trucks on a road or road segment.

In general, with respect to rules of the ODD, Peloton has defined and will continue to define initial rules with margins of safety based on conservative modeling, e.g. of thresholds of traffic density appropriate for operation of Platoons. The rules of the ODD may become more permissive of Platoons over time as iterative learning about the performance of Platoons allows for greater certainty of safety-relevant modeling at the boundaries of the ODD.

Finally, the ODD may be modified so as to prevent *any* operation of Platoons as warranted in response to an emergency (e.g. a statewide weather emergency), identification of a System defect or a legal order. Any modification of the ODD, including a statewide withdrawal of authorization of Platoons, can be communicated to all Trucks within 60 seconds."

Importantly, note that in the Peloton approach, drivers do not set or alter the separation distance while platooning except for when they dissolve the platoon.

Daimler Trucks' Approach to Platooning Operational Design Domain

Daimler Trucks (parent company of Freightliner Trucks) has provided information on their approach to platooning, called "Highway Pilot Connect" (Daimler, 2016). Their press literature describes the system at its developmental stage, in which three trucks are platooned and both lateral and longitudinal control is provided (a Level 2 system). While this system capability exceeds the functionality of the DATP definition, it is reasonable to assume it could operate in DATP mode. As a developmental system, the focus of information released to date is more on system equipment and features rather than operational approaches. The system is currently being tested on motorways in Germany.

The Highway Pilot Connect uses DSRC V2V communications and takes advantage of a "three-dimensional high digital map" so as to always be aware of the highway geometry and topography. Forward-looking sensors include radars and stereo cameras. The stereo camera "identifies one- and two-lane roads, can precisely measure gaps and registers the information from road signs."

A camera in the lead vehicle transmits images of the driving situation ahead of the truck to a monitor in all following vehicles. Platooning occurs at a spacing of 50 feet.

The Daimler approach accommodates any need to open up the inter-vehicle gap for traffic situations or infrastructure elements. Currently this is implemented manually by drivers but system developers envision this being an automatic process in the future.

Discussion of TTI, Peloton, and Daimler Operational Design Domain Approaches

Note that the basic functions described for the TTI experimental system, the Peloton pre-commercial system, and the Daimler developmental system are well aligned. However, an important difference is found in that the headway setting is left to the driver in the TTI experimental system and set by the system in the pre-commercial systems. Additionally, the description of the experimental system implies that the Lead Vehicle system may make decisions regarding lane changes independently of the driver. The Peloton approach appears to rely completely on the driver's skill and situational awareness to enact lane changes. The information on the Daimler approach does not address lane changes.

The TTI approach seems to be based on an assumption that platoons are unique traffic participants presenting a set of risks. With regard to Level 1 DATP systems, industry players (tech developers and freight carriers) would likely make the case that the drivers in both vehicles will be well trained to assess conditions (traffic, weather, etc.) and make reasonable choices as to whether to engage / continue platooning; in essence, the operational factors of the vehicle – other than following distance -- are not significantly different than for trucks on the roads today. Given the wide variety of dynamic conditions on public highways, it could be quite difficult to implement a comprehensive set of prescriptive measures as laid out in the TTI study. For instance, to "disengage in a work zone" does not address the wide variety of work zones, some of which would be relevant to a platooning disengagement decision, whereas others would be benign. As another example, restricting platooning based on spacings between ramps alone does not take into account traffic volumes – which is the core issue; if traffic is light, ramp spacing does not play an obvious role. Lastly, some of the issues raised here become more acute with platooning at higher levels of automation and/or longer platoons.

II.G.iii. Understanding the Critical Role of Connected Braking in Safe DATP Operations

Understanding Connected Braking is fundamental to understanding how DATP can be implemented within acceptable safety bounds. The TMC Information Report provides this explanation (TMC Information Report, 2015):

> "The value of electronic coupling is illustrated conceptually in Figure 4, in which the horizontal axis is time. The top example depicts the braking process in which the following driver is performing the braking with no assistance. When the front truck

brakes are applied, actual braking occurs after some lag. The following driver takes time to perceive and react to this to apply the rear truck brakes, which also occurs after some lag. The middle example shows the lags in an automated system without V2V. The sensor in the rear truck only becomes aware of front truck braking after braking actually occurs, some time after the front driver has initiated braking. Perception and reaction time to automatically brake is required here as well, but it is very quick compared to a human driver. Thus, safe following distances can be reduced compared to a human driver. The advantage of V2V-based platooning is shown in the bottom third of the chart. Because brake application on the front truck is communicated instantly to the rear truck, very little time elapses between brake initiation on the front and rear trucks. This enables the much smaller inter-vehicle gaps which provide fuel economy gains due to drafting."

Peloton Technology provides a video on their website illustrating the above concepts. The video shows their DATP system maintaining the inter-vehicle gap during "extreme braking" by the lead vehicle from highway speed down to a stop, on a closed test track (Peloton Technology, "For Drivers," 2017). The company further notes that reaction time with connected braking is reduced from approximately 1.5 seconds to approximately 0.1 seconds.

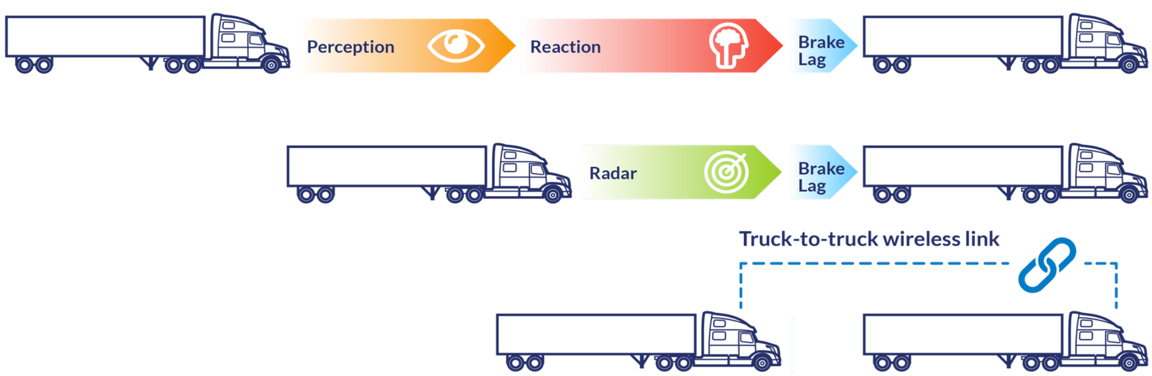

Figure 4: Brake Application Timing w/ Coordinated V2V Operation
(Source: Peloton Technology)

Insight into Peloton's commercial product is provided in their General Plan for Platooning submitted to Michigan DOT (Peloton Plan, 2017), as follows:

"The System consists of software and hardware developed by Peloton and integrated with commercial third-party technologies, including vehicle-to-vehicle (V2V) and vehicle-to-Internet cloud (V2C) communications devices and radar-based collision avoidance systems (CAS).

Each Truck in a platoon is equipped with a commercial radar-based [FCAM] for heavy trucks, e.g. Bendix Wingman® Fusion™ or WABCO OnGuard ACTIVE™. For purposes of the System, important common features of these [FCAM] include: (a) automatic emergency braking (AEB), which enables both Trucks to brake rapidly and in coordination in response to a vehicle cutting in front of the Lead Truck (Cut-off Vehicle), and enables the Follow Truck to brake rapidly in response to a vehicle cutting in between the Trucks (Cut-in Vehicle); and (b) adaptive cruise control (ACC), which a Driver of the Lead Truck in a Platoon may use to regulate its speed automatically. In addition, the System is integrated with the stock front-facing radar, or radar and camera, sensor(s) of the CAS on a Truck. The CAS is active whether a Truck is operating in or out of a Platoon."

The EPTC Stakeholder Consultation process identified platooning sequencing – accommodating trucks with various torque ratings, brake capacity, and loading weights – as an additional important factor (Rijkswaterstaat, 2016). At least one platooning developer, Peloton Technology, has stated plans for ordering trucks in a platoon according to these factors to maximize safety (Peloton Technology, 2017).

The FHWA-funded Caltrans project on truck platooning Concept of Operations (Nowakowski et al., 2015) examined approaches to determining which truck should be in the lead in a platoon. They considered and discussed the following three alternatives:

a. "The lead truck assignment could simply be determined according to the initial location. Whichever truck happens to be in front or furthest ahead along the roadway defaults to the lead truck.
b. The lead truck assignment and subsequent truck ordering could be determined based on the truck attributes of engine performance, weight and braking performance, or aerodynamics.
c. When it comes to stopping the CACC string, placing the trucks with the worst braking performance up front will increase safety, but in terms of overall efficiency, it may make sense to place the most aerodynamic vehicle in front. An argument can also be made to order the trucks from lowest to highest engine power to total mass ratio (including tractor, trailer, and load), so that the lead trucks can't pull away from the following trucks when accelerating or on hilly terrain."

When it comes to reacting to other traffic, the primary action comes from the FCAM technology, which forms the foundation of DATP systems. As the NACFE Confidence Report on Platooning (Roeth, 2016) notes, "A commonly cited concern is how the platooning trucks and the individual drivers will react if passenger cars move into the gaps between platooning trucks to get out of a passing lane or get to a highway exit ramp. However, each vehicle's active safety systems would react exactly as they would if a vehicle cut a single truck off in traffic today: The brakes would immediately engage and slow the truck until it achieves a safe following distance behind the intruder vehicle. Likewise, any trucks behind the threatened truck would react accordingly."

A recent NHTSA study (NHTSA, 2016) which examined today's traffic concluded, "Collision Avoidance System activations generated prior to a safety critical event were most likely a result of lead vehicle actions, such as braking, turning, switching lanes, or merging. This finding is corroborated by research that found 78% of light-vehicle and heavy-vehicle conflicts are instigated by light vehicles around the heavy vehicle (Hanowski et al., 2007)."

Nowakowski (Nowakowski et al., 2015) notes a critical safety situation unique to the "team driving" concept that will occur with DATP operations:

> "If there is a stopped car or obstruction in the roadway, the lead truck cannot simply change lanes to avoid the hazard because doing so will surprise the following trucks' drivers, and the following truck drivers may not have enough time to act appropriately.
>
> Given that the forward vision of the following trucks in a CACC string will be obscured or occluded, the lead truck driver in a CACC string will have some increased responsibility, especially in terms of scanning the roadway and traffic ahead for hazards.
>
> In the longer term, the CACC DVI will need to incorporate an ability for the lead truck driver to communicate simple commands or hazardous conditions ahead to the following trucks. For example, if the lead truck driver decides that the CACC string should change lanes, then there needs to be a clear way to communicate that instruction to the following drivers; otherwise, the following drivers won't know whether the lead truck wishes to continue to be the lead truck, just in a different lane, or wishes to exit the string."

The basic point is valid regarding a stopped vehicle ahead. However, an emergency lane change can be dangerous. The assertions from Nowakowski do not take into account the support provided by FCAM systems. Nevertheless, in DATP operations, in-lane deceleration will be preferred over sudden lane changes in these cases of stopped vehicles or debris ahead. When somewhat more time is available, inter-vehicle voice communications by drivers could provide time for a safe lane change.

With regards to cut-ins by other vehicles, the Caltrans Concept of Operations (Nowakowski et al., 2015) also concluded that:

> "the platooning system needs to be designed to automatically handle a cut-in by splitting the string and commanding the new lead truck, directly behind the cut-in, to fall back to a longer ACC gap setting and following strategy. Once the unequipped vehicle departs the lane, the CACC system can automatically re-join the two split strings and close the gap. How well the implemented CACC system can automatically handle the cut-in will depend on the field of view of the forward sensors on the trucks and the quality of the target tracking algorithm. A wider field of view will result in the detection of the cut-in vehicle sooner, resulting in a smoother transition to the longer gap settings, while a narrower field of view will result in later detections and more abrupt transitions. In either case, the driver will still be responsible for monitoring for cut-ins and disengaging the CACC system through manual braking should the system fail to respond appropriately."

Regarding this view, we would observe that having an additional wide field of view sensor to detect cut-ins is only one of several approaches to safe handling of cut-ins; i.e., a technological one. Another approach is to rely on an attentive driver to act to dissolve or lengthen the gap of the platoon; e.g., by initiating braking, when they detect a cut-in is impending, with a radar-based FCAM system serving as an automated back-up to the driver's customary role in detection; this could be bolstered by DATP-specific driver training.

Tennessee DOT (TnDOT, 2017) provides a succinct summation of connected braking, as follows:

> "From a safety standpoint, the constant monitoring and updates among the vehicles in the platoon, estimated at 50 times per second, reduces the impact among vehicles in case of a crash and provides reaction times much faster than humans."

II.G.iv. Functional Safety for DATP

Within the automated vehicles domain, functional safety refers to the ability for an AV to handle hardware or software failures in a safe manner. The focus is generally on cases where control cannot be handed back to a human driver. In DATP, a professional truck driver is engaged in the driving task (steering and monitoring) and can resume longitudinal control at any time.

Functional safety for light vehicles is defined by ISO 26262-1:2011, which "is intended to be applied to safety-related systems that include one or more electrical and/or electronic (E/E) systems and that are installed in series production passenger cars with a maximum gross vehicle mass up to 3 500 kg. ISO 26262 addresses possible hazards caused by malfunctioning behaviour of E/E safety-related systems, including interaction of these systems" (ISO, 2011). A version of ISO26262 focused on heavy trucks has not been created; however, the standard can be adapted to some degree to this type of vehicle. For instance, Peloton notes that integration of their software and hardware with third-party vehicle systems is designed and tested in accordance with ISO 26262 (Peloton Platooning Plan, 2017).

If the driver has control over the inter-vehicle gaps, the DATP system may implement a minimum following gap, disabling the accelerator pedal beyond this point (Nowakowski et al., 2015). In the Peloton system, the gap is not set or maintained by drivers; instead this is controlled by the system.

II.G.v. DATP Potential Benefits

Fuel Savings

The primary motivator for industry investment in DATP is in the potential for fuel savings. The TMC Information Report (TMC Information Report, 2015) provides a perspective on the importance of fuel use within the trucking sector, noting that "long haul trucking alone represents more than 10% of US oil use, with fuel representing 38% of fleet operating expenses. Trucks are only 4% of the vehicles on the road but consume 20% of transportation fuel. To illustrate this, in 2013, trucking consumed more oil than the U.S. imported from the Persian Gulf." At highway speeds, aerodynamic drag is responsible for over 60% of fuel use (National Academy of Sciences [NAS], 2010), and thus the drag reduction due to close following has a significant translation to fuel savings.

The NCHRP CV AV report (Fitzpatrick, 2016) provides an excellent summation of recent evaluations of platooning fuel economy benefits (Table 4). Based on a broad survey of the various tests (all in test track or protected lane environments), results show savings of roughly 4-6% for the lead vehicle and 8-10% for following vehicles. Testing has been performed and reported by:

a. National Renewable Energy Laboratory (NREL) (Lammert et al., 2014)
b. California Partners for Advanced Transit and Highways (PATH) (Browand, 2004)

c. Federal Highway Administration (FHWA) (Humphreys et al., 2016; Auburn University, 2016)
d. North American Council for Freight Efficiency (NACFE) (Roeth, 2013)
e. Japan Ministry of Economy, Trade, and Industry (METI) (Tsugawa, 2012)
f. Safe Road Trains for the Environment (SARTRE) (Davila, 2013)

Test, Year, and Country	Example of Reported Savings for Lead Truck (%)	Example of Reported Savings for Following Truck(s) (%)	Notes
FHWA/Auburn test, 2015, U.S.	2.0	10.2	Peloton [developmental] system run on test tracks; driver steering; results shown for 65k lbs Gross Vehicle Weight, 50' following distance and platoon speed of 65 mph
NREL test, 2014, U.S.	3.1	9.2	Peloton system run on test tracks; driver steering; results shown for 65k lbs Gross Vehicle Weight, 50' following distance and platoon speed of 65 mph
NACFE test, 2013, U.S.	4.5	10.0	Over-the-Road (OTR) tests on Utah I-80 of 2 fully loaded trucks, using Peloton system and with driver steering; results shown for 36' following distance and platoon speed of 64 mph
SARTRE test, 2012, E.U.	~ 4.8	~ 9.5	2 Volvo trucks run on test track; results shown for 12 m gap and platoon speed of 84 km/h
"Energy ITS" Project, 2010, Japan	7.5	17.0	3 truck tests on flat expressway, empty-loaded; automated steering; results shown for 10 m gap and platoon speed of 80 km/h
PATH, 2003, U.S.	6	10	2 empty-loaded trucks; 10 m gap and platoon speed of 55 mph

Table 4. Comparisons of Fuel Consumption Savings Measured in Selected Platooning Tests (Fitzpatrick et al., 2016).

The study concludes that "though direct comparisons are impossible due to differences in the tests' operating characteristics, there does appear to be a level of consistency in the general magnitude of savings due to platooning." At the same time, they note several factors that will affect fuel economy in a real-world platooning operation:

a. Headway between trucks
b. Number of trucks and position of the truck within the platoon
c. Truck geometry ("nosed" cabs versus "cab-over")
d. Lateral offset of the trucks
e. Operating speed
f. Vehicle weight

The evaluations performed under the FHWA-Auburn study of DATP (Bevly et al., 2017) (listed in the first row of Table 4) deserve special attention, as these vehicles were most strongly aligned with the definition of DATP in the Florida statute. In addition, in comparison to other testing done over recent years, the Peloton prototype DATP systems used in this project incorporated significant engineering aimed at commercialization (however, these were still developmental systems, not mature products).

Although standardized fuel economy test protocols have yet to be developed, these tests were conformed to the (1986) Joint TMC/SAE Fuel Consumption Test Procedure - Type II, J1321, within the context of platooning. The vehicles and standard 53-foot trailers were transported to the Transportation Research Center (TRC) in Ohio in August 2015 for controlled fuel economy testing. Testing was performed at following distances of 30ft, 40ft, 50ft, 75ft, and 150ft. These distances were chosen to correlate with the predicted trend (in simulations conducted by Auburn) between vehicle separation and drag reduction. Tests were conducted utilizing late model Peterbilt 579 tractors with full aerodynamic packages and Smartway-compliant, 53-foot trailers loaded to a total weight of 65,000 lbs, operating at 65 mph. The results from the test are presented in Figure 5.

> While track testing found the peak team (two-trucks) fuel savings was 6.96% at 30 feet, typical commercial operations of DATP systems are expected to operate in the range of 50-75 foot following distances due to driver comfort and public acceptance. -- Auburn University DATP Study funded by FHWA

The peak team (two-trucks) fuel savings was 6.96% at 30 ft, while the peak following truck fuel savings was found to be 10.24% at a following distance of 50 ft. The report noted that "typical commercial operations of DATP systems are expected to have minimum allowable following distances to be in the range of 50-75 ft due to driver comfort and public acceptance. Longer following distances of around 75 ft could be utilized during adverse traffic or weather conditions and still yield fuel savings of 10.11% for the following truck and 5.59% average for the team." The Auburn team concluded that that "the DATP system provides a significant net improvement in fuel savings. "

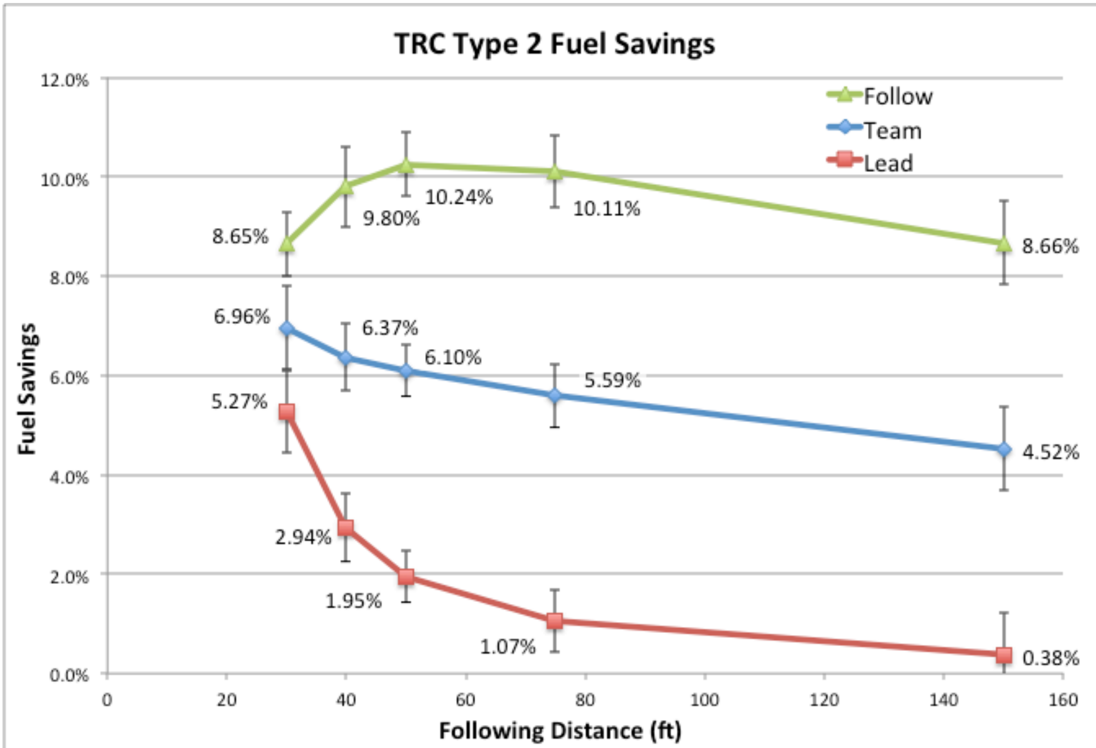

Figure 5: Percent Fuel Saved from TRC Type II Fuel Economy Testing (Bevly et al., 2017)

Test track evaluations are an indication of maximum benefit under controlled conditions. In their Confidence Report on Truck Platooning (Roeth, 2016), NACFE then took a next step to estimate fuel economy performance that might be obtained from DATP operations in real traffic. The Report aimed to "provide an unbiased overview of the benefits and challenges related to platooning; and help fleets rationalize their investment in two-truck platooning."

Noting the many fuel consumption evaluations of truck platooning conducted in recent years, NACFE took into account real-world factors that could degrade fuel savings. These included congestion, terrain, weather, and road construction unique to a particular route. NACFE estimated these factors to reduce fuel economy benefits by about 25%, but noted that "very little data exists for this prediction." NACFE then addressed the percentage of operating time that the truck equipped with platooning would actually travel in platoon mode; this would be less than 100%. They then assumed that if platooning-capable trucks platooned 75% of the time, then the real-world, expected savings would be on the order of 4% average for both trucks. However they noted that "even if a truck is platooning 50% or less, it still represents significant potential improvement in fuel use for the following vehicle in a platoon."

To assess the degree to which surrounding traffic may affect platooning fuel economy benefits, NACFE researchers referred to the results of the NHTSA Field Study of Heavy-Vehicle Crash Avoidance Systems (NHTSA, 2016). This study collected Collision Avoidance System (CAS) data from 169 drivers operating 150 CAS-equipped trucks over a one-year period, involving seven fleets and three million miles. It found that the truck drivers averaged between 2.4 to 2.8 seconds time headway at highway speeds. Those headways translate to separation distances at 55 mph of 194 to 226 feet, or about three truck lengths.

At 75 mph that translates to 282 to 308 feet, or about four truck lengths. Based on a subset of drivers/trucks using ACC, the study concluded that CAS following distance alerts (causing ACC to deactivate) occurred at a rate between 4.3 and 7.2 times per hour. NACFE used this result as a basis to make their "time while platooning" assessment, noting that "the amount of time a platooning group is operating in a steady state conditions varies, possibly considerably, from controlled track test results." And, the NHTSA study results "indicate that vehicles outside of the platooning group may significantly interfere with steady state platooning."

The European COMPANION project conducted physical testing for two- and three-truck platoons. For a two truck platoon, the follower vehicle saw fuel consumption reductions of approximately 6%-8% across gaps varying from 10-20 meters at speeds of 70 kph and 80 kph (Companion, 2016).

The Dutch research group TNO published an extensive study on two-truck platooning in early 2015 (Janssen et al., 2015). The authors note that the political and economic climate there is positive for a broad deployment of platooning; initial legislation changes have already been proposed to allow testing and experimentation on Dutch roads.

Using rough estimates for system cost and costs of service providers, maintenance, and driver training, they performed a case study based on typical operations of two specific over-the-road fleets operating in the region. The fuel savings were much greater than the costs; both Fleet A and Fleet B saved approximately $14,000 per truck per year. They also calculated savings for a "one-driver" platoon, in which a driver is not needed in the follower truck. Although beyond the scope of this DATP-focused study, the results in terms of overall cost reductions are compelling: $36,000 per truck per year for Fleet A and $21,000 per truck per year for Fleet B.

Emissions Benefits

Compared to fuel economy studies, less work has been focused on related emissions improvements. The Japanese Energy ITS project (Tsugawa, 2012) used a simulation to estimate the CO2 emission reduction potential with platooning. The simulation scenario was a Tokyo region expressway populated 31% by heavy vehicles of which 40% were platooning. The simulation found that, for platoon gaps of 10m (in the range expected for first generation commercial DATP) and vehicles traveling 80 km/hr, emissions were reduced by 2.0%. The emission reduction rose to 3.5% when the gap was decreased to 4m (much close than that expected for first generation DATP).

Daimler notes that their Highway Pilot Connect platooning system lowers CO2 emissions by about 5% percent with an inter-vehicle gap of 15 meters (50 feet) at 80 kph (50 mph) (Daimler, 2016).

Safety Benefits

Tennessee DOT (TnDOT, 2017) addresses safety benefits of DATP as follows:

> "The constant monitoring and updates among the vehicles in the platoon, estimated at 50 times per second, reduces the impact among vehicles in case of a crash and provides reaction times much faster than humans."

The EPTC Stakeholder Consultation noted that road safety at the level of top-safety-performing EU countries as a key goal, based on safe and reliable braking behavior in emergency situations. The conclusion regarding safety from the EPTC team was as follows (Rijkswaterstaat, 2016):

> "Truck platooning has the potential to increase traffic safety by reducing the number of head-tail collisions due to the ACC and/or emergency braking functionality. This applies both to the actual platooning trucks and between platoons and preceding traffic. No changes are expected for traffic following the platoons. The safety effect is even greater for platooning trucks, as the fact that they are connected enables a faster mutual reaction. Moreover, improved compliance with speed limits – as is the case with platooning trucks – also increases traffic safety."

The NCHRP Truck CV AV report (Fitzpatrick, 2016) provides a useful summary of the safety benefits relating to DATP, quoted here as follows:

> "Safety Benefits. Truck platooning holds a promise of improving safety through the reduction in frontal collisions, the most common highway accident type for heavy trucks in the U.S. Additional testing is needed to both validate this assertion and look more holistically at how highway safety might be affected by platooning deployments. Conceptually, the automated control of a truck's movements, whether lateral control is included or not, should reduce accidents as the driver reaction time is eliminated as a concern. Even if the platooning function is not engaged in a platoon-ready truck, the radar and CV technologies can at least shorten the driver awareness of a situation. Improved safety affects a business case via higher system productivity and fewer injuries and damage costs."

Current FCAM products provide automated braking in a potential collision situation. Thus, even if the driver is not responsive, the vehicle decelerates automatically to either avoid a collision completely or greatly reduce the energy if a collision occurs. (The energy in a collision is calculated by the square of the relative speed. Therefore, if speed is reduced by X, the energy in the crash is reduced by X^2.)

The NCHRP Truck CV AV report (Fitzpatrick, 2016) also makes several statements that the authors of this study feel are unsupported or incorrect based on the broader body of literature. Since this report has been published by the National Academy of Sciences Transportation Research Board, it is valuable to discuss the points made and provide a rebuttal here; Appendix C provides further detail. The report makes the following statements:

> "Adoption of automation technologies will create mixed traffic situations where drivers in non-automated vehicles are next to platoons of heavy vehicles with short time headways. Although truck automation promises to improve safety issues at full market penetration, it may adversely affect the safety of non-automated vehicles under mixed traffic conditions consisting of both human driven vehicles and automated vehicles especially trucks. In addition, driver behavior will be impacted while operating in a mixed CV and AV environment. For example, drivers in the vicinity of platoons may demonstrate behavioral adaptation by reducing their own time headways (Gouy et al., 2014). Therefore, transitional periods of technology adoption may decrease safety for conventional vehicles. The expectation for zero fatalities is unrealistic for any type of self-driving vehicle (Sivak and Schoettle,

2015) due to reasons such as mechanical failure or software failure. Such incidents, if they occur, may result in more fatalities involving heavy vehicles."

Discussion

a. As a general comment on this excerpt, these broad statements seem to emphasize only negative, as opposed to net, safety outcomes based on a generic form of automation during the transitional period. It is certainly true that crashes can still occur with automated systems, however these outcomes must be compared to today's outcomes with only human responses (this comparison is neglected, for example, in the assertion that incidents caused by truck automation "may result in more fatalities"). Plus, system developers are strongly focused on fail-operational and fail-safe designs, including functional safety, as part of the commercialization process. In Level 1 DATP in particular, a human driver is always in the loop. All that can be said at this time is that safety outcomes are an unknown, but with recognition that significant engineering and testing is underway to create a net safety benefit.
b. Regarding the statement that truck automation "may adversely affect the safety of non-automated vehicles under mixed traffic conditions consisting of both human driven vehicles and automated vehicles especially trucks" – this is an unsupported speculative statement.
c. "driver behavior <u>will be</u> impacted while operating in a mixed CV and AV environment." -- The referenced Gouy et al. study provided interesting insights regarding shorter headways adopted by drivers adjacent to platoons, but it is not definitive enough to make this "will be" statement. The Gouy et al. study team noted that "further work needs to investigate whether behavioral adaptation of non-platoon drivers to short time headways in platoons is the result of a combination of social and perceptual mechanisms or if one of the mechanisms is predominantly influencing behavioral adaptation. Trucks were selected in this study as their salience was meant to increase the visual attention directed to the platoons. However, drivers are perhaps more likely to reproduce behavior from other drivers that are similar to themselves. Therefore, the employment of cars to form platoons actually enables to investigate the social mechanisms of behavioral adaptation of non-platoon drivers whereas trucks enable to investigate perceptual mechanisms. Further work is required using this factor to investigate the underlying mechanisms of behavioral adaptation of unequipped vehicle drivers to short time headways."

To bolster the above discussion, the TMC Information Report (2015) notes that:

> "Today, truckers experience other vehicles on the highway cutting them off, requiring immediate braking by the driver (or automatic braking systems). In platooning, these 'cut-offs' from other vehicles ahead of the lead truck can still occur. Plus, passenger car drivers may 'cut-in' between two platooning trucks. The system must adapt to both situations to maintain safety.
>
> Cut-offs and cut-ins by passenger vehicles are unfortunately a too common scenario in highway operations. DATP often builds on radar-based Adaptive Cruise Control (ACC), which has been in use by the trucking industry for almost a decade, as well as more recent collision mitigation systems (CMS) which aggressively brake in a situation in which the truck may strike the rear of an encroaching vehicle. Thus, ACC/CMS systems assist the truck driver in braking as quickly as possible to a cut-in vehicle with a speed differential that may cause a forward collision.

> Due to the laws of physics, not all collisions can be avoided but these systems can at least reduce the energy in a crash that is unavoidable. A 'safe' DATP system should therefore be viewed as one which responds to a developing crash situation as quickly as possible (and significantly faster than a human driver could) to either avoid the crash or slow the vehicle speed to reduce the energy in a crash.
>
> Relative to the use of today's Adaptive Cruise Control, the potential for a near-crash or crash due to passenger vehicle cut-offs or cut-ins does not change with platooning; however the potential of cut-ins may be somewhat reduced due to the closer spacing between trucks. At the same time, a passenger car that does choose to cut-in between two platooning trucks [could create] a safety critical situation. Analyses should be conducted to estimate the likelihood of such events for various platooning following distances. Initial results from a DOT study (Nodine, et al., 2016) indicate that cut-ins by passenger vehicles are uncommon with inter-vehicle distances of 100 feet or less. "

Interestingly, the definition of "optimal" headways in a platoon can vary. As the EPTC Lessons Learned document (Rijkswaterstaat, 2016) notes, "There is a difference between vehicle safety and traffic safety. From the vehicle safety angle, one could argue that a wider distance between two platooning trucks is better. Meanwhile, from the traffic safety angle one could also argue that overly long distances increase the number of cut-ins by other traffic, including by other trucks. This disrupts the traffic flow and can have a negative impact on traffic safety, as was observed in various situations during the Challenge."

Traffic Benefits

The EPTC Lessons Learned document (Rijkswaterstaat, 2016) noted that less frequent decoupling by platoons increases the stability of traffic flow, and enhances throughput. Additionally, platoons can better utilize existing road capacity if headways are shorter than with non-equipped trucks.

The TNO Study (Janssen et al., 2015) also notes that platooning will allow a more optimal use of the available road capacity. In a typical scenario, they calculate that two trucks platooning at a .3 second gap (9m at 60 mph) would decrease the length of those two trucks by 46%, from 82 to 44 m. Thus, the amount of road space taken by the two trucks is essentially halved.

The NCHRP Truck CV AV report (Fitzpatrick, 2016) notes that road capacity utilization would likely improve, but the level of improvement is not known. The authors posit that "in conditions where a road is approaching capacity, there may be traffic flow improvements due to the predictability and reduction in the inter-truck gaps."

Researchers at the Technical University of Delft (Calvert et al., 2017) performed an extensive evaluation of platooning operations in traffic using simulation. Their results are not conclusive; they note that true effects on traffic flow "remain unclear" (for a deeper understanding, they propose extensions to traffic simulation software beyond those done for the study). A portion of the Trans-European ITS Corridor was used for the simulation. The effects of truck platooning were assessed across various traffic states, truck gap settings, platoon sizes, and the on-road penetration of equipped trucks. Results addressed the total traffic performance, the performance of traffic at interchanges, and the ability of a platoon to remain platooning (i.e., not interrupted by non-platooning vehicles).

Simulation results indicated that:

a. platoon gap settings did not significantly affect the merge time, while a higher gap led to a higher number of disengagements
b. the ability of trucks to platoon was positively affected by a greater percentage of equipped trucks and by larger platoon sizes
c. shorter gap times slightly improved the ability of trucks to remain in platooning formation

Regarding traffic effects, the TU Delft study concluded:

> "Truck platooning was found to have a small negative effect on traffic flow performance. However, the effect may be considered marginal and acceptable. However, the negative effect for near congested or congested traffic flow was large and therefore a strong recommendation is made to not allow truck platooning under these traffic states, unless a relevant or specific algorithm is applied. However, there is little relevance to allowing truck platooning in congestion as the main emission and energy consumption effects are not present. Such a restriction on truck platooning may be achieved by not allowing truck platooning within certain peak periods on specified corridors in which congestion or very busy traffic could be present. Furthermore, restricting truck platooning below a certain traffic speed may also be considered in cases of unexpected congestion.
>
> A final recommendation considers platooning strategies. As far as this research can validly comment on platooning strategies, we find no substantial concerns in allowing truck platoon sizes of two or three trucks, or allowing gap settings between trucks in the range of 0.3-0.7 seconds in regard to the traffic flow. However, further considerations will obviously be required regarding safety of such strategies."

Benefits Summary

The TNO team provided a useful summary of overall benefits; see Figure 6. Fuel economy testing conducted by both private entities and government agencies shows clear benefits, while the TU Delft simulation study supports the general conclusion of "traffic optimization" shown in the figure (or at least minimal traffic disruption). There are various discussions of safety impacts of platooning in the literature; the most concrete conclusion is the benefits that come from platooning systems working in tandem with FCAM systems, for which safety benefits have been shown to be significant.

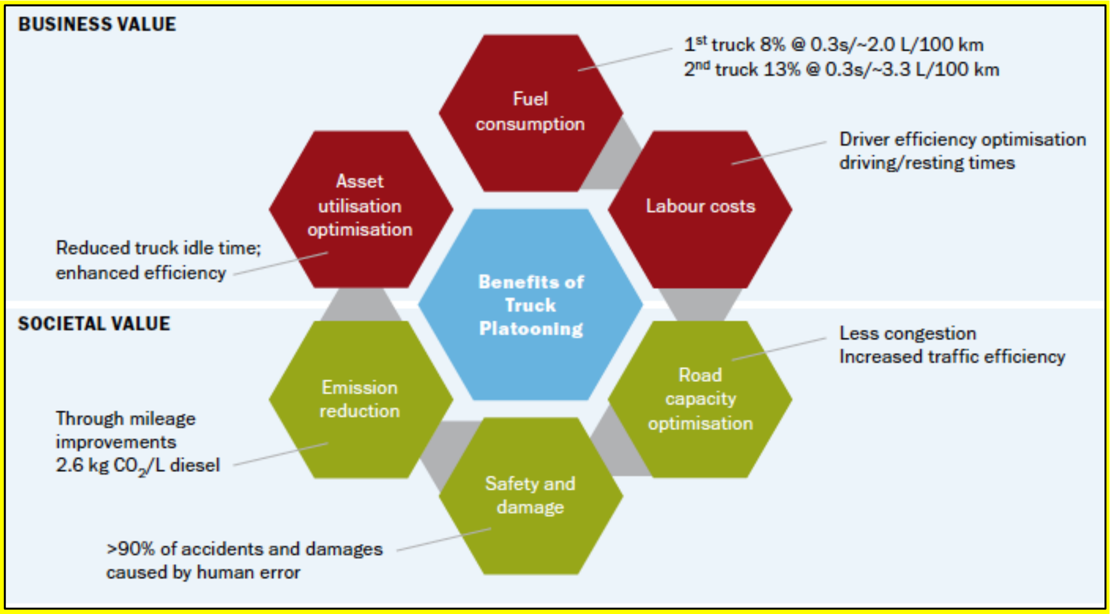

Figure 6: TNO Summary of High Level Truck Platooning Benefits (Janssen et al., 2015).

II.G.vi. DATP Operational Factors

Platoon Formation

Platoon Formation: Strategic Level

Approaches to DATP pairing have been modeled by researchers and developed by platooning providers. Fleets may have to establish the rules of engagement, and/or inter-fleet platooning could be arranged spontaneously using either V2V or cellular communications. The process has to be done in such a manner that the route, logistics, and safety are not compromised.

The EPTC Stakeholder Consultation (Rijkswaterstaat, 2016) identified these factors as key:

a. identifying and guiding trucks that could meet up together to dynamically form an ad-hoc platoon
b. deciding on the best method of platoon formation: scheduled or ad-hoc platooning or a combination of both
c. using real-time data logistics “control towers” for ad-hoc platoon formation, possibly in the form of a platooning service provider to execute platoon formation from differing fleet-owners and brands

To maximize benefits, the TNO platooning study (Janssen et al., 2015) introduced the concept of a Platooning Service Provider (PSP) to support ad hoc formation of platoons. The PSP would help platoon partners find one another on the road, as well as certify participants:

> “For on-the-fly platooning it is not necessary to know exactly where your platoon partner is going. However, for reasons of safety and trusting your platooning partner – especially if you are the driver of the Following Vehicle – you might want to know where your platoon partner is going, whether the leading driver took the

required rests, and whether the Leading Vehicle is in good mechanical condition and is properly maintained. PSPs can establish quality schemes such that truck drivers can have the confidence that on-the-fly platoons are only formed with 'trusted partners'. The PSPs also deal with administrative duties from the platooning activities, arrange insurances, and make sure that benefits of platooning are distributed fairly among the platooning partners."

Peloton Technology, in preparing their DATP system for commercial use, has defined a Network Operations Center much like the TNO concept (Peloton Technology, 2017). Peloton describes their approach as follows:

"How do trucks form a platoon?
For scheduled platoons, the Network Operations Center (NOC) assists fleets in planning for and dispatching pairs of trucks together. For ad hoc linking, the NOC matches trucks with potential platooning partners within the same or other equipped fleets by forward-projecting their location based on current speed and heading or planned route. To form a platooning link, a driver requests to pair with a potential partner. When the other driver agrees, the drivers bring their trucks to within linking range. When potential linking partners are identified and before the truck-to-truck link is engaged via DSRC, the NOC must authorize the link based on several safety parameters. The NOC also informs drivers of how the trucks must be ordered based on their relative real-time braking abilities, which depend on vehicle specs conditions as well as cargo load.

How do trucks separate from a platoon?
During platooning operations, trucks are monitored continuously by the NOC to ensure appropriate operating conditions. The platooning link will automatically be disengaged if conditions move outside acceptable parameters, resulting in a smooth separation between the trucks. The system will automatically move the trucks farther apart when it recognizes a vehicle cutting in between them -- and will then draw the trucks back together once they are clear of the cut-in risk. Drivers also maintain discretion to disengage the link and separate the trucks at any time.

Do truck platoons get in the way of traffic?
Before two trucks form a platooning link, the NOC must authorize the platoon based on several safety parameters. For starters, platooning only occurs on multi-lane divided highways, ensuring that traffic will always have the opportunity to pass the platoon. The Peloton system's forward radar also allows the platooning trucks to recognize vehicles cutting in between the trucks, for example, to exit the highway. To make way for cut-ins, the following distance between the trucks is increased and then reduced again once the trucks are clear of the other vehicle.

Is platooning safe in bad weather?
In addition to the type of highway traveled by the trucks, the NOC also accounts for driver, vehicle, road and weather conditions before authorizing two trucks to form a platoon."

Within the FHWA-Auburn study (Auburn University, 2015), the research team performed a detailed analysis of the potential likelihood of pairing opportunities under the FHWA-sponsored truck platooning project. The case study analyzed truck fleet data (individual truck locations recorded over an eight-day period along a 300-mile section of Interstate 94 in North Dakota) to determine the impacts of platoon formation on several key metrics, including the number of platoons that may be formed from historical truck routes, the maximum size of any platoon formed, and the total time lost as a result of trucks slowing down to form a platoon. The analysis assumed that all of the trucks in the datasets were platoon eligible.

Auburn researchers developed optimization algorithms that determined which trucks should join to form a platoon, given the starting location of each truck. A core research question addressed the relative likelihood that trucks would be able to find platooning partners, given typical distributions of within-fleet trucks on highways. This analysis found that formation of two-truck platoons among platoon-eligible trucks was between 30%-45% depending on the fleet. Further, trucks forming two-truck platoons in these datasets traveled within a platoon between 30-75% of the distance of the 300-mile road segment, on average.

Researchers within the COMPANION project developed an algorithm for coordinated fault-tolerant real-time scheduling of platoons (Companion, 2016). The system takes in cab/truck route information like start and end positions and desired arrival time. Fuel efficient routes are determined and potential pairings of trucks are identified. The algorithms provide optimal routes for pairings as illustrated in Figure 7. The figure shows a road network and start-stop points (and starting times) of trips for individual trucks. The trucks in the simulation embark from different locations but at some point their routes and positions align, creating the opportunity for platoon pairing for a portion of the trip.

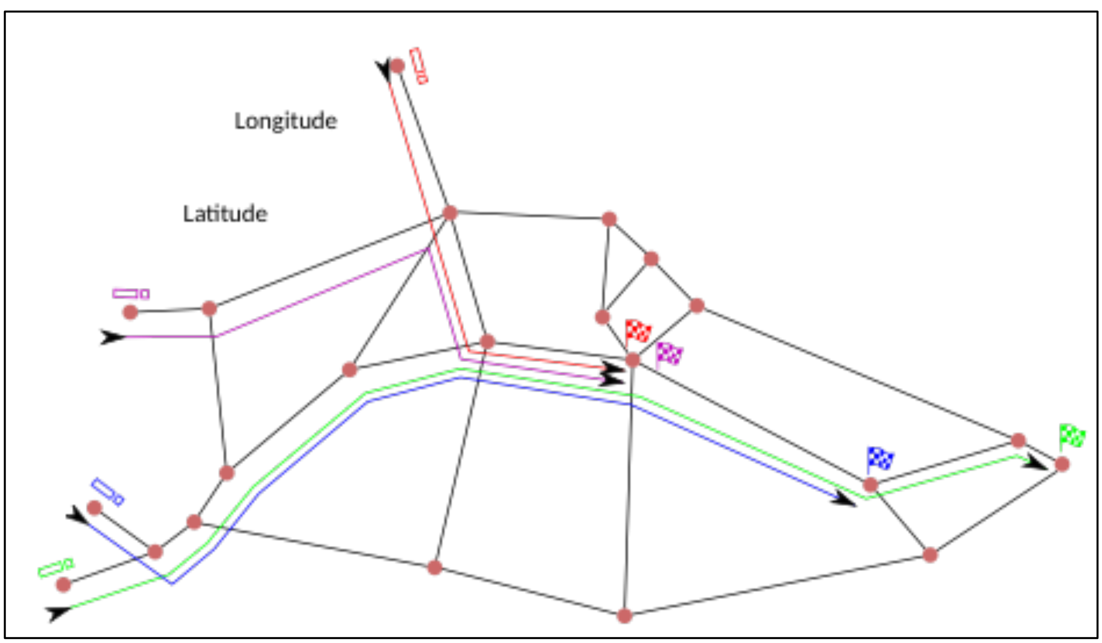

Figure 7: Example Result of Platoon Pairing Algorithm (Companion, 2016)

The NCHRP Truck CV AV Report (Fitzgerald, 2016) also addresses the issue of platoon formation. They note that "early adopters are likely to be operators with large fleets and a degree of predictability to their routes. Such adopters will have ultimate control over the protocols used to form and dissolve platoons. There is an added layer of complexity if or when operators decide to permit platooning with other fleets." The report goes on to discuss the issue of truck ordering in platoons as follows:

> "A vital consideration in formation is the ordering of the trucks. Because trailing trucks enjoy greater benefits (from fuel savings), this becomes a business issue that requires deliberate processing. More importantly, the ordering could be a safety issue if a trailing truck has a longer braking distance than a lead truck. Factors affecting braking distances, such as brake maintenance status and trailer loadings, are a challenge to reliably measure in an operational environment."

As noted above, Peloton Technology addresses this issue by requiring the truck with the best braking ability to take the rear position in the platoon, as one aspect of reducing risk (Peloton Technology, 2017).

If both trucks are part of the same fleet, disparities in fuel economy benefits are not an issue. If the two trucks come from different fleets, interviews with trucking fleet executives (Auburn, 2017) have indicated that this is not a concern because "the benefits will be redistributed in the back office."

Platoon ordering is one of the many reasons that "managed platooning" is valuable versus an ad hoc approach of one truck virtually connecting to another at will. This is feasible technically but does not satisfy requirements such as placing the truck with the best braking in the rear, nor does it address the trust factor – each truck driver (and the fleet owner and the cargo owner) will want to be assured that the other driver is well trained with a good driving record and that the vehicle is well maintained.

Platoon Formation: Tactical Level

At the tactical level, Peloton describes the process of forming a platoon (Peloton Plan, 2017). This occurs when

> "1. the System's NOC provides a pair of Trucks with Safety Approval to form a Platoon; *and*
> 2. while the Safety Approval is valid, the Driver of the Lead Truck manually acts to approve formation of the Platoon via the System's dashboard-mounted manual HMI controls; *and*
> 3. while the Safety Approval is valid, the Driver of the Follow Truck manually acts to approve formation of the Platoon via the System's dashboard-mounted manual HMI controls."

Similarly, Peloton notes that a truck platoon dissolves when:

> "1. Safety Approval expires or is withdrawn by the NOC; or
> 2. the Driver of any Truck in the Platoon manually acts to dissolve the Platoon via the System's HMI controls; *or*
> 3. the Driver of the Follow Truck overrides longitudinal motion control by the System by manually applying the Truck's throttle or brake controls; *or*
> 4. any Truck in the Platoon (a) detects a System failure, e.g. excessive latency or insufficient throughput of V2V communications between the Trucks, sustained disconnection between the Truck and the NOC, sustained loss of GPS signal, or (b) detects a Cut-in Vehicle via radar or another sensor.

During dissolution of the Platoon, Peloton notes that “the System controls the speed of the Follow Truck to increase the inter-vehicular headway between the Trucks. The Driver of the Follow Truck can override longitudinal vehicle motion control by the System during dissolution of the Platoon as the Driver deems appropriate in order to achieve a minimal risk condition (Fallback).”

Platoon Lengths

DATP is defined as two-truck platooning. Current commercialization activity of platooning focuses on two-truck configurations. Current research activities include three-truck platoons as well. Once two truck platooning is established in the market, there will likely be user demand for longer platoons.

The NCHRP Truck CV AV report (Fitzpatrick, 2016) notes that most testing to date has occurred with two- and three-truck platoons. Further:

> “The operational use of longer platoons is both possible and anticipated at least in an exploratory phase, and could accrue proportionally more benefits as a higher proportion of platooned vehicles enjoy the slipstream benefits of being behind a truck to the front of them.
>
> There are no limiting technical constraints with the technology solutions to running platoons of longer than three trucks. With the likelihood of using DSRC-based communications, a technical limitation on platoon length comes as the communications range of the DSRC technology begins to be reached (around 300m). As an example, eight tractors linked to 53’ trailers, platooned with 50’ headways, might safely operate within this framework.
>
> Operational and policy constraints would likely intercede on maximum platoon lengths before such a technology-driven constraint became active. Specifically, finding and coordinating many trucks traveling together along the same corridor at the same time will be challenging. The public’s acceptance of very long platoons is likely to be a constraint, particularly with early deployments. Unease over the concept of platoons, including how non-platooned vehicles would navigate through such a trail of platooned vehicles, may limit this acceptance. Over time, if it is demonstrated through deployments that this concern is not real, then public concern may dissipate.”

Daimler Trucks asserts (Daimler, 2016) that “the maximum length of a platoon is not limited by the range of the transmission signals, but by the number of vehicles,” as instability would occur between vehicles during normal traffic interactions. They state that “it is not appropriate to link more than ten vehicles.”

Calvert et al. at the Technical University of Delft performed extensive traffic simulations to assess platooning. Regarding platoon length, they found “no substantial concerns in allowing truck platoon sizes of two or three trucks, in regard to the traffic flow” (Calvert et al. 2017).

Platoon Gaps Versus Typical Gap Sizes

Based on the fuel economy testing noted above, plus statements by system developers, gaps of 30-80 feet are of interest for initial deployment (Peloton Plan, 2017).

What are typical gaps maintained by truckers now with no technology assist? A NHTSA evaluation of FCAM systems documented truck following distances averaging at headways of 2.8 seconds (248 feet at 65 mph) (Grove et al. 2016). Another USDOT study found that steady-state following distances of trucks averaged 170 feet (Nodine, et al., 2016). As an additional data point, in May of 2016, FDOT sponsored a small task to film on-highway operations for 4 hours on Interstate 75 to address this question (Field Data Collection Notes, FDOT 2016; Evaluation of Truck Clearances, FDOT 2016). Clearance was defined as "distance from rear of front truck to the front of rear truck traveling in the same lane."

Observations were made for both northbound and southbound lanes, for the outside and middle lanes. Results are shown in Table 5.

Table 5: Evaluation of Truck Clearances on I-75 in North Florida

Lane	Number of trucks observed	% less than 300 feet	% more than 300 feet	Observed minimum clearance, feet
Northbound Outside Lane	523	78%	22%	48
Southbound Outside Lane	646	10%	90%	55
Northbound Middle Lane	87	52%	48%	29
Southbound Middle Lane	133	32%	68%	48

This limited study indicates that substantial numbers of trucks now travel at less than a 300-foot clearance distance. Of this sample of a total of 1,389 trucks however, over 800 traveled at greater than a 300-foot clearance.

Calvert et al. at the Technical University of Delft performed extensive traffic simulations to assess platooning. Regarding platoon gaps, they found "no substantial concerns in allowing gap settings between trucks in the range of 0.3-0.7 seconds (27 ft to 62 ft at 65 mph) in regard to the traffic flow."

II.G.vii. Responsibilities for Freight Carriers When Operating DATP Systems

Peloton Technology, which is bringing commercial DATP systems to market, specifies these carrier responsibilities in a platooning plan provided to Michigan DOT (Peloton Plan, 2017):

a. *"General legal compliance.* To the extent applicable to the owner of any Truck, Carrier-users of the System are responsible for general compliance with laws including, but not limited to, registration requirements of Trucks to operate in the State of Michigan, registration requirements of the Federal Motor Carrier Safety Administration, and Federal Motor Vehicle Safety Standards and Federal Motor Carrier Safety Regulations.

b. *Maintenance.* To the extent described in user agreements between Peloton and Carrier-users of the System and as required by law, Carrier-users are responsible for performing Peloton-approved Maintenance of the System."

II.G.viii. DATP Driver Considerations

Lead Driver Responsibility

Within the FHWA-funded Caltrans project on truck platooning, the project Concept of Operations (Nowakowski, 2015) notes that the lead truck driver in a platoon "will have some increased responsibility, especially in terms of scanning the roadway and traffic ahead for hazards." This is a critical safety situation unique to the "team driving" concept that will occur with DATP operations, since a sudden lane change would expose the follower vehicle to the hazard with little advance warning.

Driver Preferences in Inter-Vehicle Gap Setting

The FHWA-funded Caltrans project in Level 1 truck platooning assessed driver preferences for inter-vehicle gap distances during on-road driving trials of three truck platoons. The trucks operated in mixed traffic on California freeways I-580 (suburban) and I-5 (rural) for approximately 3 hours. The experimental subjects were nine experienced long-haul truck drivers, driving both truck two and truck three at their choice of gap setting. The study found that a gap of 1.2 seconds (at 55 mph, 29.5m or 97 feet) was most preferred, but some drivers (the most experienced group) preferred the shortest gap setting of 0.6 seconds (at 55 mph, 14.7m or 48 feet). The drivers had no preference regarding the truck two or three position (Shladover, 2016, Shladover, 2017).

Driver Role in Gap Setting

As noted previously, in the Peloton approach, drivers do not set or alter the separation distance while platooning except for when they dissolve the platoon; the inter-vehicle gap is set by the system through the Peloton Network Operations Center.

No information has been published on this point by truck OEMs or other DATP developers.

Driver Situational Awareness

The EU COMPANION project (COMPANION, 2016) concluded that it would be necessary for all the drivers to have a good front and rear vision field. With vehicles in the platoon driving closely, it was considered that these fields of vision have to be provided by cameras, as it is not possible to have direct vision with mirrors in a tractor-trailer combination.

The COMPANION researchers assessed driver situational awareness using the Situation Awareness Rating Technique (SART) questionnaire. This is a well-established technique for post-trial subjective ratings. It uses 10 dimensions to measure situational awareness:

a. familiarity of the situation
b. focusing of attention
c. information quantity
d. information quality
e. instability of the situation
f. concentration of attention
g. complexity of the situation
h. variability of the situation

i. arousal
j. spare mental capacity

After each vehicle testing session, the project drivers were asked to rate each dimension on a seven-point scale (1= Low, 7=high) based on their experience with the system. The COMPANION team used a quicker version of SART which groups the aforementioned 10 dimensions into three groups:

a. Demand on attentional resources = Instability + Variability + Complexity
b. Supply of attentional resources= Arousal + Spare Mental Capacity + Concentration + Division of Attention
c. Understanding of the situation = Information Quantity + Information Quality + Familiarity

For each testing session, a metric for situational awareness was calculated based on the driver's position in the platoon, demand and supply of information resources, and understanding of the situation. Results showed that in all platooning maneuvers, the situation awareness of the following truck drivers that were using the on-board HMI was relatively higher than the driver of the platoon leader truck. The research team concluded that these results support the assumption that the benefit from information provided by the HMI makes drivers more aware of the situation in different maneuvers.

System Usability

The COMPANION research team also assess usability of the system using the System Usability Scale Questionnaire (SUS) technique (COMPANION, 2016). This questionnaire consists of 10 statements, which are rated 1-5 from strongly agree to strongly disagree (Likert scale). These statements are:

a. I think that I would like to use this system frequently
b. I found the system unnecessarily complex
c. I thought the system was easy to use
d. I think that I would need the support of a technical person to be able to use this system
e. I found the various functions in this system were well integrated
f. I thought there was too much inconsistency in this system
g. I would imagine that most people would learn to use this system very quickly
h. I found the system very cumbersome to use
i. I felt very confident using the system
j. I needed to learn a lot of things before I could get going with this system

Results showed that the overall SUS was 71.66, resulting in the conclusion that the COMPANION system as designed was usable (over 68% is the agreed-upon "threshold" according to researchers). However, due to the small number of participants, this score cannot be confirmed with full confidence. Therefore, the team decided to analyze the results on each statement to determine strong and weak points.

The highest "agreement" ratings were for statements a. and g., which address frequent use and the learnability of the pre-commercial system as implemented in the COMPANION project. All drivers agreed that they would like to use the system frequently and found it easy to learn. The strongest negative response was for statement f., which addresses the inconsistency of the system. The drivers said they could not map what they saw on the screen with what they observed on the road; however, they noted they understood that the system was not a finished commercial product.

Human Machine Interface

Insight into one implementation of a DATP Human Machine Interface (HMI) is provided by Peloton Technology (Peloton Plan, 2017).

> "The System's HMI consists of a dedicated windshield-mounted display (Display); dashboard-mounted manual controls (Controls); a radio-based, direct Driver-to-Driver voice communications system; and an audio notification system.
>
> The Display shows (a) current and prospective Platoon status, e.g. whether a Truck is or is not in a Platoon, whether a Truck has or does not have Safety Approval to form a Platoon, and the location of any available Truck(s) with which to form a Platoon; (b) Platoon instructions, e.g. driving instructions to set up formation of a Platoon; and (c), on the Display inside the Follow Truck, a video feed that covers the forward blind spot of the Driver of the Follow Truck by showing a frontal view from the Lead Truck.
>
> Controls are used for Platoon formation and dissolution and to adjust HMI settings, e.g. the brightness of the Display. The Driver-to-Driver communications system enables the Drivers in a Platoon to speak directly with one another. The audio notification system communicates feedback and alerts to Drivers."

Driver Experience

Key considerations for driver experience were offered by the TMC Information Report and Peloton Technology.

The TMC Information (TMC Information Report, 2015) stresses that the platooning technology provider must account for the impact of various driver issues when designing the capabilities and logic of the automation system. These driver issues -- trust, driver acceptance, training needs, and generational issues -- will have influence on the effectiveness of the complete system. Two specific points were made:

a. "The drivers must keep in mind that they are the prime control system no matter what the vehicle is capable of doing. While the vehicle may be able to operate without the driver's hands and feet, the driver must understand that the electronic controls are to assist the driver in saving fuel and improving safety.
b. Drivers that slip seat between vehicles will have to be aware at all times of the features of the vehicles that they are driving. They must be aware of the abilities of the vehicles that they are currently driving. Two trucks of the same make and model may be equipped differently."

The EPTC Stakeholder Consultation process (Rijkswaterstaat, 2016) noted that "certification of drivers and transport companies could be crucial in building driver acceptance – especially for drivers in the following trucks." The survey results identified the following perceived challenges:

a. driver acceptance by demonstrating safety and learning to trust the system
b. driver task trade-off: attention versus boredom, as well as anxiety and exhaustion due to small gap distance

Similarly, Peloton Technology noted the following within the Frequently Asked Questions portion of their website (Peloton Technology, 2017).

a. When platooning, the front driver continues to drive as normal. The experience of the rear driver is similar to using cruise control – continuing to steer with feet off the brake and gas pedals. The rear truck's acceleration and braking are wirelessly linked to that of the front truck to maintain a safe gap between the two trucks at all times.
b. During platooning, the rear driver's system display shows the view from the front truck, allowing the rear driver to see further down the road.
c. During platooning, the front driver's system display shows the view from the rear truck, allowing the front driver to view the back of his/her trailer and associated blind spots.
d. Drivers always retain final decision-making authority to form, continue, or dissolve a platoon as required to ensure road safety.

The above two statements represented desired aims. But what is the experience so far, for drivers actually operating platoons in open traffic? To this question, two sources were very useful in that they directly addressed driver experiences while platooning; these are the European Truck Platooning Challenge (EPTC) Lessons Learned document (Rijkswaterstaat, 2016) and the North American Council on Freight Efficiency (NACFE) Confidence Report on Platooning (Roeth, 2016).

Drivers within the six individual truck platoons operated during the European Truck Platooning Challenge EPTC provide a particularly useful perspective. These drivers were either ordinary truck drivers, test drivers employed by the truck manufacturers, or system developers. Of the total group of eighteen drivers, seven were in a lead truck and 10 drove following trucks; all were trained drivers and familiar with driver support systems and had experience with truck platooning. After the event, drivers were interviewed to learn about their experience and the interaction of truck platoons with other road users.

For the NACFE Confidence Report, four test drivers were interviewed. The authors acknowledged that the drivers worked for a leading platooning technology developer. They noted that while the responses from these drivers cannot be considered unbiased, "their thoughts and experiences did shed light on several important aspects of platooning from a driver's perspective." The NACFE drivers, who were quite positive about platooning, averaged approximately 55 years old, which NACFE noted might "dispel the notion that younger drivers will naturally feel more comfortable with platooning."

While these two groups of drivers represent a relatively large portion of any drivers who have operated while platooning, their numbers are small in absolute terms and cannot be considered definitive. Nevertheless, their perspectives are valuable and the reports findings are presented in some depth here.

Findings from European Truck Platooning Challenge Platooning Driver Interviews

Similar to Florida DOT's convening statewide stakeholders in 2016 to identify issues and concerns to prepare for the Study and DATP Pilot, EPTC organizers held workshops prior to the running of the platoons to identify perceived risks and concepts to mitigate those risks. Based on the outcomes of the Challenge, these topics were revisited.

The results relating to driver perspectives are shown in Table 6. Following the Table, several key findings are discussed; these are also replicated in topic-specific sections elsewhere in this Study. Importantly, recall that the EPTC operations consisted of <u>three-truck</u> platoons.

Table 6: EPTC Platooning Risk Assessment Relative to Driver Interviews		
Expected Risk	Pre-Trial Concepts re: Mitigating Expected Risk	Post-Trial Findings from Driver Interviews
Increased risk of disturbance of traffic flow due to the behavior of the truck platoons as a single vehicle entity	Requirements on Visibility/recognition for the truck platoon, de-coupling at on- and off-ramps, restrictions / recommendations on specific maneuvers, prescribed following distance, maximum speed.	The main difference between driving a truck platoon and a single truck is being part of an entity. When evaluating traffic situations, the lead truck driver has to take account of the full length of the platoon. He has a sense of responsibility for drivers in the following trucks. Truck platoon drivers are strongly inclined to keep the platoon together. They regard merging traffic as breaching the integrity of the platoon and view on- and off-ramps as the most challenging traffic situation. Truck platoon operators are not inclined to increase the following distance for overtaking single trucks when this maneuver takes longer than the driver of the single truck expects. In the driver's experience, interaction of the truck platoon with single trucks is more complicated than with car drivers. Minor speed differences could be a reason here. Miscommunication is mainly due to the fact that the truck platoon is not recognizable as such. Some drivers would prefer a means of visibility / recognition between the truck platoon and other road users. Maximum speed is a determining factor for the number of overtaking maneuvers by single trucks. A maximum speed of 80 kph means that the truck platoon could hold up traffic flow. A speed limit tolerance of 80-85 kph is needed to re-form the truck platoon when broken up.
Increased road/bridge wear and tear due to truck platoon as a single entity	Restrictions on maximum weight and division of load, decoupling at bridges	No information from interviews
Limitations of the platooning system in complex traffic. A truck driver unfamiliar with the platooning system	Decoupling in complex traffic situations like motorway junctions, traffic density, traffic jams, (mobile) road works and weather conditions, set procedures	Drivers decoupled at complex traffic situations on their own initiative, even when not required. The main traffic situations where the truck platoons decoupled were at motorway junctions, on- and off-ramps, and in dense traffic situations.

not knowing how to deal with the transition of control.	for truck drivers, prescribed following distance	The platooning support systems functioned very well, also in complex traffic situations. The driving task is getting easier in free-flow traffic situations, different driver competencies are required than for a single truck. The effectiveness of the truck platooning concept decreased apace with a large number of on- and off-ramps in close succession. A following distance of .5 seconds (11 meters) works better in keeping the truck platoon intact. A following distance of .8 seconds (18 meters) and above means more frequent merging in traffic and overtaking maneuvers.
Failure of the system in specific infrastructural situations: tunnels, slopes, and curves	Decoupling at tunnels, x gradient values and x radius values of curves	The interviews yielded minimal information on these expected risks. One driver stated than the steepness of the road is more stressful than the shorter following distance. Another driver stated that they de-coupled at flyovers.

Drivers and System Operation

Drivers found the platooning systems functioned well in normal as well as complex traffic situations; this included maneuvers to open up the platoon for merging and then increasing speed to re-form the platoon.

Lead truck drivers recognized the importance of their role to be aware of the full length of the platoon, as well as to "look ahead, watching out for potential problems."

The platooning trucks changed lane simultaneously, with the lead driver ensuring there is sufficient room for both trucks before changing into the new lane and the driver of the last truck monitoring the area beside and behind the platoon for other road users.

"A following distance of .5 seconds (11 meters) works better in keeping the truck platoon intact. A following distance of .8 seconds (18 meters) and above means more frequent merging in traffic and overtaking maneuvers. " – Post-Trial Findings from EPTC Driver Interviews

Driver Inter-Vehicle Communication

Drivers considered radio communication between themselves to be important in informing drivers of following trucks.

A screen in the cab showed the traffic situation in front of the leading truck. This was considered helpful and useful for verification.

Traffic Interactions / Merging

There were mixed opinions among drivers regarding this topic. Some said other road users reacted no differently to the truck platoon and were not aware that they were driving near a truck platoon. Others cited differing behavior when passing and merging.

The most typical situations for de-coupling were motorway junctions and on- and off-ramps. The most salient interaction was between platooning trucks on the main lanes and single tractor-trailers seeking to merge.

However, this experience may not translate well to U.S. roads, as the operating protocols for inter-vehicle gaps imposed by the EPTC organizers created unusual traffic dynamics, as noted in their Lessons Learned document and elaborated upon further in Section II.H.

Communications with Other Road Users

The platooning vehicles had bold signage regarding platooning (more of a marketing style) and — in Germany — flashing lights on the trucks. Drivers felt this worked well in communicating with other road users; they observed other drivers tended not to cut between platooning trucks.

For the special case of communicating with other (non-platooning) truck drivers, EPTC drivers felt that some type of meaningful communication between truck platoon drivers and colleague single truck drivers was important. They noted that "text is helpful, but visual effects are preferable."

Findings from NACFE Platooning Driver Interviews

The driver interviews conducted for the NACFE Confidence Report on Truck Platooning (Roeth, 2016) were motivated by the following perceptions the researchers encountered across the trucking industry:

a. given the shorter following distances tractor-trailers maintain while platooning, there is currently widespread concern among fleet managers as to how drivers will cope with limited situational awareness (i.e., a severely restricted field of view, particularly to the front of the vehicle). To compensate for this situation, it's been suggested that platoon-capable trucks come with cameras and video screens to give all drivers, regardless of their position in a platoon, access to real-time information of dynamic road conditions around them.

b. in spite of these measures, many fleet managers currently feel platoon drivers – particularly drivers in trailing vehicles – will not have sufficient fields of view and information to anticipate and react to threats while platooning. Fleet manager concerns about driver reaction times are closely linked to similar concerns regarding following distances and situational awareness.
c. many fleet managers feel drivers will either be too distracted or too bored to react quickly when a threatening road condition arises. Or, even if the driver is fully engaged in operating the vehicle, many feel the driver simply will lack the reaction time required to react safely in a crisis, similar to experiences most of us have had as tailgating drivers.

This section of the NACFE report opens by providing some broad perspectives held by the four drivers interviewed, most of whom had 20-plus years of experience.

First, they noted that many truck drivers today already "unofficially" platoon (i.e., without DATP systems) to one degree or another, especially out west on sparsely populated highways. Further, using platooning technology vastly increased the safety aspects of reduced following distances and noted that their individual comfort levels with platooning rose very quickly as they became familiar with it. The report states that "it was the consensus among the interviewed drivers that the main reason the trucking industry at large is currently so skeptical regarding platooning is because people do not understand how quickly and effectively the integrated safety systems work," also stressing that the system they were testing uses real-time road data from vehicles ahead, which the system processes, tracks, and reacts to in order to improve safety performance.

With regard to driver acceptance, those interviewed felt that "drivers must learn, and become comfortable with, an entirely new operational dynamic behind the steering wheel. However, despite widespread industry concerns of driver physiology and safety, it appears that platooning technology and its integrated safety systems are powerful and fast enough to substantially overcome reduced driver fields of view and reaction times."

Specific statements made by these drivers provide an interesting viewpoint into the experience of driving while platooning; these are excerpted from the report:

a. Driver 1 noted that before he actually participated in a platooning drive, he felt he would have to "stand on the brakes" in an emergency situation. Instead, he found that the system reacted far faster than he could apply the brakes; so fast in fact, that he found his trailing truck only gained "about a foot or two" on the lead truck before the vehicles began slowing at a simultaneous rate.
b. Driver 2 (the most junior driver in the interview), said, "One of my earliest jobs was to test the system's ability to deal with hard-braking events. And it surprised me how effectively the safety system applied the brakes. I wasn't told when to hit the brakes, so each event was a surprise. The first few times, I kept my foot hovering over the pedal waiting to hit it hard when the lead truck's brake lights came on. But I never had to. The system handled the event before my foot could get to the pedal. Even at 50 mph, the response was immediate and

backed my truck off by 50 to 60 feet each time."

c. Driver 3, who had spent several years as a driver/instructor for the National Highway Traffic Safety Administration, cited the organization's textbook section on truck braking, which notes that a fully loaded tractor-trailer traveling at 55 mph takes approximately 657 feet to come to a complete stop. But, he says, the safety systems used in platooning can bring a similarly spec'd and loaded tractor-trailer to a full halt in less than 200 feet safely.
d. Drivers also reported that pre-platooning anxiety about passenger cars breaking into a truck platoon had fallen off to the point that it was a "non-event" when it occurred to them now. Driver 4 explained that the system was so quick to respond to an intruding vehicle that it was "not a problem at all."
e. "Most of those cars transit in and out of the platoon rapidly," Driver 4 said. "The system detects them coming in, taps the brakes and backs off – usually only about 50 or 60 feet. Once the car is gone, you hit the 'resume' button and the platoon closes back up quickly."
f. On a similar note, Driver 4 noted that the system works so smoothly, that drivers can feel how quickly both brakes and throttle are applied by the platooning safety systems. "It works very smoothly," he noted. "There's not a lot of a 'yo-yo' effect between the trucks as they establish and maintain position."
g. "The view is a little different from a trailing truck," Driver 3 noted. "But you can see just fine. It's not like the entire world is blocked out. It's a different mode of driving, yes. But it's not going to drive you crazy. You have plenty to keep you occupied."
h. Driver 4 added, "We understand that a lot of people feel this is a major problem. But we don't see it that way. We are communicating much of the time and you still have to be alert. I don't believe you'd ever get so bored that you'd fall asleep or run off the road. If you have those issues, you shouldn't be driving a truck, anyway."
i. "If you get tired, you can always leave the platoon," Driver 3 noted. "You're not obligated to stay there. If you feel fatigued, you can take a break."
j. "I drove 1,000 miles across Utah and Nevada recently, all of it in a trailing position," Driver 2 added. "And it wasn't a problem. There's not a lot to see out there, anyway. I'll be blunt: I've been [doing this] for more than 20 years. And driving can get pretty boring sometimes. So there's not a whole lot of difference when you're platooning. I may get tired when I've been in a trailing truck in a platoon all day. But I'm not any more tired than I can be if I'm driving a solo truck all by myself all day."

In sum, all drivers interviewed by NACFE "were adamant that platooning – even in a trail truck position – did not increase anxiety levels at all. Nor did they feel they were disengaged from driving the truck or unable to process and track road conditions around them."

The TMC (TMC Recommendations, 2015) document regarding truck platooning recommended that industry "Study truck driver's capability of controlling a vehicle with minimal following distances for long periods of time while experiencing the lack of a large field of view, especially behind a van trailer. Such studies should assess the issues and also investigate means of countering any negative effects." The information above from the NACFE report addresses these concerns to some degree. Also, at a practical level the "lack of a large field of view" would be the case for gaps of approximately 30 feet and under;

initial DATP systems will operation at gaps of 40 feet and above based on statements from system developers.

Interviews conducted as part of the business case analysis within the Auburn study (Auburn University, 2017) assessed views on driver acceptance from several major truck fleet executives. They had no major concerns as to how platooning could be introduced to drivers to gain their acceptance. They expected the process would be similar to that used successfully with introduction of Adaptive Cruise Control, Collision Mitigation Braking Systems, and similar technologies, which has involved trialing the technology with an initial set of drivers who then serve as trainers and ambassadors of the technology to other drivers.

"platooning… has an extremely shallow learning curve and requires minimal additional training for drivers to become proficient." -- NACFE Confidence Report on Truck Platooning

Driver Training

The TMC Information Report (2015) noted that "the degree of training needed will vary with each level of automation and each particular system. For instance, drivers accustomed to using Adaptive Cruise Control may adapt more quickly to truck platooning than those who are not. Driver training can most likely be managed by industry working closely with fleets as is the case with training for other advanced safety and driver assistance systems, rather than via some form of regulatory / special driver licensing requirements."

Specific to DATP, the NACFE Confidence Report on Truck Platooning (Roeth, 2016) found that "platooning… has an extremely shallow learning curve and requires minimal additional training for drivers to become proficient."

The EPTC Stakeholder Consultation process identified driver training and certification for platooning as a key issue (Rijkswaterstaat, 2016).

Driver "Copycats"

During the European Truck Platooning Challenge (Rijkswaterstaat, 2016), drivers platooning on German motorways noted "copycat" behavior, i.e., other single trucks in the vicinity of the truck platoons driving more closely to a truck ahead that would normally be considered safe. However, no data was collected as to the frequency and circumstances of this behavior.

Driver Considerations Summary

The NACFE Confidence Report on Platooning and other sources summarized the main concerns regarding driving while platooning:

a. how will drivers will cope with limited situational awareness?
b. will platoon drivers in trailing vehicles have sufficient fields of view and information to anticipate and react to threats while platooning?
c. will drivers will either be able to react quickly and safely when a threatening road condition arises?

Access to perspectives of three groups of drivers with direct experience of platooning provides valuable insights, even though their numbers are small and cannot be considered definitive.

Drivers reported that they quickly learned to use the system and that they would likely use the system frequently. The NACFE Confidence Report on Truck Platooning also noted that "platooning… has an extremely shallow learning curve and requires minimal additional training for drivers to become proficient."

NACFE also concluded that "driver stress will likely be less than perceived to date." In fact, drivers interviewed by NACFE were "adamant" that platooning did not increase anxiety levels, nor did they feel they were disengaged from driving the truck or unable to process and track road and track conditions around them." Additionally, Auburn's interviews with fleet managers noted no major concerns as to how platooning could be introduced to drivers to gain their acceptance.

Drivers operating on California freeways for several hours generally preferred an inter-vehicle gap of 97 feet at 55 mph, while the most experienced drivers preferred the shortest available gap setting of 48 feet.

Several sources noted that driver readiness to respond to critical situations is enhanced by transmission of real-time video between trucks, providing greater access to real-time information of dynamic road conditions around the platooning vehicles. Drivers considered radio communication between themselves to be important as well. With this type of human-machine interface, the COMPANION project found that situational awareness was higher for the following truck driver compared to the leader.

In the European Truck Platooning Challenge, platooning trucks changed lane simultaneously, with the lead driver ensuring there is sufficient room for both trucks before changing into the new lane and the driver of the last truck monitoring the area beside and behind the platoon for other road users. The most challenging issue reported by these drivers was interaction of the truck platoon with single trucks. Single truck drivers were confused and frustrated in seeking to pass or merge with these three-truck platoons. This was in part due to artificial rules set by the EPTC organizers for the pilot (especially in stipulating low maximum speeds, which increased speed differentials with non-platooning trucks). EPTC drivers felt it was important that other trucks are aware when trucks are platooning.

EPTC drivers platooning on German motorways noted "copycat" behavior, i.e., other single trucks in the vicinity of the truck platoons driving more closely to a truck ahead that would normally be considered safe. Although no data was collected to document the extent of such behavior, this is a highly important issue to monitor going forward.

II.G.ix. The DATP Business Case: What is Motivating Deployment?

It is important to consider to what degree DATP is "real" in the near term and, if so, worthy of state agency resources proactively addressing deployment issues. This short section addressing the business case as perceived by industry provides insight into this question.

The NCHRP Truck CV AV report (Fitzpatrick, 2016) noted that "industry needs to understand the business case that these new technology-driven opportunities present, and ensure that new solutions meet thresholds for adoption. Governmental agencies need to know that these business cases exist, as one input to creating a proper regulatory environment that respects the vitality of the private enterprises."

Based on this literature survey, these are the factors driving the industry toward deployment of DATP as soon as possible.

Cost Effectiveness

The truck industry is highly cost sensitive. A study sponsored by the Intelligent Transportation Society (ITS) of America (ITS America, 2015) examined attitudes regarding advanced safety technologies, which revealed that 13% of carriers expect a return on investment within 12 months, 40% within two years, and 39% within three years; only 8% thought it would take longer than three years.

The Auburn DATP research project found, predictably, that cost is a key priority for fleet adoption. A survey was conducted in Phase I of the project assessing willingness to pay for DATP adoption. In the survey, for-hire and private carrier fleet managers (the most likely first adopters) generally expected a break-even threshold of 18 months (note, however, that in this 2014 survey, almost none of the respondents were aware of the concept of DATP and had no direct experience of it prior to receiving the survey) (Auburn University, 2015).

Also, the EPTC Stakeholder Consultation (Rijkswaterstaat, 2016) identified system cost and business case for SAE Level 1 or 2 platooning as an issue.

Fuel Economy

Clearly, fuel economy is a major motivator for adoption, as found within the results from several projects (COMPANION 2016) (Janssen et al., 2016). In interviews conducted with trucking fleet executives within the Auburn DATP project, one large fleet representative noted that, with economies of scale such that hundreds of millions of gallons of fuel would be saved, the fuel benefit alone is sufficient motivation to adopt DATP (Auburn University, 2017).

Safety

Initial commercial DATP systems will also include FCAM safety systems and air disc brakes, among other safety features (Peloton Plan, 2017). These systems will be providing safety benefits whether platooning is active or not. The COMPANION project as well as in interviews conducted with trucking fleet executives within the Auburn DATP project both found that these safety benefits are an important part of the business case for DATP (Companion, 2016; Auburn University, 2017).

Asset Utilization

The NCHRP Truck CV AV study (Fitzpatrick, 2016) posited that while platooned trucks are likely to be operated more efficiently, this is strongly tied to the specific platooning concept deployed: "the extent to which trucks in a fleet are physically able to create a platoon is also a major factor, that is, traveling along the same corridor at roughly the same time, and in sufficiently compatible equipment. Companies operating large private fleets, with homogeneity in their tractor OEM, and predictable routes may gain the best savings along their high density routes. Truckload (TL) and Less-Than-Truckload (LTL) trucking operations would also be early candidates to gain the best utilization savings."

Similarly, business case analyses within the Auburn DATP project (Auburn University, 2017) concluded that "large, for-hire, over-the-road (OTR) truckload (TL) and less-than-truckload (LTL) line-haul fleets and private fleets are best positioned as early adopters of DATP, due to their financial resources and operational aspects including density of freight movement on specific road corridors (freight lanes) density and trip length. While other sectors and fleet sizes are potential target markets, the larger OTR fleets have the opportunity to resolve key challenges and lower adoption prices through economies of scale." Further, interviews conducted as part of the business case analysis assessed views from executives representing eight major (primarily long-haul) trucking fleets; regarding asset utilization, the group generally agreed that "platooning fits with line haul truckload operations and dispatching. A fleet working predictable routes would find dispatching to facilitate platoons feasible, if it would mean holding trucks for around 15 minutes to pair them up." Note that such delays of dispatching are not a trivial item within many truck fleets, so this latter statement is a strong indication of the perceived value of platooning.

Logistics Process Integration

The EPTC Stakeholder Consultation (Rijkswaterstaat, 2016) identified logistics process integration to adapt to platooning, in areas such as routing, inventory management, warehouse operations. Ideally, shippers and carriers could make platooning more attractive by consolidating more loads in the same direction.

Summary of DATP Business Case

Is DATP commercially feasible? This was the key question posed at the outset of the Auburn project. After completing the analytical phase of the project, the Auburn team concluded that "based on fuel economy improvements observed in testing, a strong business case exists for introducing this technology. In general, the extensive track testing helped support the overall hypothesis that DATP technology is near market ready." Overall, the Auburn University team concluded that "DATP operations are highly likely to be feasible for a substantial portion of trucking operations, and that key fleets clearly see this value."

> "…based on fuel economy improvements observed in testing, a strong business case exists for introducing this technology. In general, the extensive track testing helped support the overall hypothesis that DATP technology is near market ready. DATP operations are highly likely to be feasible for a substantial portion of trucking operations, and that key fleets clearly see this value." -- Auburn University DATP Study funded by FHWA

Conclusions in the NACFE Confidence Report on Truck Platooning (Roeth, 2016) took a more nuanced view:

a. The real-world fuel savings of two-truck platooning is likely to be a 4% average across the two trucks. Intervals of 40 to 50 ft. will likely have sufficient payback for early adopting fleets, and then shorter distances, with their higher fuel savings, can be implemented with product improvements.
b. The bulk of the required technology is currently available and being purchased by many fleets.
c. Platooning will accelerate the adoption of other technologies such as collision avoidance and adaptive cruise control.
d. Initial platooning operations in North America will be limited to intra-fleet activity until the industry has a better feel for how platooning works in the real world and concerns regarding data transmission between vehicles have been alleviated.

II.G.x. DATP Commercialization Activity

Truck OEMs Daimler, DAF, IVECO, MAN, Scania, and Volvo have developed and tested various forms of truck platooning for quite some time. Daimler, Iveco, and Renault Trucks (now part of Volvo Group) partnered in the European CHAUFFEUR project from 1996 to 2003. CHAUFFEUR implemented fully automated on-road platooning and performed on-road testing on Germany highways (CORDIS, CHAUFFEUR).

Scania has been active in the field of platooning for almost 10 years (Scania is not active in the North American market, though its parent company, Volkswagen Truck & Bus, acquired a 16.6% stake in U.S.-based Navistar in February 2017). During the period 2011-2014, Scania gathered practical experience of platooning in real traffic and transport operation through the project "iQFleet." The project conducted field trials in Sweden including 38 trucks and 130 drivers, driving platoons with between two and five vehicles between Södertälje and Helsingborg. During the project, more than 4M km were driven in platooning mode (Hedström, 2017).

In March 2016, Daimler Trucks unveiled their Highway Pilot Connect, a truck platooning system offering "up to 7% lower fuel consumption." The system has been approved for use in a limited area in Germany. Daimler is the parent company of Freightliner Trucks, the largest seller of heavy trucks in North America. The Freightliner Inspiration concept vehicles are also capable of platooning; a Freightliner online video refers to both 3-truck and 5-truck platooning (Freightliner, 2015, Freightliner, 2017).

As described in Section II.J., DAF Trucks, Daimler Trucks, IVECO, MAN Truck & Bus, Scania, and Volvo Group participated in the European Truck Platooning Challenge in 2016. More recently, in September 2017, Daimler announced that it is testing integration of platooning technology with its existing vehicle automation systems (Daimler, 2017).

Peloton Technology is a Silicon Valley startup founded in 2012 focusing on connected and automated vehicle technology in the freight sector. Their initial focus has been on commercialization of DATP, augmented by a cloud-based Network Operations Center that limits platooning to appropriate roads and conditions. Platooning for initial products is limited to two trucks. Peloton notes that their products can also improve the safety of individual trucks "by requiring best-in-class forward collision avoidance systems and other safety features that are active both in and out of platoon." Peloton plans to have their first production DATP systems in use by customers in 2018 (Peloton 2017). Peloton's "Platooning Plan" submitted in early 2017 to the State of Michigan has provided the most detailed information on pre-commercial DATP systems, serving as an important reference point for addressing key aspects of DATP in this study.

For the U.S. trucking market, DATP will likely become available via Freightliner Trucks and Peloton Technology, Inc. working with other truck-makers. Freightliner is the market leader in Class 8 trucks. Truck-maker Navistar plans to make the Peloton system available in their vehicles in 2018 (Transport Topics, September 2017).

The NACFE Confidence Report on Truck Platooning (Roeth, 2016) concluded that "it is extremely likely that in the near future, Class 8 tractors will be sold as platooning capable 'right out of the box,' making it extremely easy for fleets to take advantage of platooning as a fuel-saving technique. Over time, as both industry and general-public comfort levels concerning platooning rise, it is likely the scope and scale of platooning as an industry practice will grow and fleets will see the percentage of time trucks spend in platooning mode rise accordingly."

II.H. DATP High-Level Requirements As Defined by Freight Carriers

The TMC Information Report listed a set of system requirements that the trucking industry (as represented by ATA) considered essential to safe and effective operation (TMC Information Report, 2015). These requirements drew extensively from the High-Level Requirements document generated within Phase I of the FHWA-Auburn project on platooning (Auburn University, 2015).

Many of the issues and concerns raised in the previous sections are addressed in these TMC requirements, which are excerpted here.

One DATP technology supplier, Peloton Technology, extensively references these requirements in describing their approach to their commercial product (Peloton Platooning Plan 2017).

Additionally, the TTI Platooning Feasibility Study (Kuhn et al, 2017) provided operational requirements and a specification for a truck platoon system to be used for field testing of truck platoon operations; the content of this specification aligns well with the TMC requirements.

II.H.i. Setting Inter-vehicle Gap

a. It is important that the inter-vehicle gap setting take into account several factors to set a safe gap. Key factors are:
    a. Engine horsepower
    b. Estimated mass of each vehicle
    c. Estimated braking ability of each vehicle (measured in real time). Factors affecting braking performance include:
        1. Estimated mass of each vehicle
        2. Weather conditions
        3. Brake condition
        4. Road conditions
    d. Ability to cool engine with adequate air flow
    e. Driver acceptance
    f. Traffic conditions
    g. Road configuration (including tight curvature and/or dense entry/exit sections)
b. There will be conditions in which platooning is not advisable. Platooning system developers should consider how to adapt platooning protocols under these conditions.
c. A set of performance parameters have to be met to ensure trucks are compatible for platooning, i.e., to "match up" two vehicles. System developers must work with carriers to clearly define parameters that determine this proper match in equipment.
d. Public acceptance must also be considered. Impacts on surrounding traffic seeking to merge on or off the highway could be a factor; however, platoons of only two trucks are unlikely to be considered a problem in free-flowing traffic.

II.H.ii. Equipment Factors

a. DATP systems should be interoperable among trucks of different brands and with different options.
b. DATP-equipped trucks should feature forward collision mitigation and avoidance systems such as systems available from vendors today. DATP applies these systems to enable cooperative braking between the two trucks, although other cooperative braking solutions could be developed outside of the collision mitigation and avoidance systems available today.
c. Vehicle brakes must be in compliance with FMVSS standards and FMCSA compliance requirements.

d. The DATP system must accommodate differing braking capabilities between the paired vehicles. The relative braking ability of each truck should be estimated and taken into account for vehicle control, for example, so that the front and rear trucks in platoon can be arranged according to their relative braking capabilities.
e. The mass of the tractor-trailer combinations and their impact on platooning operation must be known or estimated. This is a factor in calculating relative braking capabilities.

II.H.iii. General Operations

a. The DATP system should operate on limited access highways such as interstate highways and major US highways, and operate across typical cruising speeds.
b. The DATP system should operate across a defined set of weather conditions; operations shall be adjusted based on weather conditions as needed to maintain safety. System developers need to clearly specify limitations relating to weather.
c. The DATP system should control engine torque, gear selection (for automated manual transmission vehicles), and braking including engine brakes/retarders as well as foundation brakes.
d. The DATP system should allow the driver to control throttle, braking, gear selection, and steering at any time.

II.H.iv. Designing for Safety

a. Based on estimated braking ability, the vehicle with the better braking ability shall be designated as the rear vehicle for maximum safety.
b. The DATP system shall adapt to variances in braking capability between the two trucks and variation on each truck, in terms of defining the ordering of vehicles (leading, following) and in setting inter-vehicle spacing. The degree of uncertainty in estimating braking ability of both trucks must be included in the inter-vehicle spacing determination.
c. System developers should implement the system such that varying levels of brake performance (within acceptable bounds) are not an impediment to use of the platooning system.
d. The DATP system shall use data from both vehicles to continually calculate optimum inter-vehicle distance to maintain a safe stopping distance in an emergency braking situation.
e. The DATP system shall adjust operating parameters to respond to weather conditions that could affect braking distance. This could include maintaining platooning and separating the trucks up to a distance typical of manual driving. .
f. The J1939 bus of the truck will contain any faults from the stock ECUs of the truck. These include items such as emissions issues, which can impose limits on torque production or otherwise impact the operation of the platooning system. These will be read directly from the J1939 bus, and conform to the standard. The system shall respond to faults in a manner to ensure safety.
g. Redundancy: Redundancy in its simplest form is an overlap between functional safety and business case. Functional safety demands redundancy, and the greater the amount of redundancy, the more sophisticated failure management is possible. With no redundancy, loss of a sensor or processor could compromise system performance. System developers need to address the degree of redundancy required to fulfill safety and performance requirements.

h. Communications: Integrity of communications must be maintained to the maximum extent; the system must effectively handle degradation / loss of communications.
i. In the case of loss of satellite positioning data, the DATP system shall use the sensing subsystem to maintain spacing in relation to the lead vehicle, sufficient to safely separate the two vehicles while this condition persists.
j. In the event of faults or failures, the system should be designed in a "fail operational" manner to ensure driver and vehicle safety.

II.H.v. Maintenance Considerations

a. It is vital to ensure that today's technicians are able to troubleshoot problems with the electronics and sensors needed for this type of operation; systems should be designed with this in mind. Ideally, maintenance protocols and diagnostic tools already used for advanced technology systems (such as ACC and lane detection) can be used with only minor adaptations. Techniques for maintaining DSRC-based V2V communications need to be developed.
b. Various forms of automatic vehicle health monitoring are being offered by manufacturers which may be helpful in maintaining DATP systems. In particular, brake condition monitoring is important.
c. The degree to which technicians need to be trained and/or certified to maintain DATP systems needs to be defined.

II.H.vi. Driver Considerations for Platooning

a. Accommodating truck drivers' needs and expectations will be one of the most important requirements of a successful DATP system. With the growing economy and baby boomer retirements, the truck driver shortage crisis will become more critical.
b. Drivers must keep in mind that they are the prime control system no matter what the vehicle is capable of doing. It must be clear what degree of situational awareness the autonomous commercial vehicle has so that the driver has a clear understanding of what situations they must handle.
c. Drivers that slip seat between vehicles will have to be aware of the features of the specific vehicle they are driving, since two trucks of the same make and model may be equipped differently.

Driver Interface for Platooning

- a. Technology developers must create intuitive driver interfaces that allow driver to cooperate with nearby vehicles to establish a platoon. These key interfaces include:
    - a. Following-vehicle request to join
    - b. Lead-vehicle accept to join
    - c. Headway adjustment
    - d. Disassociate from platoon
        - a. Notification of disassociation
        - b. Request for disassociation
        - c. Acceptable frequency
    - e. Other vehicle intrusion (cut-ins)
        - a. Notification to platoon
        - b. Resolution

a. Any system-induced changes to operational mode (such as delinking or fault handling) shall be indicated appropriately and be understandable to the driver; the driver's responsibilities in these cases (if any) shall be clearly indicated.
b. The delinking operation should be smooth and predictable to the driver, providing sufficient time for the driver to retake full control of the vehicle. For example, within the delinking process, the vehicle could maintain longitudinal control until the driver re-engages the throttle and /or brake. A smooth and predictable delinking operation shall apply whether the driver or the system initiates the delinking process.

II.H.vii. Training Needs

a. As automated technology is implemented in heavy trucks, developers need to ensure that drivers are educated on the functions of the system, protocols for lead drivers and following drivers, and procedures for irregularities in the system performance.
b. In particular, asking drivers to operate at inter-vehicle distances that are foreign to their normal operation (and training) must be approached with appropriate understanding and new training protocols.
c. Drivers must also be trained to be fully aware of the capabilities of the vehicle they are driving and the mode of automation that is active (and the system itself should clearly indicate the current mode of operation). Drivers operating automated trucks in platooning mode and non-automated trucks will become used to following the vehicle ahead very closely. When not in automated platooning mode, drivers must be trained to back off from the preceding vehicle when there is no electronic assistance in operation.
d. As a new field, only limited work has been done to develop training programs for future driving with platooning technology. This is an area that needs further attention.

II.H.viii. Driver Responsibilities

a. While linked, the rear driver's task is very similar to that with adaptive cruise control. Braking and acceleration shall be fully automated and the rear driver is responsible for lateral control of the vehicle at all times.
b. The driver should take over full control at any time he or she is not confident the system is operating properly.
c. If the front vehicle changes lanes, the rear driver shall do so as well whenever it can be safely achieved, if continued linking is desired.

II.H.ix. Standardization and Interoperability

a. The DATP system shall provide critical vehicle operational parameters between paired vehicles. The minimum parameters are:
    a. Braking status: deceleration, torque, and pressure
    b. Engine torque
    c. Acceleration/Deceleration in the longitudinal direction
    d. Location, vehicle velocity, and direction
    e. System status (truck and DATP system)
    f. Vehicle size
b. This data shall be coded into messages consistent with applicable standards.

c. The inter-vehicle communications system shall continuously monitor the communication quality and reliability and provide this information to the system controller, such that a loss of communication is detected within 50ms.
d. The inter-vehicle communications system shall include one or more 5.9 GHz DSRC antennas installed so as to preserve line of sight between the vehicles when a trailer is attached.
e. The radios shall handle antenna diversity as well as standard protocols to optimize robustness of communications.
f. Bandwidth of the communications channel shall be adequate to support continuous video streaming as well as data exchange. The inter-vehicle communications system shall implement information security measures to prevent intentional disruption of or tampering with the communications link.

II.J. DATP: Traffic Interactions on Public Roads

II.J.i. Proposed Performance Measures for Platooning Corridors

The TTI Platooning Feasibility Study provided a discussion of corridor-level performance measures. The study report recommended that data such as the following be collected to conduct performance evaluations:

a. Number of collisions involving truck platoons (total and by severity category).
b. Number of collisions involving automobiles and trucks not in platoons (total and by severity category).
c. Number of truck miles traveled in platoons.
d. Average number of platoon disengagements/re-engagements per trip/mile, etc.
e. Average duration of disengagement.
f. Ratio of time disengaged to time engaged per trip.
g. Locations of segments and times where platoons forced to disengage.
h. Number of total vehicle miles traveled in the corridor (both automobile, trucks not in platoons, and trucks in platoons).
i. Percent of trucks traveling in platoons and not operating in platoon.
j. Number of hours per day/percent of hours per week in which truck platooning was active.

The UF research team would counter that deployment of DATP is less likely to occur in specific "corridors" and instead be driven by the fleets initially deploying DATP. That said, evaluation of platooning impacts where DATP operations are occurring may be useful, but some items in the list above could be reconsidered. For instance, data on number of platooning miles driven and disengagements may not be meaningful without context information. Calculating platooning miles driven is more meaningful when context as to traffic density is taken into account. Further, disengagements can occur to a variety of benign reasons relating to needs of drivers or the freight route rather than traffic factors. Platoons being "forced to disengage" may be more relevant to traffic interactions; therefore, focusing specifically on "cut-ins" by other traffic may be more to the point.

The TTI team created a detailed framework for corridor evaluation, which included the following factors:

a. General considerations
    a. Rural interstate roadways
    b. Rehabilitation schedule

        c. Air quality rating
    b. Geometric features.
        a. Number of exits and entrances
        b. Number of left vs. right exits/entrances
        c. Number of sharp curves or other extreme features
        d. Lane width
        e. Shoulder width
        f. Horizontal alignment
        g. Vertical alignment
    c. Infrastructure quality
        a. Pavement type
        b. Pavement quality
    d. Bridge quality
    e. Freight network considerations
        a. Truck volume and fleet mix
        b. Potential staging areas
        c. Locations of activity centers

Based on other literature, particularly the Peloton Platoon Plan (Peloton Plan, 2017), in Level 1 DATP operations the driver in the lead truck, who is fully engaged in the driving task, would adapt driving as needed to road issues such as sharp curves, extreme topography, and pavement quality just as regular truck drivers do now.

Based on the planned Phase 3 deployment of platooning in Texas, the TTI team proposed to evaluate platooning across the five categories shown in Table 7, which is excerpted from the study report.

Category	Measures of Effectiveness
Safety	• No significant increase in overall crash rates in the corridor. • No significant increase in the number of truck/automobile collisions. • No significant increase in the number of severe (K,A) collisions involving trucks or caused by truck platoons in the corridor.
Mobility	• Significant increase in the number of trucks (as percent of average annual daily traffic [AADT]) in corridor. • No significant change in automobile travel time times/travel speeds through the deployment corridor. • No significant change in truck travel times/travel speeds through the deployment corridor. • No significant change in travel time variability of automobiles traveling through the deployment corridor. • Significant change in travel time variability of truck traveling through the deployment corridor.
Capacity/ Throughput	• Significant increase in the effective capacity[9] in the deployment corridor. • Significant change in the vehicle throughput through the deployment corridor. • Significant increase in the freight throughput[10] through the deployment corridor.
Energy & Environment	• Significant reduction in truck emissions in the deployment corridor. • Significant reduction in truck fuel consumption in the deployment corridor.
Infrastructure Preservation	• No significant increase in pavement damage in the deployment corridor. • No significant detrimental impact to bridge structures in the deployment corridor.
Customer Satisfaction	• No significant negative subjective feedback from automobile users. • Positive subjective feedback from commercial vehicle operators (drivers). • No significant negative subjective feedback from TxDOT district operations and maintenance personnel. • No significant negative subjective feedback from state/county/local elected officials. • Positive subjective feedback from commercial fleet operators.

Table 7: Proposed Measures of Effectiveness for Evaluating Truck Platooning Alternatives in Texas (Kuhn, et al., 2017; Table 17)

II.J.ii. Simulation of Platoon Traffic Interactions

Simulations Performed by the Technical University of Delft

Calvert et al. at the Technical University of Delft performed extensive traffic simulations to assess platooning. The study found that:

a. truck platooning had a small negative effect on traffic flow performance in normal traffic conditions, which the researchers considered "marginal and acceptable."
b. truck platooning had a large negative effect for near-congested or congested traffic; the researchers recommended against allowing platooning in these conditions (but also noted that since fuel economy benefits are unlikely to accrue at low speeds, users would generally not elect to operate platoons in these conditions anyway).
c. there are "no substantial concerns in allowing truck platoon sizes of two or three trucks, or allowing gap settings between trucks in the range of 0.3-0.7 seconds in regard to the traffic flow."

Simulations Performed by TTI

Within the TTI Platooning Feasibility Study (Kuhn et al., 2017), researchers conducted a truck platooning simulation for two-truck platoons in a mixed-traffic condition using the Vissim microscopic simulation software.

According to the study report, the simulation results "confirm that freeway capacity can be increased with platooning technology without any infrastructure expansion even with two-vehicle platooning." Further, that "the cumulative vehicle throughput over time measures a number of vehicles that can pass through a cross section for a given scenario. In this case, the peak volume of 3000 vph did not show any pronounced increase in vehicle throughput regardless of market penetration because the traffic volume did not exceed normal freeway capacity. However, there is a pronounced increase in vehicle throughput over time for the peak volume of 10,000 vph. … The increases are consistent when the market penetration is over 30 percent. The throughput increase benefits remain regardless of market penetration rates under high volume scenario but the fuel consumption benefits for individual platooning vehicles no longer exist under the same volume condition when the market penetration rates exceed 50 percent. This is likely because the traffic flow becomes unstable under high mix of platooning trucks, which led to conditions where platoon leaders are mostly governed by stop-and-go traffic conditions." Figure 8 below, excerpted from the TTI report, depicts the increase in cumulative vehicle throughput over time when comparing the platooning scenarios with the corresponding base cases. The label in the plot represents a combination of platooning status (on/off), desired gap setting (seconds), and minimum time required for platoon formation (seconds).

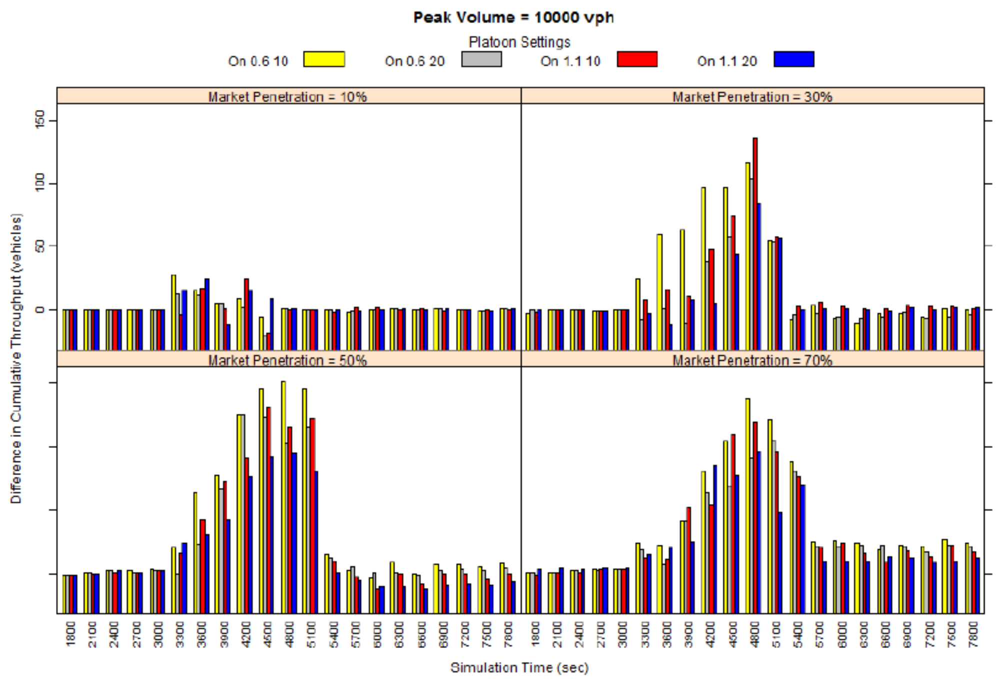

Figure 8: TTI Traffic Simulation Results for Truck Platooning
(Kuhn et al., 2017; Figure 21 in original report)

The TTI researchers noted that "future research should consider expanding the limit on platoon size, consideration of platoon restricted lane, and the effects of ramp traffic on vehicle throughput and fuel consumption performance."

II.J.iii. Traffic Interactions with EPTC Trucks in Public Traffic

The EPTC provided unique insights into platooning on public roads. However, the applicability of the EPTC experiences to deployment in Florida is limited. This is because the EPTC Rules of Engagement regarding speeds, de-coupling, and gap sizes (which varied somewhat across the participating countries) in some cases created unnatural traffic behavior that caused traffic disruptions. Speeds were lower than that for regular trucks, gap sizes larger than for (likely) commercial operations, and de-coupling situations were fairly frequent. While these rules were created out of an abundance of caution due to the new and unknown nature of platooning on public roads, the traffic interaction effects are unlikely to apply to truck platooning once commercially deployed (unless other jurisdictions apply similar rules). Examples are:

a. Passing maneuvers: some drivers observed that road users (car and truck drivers) were more reluctant to pass and took longer to decide on passing. Occasionally, single truck drivers would abort the overtaking maneuver when they realized the full length of the platoon. In contrast, other drivers observed more passing maneuvers, especially by trucks. Platooning drivers observed that single truck drivers were frustrated how long it took to get by the full length of the platoon.
b. Merging: EPTC drivers noted that platooning with a required following distance of 0.8 seconds (18 meters at 80 kph) seemed to confuse drivers of single trucks. In these cases, there appears to be room to initiate a merge, with the expectation that the trucks in the target lane would widen the gap (typical driver etiquette); but of

course the platooned trucks (under automated longitudinal control) did not do so. The drivers noted that when platooning at 0.5 seconds (11 meters at 80 kph) headway, the situation is clearer for drivers of single trucks.

c. Speed differentials and passing: speed is a determining factor in the number of passing maneuvers. If the speed of platooning trucks roughly matches the typical speeds of other trucks, there is much less motivation to pass. The EPTC Rule to limit speed to 80 kph disrupted traffic flow and caused single trucks to initiate passing. This caused "substantially more overtaking maneuvers by other trucks than would be the case if the truck platoons were driving more in accordance with the actual driving speed of normal single trucks." In fact, in Belgium -- where the maximum speed is 90 kph (56 mph) – passing maneuvers were less frequent.

Analysis: Overhead Video of EPTC Platooning

During the European Truck Platooning Challenge, video of several platoons was captured from a light aircraft as they drove through the Netherlands. Reference material was also collected concerning unequipped trucks driving both in free flow and in groups similar to platoons. The Technical University of Delft examined the aerial footage with regard to interactions with other road traffic. Within the context of the EPTC overall, this was only a limited amount of video in one location but nevertheless the observations made by TU Delft are instructive, as excerpted here:

> "The main purpose of observing the platoons from the air was to obtain information on the way the platoons interacted with other traffic. Generally speaking, the focus was on two particular issues with potentially negative impacts on truck platooning. This involved the possibility – or not – of merging and overtaking by regular traffic where platoons were involved. Perceptions here are often fuelled by the idea that platoons are made up of a lot of trucks rather than just two or three, as with the Challenge; the point of reference being that traffic flow is only made up of ordinary cars rather than trucks. However, the images do not seem to show any such adverse effects.
>
> Merging: there were no problems in merging traffic at on- and off-ramps, as most of the time the truck platoons gave way to traffic by creating larger gaps after deactivating (or decoupling) the systems, as set out in the Code of Practice. However, we did notice a situation, making us rethink whether this is invariably a good idea [see case study following]. In fact, what we saw was that for most platooning trucks, with headways in the Netherlands ranging from 0.7 to 1.3 sec., gaps were larger than with non-equipped trucks. [The Report notes that this is consistent with the findings from earlier Dutch studies of the A15 highway, showing headways typically in the range of .4 – 1.5 seconds.]
>
> Gap acceptance: the temporarily decreased gap acceptance for merging traffic does not seem to be affected by the concept of platooning. This is because most traffic was unaware that the trucks encountered were platooning. They simply did or did not accept an available gap on the basis of the actual length and irrespective of truck mode.
>
> Formation and regrouping: as a result of decoupling in the vicinity of on- or off-ramps, platoons have to regroup once they have passed by. This process takes some

time, ranging from 30 to 60 seconds. The benefits of platooning will cannot occur during this process. This is also the case when another vehicle 'invades' the platoon and the following truck automatically increases its headway. Occasionally, in these case more cars then cut in, making it quite difficult for the platoon to regroup.

Overtaking: queues of ordinary cars overtaking truck platoons on the adjacent lanes do not show much difference from overtaking unequipped trucks. The main cause here is the difference in velocity rather than the length of gaps between trucks. We also noted that in general cars are reluctant to drive between trucks, whether or not they are platooning.

Following distance: as we noted, the distance between the lead truck of a given platoon and the traffic in front was often larger than for normal trucks.

Lane changing: apparently, for platoons to change lanes as a 'team' is a relatively swift maneuver, often taking less than 10 seconds. When they decouple to change lanes individually it takes a bit longer, due to the presence of other traffic."

Case Study: Truck-to-Truck Merging and Overtaking

TU Delft researchers also offered the following case study, providing insight into merging behavior with large versus small inter-vehicle gaps. The Code of Practice stated that trucks should decouple when approaching on- and off-ramps to permit other traffic to merge. In Figure 9 a two-truck platoon approaches an on-ramp. The platoon decouples in Figure 10, increasing headway from approximately 15 m to 26 m, which translates as 0.7 sec. and 1.2 sec. respectively, at a velocity of 80 kph (50 mph). At the same time, the merging truck on the on-ramp lines up with the gap created. This creates a situation in which there is a merging truck on the on-ramp and an overtaking truck on the lane to the left of the two-truck platoon. In Figure 11 the truck merges and accepts a very short 3 m headway (0.14 sec. at 80 kph (50 mph)). The truck continues to merge onto the lane to the left of the platoon, cutting in front of the overtaking truck, as can be seen in Figure 12. The researchers make the following observation: "in this situation it is fair to ask whether it would not be safer for the platoon not to decouple. The merging truck would have to merge behind the platoon, giving it a better view of traffic."

Figure 9: EPTC Overhead Video: Two-truck Platoon Approaching On-ramp

Figure 10: EPTC Overhead Video: Platoon Decouples and Creates a Larger Gap

Figure 11: EPTC Overhead Video: Merging Truck Accepts a 3m Headway

Figure 12: EPTC Overhead Video: Merging Truck Cuts in Front of Overtaking Truck

Based on this post-EPTC analysis, the TU Delft team specifically addressed some of the risks of increased risk of disturbance of traffic flow due to the behavior of the truck platoons as a single vehicle entity identified in pre-EPTC stakeholder workshops. The pre-trial discussions postulated placing requirements on visibility/recognition for the truck platoon, de-coupling at on- and off-ramps, restrictions / recommendations on specific maneuvers, prescribed following distance, and maximum speed. Based on the analysis of aerial video footage, the TU Delft team concluded that is not feasible to keep the truck platoon together at all times. Reasons for breaking up the platoon may be deliberate or unintended and are mainly associated with merging and overtaking. When deliberately decoupling, platoons mainly decouple in the vicinity of on-and off-ramps so that other traffic can merge (however, in one situation observed, this prompted a debate on whether it was actually necessary as the observed situation appeared unsafe compared to a platoon sticking together). For unintended decoupling, when other traffic (cars or unequipped trucks) "invade" a platoon, the automated decoupling procedure that is initiated causes the leading trucks to "fall back." Given the large headways enforced by the EPTC, other traffic (even trucks) were more inclined to merge in a platoon and initiate decoupling. In fact, researchers noted that "due to the fact that the truck platoons were driving slower than other trucks we noticed that the latter were either getting 'stuck' behind platoons or would overtake them if they had the opportunity. Overtaking platoons seemed to be more frequent than overtaking normal trucks."

II.J.iv. Consideration of Exclusive Lanes for Truck Platooning

The TTI Platooning Feasibilty Study (Kuhn et. al., 2017) suggested that TxDOT may want to consider implementing special lanes dedicated to the exclusive use of truck platooning. The researchers postulate that these roadways could be normal lanes that would be dedicated for use by truck platoons at night on intercity divided rural highways, or HOV/managed lanes at night or off-peak in urban areas. Another approach is for certain sections or lanes to be designated for through platoons only (traveling the entire distance of dedicated lanes) in order to improve freight flow through an urban area. They note that if such measures were to be implemented, "TxDOT may wish to open the shoulder to passenger vehicles and require trucks to operate in leftmost (or inside) lane."

Advantages and disadvantages of such approaches were briefly discussed. Advantages of exclusive truck platooning lanes were noted as providing separation of platoons from normal traffic, making better utilization of existing roadway capacity, and taking advantage of similar operational capabilities of trucks in separated traffic. Disadvantages noted were a reduction in available capacity of roadway and operational flexibility for non-platooned vehicles (cars and other trucks), complexities relating to enforcement of hours of operation/designated lanes, creating special requirements for incident management to keep lanes open, plus potential public opinion problems at times when the truck-only lane is unused while the general purpose lanes are congested with traffic.

II.J.v. Sharing the Road with Platoons: Public Education and Acceptance

The EPTC Stakeholder Consultation process identified issues regarding interaction with other road users when entering and exiting motorways in the vicinity of platoons, in particular the potential for public opinion backlash against a "wall of trucks" (the EPTC platoons consisted of three trucks). The EPTC Lessons Learned report offered the possibility of training other road users to accommodate platoons, thereby promoting societal benefits through positive communication (Rijkswaterstaat, 2016).

Peloton Technology (Peloton Plan, 2017) notes that their commercial DATP system will comply with Michigan law to ensure "a Truck operator to leaves "sufficient space… so that an overtaking vehicle may enter and occupy the space without danger" and to "allow reasonable access for other vehicles to afford those vehicles safe movement among lanes to exit or enter the highway." The driver plays an important role and is trained "to monitor the driving environment for Cut-in Vehicles, and to act as appropriate to ensure that a Cut-in Vehicle is able to (a) enter and occupy the space between the Trucks safely, and/or (b) move safely between lanes to exit or enter the highway. A Driver may do so either by (a) acting to dissolve the Platoon, or (b) steering the Truck between lanes." Additionally, the Peloton system "will automatically dissolve a Platoon when it detects a Cut-in Vehicle via radar or another sensor." More broadly:

> "The System prevents operation of Platoons in traffic conditions that are reasonably expected to degrade the safety performance, fuel efficiency benefits and/or Driver experience of Platoons, accounting for speed, traffic flow and the likelihood of a vehicle entering between Trucks in a Platoon, based on traffic data from Truck and exogenous sensors, including, but not limited to, vehicle speed and radar sensor data and traffic service data. In addition, as with respect to weather conditions, Peloton-approved Training instructs the Driver to exercise due care in selecting whether or not to travel in a Platoon even in traffic conditions in which the NOC is providing Safety Approval."

The effectiveness of such measures could be evaluated once DATP deployment commences.

II.K. Considerations for Identifying Platooning Corridors

The research team conducting the TTI Platooning Feasibility Study (Kuhn et al., 2017) was tasked with identifying "potential sites or corridors for commercial truck platooning in Texas where truck platooning may benefit both TxDOT and fleet operators." To do so, the researchers applied the following criteria:

a. Facility Type: Freeways (primarily interstate highways) located outside major urbanized or highly developed areas.
b. Daily Traffic Volume: (suggest a range in vehicles per day) Relatively low Annual Average Daily Traffic (AADT) to ensure that roadways will operate at a high Level of Service during the majority of the day.
c. Daily Truck Volume: A 24-hour truck percentage of at least 15%.
d. Minimum Length of Test Corridor: Relatively long stretch of highway should exist between urban centers to ensure that platooning would be appropriate
e. Speed Limit Range: The posted speed limit should be 65 mph or greater.

Regarding the Daily Traffic Volume, if AADT is high for a particular corridor yet truck platoons are operating at times of low traffic (such as overnight runs), this factor may have less impact. This could apply when traveling through urbanized or highly developed areas as well.

Regarding the criteria for daily truck volume to be greater than 15%, the research teams assumed that the opportunities for trucks to form platoons would be higher on roadways that experience a higher percent of trucks. This could be the case for ad hoc platooning but is not relevant for managed platooning, i.e., freight carriers relying on a Platoon Services Provider to arranging pairings.

Regarding minimum length of test corridor, given that platooning fuel savings are cumulative for each mile traveled, even relatively short freight runs could be considered "appropriate."

The TTI team identified 12 corridors across Texas as "candidate testbed site locations for demonstrating truck platoons." The approach in Texas differs dramatically from that used in States that have thus far allowed commercial platooning operations; in these States, no criteria are defined as to specific roadways preferred for platooning operations.

III. Potential DATP Effects on Roadway Structures

III.A. Key Findings

The structural implications of truck platoons passing over highway bridges and under sign support structures and toll plazas must be considered in planning and regulatory processes. DATP effects on structures depend on the size of the platoons (number of vehicles) and the axle-to-axle spacing between the trucks in the platoon.

Bridge Loading Effects

- An FDOT analysis found that 6 out of 2,467 highway bridge structures are not suitable for DATP operations at a 30-foot spacing, and all structures are suitable at a 60-foot spacing for legally loaded tractor trailer combinations. Note that the shortest distance currently expected for initial DATP deployment is about 40 feet.
- A more complete understanding of bridge effects from various DATP following distances will require modeling, simulation, and empirical studies.

Aerodynamic Effects on Structures

- Aerodynamic effects of DATP vehicles affecting structures within toll plazas have been theorized. Trucks also induce impulse loads on structures under which they pass. For light and/or flexible structures, such as sign support structures and toll booth plazas, platooned trucks will impose pressure impulses that may be more closely spaced in time than non-platooned trucks, which may result in greater relative vibration amplification. Analytical evaluation and testing may be useful to quantify this effect on in-service sign support structures and toll plazas. No analyses have been completed to date.

If it is determined that weight or aerodynamic effects exist and must be addressed, it would be straightforward for DATP systems to apply geo-fencing protocols such that platooning is suspended temporarily when encountering these infrastructure elements. This would require the State to maintain a geo-referenced list of such zones and communicate these to DATP fleets.

III.B. Bridge Structures

To assess the implications of DATP on bridges, three approaches may be undertaken for a range of DATP configurations: 1) the evaluation of past and current bridge design codes to assess their applicability and adequacy, 2) analytical methods to evaluate in-service bridge responses, and 3) instrumentation and testing of bridges found to be potentially vulnerable through analytical evaluation methods.

Bridges in Florida are designed to satisfy code requirements based on AASHTO LRFD Bridge Design Specifications (FDOT 2017, AASHTO 2014). The specifications for design loads consider 90% of two design load trucks with 50-ft spacing (rear axle of lead truck to front axle of following truck). In addition to the design truck loads, a design lane load is also applied to account for other traffic and loading on the bridge simultaneously.

This loading configuration is comparable to the configuration considered in this current study: two trucks with 40-ft bumper-to-bumper spacing. Note that the minimum spacing published by Peloton Technology is 36 feet measured from the rear of the front trailer to the front of the rear tractor (Peloton Plan 2017); the distance from rear axle on the front trailer to the end of that trailer (overhang) should be taken into account for an equivalent comparison. Given that a 5-ft overhang is not unusual for a van trailer, a Peloton platoon at 36-ft inter-vehicle spacing could in effect be operating at an approximately 40-ft spacing as defined in bridge loading analyses.

Therefore, bridges are currently designed to withstand loads and configurations similar to a two-truck platoon with 40-ft spacing.

The authors note that closer axle spacing and additional platoon trucks will require further structural assessment. There are also expected to be in-service bridges that are not designed according to current standards or may have other deficiencies. Analytical methods should be used to assess bridge inventories for such vulnerabilities. Preliminary analysis of bridge inventories may be carried out with load rating/permitting software for initial identification of vulnerable bridges. More detailed analysis (e.g., finite element analysis) should then be used for a more comprehensive assessment of potentially vulnerable bridges. If necessary, bridge instrumentation and testing under-prescribed platoon configurations would provide a definitive assessment of bridge response and capacity limits.

In late 2017, the Florida DOT Office of Maintenance used analytical methods to assess platoons for State interstate and turnpike roadways at 30-ft spacings for both 80,000-lb and 88,000-lb GVW trucks (DeVault, 2017). The analysis results are presented here:

> "Based on the bridge inventory data effective 10-06-2017, nearly all State-owned bridges can carry two-truck platoons at the maximum allowable Operating Level. Among 2,467 structures on interstate and turnpike mainlines, only 6 are not suitable for the 80,000 lb platoon, and 22 are not suitable for the 88,000 lb platoon.
>
> If the truck spacing is increased from 30 feet to 60 feet, all structures are suitable for the 80,000 lb two-truck platoon, and 10 remain unsuitable for the supralegal 88,000 lb platoon. These 10 remaining bridges are only sufficient for 80,000 lb legal weight trucks."

Thus, this FDOT analysis found that well less than 1% of bridges on interstate and turnpike mainlines might be subject to stresses exceeding bridge design specifications with trucks platooning at a 30-ft spacing. First generation platooning systems are expected to operate at spacings over 30 feet.

III.C. Overhead Structures

In addition to loads on bridges, trucks also induce loads on structures under which they pass. These impulse loads, induced both vertically and horizontally, must be considered for light and/or flexible structures, such as sign support structures and toll booth plazas. While the amplitude of the pressure impulses induced by trucks is below static design loads, the induced vibration contributes to structural fatigue loads (Creamer et al., 1979, Foutch et al., 2006). Platooned trucks will impose pressure impulses that may be more closely spaced in time than non-platooned trucks. Impulse loads induced by subsequent trucks may generate vibration in the overhead structure while the vibration induced by the previous truck is still damping out. The resulting condition may be vibration amplification over the impulse from a single truck. Analytical evaluation and testing may be useful to quantify this effect on in-service sign support structures and toll plazas.

IV. Task 4: DATP Deployment Implication Analysis

Based on findings of the Task 1 literature search and Task 3 industry discussions, this section addresses FDOT and DHSMV implications with respect to infrastructure, public safety, and administrative processes. Each of these is discussed in the sections below, followed by a summary that proposes DATP operational parameters going forward.

In addition to a general discussion of key issues, questions raised during the 2016 FDOT DATP Task Force meetings are interspersed and addressed. Each question is provided a thorough response so that it is complete within itself; this results in repetition of text but also allows a reader to get a full view of the issue if only interested in one of the many questions.

This section is organized across the following key areas:

a. Infrastructure
b. Public Safety
c. Administrative Processes
d. State Liability and Legal Implications

IV.A. Key Findings

Infrastructure

- All industry activity is focused on platooning systems that are completely self-sufficient with on-board equipment, i.e., no V2I / I2V communications are required.
- A TTI Platooning Feasibility Study (Kuhn et. al., 2017) found that "freeway capacity can be increased with platooning technology without any infrastructure expansion even with two-vehicle platooning," particularly in higher volume conditions.
- While stakeholders have raised the possibility of platooning restrictions in areas with high interchange density, we note that traffic conditions can at times be very light even in these and similar areas. Therefore, driver judgment regarding when to platoon appears to be a better approach than road segmentation or placing restrictions upon DATP use based on traffic density.
- Regarding merging and diverging, the road etiquette and laws regarding truckers allowing for "reasonable access" for merging traffic, which have long been in place, also encompass DATP operations.
- Planning processes would benefit by adapting travel demand models to include DATP operations to support future planning studies. Traffic simulations incorporating DATP behavior would also be useful to understand the potential effects of extensive DATP operations. However, it will take time after initial DATP deployment to gain a sense for operating parameters (inter-vehicle gaps preferred by fleets, for instance) and adoption rates. Therefore, any assessments of the need for dedicated lanes and/or environmental impacts should be deferred for the time being.
- Operations activities do not require any specific actions at the outset of DATP deployment. However, as DATP operations begin to proliferate in certain corridors, this provides an opportunity to evaluate any occurrences of traffic disruptions (near interchanges or other areas), as well as assess any detrimental behavior of other traffic near the platoon. If any restrictions need to be applied, the State should

develop an approach to notifying platooning operators of such areas and what operating parameters should be observed by platoons.

- Platoons of greater than two trucks may be beneficial to both the public and private sector in certain situations, such as roads that are dominated by truck drayage services near seaports. This could be a unique innovation opportunity for the State and should be examined.

Public Safety

- It is essential that DATP systems operate at a high safety level on public roads. The literature review has documented the industry's approach to DATP system safety, which depends on both technical and operational measures. These include:
    a. commercial air disc brakes on all tractor axles
    b. radar-based FCAM systems to automatically initiate braking when needed
    c. commercial electronic stability control system
    d. commercial Anti-Lock Braking Systems on tractors and trailers
    e. Platoon Operations Center to monitor safety-relevant conditions and adjust platooning parameters as needed (including adherence to speed limits as they change)
    f. fail-operational measures so that platooning is gracefully dissolved if, for example, V2V communications is disrupted
    g. driver engaged in the driving task (who can react early to cut-ins if needed)
    h. truck-to-truck video, plus driver-to-driver audio, enabling drivers to maximize situational awareness by teaming
    i. training of DATP drivers in both leader and follower roles
- Given these factors, DATP-equipped trucks are likely to have safety enhancements not found on many of the trucks on the roads today.
- Across states allowing platooning, self-certification of safe operations and practices is the norm. Tennessee law permits platooning on all Tennessee roads (TnDOT, 2017). The state requests the information via an online "Vehicle Platooning Operations Request" that includes addressing "contributing technologies to be used, safety validation, operational design domain, platoon formation method, platoon dissolution method & fallback, and vehicle description."
- In addition to equipment, the Peloton Network Operations Center enforces operational aspects of the safety approach: platooning can occur only on multi-lane, divided, controlled-access highways and pre-approved road segments on those highways; speed is kept at or below the legal speed limit; weather and traffic conditions must be appropriate; and the truck in the platoon with the best estimated braking capability is placed in the rear position.
- Both the Daimler and Peloton approaches accommodate any need to open up the inter-vehicle gap for traffic situations so that other vehicles may safely merge or change lanes.
- Enforcement personnel on the road can be informed that tractors are DATP-capable via a state-issued decal (issued based on a permitting process). This is seen as a simple initial approach for the early phase of DATP deployment, in which relatively few DATP-equipped trucks are expected to be operating in Florida. This gives the State the opportunity to evaluate the approach to DATP deployment and coordinate with fleets and manufacturers to develop the best legislative and operational approaches as the technology continues to mature.

- Because DATP builds upon proper brake operation, current inspection protocols are sufficient for DATP. Given the safety best practices described above, DATP vehicles can be expected to operate well above minimum standards. This approach can be evaluated during the initial phase of deployment.
- Enforcement operations would benefit from evaluating the degree to which "copycat" behavior (non-DATP vehicles closely following behind a platoon) is occurring, if at all. This can be augmented by discussions with early deployment fleets. During the DATP Pilot in December 2017, there was one instance in which a vehicle behind the rear DATP vehicle appeared be following closely. The Peloton drivers noticed this, coordinated with one another, and took action to interrupt this behavior by slowing down, prompting the close-following vehicle to pass the platoon. If "copycat" behavior is deemed to be an issue, develop training and methods for troopers to detect and respond to such instances.
- Collaboration on public communications between state agencies and DATP-equipped fleets and system developers is recommended.

Administrative Processes

- For DATP, as a Level 1 system with the professional driver fully engaged in the driving task, there is no apparent need for changes in licensing procedures. DATP drivers report that use of DATP is quickly learned and not significantly different from regular driving.
- No need is seen for any changes in registration and titling processes for DATP.
- Of the states that now allow commercial deployment of DATP, some allow for platooning operations "carte blanche" while others require a "Platooning Plan" or a notification. The "notification form" approach which Tennessee has established may be a good model for Florida, as it provides opportunity for a two-way process with applicants. Based on an applicant submitting a notification form, state agencies can receive key information specified by the State (such as approaches to system safety design and validation), seek further information if needed, and disallow an entity from proceeding if they determine there are concerns. If an entity is allowed to proceed, a simple DATP-specific permit could be issued by FDOT.

Liability

- European stakeholders discussed public sector liability aspects of truck platooning by acknowledging "this is new territory"; legal experts felt that although "change will be minimal, case law should create greater clarity."
- For DATP, having engaged drivers in both trucks serves to keep the liability questions very similar to regular driving. State liability relates to well-marked and maintained infrastructure, as is the case now.

IV.B. Infrastructure

Question from 2016 FDOT DATP Task Force Meetings:
What electronic or physical infrastructure is needed?

None. All industry activity (system developers and freight carriers) is focused on platooning systems that are completely self-sufficient with on-board equipment. Information in the Peloton Platooning Plan bolsters this conclusion (Peloton Plan, 2017). To our knowledge, no DATP system approaches relying on electronic or physical infrastructure are being developed by the industry.

However, data provided from the infrastructure could play a role at some point in the future. As noted in the TTI Platooning Feasibility Study (Kuhn et al., 2017): "The platoon controller reflects an operational environment in which platoon-related decisions are made within the vehicles themselves and potentially supplemented by external information. This approach was taken because vehicle-based decision-making would be sufficient to organize and coordinate vehicles effectively within a local platoon, but platoon-level speed recommendations and advisories could come from an external entity (such as a traffic management center) that has visibility into the conditions of the entire road network."

IV.B.i. Planning

Potential planning measures could include capacity change considerations with higher truck platooning penetration. Although capacity increases can be theorized for rural highways, these are typical road segments in which there is spare capacity. To the degree platooning is deemed appropriate on urban or suburban highways, a net benefit may occur.

MPO policies could address the creation of "truck platooning opportunity corridors. However, based on the literature and discussions with stakeholders, DATP operations would not require dedicated lanes.

More efficient trucking operations due to DATP can potentially impact/reduce the need for future expanded infrastructure. The "Driving Towards Driverless" report (Issac, 2016) recommends that travel demand models be updated as driverless vehicles take hold. This would include freight aspects in addition to passenger transport. The report notes that a research paper prepared by the Puget Sound Regional Council has explored an approach to updating an existing activity-based travel model.

Within the TTI Platooning Feasibility Study (Kuhn et al., 2017), researchers conducted a truck platooning simulation for two-truck platoons in a mixed traffic condition. According to the study report, the simulation results "confirm that freeway capacity can be increased with platooning technology without any infrastructure expansion even with two-vehicle platooning." For more detailed future work, the TTI team proposed to evaluate platooning across five categories, including mobility and capacity/throughput. This study also suggested that TxDOT may want to consider implementing special lanes dedicated to the exclusive use of truck platooning. The researchers postulate that these roadways could be normal lanes that would be dedicated for use by truck platoons at night on intercity divided rural highways, or HOV/managed lanes at night or off-peak in urban areas. Another approach is for certain sections or lanes to be designated for through platoons only (traveling the entire distance of dedicated lane) in order to improve freight flow through an urban area. Advantages of exclusive truck platooning lanes were noted as providing separation of platoons from normal traffic, making better utilization of existing roadway capacity, and taking advantage of similar operational capabilities of trucks in separated traffic. Disadvantages noted were a reduction in available capacity of roadway and operational flexibility for non-platooned vehicles (cars and other trucks), complexities relating to enforcement of hours of operation/designated lanes, creating special requirements for incident management to keep lanes open, plus potential public opinion problems at times when the truck-only lane is unused while the general purpose lanes are congested with traffic.

Although the scope of this study is two-truck platoons, at some point in the future three-truck platoons may be deployed. If so, this could bring additional complexity to planning.

Question/Issue from 2016 FDOT DATP Task Force Meetings:
Reference FDOT strategic plans and understand how this is addressed and if the plans need to be amended to include impacts from DATP (Florida Transportation Plan, Freight Plan, and the Emerging Motor Carrier System Plan).

> The TNO study addresses larger scale effects of DATP operations. A next step after the completion of this study could be the analysis of FDOT strategic plans to make DATP-focused recommendations if/when Florida statutes are changed to allow DATP operations (such an analysis is not within the scope of this study).

Long Term Lane Capacity Effects

Research into heavy truck platooning (Bergenheim et al., 2012) found that operating tractor-trailer trucks in close-formation automated platoons of three trucks could enable a capacity of about 1,500 trucks per lane per hour, which is twice the capacity achievable with trucks driven individually.

The TNO study (Jannsen, 2015) noted that platooning will allow a more optimal use of the available road capacity. In a typical scenario, they calculate that two trucks platooning at a .3 second gap (29 feet at 60 mph) would decrease the total length – including the inter-vehicle gap – of those two trucks by 46%, from 262 feet to 141 feet. Thus, the amount of road space taken by the two trucks is essentially halved.

In terms of DATP traffic impacts over the long term, traffic modeling within the FHWA-Auburn study (Auburn University, 2015) found that:

> "as market penetration of DATP increases, small increases in average speed of traffic, and therefore reductions in travel time, should be expected. A similar trend occurs as headways are reduced but the effect is less pronounced. Significant positive impacts on road capacity can be expected in a future in which most highway trucks are platooning in long platoons (i.e., longer than the DATP two-truck platoons)."

Within the TTI Platooning Feasibility Study (Kuhn et al., 2017), researchers conducted a truck platooning simulation for two-truck platoons in a mixed traffic condition. The simulation results "confirm that freeway capacity can be increased with platooning technology without any infrastructure expansion even with two-vehicle platooning." Further, "The peak volume of 3000 vph did not show any pronounced increase in vehicle throughput regardless of market penetration because the traffic volume did not exceed normal freeway capacity. However, there is a pronounced increase in vehicle throughput over time for the peak volume of 10,000 vph. … The increases are consistent when the market penetration is over 30 percent. The throughput increase benefits remain regardless of market penetration rates under high volume scenarios."

The NCHRP Truck CV AV study found such vehicles will have a significant impact on infrastructure capacity, noting that "although passenger vehicles occupy a major role in the determination of road capacity the consideration of trucks is also crucial." They cite several studies which hold that CV and AV vehicles "will enable shorter headways, permitting higher volumes at high speeds," noting that the application of CV and AV for freight "can lead to increases in capacity particularly on rural and interstate highways where truck platooning is more likely." Citing additional studies showing wide variation in projected roadway capacity increases, they note the difficulty of anticipating increases in roadway capacity with certainty, particularly since it is too early to know what inter-vehicle gaps will come into common use as the technology matures, affecting capacity outcomes (Fitzpatrick, 2016).

Although capacity increases can be theorized for rural highways, these are typical road segments in which there is spare capacity. To the degree platooning is deemed appropriate on urban or suburban highways, a net benefit may occur.

Questions/Issues from 2016 FDOT DATP Task Force Meetings:
Consider the amount of truck traffic and percent of trucks on the roadway.
Can road capacity be enhanced with platoons? Simulation estimates that 60% saturation would return capacity benefits, but 20% has no net effect.

> From the citations above, it is clear that the potential exists for enhancement of road capacity, but effects are difficult to quantify at this time since the parameters of DATP are still evolving.

Dedicated Lanes for Platooning

The study team was asked to address MPO policies associated with providing for truck platooning opportunity corridors. The EPTC Stakeholder Consultation (Rijkswaterstaat, 2016) suggested defining specific portions of the road network for platooning (but did not define criteria for doing so). On limited access highways, allowing DATP operations can span the gamut of allowing unconstrained operations to very specific DATP-approved road segments. DATP-specific regulatory actions thus far in other States have allowed unconstrained operations, in some cases seeking notification of where DATP will be operating.

The NCHRP AV CV truck report (Fitzpatrick, 2016) notes that truck platoons do not require dedicated lanes to operate. However, the authors posit that some jurisdictions may choose this approach to mitigate concerns about mixed traffic environments and the potential difficulties of individual non-platooned vehicles engaging in the lanes occupied by a platoon (they also note that no empirical evidence exists to justify taking or not taking this action). If dedicated truck lanes were implemented, they see benefits in terms of greater safety from segregated traffic, more efficient formation of platoons, and the ability to further reduce the headway between trucks while maintaining safety.

The TTI Platooning Feasibility Study (Kuhn et al., 2017) suggested that TxDOT may want to consider implementing dedicated lanes for truck platooning. The researchers postulate that these roadways could be normal lanes that would be dedicated for use by truck platoons at night on intercity divided rural highways, or HOV/managed lanes at night or off-peak hours in urban areas. Another approach is for certain sections or lanes to be designated for through platoons only (traveling entire distance of dedicated lane) in order to improve freight flow through an urban area. They note that if such measures were to be implemented, "TxDOT may wish to open the shoulder to passenger vehicles and require trucks to operate in leftmost (or inside) lane." Advantages and disadvantages of such approaches were briefly discussed. Advantages of exclusive truck platooning lanes were noted as providing separation of platoons from normal traffic, making better utilization of existing roadway capacity, and taking advantage of similar operational capabilities of trucks in separated traffic. Disadvantages noted were a reduction in available capacity of roadway and operational flexibility for non-platooned vehicles (cars and other trucks), complexities relating to enforcement of hours of operation/designated lanes, creating special requirements for incident management to keep lanes open, plus potential public opinion problems at times when the truck-only lane is unused while the general purpose lanes are congested with traffic.

Environmental Considerations

The NCHRP AV CV truck report (Fitzpatrick, 2016) finds that platooning fuel/emissions improvements can "change the benefit cost analysis of potential projects drastically and can be especially useful in regions of non-conformity as per the definitions of USEPA." At the same time, "Two contrary effects need to be analyzed with respect to environmental considerations: (1) increases in truck volume due to automation, and (2) decreases in fuel consumption and advancement in engine efficiency leading to decreased environmental impacts."

Question/Issue from 2016 FDOT DATP Task Force Meetings:
The acceleration and deceleration setting should be carefully reviewed in a micro-simulation model, if funding allows, to predict anticipated operational and environmental benefits.

> The literature review notes the results from simulation and track testing show clear environmental benefits. Results from the Auburn study note that traffic operations benefits are not expected until on-road DATP operations are occurring for the majority of trucks on the road. This finding is bolstered by the results from simulations conducted within the TTI Platooning Study and TU Delft. The latter study assessed truck platooning across various traffic states, truck gap settings, platoon sizes, and the on-road penetration of equipped trucks. Results addressed the total traffic performance, the performance of traffic at interchanges, and the ability of a platoon to remain platooning (i.e., not interrupted by non-platooning vehicles). Results indicated that platooning – depending on the level of market penetration -- would have a "marginal and acceptable" effect on traffic flow performance in general but would have a large negative effect for near congested or congested traffic flow. (Note that platooning would typically be discontinued in heavy traffic, as fuel economy benefits at low speed are minimal.) The researchers also found "no substantial concerns in allowing truck platoon sizes of two or three trucks, or allowing gap settings between trucks in the range of 0.3-0.7 seconds in regard to the traffic flow."

Planning Recommendations

a. travel demand models should be adapted to include DATP operations so as to support future planning studies
b. defer including DATP in determination of the need for dedicated lanes and/or environmental impacts, as it is far too early to estimate adoption rates of platooning technology and the percent of miles driven while actually in platoon mode
c. once DATP operating parameters are clarified, conduct traffic simulations to understand the potential effects of extensive DATP operations

IV.B.ii. Operations

Platooning benefits occur at highway speeds, due to the aerodynamics of drafting. Therefore, commercial development of platooning focuses on highway operations. Further, commercial development strongly favors an Operational Design Domain on limited-access highways because this is a more orderly environment which is well suited to the safety systems underpinning DATP. From the state agency perspective, DATP operations could also occur on other types of roadways if safety levels are maintained.

Although the scope of this study is two-truck platoons, at some point in the future three-truck platoons may be deployed. If so, this could bring additional complexity to operations.

Road Segmentation

On limited access highways, allowing DATP operations can span the gamut of allowing unconstrained operations to very specific DATP-approved road segments. DATP-specific regulatory actions thus far in other States have allowed unconstrained operations, in some cases seeking notification of where DATP will be operating. For instance, the Tennessee law permits platooning on all Tennessee roads (TnDOT, 2017).

The EPTC Stakeholder Consultation (Rijkswaterstaat, 2016) suggested defining specific portions of the road network for platooning (but did not define criteria for doing so).

Given that traffic conditions can at times be very light even in areas with dense interchange spacing, driver judgment regarding when to platoon appears to be a better approach than road segmentation. No data to date have indicated that merging when a DATP pair is passing an interchange to be a problem; however, this should be monitored if/when DATP deployment occurs.

Managed Lanes

The NCHRP AV CV truck report (Fitzpatrick, 2016) observed that managed lanes might be created as a solution to automated vehicular traffic in general, with platoons possibly being a part of this. The authors noted that "whether such a scenario would provide adequate benefit to jurisdictions that pursued it is an open question. Answers are likely to be forthcoming as small-scale deployments begin in the U.S. and elsewhere."

The EPTC Stakeholder Consultation (Rijkswaterstaat, 2016) identified for future exploration the availability of dynamically dedicated lanes for platoons.

Kockelman also notes that "as Connected Automated Vehicle (CAV) development increases and the state begins to reap the anticipated benefits of CAV use, lane management in the form of CAV-only lanes could potentially serve as a method of incentivizing the use of CAVs. In addition to speeding up travel for CAVs on roads with a CAV-only lane, this form of lane management would help alleviate the effects of heavy vehicles and CAVs mixing on the same routes. Additionally, removing CAVs from lanes with normal access using lane management will improve travel times for conventional vehicles slightly" (Kockelman, 2016). DATP-only lanes would have similar advantages, but these are not required for DATP deployment.

Managed Platooning

The inter-vehicle gap is not fixed, but variable. Platooning systems now being commercialized will have the ability to expand inter-vehicle gaps as needed, such as when passing through a dense interchange zone, then coming back together when conditions return to normal (Peloton, 2016). The concept of "managed platooning" is based on these factors, as well as weather and other conditions.

Similarly, the EPTC Stakeholder Consultation identified the possibility of dynamic gap distance determination depending on road network suitability and for specific situations (such as bridges or tunnels) (Rijkswaterstaat, 2016). The EPTC document does not address the specifics of how government agencies would distribute information on restricted situations or enforce compliance.

While these measures are defined by the system developers, FDOT would have the opportunity to define certain areas / situations that would benefit from modifying typical platoon operations based on specific studies.

Managing Traffic Interactions

Questions/Issues from 2016 FDOT DATP Task Force Meetings:
Look at MUTCD for sight distance and advance warnings (work zones).

> No changes to current practices are needed, as the lead DATP driver is "like any other driver" with respect to sight distance.

Examining potential operational impacts from multiple vehicle trains (more than two-truck platoons) should be considered.

> Platoons with greater than two trucks exacerbate some but not all platooning issues. Based on industry activity, three-truck platoons can be expected if initial experiences with two truck platoons are positive. The Tennessee law considers "two or more vehicles to be a platoon" (TnDOT 2017). Since the Florida Statute defines DATP as two trucks, this study is limited to two-truck platoons.

Consider possible impacts to other vehicles in the traffic flow streams, meaning, will other vehicles slow down and behave differently when they see a platoon of, say, 4 or more trucks in the train?

> ETPC truck drivers noticed some "copycat" behavior by other truckers in non-equipped vehicles; however, the frequency of such behavior was not documented. This was also raised in the NCHRP Truck CV AV report but the sources cited are not definitive. Drivers interviewed in the NACFE Confidence Report expressed opinions that cars cutting in between platooning trucks are a "non event" since the system control handles this situation well. There is no published empirical evidence of other traffic reacting (or not reacting) to platoons. Regarding four or more trucks in a platoon, this is beyond the scope of this study as DATP is defined as two-truck platooning.

The study may provide clarity for readers on the fact that truck platooning is not the same as, and in fact quite different from, cooperative adaptive cruise control (CACC). In fact, it is worth noting the way CACC functions and look for commonalities with DATP as regards to traffic flow characteristics.

> This has been addressed in the literature review. Detailed studies of CACC and traffic flow impacts to date have focused on passenger cars.

Should there be limitations on traffic density for platooning. How does platooning affect traffic density? How will platooning affect traffic flow?
Consider which lane the platoon runs in. If traffic disruptions are expected to occur, consider running pilot in the middle of a 3-lane segment.

Platooning effects across traffic density levels is discussed by various sources in the literature, and simulations making various assumptions about DATP parameters have shown potential effects. The Delft simulation study (Calvert et al., 2017) showed negative traffic impacts of platoons at interchanges in congested traffic; however, according to one system supplier, Peloton, platooning would be suspended in congested traffic based on driver assessment of the situation.

TTI platooning simulation results (Kuhn et al., 2017) "confirm that freeway capacity can be increased with platooning technology without any infrastructure expansion even with two-vehicle platooning," particularly in peak volume conditions.

Supplier Peloton Technology (Peloton Plan, 2017) notes that their system "prevents operation of Platoons in traffic conditions that are reasonably expected to degrade the safety performance, fuel efficiency benefits and/or driver experience of Platoons, accounting for speed, traffic flow and the likelihood of a vehicle entering between Trucks in a Platoon." Further, "Consistent with Driver functions of monitoring the driving environment and intervening in vehicle motion control as appropriate during performance of the DDT, the Peloton-approved Training that a Driver receives prior to operating a Truck in a Platoon instructs the Driver to monitor the driving environment for Cut-in Vehicles, and to act as appropriate to ensure that a Cut-in Vehicle is able to (a) enter and occupy the space between the Trucks safely, and/or (b) move safely between lanes to exit or enter the highway. A Driver may do so either by (a) acting to dissolve the Platoon, or (b) steering the Truck between lanes."

There is no definitive basis to designate specific lanes for platooning. In the EPTC, one German state did not allow truck platooning on two-lane motorways, and another state allowed truck platooning only on motorways with an emergency lane. Belgium confined truck platooning to the right lane, and the Netherlands placed a general ban on overtaking. These measures were taken due to an abundance of caution, as regulators were dealing with many unknowns. Following the EPTC on-road portion, the efficacy of these measures was not evaluated. During the Florida DATP Pilot in December 2017, the platooning trucks were not restricted to specific lanes; the platoon drivers coordinated via radio as needed to change lanes and choose the best running lane for conditions, taking into account upcoming lane drops and interchanges. FHP personnel experienced DATP system operations and observed no clear safety concerns during the three-day pilot phase. Additionally, state transportation officials observing operations in the Pilot did not observe any instances of the platoon interfering with traffic or inconveniencing other motorists. Demo participants observed platoon drivers accommodating merges and lane changes for other traffic. The FTE Traffic Management Center monitored the 1,100 miles of testing and recorded no impacts on daily operations.

While the above discussion offers useful insights, no quantitative empirical evidence has been produced to date to address these questions.

Can there be more than two combinations in a sequence?

Assuming this refers to two two-truck platoons following one another, this could certainly occur. The spacing between the rear of the first platoon and the front of the second platoon would have to comply with following distance requirements for non-equipped trucks.

Assess the impact of turbulence and aerodynamic drag created by a platooning train on the adjoining non-truck traffic.

No literature was found that directly raises or addresses the aerodynamic effects of platoons on adjoining traffic.

One of the major field-level issues is about the merge and diverge points; in particular, the impact of decelerating vehicles (as they head to a rest area or exit the freeway) and merging/acceleration (from rest areas or freeway entry) are areas of traffic operations concern, especially during truck platooning. Similarly, merging between lanes due to construction or road closures.

Merge / diverge points: DATP trucks would simply slow down to accommodate decelerating vehicles approaching an exit, as truckers do now. For merging into traffic, research and testing (EPTC) shows that smaller gaps are less disruptive to other traffic, and the Florida limitation of DATP to two trucks results in a fairly benign situation. In many cases, it could be simpler to let both trucks pass rather than try to merge between trucks. However, this will not always be the case; Michigan law requires a platoon operator to “allow reasonable access for other vehicles to afford those vehicles safe movement among lanes to exit or enter the highway,” consistent with a substantially similar requirement in many states imposed on drivers of trucks following other trucks. A likely scenario is the front truck driver seeing a vehicle on an on-ramp (or adjacent lane) which will soon need to merge, and the front truck driver opts to slow down to accommodate that vehicle. If that merging vehicle is closer to the rear truck, the rear truck driver can do the same, with platooning re-established shortly thereafter. For approaching a lane drop in a construction zone, this same process would apply. Or, if the speed limit is reduced for the work zone below the system speed threshold, platooning would cease.

During the Florida DATP Pilot in December 2017, state transportation officials observing operations in the Pilot did not observe any instances of the platoon interfering with traffic or inconveniencing other motorists. Demo participants observed platoon drivers accommodating merges and lane changes for other traffic. The FTE Traffic Management Center monitored the 1,100 miles of testing and recorded no impacts on daily operations.

Simply put, the road etiquette and law regarding truckers allowing for “reasonable access” for merging traffic that has long been in place also encompasses DATP operations.

Communications/ Data

Questions/Issues from 2016 FDOT DATP Task Force Meetings:

Define specific standards for V2V and V2I communication.

Should we identify minimum data requirements for ad hoc truck platooning? (i.e., braking characteristics, load type, vehicle/trailer weight, power/weight ratio, DATP technology specifications, v2v system requirements, etc.)

Regarding standards and minimum data requirements, there is no literature or existing regulations which address state agencies defining technical aspects of vehicle control systems. This could fall into the Federal domain (NHTSA) but since DATP is not primarily a safety system, this could be out of NHTSA's scope. The more typical approach is to leave this to industry. The International Standards Organizations and the Society of Automotive Engineers are addressing standardization of Cooperative Adaptive Cruise Control, of which platooning is a subset. However, standards are not needed for safety or for deployment within major fleets. Although standards are important, they generally come several years after first product introductions – this is typical in the vehicle industry.

While no formal industry standards or recommended practices have been published, the "Automated Driving and Platooning" Information Report published by the American Trucking Association Technology and Maintenance Council (TMC) serves as a highly useful reference; key points from this document are included in this study, in particular high-level functional requirements for DATP. Information from DATP developers indicate they are addressing many of these requirements.

FDOT does not want to broker platooning but rather plug/pull data into system.

The DATP Pilot held in December 2017 with Peloton Technology could be a basis for discussions regarding ongoing data sharing. It would be useful for FDOT to clearly define what data is of interest and how it would be used.

What cybersecurity standards should be established?

Due to the complexity of both the risks and countermeasures in the cybersecurity realm, standards per se have not been pursued. Cybersecurity guidelines have been issued by NHTSA and the UK government. These call for "best practices" and adherence is left to the industry.

V2I/I2V

The EPTC Stakeholder Consultation (Rijkswaterstaat, 2016) discussed a role for I2V/V2I communications for platooning, including using V2X communication infrastructure to enhance platooning, I2V communications to alert platooning vehicles of unforeseen events, and platoon driving prioritized by traffic management (green waves). No clear role for use of V2X has been described in other literature; warning of unforeseen events in particular would require a very dense deployment of I2V roadside units to accomplish this effectively (and this could be done instead through cellular communications). "Green waves" imply signalized corridors; however, commercial interest in platooning focuses on limited-access highways.

While no role is currently seen by system developers for V2I/ I2V in enabling platooning, data provided from the infrastructure could play a role at some point in the future. As noted in the TTI Platooning Feasibility Study (Kuhn et al., 2017):

> "The platoon controller reflects an operational environment in which platoon-related decisions are made within the vehicles themselves and potentially supplemented by external information. This approach was taken because vehicle-based decision-making would be sufficient to organize and coordinate vehicles effectively within a local platoon, but platoon-level speed recommendations and advisories could come from an external entity (such as a traffic management center) that has visibility into the conditions of the entire road network."

This type of data could be transmitted via commercial wireless networks or I2V. Regarding I2V, since advisories would not require sub-second latency as there is no need to transmit this data directly from the roadside.

Questions/Issues from 2016 FDOT DATP Task Force Meetings:

Can V2I be tested during platooning testing as well?

No role is seen by system developers for V2I/ I2V in enabling or enhancing platooning.

Operations Recommendations

a. Operations activities do not require any specific actions at the outset of DATP deployment.
b. As DATP operations begin to proliferate in certain corridors, this provides an opportunity to evaluate any occurrences of traffic disruptions (near interchanges or other areas), as well as assess any detrimental behavior of other traffic near the platoon. If any restrictions need to be applied, the State should develop an approach to notifying platooning operators of such areas and what operating parameters should be observed by platoons.
c. Platoons of greater than two trucks may be beneficial to both the public and private sector in certain situations, such as roads that are dominated by truck drayage services near seaports. This could be a unique innovation opportunity for the State and should be examined.

IV.B.iii. Maintenance

Bridge Effects

Subsequent to the EPTC, Sweden indicated that future Field Operational Tests will require a longer following distance between platooning trucks on bridges. The EPTC Lessons Learned report notes that "more research is needed on the impact of truck platooning on the wear and tear to pavements and bridges" (Rijkswaterstaat, 2016).

FDOT bridge engineers have raised the possibility that live load effects of DATP truck pairs on bridges could be detrimental. These effects, if any, would likely increase in severity as truck platoons go beyond two trucks (DATP) to longer platoons. The NCHRP AV CV truck report (Fitzpatrick, 2016) noted "uncertainty" regarding the impact of closely spaced truck platoons on bridges and called for additional research on this issue. It is believed that these factors have not been studied prior to this FDOT-sponsored DATP study.

Per the UF assessment, although bridges are currently designed to withstand loads and configurations similar to a two-truck platoon with 40-ft spacing, closer axle spacing and additional platoon trucks will require further structural assessment. There are also expected to be in-service bridges that are not designed according to current standards or may have other deficiencies. UF recommended using analytical methods to assess bridge inventories for such vulnerabilities. In late 2017, an FDOT analysis (see Section III.B) found that well less than 1% of bridges on interstate and turnpike mainlines might be subject to stresses exceeding bridge design specifications with trucks platooning at a 30-ft spacing (DeVault, 2017). First generation platooning systems are expected to operate at spacings over 30 feet.

If DATP pairs are shown to be detrimental, "platoon management" will be an important concept for deployment. Based on a database of bridges with weight restrictions that would apply to trucks in typical platoon spacing, a Platoon Management Center could extend following distances ahead of the bridge, re-establishing the closer inter-vehicle gap after crossing the bridge.

<u>*Questions/Issues from 2016 FDOT DATP Task Force Meetings:*</u>
Prolonged use/heavy saturation rate of DATP could decrease life of structures.
Consider identifying a saturation rate of DATP in use on public roadways that could lead to a decrease in lifespan.
Florida bridges designed for 80,000 lbs., NY designed for 100,000 lbs., so rules may vary from State to State. Many bridges can take legal loads only.
State has heavy freight corridor study; this one should coordinate with that.
There are 12 structures that are concerning with weight limits. All are in urban areas.
Consider a cost/benefit analysis of increased freight movement vs. cost to replace structures (repair/replace intervals).

> The UF assessment addresses these questions at a high level and proposes analytical approaches to understanding real-world effects. The FDOT analysis (DeVault, 2017) described above is the only literature found which directly addresses weight effects of platoons, finding that with platoon following distances of 30 feet or more, very few bridges would be affected.

Consider establishing (and maintaining) a geo-fence app/layer that identifies structures that could pose issues for DATP (deficient bridges, dense interchange areas, cons)

> Regarding establishing geo-fence areas for various purposes, this is not addressed in the literature. But based on industry discussions, this would be feasible on a technical and business basis once structures/areas that pose issues are identified by agencies or industry.

Establish signal to driver that bridge is approaching? In cab warning/ connected vehicle device?

> No literature addressing this issue was found. Current DATP developers are considering geo-fencing to trigger any needed changes in parameters, such as separation distance, for an upcoming bridge. This is very practical to handle "in the cloud" such that a message generated at the roadside may not be necessary.

Toll Plaza Effects

Per the UF assessment, trucks also induce loads on structures under which they pass. These impulse loads, induced both vertically and horizontally, must be considered for light and/or flexible structures, such as sign support structures and toll booth plazas. Based on the literature, platooned trucks will impose pressure impulses that may be more closely spaced in time than non-platooned trucks. Impulse loads induced by subsequent trucks may generate vibration in the overhead structure while the vibration induced by the previous truck is still damping out. The resulting condition may be vibration amplification over the impulse from a single truck. Analytical evaluation and testing may be useful to quantify this effect on in-service sign support structures and toll plazas.

Questions/Issues from 2016 FDOT DATP Task Force Meetings:

Should DATP trucks disengage through tolling gantries? (FTE)

Ensure stability of roadside and overhead structures, if platooning results in additional turbulence. Is wind shear compounded by 2 trucks following within 30'-120'?

> No prior literature addresses this issue. The UF assessment indicates that platooning could impact these structures and proposes analytical approaches to understanding real-world effects. If needed, rather than disengagement, an elongation of the inter-vehicle gap could possibly adequately address this issue. This could be done automatically via geo-coding of tolling structures within the DATP software.

Should there be a minimum distance between LV and FV through gantries so as to not obscure the license plate of the LV by the FV? (for tolling by plate facilities) (FTE).

> "Disengagement" per se may not be necessary, as inter-vehicle gaps can be opened up as needed to accommodate requirements from toll authorities.

Can existing tolling technologies "capture" both the LV and FV transponders if DATP is engaged? Consider quantifying the minimum following distance and maximum speed necessary (FTE).

> No literature addresses capturing transponders of platooned vehicles; inter-vehicle gaps can be opened up as needed to accommodate requirements from toll authorities. Relatedly, Peloton Technology reports that PrePass, which offers weigh-station bypass transponders, has stated that its transponders would not be interfered with by platoons operating at the Peloton DATP system's inter-vehicle gap range of 35-80 feet.

Pavement Effects

The NCHRP AV CV truck report (Fitzpatrick, 2016) noted "uncertainty" regarding the impact of closely spaced truck platoons on roadway pavements and called for additional research on this issue. This topic has not been raised in other literature. The researchers may have been referring to platooning at Level 2 and above, in which case steering is automated. Some have postulated the potential for rutting if all automated vehicles traverse precisely the same path within a lane; however, tech developers dismiss this concern, since a minor "intentional wander" can easily be implemented in software." In DATP, the driver is responsible for steering and in this sense the platooning trucks are no different from others.

Electromagnetic Compatibility (EMC):

FDOT engineers have raised questions regarding possible interference between existing roadside equipment (with and without wireless connectivity) and DSRC transmitters on DATP vehicles. The converse could be the case as well. However, FCC rules on signal power, bandwidth, modulation, and frequency are intended to prevent interference of this type. As long as all devices are within FCC specifications, such interference should not occur.

The FCC is currently considering sharing of the DSRC spectrum with unlicensed devices (to provide greater capacity for internet service providers). If current regulations are changed to allow such sharing, this would present challenges to both on-board and roadside DSRC equipment.

Based on these factors, we conclude that electromagnetic compatibility is not a concern for DATP operations.

Maintenance Recommendations

a. perform analyses, simulations, and/or empirical studies to more deeply understand the effects of platoons on bridges and toll plazas. Such studies should address a range of platooning inter-vehicle gaps and frequencies of platoon crossings.
b. as needed, devise a process to identify specific bridges as "platoon restricted," which would include geo-fencing information plus minimum inter-vehicle gaps allowed. This must be done in such a way as to avoid publishing bridge-related classified information.
c. evaluate the ability of tolling systems to "see" transponders on both trucks in a platoon for various inter-vehicle gap sizes

IV.B.iv. Design

For highly automated vehicles, Kockelman has noted the potential need for changes in road design, including "those for sight distance, curve radii, cross-sectional slopes, and other elements of geometric design" (Kockelman, 2016). The actual need for changes, if any, will depend strongly the operational approaches and technical approaches of future HAV trucks, which cannot be predicted today.

DATP, as a Level 1 system, does not require any changes in these areas.

Specific to platooning, the NCHRP Truck CV AV report (Fitzpatrick, 2016) makes several design-relevant points which we find to be highly questionable. They envision trucks "entering and exiting in the form of platoons from interstate highways, even though with small headways" such that longer on- and off-ramps will be needed. Similarly, they assert platooning on ramps will require "better geometric design such as smoother curves for on-ramps and off-ramps, and gentle vertical curves." These points seem to be based on assumptions that do not align with current commercial activity to deploy DATP. Tech developers are focusing on platoon operations only on mainline high-speed road segments, not ramps. There is no need for DATP vehicles to be platooned before entering the highway; the platoon will be formed once the trucks are on the main roadway. Similarly, it will be the normal case to dissolve platoons on the highway prior to exiting ramps for local streets. To platoon on entry/exit ramps between two divided highways may be possible in many cases unless the curvature is extreme; if the curvature is too great, the platoon would simply be dissolved until both vehicles are on the new highway.

Therefore, there is no basis to expect that DATP will require design-oriented changes.

<u>Questions/Issues from 2016 FDOT DATP Task Force Meetings:</u>

Should there be minimum roadway design for platooning?

> Roadway design: current system development focuses on operation on roadways complying with current roadway design standards. In the case of tight curvature in mountainous or canyon areas, the nature of DATP is that the drivers, who are responsible for steering, will handle the situation. Or in the case of Peloton, the Network Operations Center may disable platooning at certain roadway grades and curves. If the trucks lose V2V communications due to the geometry, automatic de-coupling would occur (Peloton Platooning Plan, 2017).

IV.C. Public Safety

IV.C.i. Assessing Fleet Safety

Across States allowing platooning, self-certification of safe operations and practices is the norm. Tennessee law permits platooning on all Tennessee roads (TnDOT, 2017). The State requests the information via an online "Vehicle Platooning Operations Request" that includes addressing "contributing technologies to be used, safety validation, operational design domain, platoon formation method, platoon dissolution method & fallback, and vehicle description." By submitting the form, the person (fleet) submitting the request agrees to this statement:

> "I certify that the company vehicles and drivers will comply with state and federal rules and regulations and the driver-assist vehicle platooning equipment is installed properly and meets all USDOT safety standards."

<u>Questions/Issues from the 2016 FDOT DATP Task Force Meetings:</u>

DHSMV's concern about safety is the primary reason for much of the legislation language. DOT and DHSMV legislative affairs met and agreed that they are not comfortable allowing platoons without knowing more about the safety ramifications.

> "Knowing safety ramifications" centers on comparing differences in DATP operations to current operations. The requirements for safe operations, from a fleet perspective, are noted in the TMC Information Report. Additionally, one of the lead system developers (Peloton) requires the highest performing brakes (air disc tractor brakes and ABS trailer brakes) and collision mitigation systems (radar-based FCAM systems) as a prerequisite to installation and use of their system; if this were to become true of all DATP vehicles, then these trucks would have more extensive safety equipment than most other trucks on the roads (Peloton Plan, 2017).
>
> The Tennessee FAQ on platooning (TnDOT, 2017) addresses safety as follows: "From a safety standpoint, the constant monitoring and updates among the vehicles in the platoon, estimated at 50 times per second, reduces the impact among vehicles in case of a crash and provides reaction times much faster than humans."

The Peloton Technology website provides a video showing their connected braking DATP system maintaining the inter-vehicle gap during "extreme braking" by the lead vehicle from highway speed down to a stop, on a closed test track (Peloton "For Drivers" video, 2017).

Should motor carriers have a minimum Safety Fitness score? Should we look at driver motor vehicle reports and crash history to determine eligibility? Companies must ensure vehicles are fully operative and must ensure brakes are in good condition. We want only the best of the best companies (in terms of safety practices) participating. DATP operations should be limited to reputable freight operators, considering CSA scores, carrier requirements, fleet size, driver experience and driving record, and vehicle inspection protocols.

It would be unprecedented for a State government to prohibit carriers from adopting new truck technology, particularly technology with the potential to improve safety, on the basis of a safety fitness score. Also, such an approach could create a "perverse incentive" disallowing fleets from adopting technology that could help improve their safety fitness.

In 2017 FMCSA withdrew a proposed 2016 rule to create a carrier "Safety Fitness Determination" but carriers successfully argued that this would be based on "badly flawed" safety data (i.e., CSA scores) (Scullin, 2017). Additionally, a safety fitness rating is subject to change with possibly significant lags between a rating determination and notice to fleet managers, drivers, and, in the case of automation services, to service providers who would therefore be challenged to comply with a requirement to offer services only to sufficiently rated customers.

Avoid creating a scenario that creates a single proprietor situation.

The supplier base is a business issue and should be left to fleets to sort out. Currently several companies, representing both OEMs and component suppliers, are known to be developing platooning systems.

IV.C.ii. Enforcing Vehicle Safety

Robust Vehicle Operations

How should testing and certification be accomplished to ensure robust operation of DATP in public traffic? What are Federal, State, and industry roles?

DATP-equipped trucks must operate safely in the traffic stream. The DATP technical discussions above noted specific safety measures employed, including:

a. commercial air disc brakes on all tractor axles
b. radar-based FCAM systems to automatically initiate braking when needed
c. commercial electronic stability control system
d. commercial Anti-Lock Braking systems on tractor and trailer
e. Platoon Operations Center to monitor safety-relevant conditions and adjust platooning parameters as needed
f. fail-operational measures so that platooning is gracefully dissolved if, for example, V2V communications is disrupted
g. driver engaged in the driving task (who can react early to cut-ins if needed)

h. truck-to-truck video, plus driver-to-driver audio, enabling drivers to maximize situational awareness by teaming

Given these factors, DATP-equipped trucks are likely to have safety enhancements not found on many of the trucks on the roads today. Per the NACFE Confidence Report on Platooning (Roeth, 2016), “Heavy-duty truck fleets using collision mitigation systems have reported a 65 to 87% reduction in accidents.” Most truck OEMs have made FCAM standard on their highway trucks (OEMOffHighway.com, 2016; Transport Topics, 2017). With new truck sales strong in 2017 and expected to remain so in 2018, market penetration of FCAM is rising. Ryder, Penske, and UPS are examples of major truck fleets whose new truck purchases all consist of those with FCAM capability (Trucks.com, 2017).

The Tennessee online “Vehicle Platooning Operations Request” seeks a description of the DATP system Safety Validation Procedure and asks the applicant to address “contributing technologies to be used, operational design domain, platoon formation method, platoon dissolution method & fallback, and vehicle description.”

In providing a similar submission to Michigan DOT and Public Safety officials, Peloton addressed testing, certification, and safety extensively. Highlights are:

a. Each Truck in a platoon is equipped with a commercial radar-based [FCAM] for heavy trucks, e.g. Bendix Wingman® Fusion™ or WABCO OnGuard ACTIVE™. For purposes of the System, important common features of these [FCAM] include: (a) automatic emergency braking (AEB), which enables both Trucks to brake rapidly and in coordination in response to a vehicle cutting in front of the Lead Truck (Cut-off Vehicle), and enables the Follow Truck to brake rapidly in response to a vehicle cutting in between the Trucks (Cut-in Vehicle); and (b) adaptive cruise control (ACC), which a Driver of the Lead Truck in a Platoon may use to regulate its speed automatically. In addition, the System is integrated with the stock front-facing radar, or radar and camera, sensor(s) of the CAS on a Truck. The CAS is active whether a Truck is operating in or out of a Platoon.
b. In addition to equipment, the Peloton Network Operations Center enforces operational aspects of the safety approach: platooning can only occur on multi-lane, divided, controlled-access highways and pre-approved road segments on those highways; speed is kept at or below the legal speed limit; weather and traffic conditions must be appropriate; and the truck in the platoon with the best estimated braking capability is placed in the rear position.

   The Peloton Technology website provides a video showing their connected braking DATP system maintaining the inter-vehicle gap during “extreme braking” by the lead vehicle from highway speed down to a stop, on a closed test track (Peloton “For Drivers” Video, 2017).

The California DMV proposal for deployment of highly automated passenger cars could be applied to DATP, most importantly that system providers / users are expected to self-certify compliance rather than the State playing any direct role in test and evaluation. This approach was also adopted by some countries in the EPTC (Rijkswaterstaat, 2016). Relevant DATP areas would include:

a. restricting operations to a defined operational design domain (this would address weather, unique road situations, and road types)

b. requiring a event data recorder
c. requiring compliance with all applicable Federal regulations
d. self-diagnostic capabilities that meet current industry best practices for system health monitoring and cybersecurity
e. test and validation methods have been conducted such that the vehicle owner is satisfied that the autonomous vehicles are safe for deployment on public roads
f. DATP operations only being conducted by drivers who have been comprehensively trained on the system

An interesting case study is provided by the Colorado DOT's approach to a pilot test of a Level 4 Class 8 truck operated by OTTO (now Uber) in a 120-mile freight run from Ft. Collins to Colorado Springs (Hernandez, 2017). The Colorado State Patrol and Department of Transportation took extensive measures to reduce the risks associated with this Level 4 automated vehicle demonstration. These are listed here.

a. NTHSA's "Federal Autonomous Vehicle Policy" and California's autonomous vehicle laws and rules were used as guidance
b. pre-event testing was monitored for consistency and achievement through specific safety performance gates, ranging from off-road testing to extensive on-road testing.
c. the truck was inspected and deemed to be without a violation by CVSA certified roadside safety inspectors
d. the company underwent a safety audit to ensure it had the appropriate level of safety management practices in place to safely operate in commerce
e. two separate rides covering over 200 miles were conducted by a Colorado State Patrol commander to visually confirm the technology
f. the Colorado State Patrol and the Colorado Department of Transportation received detailed weekly briefings on performance through required safety and testing protocols, including testing of scenario plans for risks and fallback
g. OTTO provided certification of safety assessments, vehicle, driver and insurance. The safety assessments certification included system safety, validation and data sharing. Driver certification included lists of all drivers, driver training and overall experience. Vehicle certification included the Federal Motor Vehicle Safety Standards (FMVSS).

These measures were applied to a pre-commercial highly automated Level 4 truck. They provide a reference point for the much simpler Level 1 DATP system, whose risk is greatly reduced by having professional drivers engaged in the driving task in each vehicle.

DATP systems must operate appropriately within all road and weather conditions, as is the requirement for all other traffic. When this requirement cannot be met while platooning, the platoon can be dissolved; as a Level 1 system, the driver is fully engaged and can take over full control.

<u>*Questions/Issues from 2016 FDOT DATP Task Force Meetings:*</u>

Consider risk of cars coming in between platooning trucks; what are safeguards?

Issues surrounding "cut-ins" of cars are not straightforward. The EPTC Lessons Learned document (Rijkswaterstaat, 2016) notes, "There is a difference between vehicle safety and traffic safety. From the vehicle safety angle one could argue that a wider distance between two platooning trucks is better. Meanwhile, from the traffic safety angle one could also argue that overly long distances increase the number of cut-ins by other traffic, including by other trucks. This disrupts the traffic flow and can have a negative impact on traffic safety, as was observed in various situations during the Challenge."

As discussed in detail in prior sections, DATP systems currently being commercialized automatically brake and dissolve the platoon in the event of a cut-in, with the driver resuming longitudinal control. As a Level 1 system, the driver is monitoring the road environment and may initiate braking if he/she sees signs of the cut-in beginning. Also due to being a L1 system, drivers are always ready to resume control. This is consistent with SAE J3016 defining the automation levels, which holds that fallback responsibility for L1-L2 systems (e.g., DATP) is with the driver. The topic is also addressed in the High Level Systems Requirements for truck platooning within the TMC Information Report.

Both the Daimler and Peloton approaches accommodate any need to open up the inter-vehicle gap for traffic situations. Peloton Technology has published the greater amount of system information, noting that they have adopted the relevant requirements contained in the TMC Information Report. Specifically, Peloton states (Peloton Plan 2017) in their submission to Michigan (which refers to Michigan Compiled Laws (MCL):

> "Spacing between Trucks in a Platoon is regulated by Driver and System functions to achieve compliance with MCL 257.643, requiring a Truck operator to leave sufficient space… so that an overtaking vehicle may enter and occupy the space without danger," and with MCL 257.643(a)(2), requiring a Truck operator to "allow reasonable access for other vehicles to afford those vehicles safe movement among lanes to exit or enter the highway." These functions include:
>
> 1. *Driver supervision.* Consistent with Driver functions of monitoring the driving environment and intervening in vehicle motion control as appropriate during performance of the Dynamic Driving Task, the Peloton-approved Training that a Driver receives prior to operating a Truck in a Platoon instructs the Driver to monitor the driving environment for Cut-in Vehicles, and to act as appropriate to ensure that a Cut-in Vehicle is able to (a) enter and occupy the space between the Trucks safely, and/or (b) move safely between lanes to exit or enter the highway. A Driver may do so either by (a) acting to dissolve the Platoon, or (b) steering the Truck between lanes.
>
> 2. *System-initiated dissolution.* The System will automatically dissolve a Platoon when it detects a Cut-in Vehicle via radar or another sensor."

During the DATP Pilot in December 2017, FHP personnel experienced DATP system operations and observed no clear safety concerns during the three-day pilot phase. Additionally, FHP had its Aircraft Pilot observe the long run demonstration; from the pilot's perspective it was clear the CMV's were travelling close together and within the 300 foot allowable distance and there were no observed traffic related problem during the testing. Additionally, state transportation officials observing operations in the Pilot did not observe any instances of the platoon interfering with traffic or inconveniencing other motorists. Demo participants observed platoon drivers accommodating merges and lane changes for other traffic. The FTE Traffic Management Center monitored the 1,215 miles of testing and recorded no impacts to daily operations.

Need to understand how Lead Vehicle emergency braking impacts the Following Vehicle and vehicles behind the Following Vehicle. Does this impact minimum safe following distances between the Lead Vehicle and Following Vehicle? Will the study consider acceptable inter-vehicle gap ranges vis-a-vis a potential incident?

What are inter-vehicle gap distances guidelines for vehicles engaged in truck platooning? Who should be the lead driver -- should this be based on vehicle weight, vehicle design and driver capability?

These questions get to the core of DATP system design; designing safe systems are the focus of current commercialization efforts. This is discussed in prior sections, and these issues are also addressed in the High Level Systems Requirements for truck platooning within the TMC Information Report. Safety with regard to setting the inter-vehicle gap is dependent on several factors, but two key factors are: a) reducing the likelihood of the front truck initiating hard braking and b) the performance of the rear truck braking as that interacts with the inter-vehicle gap setting.

When it comes to reacting to other traffic, the primary action comes from the FCAM technology that forms the foundation of DATP systems. As the NACFE Confidence Report on Platooning (Roeth, 2016) notes, "A commonly cited concern is how the platooning trucks and the individual drivers will react if passenger cars move into the gaps between platooning trucks to get out of a passing lane or get to a highway exit ramp. However, each vehicle's active safety systems would react exactly as they would if a vehicle cut a single truck off in traffic today: The brakes would immediately engage and slow the truck until it achieves a safe following distance behind the intruder vehicle. Likewise, any trucks behind the threatened truck would react accordingly."

In DATP systems, V2V-based platooning enables brake application on the front truck to be communicated instantly to the rear truck, such that very little time (approximately 100 ms) elapses between brake initiation on the front and rear trucks. This enables the much smaller inter-vehicle gaps that provide fuel economy gains due to drafting. This is illustrated by a Peloton Technology video showing their connected braking DATP system maintaining the inter-vehicle gap during "extreme braking" by the lead vehicle from highway speed down to a stop, on a closed test track (Peloton "For Drivers" Video, 2017).

The EPTC Stakeholder Consultation process identified platooning sequencing – accommodating trucks with various torque ratings, brake capacity, and loading weights – as an additional important factor (Rijkswaterstaat, 2016). At least one platooning developer, Peloton Technology, has stated plans for ordering trucks in a platoon according to these factors to maximize safety (Peloton Technology, 2017).

Peloton, in their submission to Michigan (Peloton Plan, 2017), provides a useful response to these questions. In addition, information is available from Daimler Trucks (parent company of Freightliner Trucks) regarding their developmental Highway Pilot Connect system (Daimler, 2016).

Reducing the likelihood of the front truck braking keys upon the look-ahead features of the FCAM system (also known as Collision Avoidance Systems [CAS]) so that threats are identified with time available for modest braking prior to the need for emergency braking. Peloton notes that each DATP truck "is equipped with a commercial radar-based CAS for heavy trucks, e.g. Bendix Wingman® Fusion™ or WABCO OnGuard ACTIVE™. For purposes of the System, important common features of these CAS include: (a) automatic emergency braking (AEB), which enables both Trucks to brake rapidly and in coordination in response to a vehicle cutting in front of the Lead Truck (Cut-off Vehicle), and enables the Follow Truck to brake rapidly in response to a vehicle cutting in between the Trucks (Cut-in Vehicle); and (b) adaptive cruise control (ACC), which a Driver of the Lead Truck in a Platoon may use to regulate its speed automatically. In addition, the System is integrated with the stock front-facing radar, or radar and camera, sensor(s) of the CAS on a Truck. The CAS is active whether a Truck is operating in or out of a Platoon." Also, "the System's Internet cloud-based Network Operations Center (NOC) provides continuous remote management and supervision of Trucks in a Platoon" provides broader situational awareness to monitor "safety-relevant conditions of Trucks, Drivers, traffic, weather, road surfaces, road construction zones and other safety factors by drawing on data supplied via on-board Truck sensors and exogenous sources" to then authorize trucks "to form and continue to travel in a Platoon based on satisfaction of a set of real-time safety requirements (Safety Approval), and withdrawing Safety Approval if the requirements are unmet."

Regarding the ordering of trucks, Peloton used a "real-time assessment of the Trucks' relative braking capabilities and other factors" so that "the System designates the Truck in a Platoon with the lesser relative braking capability, i.e. longer estimated stopping distance, as the Lead Truck."

Regarding inter-vehicle gap settings, the Peloton system "sets the target Headway Setting between Trucks in a Platoon, i.e. the following distance from the front end of the Follow Truck to the rear end of the Lead Truck, at a point between 36 and 80 feet based on rules of the Operational Design Domain, accounting for traffic and weather conditions, certainty of the real-time assessment of relative braking capabilities of the Trucks, and other factors." Daimler Trucks has stated that their platooning system is designed for an inter-vehicle following distance of 50 feet.

Regarding non-platooning vehicles behind the following platooning vehicle, there is no published literature regarding effects on these vehicle if the lead vehicle starts an emergency braking maneuver. There is no reason to believe, however, that this would be any different than being directly behind a non-platooning truck executing the same maneuver.

During the DATP Pilot in December 2017, FHP personnel experienced DATP system operations and observed no clear safety concerns during the three-day pilot phase. Additionally, state transportation officials observing operations in the Pilot did not observe any instances of the platoon interfering with traffic or inconveniencing other motorists. Demo participants observed platoon drivers accommodating merges and lane changes for other traffic. The FTE Traffic Management Center monitored the 1,100 miles of testing and recorded no impacts to daily operations.

As agreed with state officials prior to the Pilot, Peloton provided data generated by the DATP systems during the runs. This data revealed that, while no system-initiated hard braking events occurred, the DATP system successfully handled a "cut-in" by another vehicle in front of the forward truck by automatically activating braking. Additionally, in a small number of cases, the rear truck driver detected impending cut-ins between the two platooning trucks and manually initiated braking to accommodate the merging traffic.

In summary, platooning systems coming to the commercial market use forward sensing technology plus operational practices to reduce the likelihood of emergency braking by the lead truck. To achieve the goal of avoiding collisions between the follower truck and the lead truck if such emergency braking events occur, inter-vehicle gaps take into account a broad set of relevant factors.

Given the laws of physics, there is always the possibility of a crash with a human-driven or computer-assisted vehicle system. These measures substantially reduce the risk of a crash and are highly likely to reduce the energy in any crashes that do occur.

Technology exists to ensure that the trailing vehicle adjusts the headway in the event of a rogue vehicle sneaking between the two trucks in the train. Will this pilot help with the advance vehicle "knowing or sensing" the presence of an intruder while the lagging vehicle monitors for such an entry and adjusts accordingly?
How will the vehicle respond to other obstacles that cut in-between platooning trucks, such as deer, etc.?

This question of "advance sensing" is best left to system designers seeking to meet the core functional requirements for safe operations. Regarding deer coming between the trucks, the situation is identical to that of a deer darting in front of an individual truck. Since the FCAM systems are always operating for each truck, these systems could activate braking if they are designed to react to deer.

What will be the human machine interface (HMI) requirements? What types of display will platooning vehicles have?

The TMC Information Report (TMC, 2015) lists HMI requirements from freight industry perspective. Specifics of HMI implementation are left to the vendor, based on relevant FMVSS and FMCSR requirements where relevant. Peloton Technology refers to TMC Requirements in its submission to Michigan (Peloton Plan, 2017) and describes their HMI as follows:

> "The System's HMI consists of a dedicated windshield-mounted display (Display); dashboard-mounted manual controls (Controls); a radio-based, direct Driver-to-Driver voice communications system; and an audio notification system. The Display shows (a) current and prospective Platoon status, e.g. whether a Truck is or is not in a Platoon, whether a Truck has or does not have Safety Approval to form a Platoon, and the location of any available Truck(s) with which to form a Platoon; (b) Platoon instructions, e.g. driving instructions to set up formation of a Platoon; and (c), on the Display inside the Follow Truck, a video feed that covers the forward blind

spot of the Driver of the Follow Truck by showing a frontal view from the Lead Truck . Controls are used for Platoon formation and dissolution and to adjust HMI settings, e.g. the brightness of the Display. The Driver-to-Driver communications system enables the Drivers in a Platoon to speak directly with one another. The audio notification system communicates feedback and alerts to Drivers."

Does the lead vehicle have to comply with safe travel distances for other vehicles? Regarding 316.0895 – following too closely, should it be stated that the Lead Vehicle of a platoon cannot follow within 300' of another vehicle? (address the concern of multiple 2-truck platoons forming a series of (2+) 2-truck platoons, essentially creating a 4+ truck platoon. This could also address 2 trucks simulating a DATP, even though the 2 trucks are not equipped with DATP technology.)

Since the lead truck has no DATP relationship with any traffic ahead, it must comply with normal following distance laws for trucks.

Will systems provide lane departure and similar warnings?

By definition, lane departure and other warning systems are not part of DATP functionality. However, Lane Departure Warning is offered as part of the typical package offered by safety system suppliers, and most major fleets choose to include this in their purchase of the systems (Peloton Plan, 2017). Therefore, DATP-equipped trucks may have these features.

What happens when there are radar and similar system failures? Does the platooning system disengage?

The TMC Information Report DATP requirements require that the platoon disengage upon loss of any data sources that are critical to safe operations; this would include V2V communications, GPS, and radar. System developers also note this is their design approach. Peloton references the TMC IR DATP requirements in describing their approach to component failures (Peloton Plan 2017). In addition to platoon disengagements initiated by the Network Operations Center or either driver, disengagement also occurs when:

> "any Truck in the Platoon (a) detects a System failure, e.g. excessive latency or insufficient throughput of V2V communications between the Trucks, sustained disconnection between the Truck and the NOC, sustained loss of GPS signal, or (b) detects a Cut-in Vehicle via radar or another sensor. During dissolution of the Platoon, the System controls the speed of the Follow Truck to increase the intervehicular headway between the Trucks. The Driver of the Follow Truck can override longitudinal vehicle motion control by the System during dissolution of the Platoon as the Driver deems appropriate in order to achieve a minimal risk condition (Fallback)."

DATP Operations Allowing Merging for Other Vehicles

Keeping the platoon together with a short inter-vehicle gap could be the best approach to maintaining high standards of traffic flow at highway interchanges. During the European Truck Platooning Challenge (Rijkswaterstaat, 2016), drivers were the main source of information regarding merging dynamics. While merges of passenger cars seemed no different than without platooning, interaction between platooning trucks on the main lanes and single tractor-trailers seeking to merge were of note. The EPTC concluded that, when there are a large number of on- and off-ramps in close succession, a shorter following distance (11 meters) works better in keeping the truck platoon intact than a longer following distance (18 meters), plus it reduced merging and passing maneuvers.

> The 2016 European Truck Platooning Challenge concluded that, when there are a large number of on- and off-ramps in close succession, a shorter following distance (11 meters) works better in keeping the truck platoon intact than a longer following distance (18 meters), plus it reduced merging and passing maneuvers.

The EPTC Stakeholder Consultation (Rijkswaterstaat, 2016) identified development of rules of conduct for platoon overtaking as an area for future exploration. One approach could be the recently revised Michigan Vehicle Code, which leaves the responsibility for effective merging with the operator, stipulating that "when traveling upon a highway, the operator of a truck or truck tractor that is in a Platoon shall allow reasonable access for other vehicles to afford those vehicles safe movement among lanes to exit or enter the highway."

Similarly, the operator of a truck or truck tractor in a platoon, "when traveling upon a highway outside of a business or residence district, when conditions permit, shall leave sufficient space between the vehicle and another truck or truck tractor so that an overtaking vehicle may enter and occupy the space without danger" (Michigan Vehicle Code, 2016). Peloton addresses this requirement in their Platooning Plan submission to Michigan (which refers to Michigan Compiled Laws [MCL] as follows (Peloton Plan, 2017):

> "Spacing between Trucks in a Platoon is regulated by Driver and System functions to achieve compliance with MCL 257.643, requiring a Truck operator to leave 'sufficient space… so that an overtaking vehicle may enter and occupy the space without danger,' and with MCL 257.643(a)(2), requiring a Truck operator to 'allow reasonable access for other vehicles to afford those vehicles safe movement among lanes to exit or enter the highway.' These functions include:
>
> 1. *Driver supervision.* Consistent with Driver functions of monitoring the driving environment and intervening in vehicle motion control as appropriate during performance of the Dynamic Driving Task, the Peloton-approved Training that a Driver receives prior to operating a Truck in a Platoon instructs the Driver to monitor the driving environment for Cut-in Vehicles, and to act as appropriate to ensure that a Cut-in Vehicle is able to (a) enter and occupy the space between the

Trucks safely, and/or (b) move safely between lanes to exit or enter the highway. A Driver may do so either by (a) acting to dissolve the Platoon, or (b) steering the Truck between lanes.

2. *System-initiated dissolution.* The System will automatically dissolve a Platoon when it detects a Cut-in Vehicle via radar or another sensor."

<u>Questions/Issues from 2016 FDOT DATP Task Force Meetings:</u>

Should platooning trucks be allowed to overtake slower vehicles while engaged in a platoon?

Overtaking: current DATP products nearing market introduction allow lane changes during platooning operation. Since DATP drivers are both fully engaged in steering control and road monitoring, the human judgment required to do a safe lane change and overtaking procedure is the same as that in today's driving. This would apply to differential speed of overtaking as well, i.e., "slower vehicles." Additionally, if a maneuver such as overtaking is restricted, the business case for platooning is weakened. This could be expressed as a requirement, i.e., the "system shall have a means of overtaking safely," which would primarily be accomplished by the drivers.

In providing their Platooning Plan submission to Michigan, Peloton addresses this briefly as follows (Peloton Plan, 2017):

> "*Driver supervision.* Consistent with Driver functions of monitoring the driving environment and intervening in vehicle motion control as appropriate during performance of the DDT, the Peloton-approved Training that a Driver receives prior to operating a Truck in a Platoon instructs the Driver to monitor the driving environment for Cut-in Vehicles, and to act as appropriate to ensure that a Cut-in Vehicle is able to (a) enter and occupy the space between the Trucks safely, and/or (b) move safely between lanes to exit or enter the highway. A Driver may do so either by (a) acting to dissolve the Platoon, or (b) steering the Truck between lanes."

During the DATP Pilot in December 2017, FHP personnel experienced DATP system operations and observed no clear safety concerns during the three-day pilot phase, which included lane changes for overtaking. Additionally, state transportation officials observing operations in the Pilot did not observe any instances of the platoon interfering with traffic or inconveniencing other motorists. Demo participants observed platoon drivers accommodating merges and lane changes for other traffic. The FTE Traffic Management Center monitored the 1,100 miles of testing and recorded no impacts to daily operations.

What are lane change protocols – disengage during maneuver?

Current DATP systems being commercialized allow lane changes to be made while platooning, as this is seen as essential to maximizing the number of platoon-able miles. Specific methods of performing the lane changes will likely be fleet-specific, based on recommendations from system developers.

Based on performance observed by FDOT, FTE, and FHP officials in the DATP Pilot testing conducted by Peloton Technology, the drivers in the DATP pair communicated in each case of a lane change maneuver, such that the rear truck assessed oncoming traffic and lane usage to change lanes, such that the front truck driver could easily join the rear truck in that lane. The Peloton system detected the "lateral offset" during this time and maintained the platooning connection so that once both trucks were again in the same lane normal platooning could continue.

"Copycat" Behavior

During the European Truck Platooning Challenge (Rijkswaterstaat, 2016), drivers platooning on German motorways noted "copycat" behavior; i.e., other single trucks in the vicinity of the truck platoons driving more closely to a truck ahead than would normally be considered safe. However, no data was collected to document the extent of such behavior.

During the DATP Pilot in December 2017, which encompassed over 1,215 miles of driving on the Florida Turnpike, there was one instance in which a vehicle behind the rear DATP vehicle appeared be following closely. The Peloton drivers noticed this, coordinated with one another, and took action to interrupt this behavior by slowing down, prompting the close-following vehicle to pass the platoon.

Road Speeds While Platooning

During the European Truck Platooning Challenge (Rijkswaterstaat, 2016), speeds were limited in such as way as to disrupt traffic relative to non-platooning trucks. This approach was unique to the Challenge. More generally, no basis was found in the literature supporting a special speed regime for DATP trucking.

What speeds should platooning have?

> Operating speed: There is no basis to apply a speed regime different from that applying to trucks now. Peloton asserts their vehicles can be limited to current speed limit. (Note that the likelihood of broad use of DATP would be reduced by any requirement for a lower speed of operation, as freight carriers incur a time penalty.) Platooning providers should clearly state the Operational Design Domain of their system relative to operating speed. Peloton Technology provided this information in their Platooning Plan submission to Michigan (Peloton Plan, 2017) as follows:
>
> > "The System authorizes operation of Platoons at or below posted speed limits for Trucks on a road or road segment."

Speed differential requirements when platooning trucks pass slower vehicles? (addressing the possibility of limiting queue lengths if trucks are in 2/2 lanes while passing)

> Speed differentials with regarding to platoon passing are not addressed in the literature. Given that passing decisions are made by DATP drivers, driver training could include the consideration of speed differentials in initiating a passing maneuver.

Use of Shoulder to Stage Platoons

The European Truck Platooning Challenge (Rijkswaterstaat, 2016) report describes an instance during a previous truck platooning demonstration in the Netherlands. Before going on the motorway, the three-truck platoon had to negotiate a roundabout, regulated by traffic lights, whereby one of the trucks was left behind. The truck drivers of the other two trucks decided to wait on the hard shoulder of the acceleration lane. Once the third truck approached, they moved from the hard shoulder into traffic on the acceleration lane. The Dutch officials considered this to be a misuse of the shoulder, according to their Vehicle

Code. More generally, existing laws regarding truck use of the shoulder would likely be sufficient to address DATP operations.

Enforcement: Vehicle Safety Recommendations

a. Even though industry best practices for platooning technology and operations are still at a formative stage, this study has identified key common elements being implemented by DATP developers that can be incorporated in a permit application.
b. Enforcement operations would benefit from evaluating the degree to which "copycat" behavior (non-DATP vehicles close following behind a platoon) is occurring, if at all. This can be augmented by discussions with early deployment fleets. If this appears to be an issue, develop training and methods for troopers to detect and respond to such instances.

IV.C.iii. Enforcing Driver Safety

Questions/Issues from 2016 FDOT DATP Task Force Meetings:
Changes in the Driver's Handbook to discuss platooning are anticipated. Is there other information material?

Unless there have been changes in the Driver Handbook for Adaptive Cruise Control (based on its introduction in the last decade), it could be argued that there is no basis to adjust the Handbook for DATP.

What driver training should occur? Are there certifications for lead versus following vehicle drivers? How much experience should a driver have to engage in platooning?

As is currently the case in trucking, driver training and qualifications are the responsibility of the DATP fleet operator. Based on past introduction of new technology, such as Adaptive Cruise Control and FCAM, fleets will work with vendors to develop driver training protocols. The lead driver designation is based on truck/load factors, not driver specifics. System developers such as Peloton require that all DATP drivers be fully trained as both leader and follower drivers. Fleets will assess many factors in selecting drivers to operate DATP, including years of experience.

In their Platooning Plan submission to Michigan, Peloton comments on one aspect of driver training as follows (Peloton Plan 2017):

> "Driver supervision. Consistent with Driver functions of monitoring the driving environment and intervening in vehicle motion control as appropriate during performance of the DDT, the Peloton-approved Training that a Driver receives prior to operating a Truck in a Platoon instructs the Driver to monitor the driving environment for Cut-in Vehicles, and to act as appropriate to ensure that a Cut-in Vehicle is able to (a) enter and occupy the space between the Trucks safely, and/or (b) move safely between lanes to exit or enter the highway. A Driver may do so either by (a) acting to dissolve the Platoon, or (b) steering the Truck between lanes."

Will platooning increase driver fatigue and distraction issues? Should following drivers' hours of service be changed?

The NACFE Confidence Report on Platooning (Roeth, 2016) reports no fatigue or distraction issues based on a small population of drivers. There is no basis to change hours of service rules, since DATP is a Level 1 system with the driver significantly engaged in the driving task.

Will systems manage speed or stop drivers from speeding?

Peloton Technology noted in their Platooning Plan submission to Michigan (Peloton Plan 2017) that, in effect, they will stop drivers from speeding: "The System authorizes operation of Platoons at or below posted speed limits for Trucks on a road or road segment." Their Network Operations Center requires the speed of trucks to adjust based on any change to the posted speeds on the roadway." A platoon may be dissolved by drivers when approaching a construction zone or the system will automatically dissolve the platoon below a speed threshold."

How does the system ensure against driver sabotage and potential for terrorism?

Driver sabotage and terrorism are not addressed for current trucks, which could also be used for harm. With both DATP drivers in control of their vehicles, there is no basis to apply new rules for DATP specifically.

Driver-to-Driver communications (voice, VoIP, cellular, CB radio, etc.)? What communications should be established between drivers while not violating 392.80 and 392.82?

Peloton provides voice communications as an enhancement to a driver's situational awareness. There is no basis in the literature to consider this a requirement for safety. Regarding texting and holding a mobile phone (392.80 and 392.82), DATP is an Level 1 system with both drivers responsible for steering and monitoring the road; therefore 392.80 and 392.82 fully apply.

Does the Following Vehicle driver need to read road signage while DATP is engaged? If so, what is the ability of Following Vehicle driver to read road signage if it is spaced closely behind Lead Vehicle?

Depending on gap, follower driver may be able to read signage directly. It has not been analytically or empirically determined what gap would be sufficient. Additionally, if the DATP operating speed is governed by the system and not the driver, reading speed signs is a lower priority than it would be for normal driving. Also, driver-driver communications allow a follower driver to query the lead driver regarding information on road signs. Further, an in-cab video display showing the follower driver a frontal view from the lead truck may allow him or her to read road signage; this approach is used by Peloton (Peloton Plan, 2017) and Daimler Trucks (Daimler Trucks, 2017).

IV.C.iv. Vehicle Testing and Certification

<u>Questions/Issues from 2016 FDOT DATP Task Force Meetings:</u>

How do Automated Vehicles and DATP fit into Federal Motor Vehicle Safety Standards (FMVSS)?

Are there limitations/constraints with the FMVSS that would preclude the use of DATP on public roadways? Should FMVSS be updated to address specific points, and how might that impact state governments?

DATP, as a NHTSA Level One system with the drivers fully engaged in steering and road monitoring, is not directly addressed by any FMVSS. A USDOT Volpe study reviewed FMVSS relative to automated vehicles, including truck platooning (Kim et al., 2016).

The only FMVSS with any relevance to platooning related to "light vehicle brake systems," which are not relevant to DATP as defined by the state. FMVSS thus creates no constraints on DATP usage on public roadways.

Are there specific industry standards that should be established?

DATP standards do not exist but it should not be assumed that standards would increase safety levels. In the U.S., existence of standards per se does not place any legal requirements on system developers. Although standards are important, they generally come after first product introductions to support economies of scale and/or interoperability – this is typical for the vehicle industry. Standards are not needed for safety or for deployment within major fleets; initial vendor systems will have proprietary data sets to enable DATP. Based on customer demand from freight carriers, standardization may or may not occur. Lack of standardization is not unusual in the trucking industry for many system types that are successful in the marketplace.

There is forward movement on standards, however. The SAE Dedicated Short Range Communications Committee is currently developing standards for Cooperative Adaptive Cruise Control (CACC), as is the ISO. CACC is similar to DATP but not identical. These standards activities address definitions, performance requirements, wireless data requirements, and test procedures. Given the typical pace of standards development, finalization of any standards that result from these activities is expected to take another two years or more.

While no formal industry standards or recommended practices have been published, the "Automated Driving and Platooning" Information Report published by the American Trucking Association Technology and Maintenance Council (TMC) serves as a highly useful reference; key points from this document are included in this study, in particular high-level functional requirements for DATP. Information from DATP developers indicate they are addressing many of these requirements.

IV.C.v. Public Safety Operations

Performing Traffic Stops

Performing traffic stops may be a significant issue for HAVs without a driver, but there is likely no need for changes in operations with DATP vehicles driven by professional drivers. It could be argued that having a professional driver in both truck cabs creates a situation no different than current operations.

One specific area of concern could be the ability of an FHP officer to view the front license plate of a follower truck. The visibility in-between platooning trucks for this purpose may be sufficient such that this would not be substantially different from the current situation of independent trucks. During the DATP pilot, at a separation distance of 65 feet, the front license plate of the follower truck was easily readable.

DATP Notification: Platooning-Capable and Platooning Underway

To perform their duties in enforcing truck following distance, officers on patrol may benefit from knowing if a truck is equipped for platooning and if that truck is platooning at a given time. At this time, no states that have allowed platooning operations have required either active or passive indicators. For instance, the Tennessee law allowing platooning (TnDOT, 2017) does not take steps to identify platooning vehicles to motorists; in the TnDOT FAQ, they note that you will "probably not" know if you are traveling near a platoon, "but platooning vehicles may be marked with signage to indicate they are potentially traveling together."

Ohio DOT authorized platooning administratively by interpreting the State's existing statute governing following distance to allow for truck platooning. Ohio State Highway Patrol has issued guidance to its law enforcement officers stating that truck platooning is legal in the State, while still providing officers discretion in determining whether platooning trucks are operating in accordance with the statute, taking account of close-following distances enabled by the technology.

If required, marking tractors as DATP-capable is straightforward. For the DATP Pilot, the Peloton tractors were marked with an FDOT provided magnetic sign signifying the vehicle was DATP-capable. Peloton also noted in their platoon plan submission to Michigan (Peloton Plan, 2017) that their trucks would have signage "on the exterior of both tractor doors of the Truck to indicate that the Truck is equipped with the System." With regard to signage on trailers, this is in most cases impractical since trailers are switched between tractors on a frequent basis.

As to indicating when platooning is underway, there are several candidate approaches. The most direct approach is an active indicator but this raises questions: should it simply be an off/on indicator or should it convey further information? Is the indicator meant to inform motorists as well as enforcement personnel and if so, do they comprehend the meaning correctly?

Within the EPTC, some truck platoons were required to be made recognizable by text markings and flashing lights. The German federal states also required flashing lights (as used in transportation of exceptional loads) to indicate platooning was underway. Some, but not all, platoon truck drivers felt this was useful in informing other motorists. Overall, the EPTC data and experiences were not definitive on this point. Therefore, the EPTC team noted that "a discussion must be started-up on the positive and negative effects" of the ability to recognize a truck platoon. Relatedly, the NCHRP Truck CV AV study (Fitzpatrick et al., 2016) included a recommendation to standardize the requirements for indicators for platooning, noting that "this could be done either for the national highway network or on a larger scale."

The range of options for DATP notification include an active indicator showing when platooning is underway, wireless communications between platooning trucks and trooper vehicles, as well as cloud-based data transfer from platooning operators to state agencies. These options are discussed here:

a. Active Indicators: this approach has several drawbacks. An indicator light may not be visible in bright sunlight and could also be "faked." At the regulatory level, states have a wide range of different and often conflicting rules regarding lighting on trucks (type, placement, colors, disallowed colors, meaning); achieving a harmonized approach would be challenging and time-consuming.

b. Direct Wireless Data Exchange: providing information wirelessly to the patrol vehicle would be straightforward technically but require development of standards (possibly national) for data format, integration into existing FHP IT systems, and training of troopers.
c. Cloud-Based Information Exchange: a "back office" approach could be used in which the patrol officer notes the truck identification number and queries an FHP database to at least ascertain if the vehicle is platoon-capable. Alternatively, DATP fleets and/or service providers will have information as to which vehicles are platooning at any given time and could publish this information to a secure website accessible by law enforcement.

During discussions of the Florida DATP working group, only a state-issued decal was considered practical for the early phase of DATP deployment, in which relatively few DATP-equipped trucks are expected to be operating in Florida (based on discussions with DATP vendors and early adoption fleets). This gives the State the opportunity to evaluate the approach to DATP deployment and coordinate with fleets and manufacturers to develop the best legislative and operational approaches as the technology continues to mature.

Questions/Issues from 2016 FDOT DATP Task Force Meetings:
The pilot project should have a vehicle platooning identifier; sign, light, ID. GPS, Bluetooth, RFID chip and could allow distance, location, and labeling measures. An electronic identifier might be preferred.

Note the discussion above. Regarding platooning identifiers, States have considered requiring a sign on the tractor door indicating that a truck is capable of platooning, but no States have required this. For the DATP Pilot, the Peloton tractors were marked with an FDOT-provided magnetic sign signifying the vehicle was DATP-capable.

How do FHP and other State agency staff verify that a vehicle is equipped with certified DATP technology on the roadside?

Note the discussion above. There is currently no process or standard to support a designation of "certified DATP technology." Peloton has indicated their willingness to place signage on the tractor to indicate "DATP-enabled" (Peloton Plan, 2017). Alternatively, system developers or fleets could be asked to notify FHP if they have DATP-equipped trucks running in Florida so that FHP can be aware of which fleets will be platooning.

Roadside Inspections
There is no material specific to DATP roadside inspections in the literature. Some focus has been placed on highly automated trucks. The NCHRP Truck CV AV report (Fitzpatrick, 2016) recommended taking advantage of emerging automated roadside inspection techniques for all levels of CV AV trucks; these have been piloted in recent years but are not specific to DATP.

One vendor, Peloton Technology, is only working with leading fleets that have the best safety and maintenance practices and as a result favorable CSA/SMS scores. The Peloton system also monitors several brake status parameters in real time and implements health monitoring across the entire system.

Because DATP builds upon proper brake operation, current inspection protocols are sufficient for DATP. Given the safety best practices described above, DATP vehicles can be expected to operate well above minimum standards. As noted above, only a small number of DATP-equipped vehicles are expected to be deployed on Florida highways during the initial phase. The State can evaluate inspection criteria and practices based on experienced gained and, working with fleets and manufacturers, develop best legislative and operational approaches.

Questions/Issues from 2016 FDOT DATP Task Force Meetings:
3rd party should define system requirements, that would include SMS, CSA, hours of service, maintenance, etc., for vehicle and driver eligibility (need to limit liability to the State agencies).

> The has been no government role in defining requirements for other control-critical systems for trucks introduced in the last decade, including Adaptive Cruise Control and FCAM. As a third party distinct from system vendors, the trucking industry has defined a set of system requirements specific to DATP via the TMC Information Report (TMC, 2015); these have been adopted in large part by at least one system vendor; i.e., Peloton Technology (Peloton Plan, 2017). HOS is not relevant to DATP as drivers still play a key role in driving.

Should there be standards for on screen display for platooning so it does not violate F.S. 392.60? How do we ensure the display does not obstruct vision?

> Vendors must comply with existing federal and state regulations. Note that screens for information display have been common in Class 8 trucks for some time, positioned within the constraints stated in these regulations.

Should DHSMV establish an "Approved Products List" (potentially based on FDOT's model) for aftermarket DATP devices? If so, should standards be set by a 3rd party for DATP devices to be added to an Approved Products List?

> This could be akin to the SmartWay-verified aerodynamic devices, etc., lists, which are based on meeting certain fuel-savings levels under an EPA-protocol testing performed by a 3rd party, as well as sharing similarities with FDOT's Approved Products List. However, since published standards do not exist, this would be challenging. Thus far, ten states have made allowance for commercial deployment of DATP, and no state has created an "approved product list." In three of these states, system developers must submit a plan on platoon operations, which may or may not include detailed system information. In the other six states which have allowed DATP, no such plan is required.

Should braking, communications, detection devices, etc., that are necessary for DATP operation be inspected annually to ensure safe operation?
Should there be a requirement for annual, quarterly, etc., diagnostics for brakes and system components? How often does the manufacturer, 3rd party installer, or vehicle owner/operator have to come in to verify the equipment?

> Since brakes are critical to safety regardless of platooning capability, there is no basis to add additional inspection requirements. DATP has the advantage of gracefully handing off to the human driver as one strategy to address failures. More broadly, fleets can have DATP maintenance practices in place that would identify any system problems. In some cases, fleets would make arrangements with system

suppliers to assist in periodic verification if this is viewed as needed. One vendor (Peloton) will be doing continuous monitoring via their Network Operations Center.

In their submission for platooning deployment in Michigan (Peloton Plan, 2017), Peloton Technology addresses maintenance for DATP as follows:

> "To the extent described in user agreements between Peloton and Carrier-users of the System and as required by law, Carrier-user are responsible for performing Peloton-approved Maintenance of the System."

As to failure of any system components, vendors should be expected to implement a "fail-safe" requirement so that safety is not undermined, per the TMC Information Report (TMC, 2015).

What are the best methods for providing training to law enforcement?

Law enforcement training is not addressed in the literature. However, in performing this study, it has become clear that the Commercial Vehicle Safety Alliance is closely tracking DATP developments relevant to the enforcement community. CVSA has conducted training for new technologies relevant to enforcement in the past.

Public Communications

Questions/Issues from 2016 FDOT DATP Task Force Meetings:

Need to be cautious of public perception and address as needed. What are the best methods for communicating to the motoring public?

Fleets and vendors have expressed the importance of educating the public relating to DATP, especially for Pilots and initial deployment. Lessons learned can be gleaned from demonstrations and pilots in California, Ohio, Michigan, and Virginia. Vendors would likely be interested to work with the State in public education efforts, via press conferences, press releases, explanatory materials, etc. For the Florida DATP Pilot, Peloton Technology worked with FHW, FTE, and FDOT to coordinate a public information approach.

Public Safety Operations Recommendations

a. A tractor decal should be sufficient for informing that trucks are DATP-capable in the initial phase of deployment in which relatively few DATP trucks are operating. It would be useful to re-evaluate this approach as the numbers of DATP trucks begin to increase.
b. Collaborate with DATP-equipped fleets and system developers to address public communications.

IV.D. Administrative Processes

IV.D.i. Permitting of DATP Vehicles

Regarding the use of a permitting process for the deployment of DATP, it is useful to look at actions taken by other States to date. Thus far, while some States have considered permits as a measure to expedite permission for testing of DATP (i.e., an interim solution), no States have taken the path of using permits to enable deployment of platooning.

Of the ten States that now allow commercial deployment of DATP, some allow for platooning operations “carte blanche” while others require a “Platooning Plan” or a notification. The “notification form” approach which Tennessee has established may be a good model for Florida, as it provides opportunity for a two-way process with applicants. Based on an applicant submitting a notification form, State agencies can receive key information specified by the State, seek further information if needed, and disallow an entity from proceeding if they determine there are concerns. If an entity is allowed to proceed, a simple DATP permit could be issued by FDOT. Given that no other States require permits at this time, one consideration is that the requirements and mechanism for issuing a Florida permit could deter fleets from beginning initial deployment in Florida, depending on how this is implemented.

The Tennessee law (TnDOT, 2017) permits platooning on all Tennessee roads. Two or more vehicles are considered a platoon. An appropriately endorsed driver who holds a valid commercial driver license (CDL) must be present behind the wheel of each vehicle.

Tennessee requests the following information via their online “Vehicle Platooning Operations Request”:

a. Routes
b. Operational Time Frame
c. Number of Vehicles in Platoon and VIN Number
d. Number of overall vehicles equipped as part of activity
e. Unique vehicle markings (if any, or none)
f. Hazardous Materials (yes/no)
g. Detailed Plan for Platooning (“notification must include a detailed plan for general platoon operations for your company’s proposal. This entry should address contributing technologies to be used, safety validation, operational design domain, platoon formation method, platoon dissolution method & fallback, and vehicle description”)

By submitting the form, the person submitting the request agrees to this statement:

> “I certify that the company vehicles and drivers will comply with state and federal rules and regulations and the driver-assist vehicle platooning equipment is installed properly and meets all USDOT safety standards.”

Recommended Basis to Proceed with Deployment of Platooning in Florida

Based on the findings of this study and the discussion above, the research team recommends that FDOT develop and issue DATP-specific permits on a per-vehicle basis to fleets (possibly working jointly with DATP suppliers) based on their providing information that could include some or all of the following:

a. Fleet Name and contact information
b. Supplier of DATP system and contact information (fleets may rely on the supplier to provide some of the information below)
c. Truck VIN
d. Type of trailers to be pulled plus configuration (single, tandem)
e. Routes and general timeframes for DATP operations
f. Operational Design Domain of system (includes number of vehicles in platoon, minimum inter-vehicle gap used)

g. Equipment (self-certify):
    i. Tractor:
        1. At minimum: air disc brakes on all tractor axles, forward collision avoidance and mitigation system. (Note that in order to have the latest version FCAM systems on tractors, tractors must have Electronic Stability Control (which includes Roll Stability Control) and ABS. Lane Departure Warning is offered as part of the typical package offered by safety system suppliers, and most major fleets choose to include this in their purchase of the systems.)
        2. Any other equipment applicant notes as further enhancing safety
    ii. Trailers: ABS-equipped
h. Description of Safety Validation Procedure
i. Description of operational practices to enhance safety while platooning (examples specific to Peloton: intelligent ordering, role of Network Operations Center)
j. Description of operational practices to accommodate nearby traffic while platooning.

As part of process to approve an Application, FDOT may request a demonstration of system capability on a closed-course track or equivalent.

In addition to the permit, equipped vehicles would carry documents showing the tractor is equipped with the platooning and supporting safety systems; additionally, the drivers would carry a document showing they have completed an industry-provided DATP training.

The new Michigan law also provided a useful clarification that two trucks platooning do not constitute a "single" long combination vehicle, but is instead two combinations for purposes of size and weight determination (Michigan Vehicle Code, 2016). This clarification could be useful in defining the Florida permit as well.

In implementing this process, it would be valuable to seek input from stakeholders including the Florida Trucking Association, leading fleets exploring platooning, and others as appropriate. In discussions during the preparation of this study, DATP developers and fleet industry comments have stressed the importance of keeping the requirements and mechanism for issuing permits relatively simple so as to not create a state-specific burden on industry.

Data Sharing/Reporting

The EPTC Stakeholder Consultation (Rijkswaterstaat, 2016) endorsed "logging of platooning-related accidents, traffic situations and driver status." Similarly, the Michigan "platooning plan" approach requires quarterly reporting of platooning miles traveled and roads on which platoons have run, as well as crash reporting.

Peloton's submission to Michigan to initiate platooning (Peloton Plan 2017) included this approach to data reporting Michigan DOT and Michigan State Police:

> "Within 15 days of the end of each quarter of the calendar year, Peloton will provide to MDOT and MSP a Quarterly Report on Platoon Operations (Quarterly Report) describing data on Platoon operations during the quarter:
> 1. Roadways in operation. Peloton will provide a list of all Roadways on which any Trucks traveled in a Platoon.
> 2. Platoon miles traveled (PMT). Peloton will provide the total number of miles traveled by Trucks in a Platoon in Michigan.
> 3. Traffic crash data. In the event of a traffic crash involving Trucks in a Platoon, Peloton will provide a description of details of the crash, including where it occurred, traffic events that immediately preceded the crash, any failure of the System that may reasonably have contributed to the accident, and whether or not any injuries or fatalities resulted from the crash; prior to submitting this information in the Quarterly Report, Peloton will notify MDOT and MSP of any crash involving a Truck in a Platoon as soon as practical and in no case more than 48 hours after Peloton is made aware of the crash. Quarterly reporting of traffic crash data reporting will be in addition to any other traffic crash reporting required by the State of Michigan, the National Highway Traffic Safety Administration or other public authorities."

In addition, Peloton notes that:

> "Any Data Sharing from Peloton or directly from Trucks must be consistent with System user and vehicle-related agreements to which Peloton and/or the Trucks are subject."

Reputable developers of DATP will typically generate this type of data as part of the commercialization process and data services to customers. Based on data sought by California for HAVs, plus industry and other sources, data required for a DATP permit could include:

a. test data demonstrating the technology has been tested in the operational design domain in which designed to operate
b. total test miles driven on public roads in DATP mode
c. description of testing methods used to validate DATP performance, including functional safety analyses
d. description of the general types of safety-critical incidents encountered during testing and measures taken to remediate the causes of these incidents
e. the number of collisions resulting in injuries or deaths

Questions/Issues from 2016 FDOT DATP Task Force Meetings:
Florida is an easy permit state, $5 for 36 months; a special permit for platooning trucks is preferred.

> This is the approach recommended above.

Permitting: Vehicle Issues

Questions/Issues from 2016 FDOT DATP Task Force Meetings:
What types of vehicles—truck tractors, straight trucks, TT-ST, TR-ST, Doubles, etc.—should be allowed to engage in platooning?
Natural gas powered trucks are OK for platoons. (DHSMV)

Participating trucks must be automatic transmission; therefore, only newer trucks can participate.
It is recommended that the pilot project not include dump trucks, concrete trucks, or single-unit trucks.

From a permitting perspective, there is no basis to limit the vehicle type; the physics are similar for any pair of trucks platooning. The key is that they meet minimum criteria, as noted in the recommended basis for a platooning permit above.

Will not have vehicles that are over height or dimensioned except for FTE doubles (28' doubles). (system provider)

There is no indication of freight carriers desiring to operate DATP with over height or dimensioned vehicles except for FTE doubles (28' doubles).

Are there size and weight concerns for highway infrastructure and vehicle conditions? Should [over-size and over-weight] permitted vehicles be allowed to engage in platooning?
It is also recommended that the pilot project not include overweight vehicles (permitted).

Assuming "permitted vehicles" refers to over-dimension loads, the Peloton DATP system (as one example) measures truck weight on a real-time basis (based on the engine torque required to achieve a particular speed). Peloton does not allow truck platooning for trucks carrying overweight or over-size loads. In addition, Peloton's arrangements with fleets will call for them to only plan truck platooning within segments of their operation pulling standard loads and trailer configurations.

Trucks could have RFID so trucks could be identified for weight enforcement.
FHWA's only guidance is with convoys, which recommends 60', but is in a military convoy context.

Since DATP trucks must comply with weight regulations individually, there is no basis for enforcement to be different than that for regular trucks.

Permitting: Load Issues

Should transportation of Hazardous Materials or other cargo be limited from platooning? Consult the Emergency Response Guidebook.

In the initial DATP deployment phase, it is advisable to limit platoons from hauling HazMat loads; this is not expected to have an impact on deployment. There is no call from the freight industry for using platooning for HazMat transport. In their submission to Michigan, Peloton Technology (Peloton Plan, 2017) specifically excludes HazMat:

> *"The cargo of a Truck in a Platoon must not include hazardous materials that require placarding as specified in 49 CFR §172.504."*

Which commodities should be excluded from platooning? Which combination of commodities should be excluded? For example, H2O-activated chemicals should not platoon with H2O tankers. For hazardous materials, loads requiring a placard, refer to the Emergency Response Guidebook (DHSMV). Reference the federal rules on explosive commodities (FHP).

There is no basis to exclude specific commodities beyond HazMat definitions. All industry activity currently focused on freight carried in box trailers (dry and refrigerated), but there are no commodities specifically excluded.

Permitting: Road Issues

On which roads should platooning be allowed? Consider limiting DATP to limited access facilities (4-lane divided highways with driveways would be prohibited)

All platooning system developers, plus their expected early customers, are centering their interest on DATP operations on controlled limited-access divided highways because this is a more orderly environment which is well suited to the safety systems underpinning DATP. Of the ten states allowing platooning deployment, none have placed limitations on which roads should be allowed. From the state agency perspective, DATP operations could also occur on other types of roadways if safety levels are maintained.

Should rural 4-lane divided highways with a specified (low) driveway/ intersection density (for example, below 2/mile) allow DATP?

Operation on rural non-limited access highways (based on specific criteria) may be of interest in the future; currently there is no call for this from the freight industry. The vendor design focus centers on controlled limited-access highways because this is a more orderly environment which is well suited to the safety systems underpinning DATP. From the state agency perspective, DATP operations could also occur on other types of roadways if safety levels are maintained.

Identify the simplest way for drivers/DATP systems to identify where platooning is not allowed. For example, if urban areas (high density of interchanges) should be excluded from DATP, which results in a posted speed limit of 55 mph, then consider prohibiting platooning anywhere with a posted speed limit of less than 55 mph (this would, in effect, only allow platooning if the posted speed limit is equal to or greater than 60 mph). Additionally, optimal benefits (fuel efficiency) are generally attained at higher speeds.

Identify "lowest common denominator" when identifying areas that DATP should/should not be allowed.

A potential pilot project could limit locations to those 55 mph and higher. (DHSMV)

Regarding situations not allowed or suitable for platooning: because DATP has two fully aware drivers trained in platooning operations, they can use their judgment as to when platooning is not suitable and they (with fleet managers) can use their knowledge as to where platooning should or should not occur. High density of interchanges alone is not an ideal criteria, since merging traffic could be very sparse in the overnight hours, for instance. The Peloton approach of using a Network Operations Center to gauge conditions (weather, traffic, etc.) to enable/disable platooning provides an approach in which both the NOC (broadly) and drivers (specifically) assess conditions regarding proper conditions for platooning Lastly, in low-speed congested traffic, the aerodynamic benefits of platooning are not present, thus there is no motivation to use Level 1 DATP.

In their submission submitted to Michigan for initial platooning deployment, Peloton Technology (Peloton Plan, 2017) provides this discussion relevant to the questions:

> "An overarching purpose of the NOC's functions is to ensure that Platoons operate exclusively within a specified Operational Design Domain (ODD). According to SAE International J3016, an ODD is made up of the 'specific conditions under which a driving automation system is designed to function…. The ODD may include geographic, roadway, environmental, traffic, speed, and/or temporal limitations.'

Limitations of an ODD may be static or may change over time as more is learned about the performance of a driving automation system and/or about its operating environment, allowing for more refined calculations of safety risk. Limitations of an ODD may also vary according to the legal framework for Platoons, which currently varies across jurisdictions.

The NOC stores the conditions, i.e. rules, governing the ODD of Trucks in a Platoon. Through its Safety Approval function, the NOC enforces compliance with the ODD by authorizing a Truck to form and continue to travel in a Platoon only when all rules of the ODD are met.26 Currently, the ODD is defined based on the following types of rules:

1. *Geographic*. The System can operate only in locations that have been previously included in the ODD. Geographic rules may be organized by road (e.g. a specific roadway), road segment (e.g. between two points on a roadway), terrain (e.g. road grade, curvature) or territory (e.g. a specific state). On-board GPS sensors supply a Truck's location data to the NOC, allowing for real-time enforcement of geographic rules (Geofencing).
2. *Roadway type*. The System authorizes operation of Platoons only on multi-lane, divided, controlled-access highways.
3. *Weather.* The System prevents operation of Platoons during weather conditions that are reasonably expected to degrade the safety performance of Platoons, based on analysis of weather data from Truck and exogenous sensors, including, but not limited to, traction control data and weather service data, and of System feedback from prior operation of Platoons. In addition, Peloton-approved training that a Driver receives prior to operating a Truck in a Platoon (Training) instructs the Driver to exercise due care in selecting whether or not to travel in a Platoon even in weather conditions in which NOC is providing Safety Approval.
4. *Traffic.* The System prevents operation of Platoons in traffic conditions that are reasonably expected to degrade the safety performance, fuel efficiency benefits and/or Driver experience of Platoons, accounting for speed, traffic flow and the likelihood of a vehicle entering between Trucks in a Platoon, based on traffic data from Truck and exogenous sensors, including, but not limited to, vehicle speed and radar sensor data and traffic service data. In addition, as with respect to weather conditions, Peloton-approved Training instructs the Driver to exercise due care in selecting whether or not to travel in a Platoon even in traffic conditions in which the NOC is providing Safety Approval.
5. *Temporal.* The System can authorize operation of Platoons either with or without temporal rules included in the ODD.

In general, with respect to rules of the ODD, Peloton has defined and will continue to define initial rules with margins of safety based on conservative modeling, e.g. of thresholds of traffic density appropriate for operation of Platoons. The rules of the ODD may become more permissive of Platoons over time as iterative learning about the performance of Platoons allows for greater certainty of safety-relevant modeling at the boundaries of the ODD.   Finally, the ODD may be modified so as to prevent *any* operation of Platoons as warranted in response to an emergency (e.g., a statewide weather emergency), identification of a System defect, or a legal order. Any modification of the ODD, including a statewide withdrawal of authorization of Platoons, can be communicated to all Trucks within 60 seconds."

Consider time of day, day of week, and weather restrictions. How does inclement weather impact platooning operations?

Because DATP has two fully aware drivers trained in platooning operations, they can use their judgment as to when platooning is not suitable based on time of day or weather. The Peloton approach of using a Network Operations Center to gauge conditions (weather, traffic, etc.) to enable/disable platooning provides an approach in which both the NOC (broadly) and drivers (specifically) assess conditions regarding proper conditions for platooning A NOC could also adapt to any Time of Day or similar restrictions easily; however, the benefits are greatest when this is situation dependent rather than "set in stone."

Insurance

Questions/Issues from 2016 FDOT DATP Task Force Meetings:

Review the amount of liability. Is $5M the appropriate level of insurance?

Who should pay for insurance and who should have the insurance?

Other States have not levied insurance requirements for DATP deployment. Freight carriers would be responsible for insurance and would include any insurance needs within their overall insurance portfolio. Carriers' insurance may also be related to their contracts with DATP system providers.

Florida DHSMV has noted that no extra provisions regarding insurance are needed for DATP.

IV.D.ii. Registration / Titling

No literature was identified directly addressing registration / titling of DATP vehicles. The NCHRP report (Fitzpatrick, 2016) addresses higher level AV registration and titling as follows: "Level 3-5 AVs, which do not require a human driver for an entire trip or a portion of a trip, should be identified in the vehicle's title and registration. NHTSA (2016a, p. 44) suggests that states add a new data field and code these vehicles as HAVs. States may wish to provide more detail by identifying AVs at each level and by identifying their Operation Design Domains - the situations in which they can be operated without a driver." These points would not apply to DATP as a Level 1 system, because the driver is engaged in the driving task.

An ongoing NCHRP study on Motor Vehicle Codes for AV, being led by the Virginia Tech Transportation Institute, addresses the possibility of state harmonization on registration issues as well as aftermarket devices. Results are expected to be published in 2018.

Questions/Issues from 2016 FDOT DATP Task Force Meetings:

Only AV trucks registered in FL would be identified, as other states likely do not have a field within a vehicle's title to be identified as "autonomous."

If vehicles aren't registered as autonomous, can they still participate in the study?

DATP systems are not "autonomous," which is defined as an SAE Level 3-5 automation system. DATP is a Level 1 system.

Aftermarket applications will be majority of possible candidates for pilot. Aftermarket devices are not identified on a vehicle's title. To a large degree, aftermarket devices have not altered safety critical functions of a vehicles (steering, braking, and acceleration). Aftermarket products (larger brake rotors, improved brake pads, etc.) are on the market, but they have not *impacted "decisions" by the vehicle on behalf of the driver. Does the alteration of the vehicle require a new specification certification? How do they prove it was done? Would this requirement come up in administrative code? Manufacturer installation (OEM) vs. 3rd party aftermarket. 3rd party installation requirements? Certificate to install?*

The recommended permitting process would address these issues. For collision avoidance systems, some fleets purchase factory-prepped packages and after delivery, a third party installs the system. In the early deployment phase of DATP, system developers indicate that DATP will be installed on new trucks meeting technical pre-requisites (air disc brakes, proper versions of brake system software, etc.). However, economic and environmental benefits from DATP would expand greatly via aftermarket retrofits. Self-certification of system capability may be the most appropriate area of focus, versus specifications re: factory-equipped or aftermarket.

No other States have specifically addressed aftermarket installations.

Licensing

For DATP, as a Level 1 system with the professional driver fully engaged in the driving task, there is no apparent need for changes in licensing procedures, nor is this called for in the literature. As noted in II.G.viii DATP Driver Considerations, drivers report that use of DATP is quickly learned and not significantly different from regular driving.

Licensing relates to driver training, which is a fleet responsibility in the trucking industry. The TMC Information Report (TMC Information Report, 2015) noted that "the degree of training needed will vary with each level of automation and each particular system. For instance, drivers accustomed to using Adaptive Cruise Control may adapt more quickly to truck platooning than those who are not. Driver training can most likely be managed by industry working closely with fleets as is the case with training for other advanced safety and driver assistance systems, rather than via some form of regulatory / special driver licensing requirements."

Peloton Technology, in its Platooning Plan submission to Michigan, addresses driver training in general. This includes instructing the Driver to exercise due care in selecting whether or not to travel in a Platoon based on weather and traffic conditions, as well as to:

> "monitor the driving environment for Cut-in Vehicles, and to act as appropriate to ensure that a Cut-in Vehicle is able to (a) enter and occupy the space between the Trucks safely, and/or (b) move safely between lanes to exit or enter the highway. A Driver may do so either by (a) acting to dissolve the Platoon, or (b) steering the Truck between lanes."

Administrative Processes Recommendations

a. Institute an "application"-based process seeking specific information to provide a basis to issue a DATP-specific Permit
b. Registration / Titling / Licensing: as DATP is a Level 1 system with a professional driver engaged in the driving task, no changes are warranted in this respect.

IV.E. State Liability and Legal Implications

For DATP, having engaged drivers in both trucks serves to keep the liability questions very similar to regular driving. Data recording for DATP systems is likely to provide a robust dataset for court defenses if needed.

The TTI Platooning Feasibility Study (Kuhn et al., 2017) examined liability issues for government agencies, via a literature review and expert interviews. They concluded that liability from platooning activities "is not likely to increase." Quoting the study report:

> "First, interviewees and the literature agree that government agencies receive sovereign immunity or protection from prosecution because the state is sovereign. This protection is only waived in very specific circumstances, such as when government actors are negligent in a specific manner. An example might be if the government is informed that a part of the CV system is malfunctioning (like a roadside unit), but fails to repair the equipment in a timely manner. If harm occurs as a result of the malfunction, the government could be found negligent and lose its sovereign immunity protections as a result of the notice and failure to act.
>
> A second reason governmental liability is unlikely to increase is the likelihood that the CV system, which platooning may or may not ultimately use, "does not create new or unbounded liability exposure for industry" (5). NHTSA argues that the CV system, (the development of which the federal government has funded, in which it has participated, and which state and local governments will likely implement) 'from a products liability standpoint… analytically, are quite similar to on-board safety warning systems found in today's motor vehicles.' The agency goes on to argue that it 'does not view V2V warning technologies as creating new or unbounded liability exposure for industry' and as a result, does not have 'a current need to develop or advocate the liability limiting agenda sought by industry in connection with potential deployment of V2V technologies.'"

The EPTC team addressed potential liability of road authorities as follows:

> "The EPTC brought together representatives of the participating national road authorities. The idea arose of setting a following distance per motorway junction, dependent on the distances between acceleration and deceleration lanes, the length of these lanes and the average traffic density. Some of the countries strongly argued against differing following distances per location. The argument was that in the event of an accident it would appear that the truck platoon had complied with the following distance as set, and the road authority would be responsible.
>
> There is a large grey area around the liability of road authorities. Road authorities have a duty of care for road users. Road users have the right to expect that the road is fit for purpose. The duty of care should cover all road users, even if these are autonomous cars. This field of knowledge is new territory. Although the legal experts assume that change will be minimal, case law should create greater clarity.
>
> This would be the situation when smart vehicles adapt to the roads and there are no changes in the current state of the infrastructure. The situation could change if, for example, road authorities created new standards for road markings, in support of lane departure warning systems. The system settings will be designed for the new

road markings standards. If the road markings do not match these standards, for example because of damage caused by an accident, the road authority could be responsible."

IV.F. Summary of DATP Operational Parameters

Based on the Task 1 literature search, industry discussions, and extensive discussions with FDOT, DHSMV, and the Florida Turnpike, the study team has addressed the broad set of DATP Operational Parameters defined in the work plan.

While the factors addressed in this list could be regulated, research conducted to date does not provide a rationale for doing so. Other states allowing DATP operations have not levied restrictions. Data provided by system operators based on their own testing and operations would likely be the best source for assessing these types of factors. The permit approach discussed above is seen as a useful compromise between a "carte blanche" approach and strictly defined regulations.

Table 8 below addresses key parameters to summarize the findings of this section in terms of the roles of State agencies and the private sector.

Table 8: Summary of DATP Operational Parameters				
Area of Interest	Public Sector			Private Sector
	FDOT	DHSMV	Federal	
1. Hardware / software minimum technical requirements	Require permit applicants provide information on safety equipment and system validation processes.	Platoon operators (fleets) and/or system developers should be held to same high standards as all road vehicles.	No FMVSS apply to DATP. As a Level 1 system, future Federal actions are not likely to apply. There has been no government role in defining requirements for other control-critical systems for trucks (or cars) introduced in the last decade, including Adaptive Cruise Control and FCAM.	Defined by system developers working with fleet customers; standards may come later but are not needed now. TMC Information Report provides excellent high-level system requirements from a user point of view.
2. Safety of operations				
Engagement / disengagement	Define any zones requiring large gaps / disengagement. Other states have levied no requirements.	Enforce gaps / disengagement specified.		Adjust gaps or disengage based on prevailing conditions, DATP policy agreed between system providers and fleets,

	Operations Recommendations: -- operations activities do not require any specific actions at the outset of DATP deployment. -- As DATP operations begin to proliferate in certain corridors, this provides an opportunity to evaluate any occurrences of traffic disruptions (near interchanges or other areas), as well as assess any detrimental behavior of other traffic near the platoon. If any restrictions need to be applied, the State should develop an approach to notifying platooning operators of such areas and what operating parameters should be observed by platoons. Maintenance Recommendations: -- perform analyses, simulations, and/or empirical studies to more deeply understand the effects on platoons on bridge life and toll plazas. Such studies should address a range of platooning inter-vehicle gaps and frequencies of platoon crossings. -- as needed, devise a process to identify specific bridges as "platoon restricted," which would include geo-fencing information plus minimum inter-vehicle gaps allowed. This must be done in such a way as to avoid publishing bridge-related classified			and/or geo-coded zones provided by the State.

	information.			
Vehicle cut-ins	Possible public information campaign.	Possible public information campaign.		FCAM systems apply automatic braking; platoon disengages automatically. Drivers may see impending cut-in and act early to disengage.
Behavior of other traffic participants		Public Safety Enforcement Recommendations: -- enforcement operations would benefit from evaluating the degree to which "copycat" behavior (non-DATP vehicles closely following behind a platoon) is occurring, if at all. This can be augmented by discussions with early deployment fleets. During the DATP Pilot in December 2017, there was one instance in which a vehicle behind the rear DATP vehicle appeared be following closely. The Peloton drivers noticed this, coordinated with one another, and took action to interrupt this behavior by slowing down, prompting the close-following vehicle to pass the platoon. If "copycat" behavior is deemed to be an issue, develop training and methods for troopers to detect and respond to such instances.		Early deployment fleets should maintain dialogue with enforcement regarding any occurrences of "copycat" behavior.
Changing conditions (e.g., weather, traffic)	Define any specific road sections within which platooning should	Enforce ban on platooning on any prohibited road sections.		Weather: since DATP systems from different

	not occur; provide to fleets via geo-coding. Other states have levied no requirements.			providers may have differing performance in severe weather, decision to react to weather should be left to drivers and Platoon Operations Center. Traffic: system developers have noted that platooning is automatically discontinued in heavy traffic; in parallel, drivers assess traffic complexity and may choose to discontinue platooning
Spacing between platoon sets	No different from other vehicles.			The lead truck in platoon has no DATP relationship with traffic or platoons ahead; therefore normal following distances must be observed.
Weigh station operations or requirements	None.			Based on approach from system developers, DATP drivers will disengage platoons prior to entering weigh station.
3. Locational / temporal				
Facility type	Limited access divided highways are the focus on current DATP developers. From the state			DATP system developers are planning for operations only on

	agency perspective, DATP operations could also occur on other types of roadways if safety levels are maintained.			limited access divided highways.
Lane restrictions	Literature provides no basis to define lane restrictions. Other states have levied no requirements. Florida DATP Pilot showed that DATP operations did not have a negative impact at interchanges, indicating that restrictions regarding merging lanes are not warranted for the initial DATP deployment phase. Planning recommendations: -- defer including DATP in determination of the need for dedicated lanes and/or environmental impacts, as it is far too early to estimate adoption rates of platooning technology and the percent of miles driven while actually in platoon mode			Choice of lane left up to drivers.
Interchange density	In isolation, interchange density should not be a basis to restrict platooning, since in most cases there will be times of day when traffic is light even in areas with high interchange density. Other states have levied no requirements.			System developers have noted that DATP drivers will be trained to conduct DATP operations when traffic conditions are suitable, disengaging when conditions are not suitable.

Vehicle densities	Literature provides no basis to define restrictions. Other States have levied no requirements.			System developers have noted that DATP drivers will be trained to conduct DATP operations when traffic conditions are suitable, disengaging when conditions are not suitable.
Facility level of service	Literature provides no basis to define restrictions. Other States have levied no requirements.			System developers have noted that DATP drivers will be trained to conduct DATP operations when traffic conditions are suitable, disengaging when conditions are not suitable.
Facility volume/capacity ratios	Literature provides no basis to define restrictions. Other States have levied no requirements.			System developers have noted that DATP drivers will be trained to conduct DATP operations when traffic conditions are suitable, disengaging when conditions are not suitable.
Facility truck percentage	Literature provides no basis to define restrictions. Other States have levied no requirements.			Literature does not provide substantial rationale for fleets to adjust platooning operations based on facility truck percentage.
Time of day travel patterns	State may want to define restrictions for specific road segments based on stable time of			System developers have noted that DATP drivers will be trained to

	day patterns. Otherwise should rely on driver discretion. Other States have levied no requirements.			conduct DATP operations when traffic conditions are suitable, disengaging when conditions are not suitable.
Required disengagement areas (e.g., construction zones, incident areas, bridges)	Define any specific road sections within which platooning should not occur; provide to fleets via geo-coding. Alternatively, provide signage so that drivers can initiate disengagement. Other States have levied no requirements.	Enforce platooning ban on any prohibited road sections.		Based on published geo-codes, Platooning Operations Centers can automatically dissolve platoons in these areas. Drivers can also dissolve platoons based on signage.
Tolling Operations	Maintenance Recommendations: -- evaluate the ability of tolling systems to "see" transponders on both trucks in a platoon for various inter-vehicle gap sizes			Based on published geo-codes, Platooning Operations Centers can automatically dissolve platoons in these areas if needed. Drivers can also dissolve platoons based on signage.
4. Driver / vehicle limitations				
License or training requirements		As a Level 1 system, there is no basis to require a special license for DATP. Administrative Process Recommendation: Registration / Titling / Licensing:		Fleet operator is responsible for providing adequate training for all critical vehicle systems. Training on DATP systems implemented

		as DATP is a Level 1 system with a professional driver engaged in the driving task, no changes seem warranted in this respect. Other States have levied no requirements.		by fleet operator, working with system developers.
Operating hours		As a Level 1 system, there is no basis to restrict operating hours for DATP. Other States have levied no requirements.	As a Level 1 system with driver engaged in vehicle operation, Federal HOS rules would apply as in normal trucking operations.	Unrestricted. Federal HOS rules would apply as in normal trucking operations.
Operating duration		As a Level 1 system, there is no basis to restrict operating duration for DATP. Other States have levied no requirements.	As a Level 1 system with driver engaged in vehicle operation, Federal HOS rules would apply as in normal trucking operations.	Unrestricted. Federal HOS rules would apply as in normal trucking operations.
Vehicle / trailer type	The literature provides no basis to restrict vehicle/trailer type. Other States have levied no requirements.	The literature provides no basis to restrict vehicle/trailer type. Other States have levied no requirements.		The business case focuses on van trailers due to the aerodynamic effects. Other types of trailers have not been studied; if benefits are shown, then fleets will

				want to platoon with these as well.
Vehicle cargo	The literature provides no basis to restrict cargo type. Other States have levied no requirements.	The literature provides no basis to restrict cargo type. It is advisable to restrict DATP trucks from hauling HazMat loads, at least in the early deployment phase.		Fleets should have the same freedom to transport cargo that regular trucks do. System developers and fleets voice no desire to platoon with a HazMat load.
Vehicle spacing	Other States have levied no requirements.	Fleets responsible for safe operations as with normal trucks.		Minimum gap determined by system developer based on their safety protocols. Fleet may choose to implement larger gaps.
Platoon Size	Operations Recommendation -- Platoons of greater than two trucks may be beneficial to both the public and private sector in certain situations, such as roads which are dominated by truck drayage services near seaports. This could be a unique innovation opportunity for the State and should be examined.			Current commercial activity focuses on two-truck platoons but interest is larger platoons can be expected for certain situations.
Operating infraction repercussions		No basis in literature for this to be different for DATP trucks compared to regular trucking.		
Vehicle safety inspection status/safety requirements	Other States have levied no requirements.	No basis in literature for this to be different for DATP trucks compared to regular trucking.		Fleets will maintain vehicles at or above State/Federal regulations.

		Public Safety Enforcement Recommendations: -- even though industry best practices for platooning technology and operations are still at a formative stage, this study has identified key common elements being implemented by DATP developers that can be incorporated in a permit application		
5. Driver / operator responsibilities				
Platooning notification to enforcement		FHP needs to be able to discern if closely following trucks are platooning or not. Other states have levied no requirements. A "platoon capable" placard or decal is recommended. Public Safety Operations Recommendations -- a tractor decal should be sufficient for informing that trucks are DATP-capable in the initial phase of deployment in which relatively few DATP trucks are operating. It would be useful to re-evaluate this approach as the numbers of DATP trucks begin to increase.		System developers have noted that a "platoon capable" placard on the cab is possible.

Platooning coordination between vehicles				System developers are including driver-driver voice communications plus video from other truck. Additionally, Platooning Operation Centers coordinate truck movements and platooning formation.
Engagement / disengagement				Performed by drivers with system assist, or initiated by Platooning Operations Center.
Other operational considerations (e.g., passing)		Platoons not restricted from passing. Other States have levied no requirements.		Drivers will use their judgment to ascertain when conditions are right for passing maneuvers that are safe and do not disrupt traffic.
Public Communications		Public Safety Operations Recommendations -- collaborate with DATP-equipped fleets and system developers to address public communications		DATP-equipped fleets and system developers collaborate with enforcement community to address public communications
6. Permitting / Data				
DATP Permit Process	Administrative Processes Recommendation: -- Institute an "application"-based process seeking specific information to provide a basis to issue a DATP-specific permit	Drivers carry permit for FHP inspection.		DATP vendors and /or freight carriers apply for permit, self-certifying system safety and related aspects.

Notifications: approved corridors for operation / time of operation	State could provide via a web portal. Other States have levied no requirements.	State could provide via a web portal. Other States have levied no requirements.		Platoon Operations Centers can implement any restrictions levied by State in real time with trucks on the road.
Notifications: required disengagement areas (e.g., construction zones, incident areas, bridges)	State could provide via a web portal. Other States have levied no requirements.	State could provide via a web portal. Other States have levied no requirements.		Platoon Operations Centers can implement any restrictions levied by State in real time with trucks on the road.

V. Task 5: DATP Pilot Planning and Results

As noted in the Introduction, Florida House Bill 7027 (2016-81) states:

> The Department of Transportation, in consultation with the Department of Highway Safety and Motor Vehicles, shall study the use and safe operation of driver-assistive truck platooning technology, as defined in s. 316.003, Florida Statutes, for the purpose of developing a pilot project to test vehicles that are equipped to operate using driver-assistive truck platooning technology.

Planning for the DATP Pilot started in mid-2017 based on early results of this DATP study. A key priority in initiating the Pilot was to gauge industry's interest in participating. Truck fleets (as well as technology providers truck manufacturers, startups) were gauged to be interested, but nevertheless there was a need to assess the Florida opportunity against other options for testing nationwide. Thus, a Request For Information (RFI) was prepared and publicly announced, giving these entities the opportunity to express their degree of interest and their key objectives in participating. This section summarizes the content of the RFI, RFI responses, and the results of the DATP Pilot in December 2017 with Peloton Technology.

The DATP Pilot project was composed of two components: a demonstration phase and an operational phase. In the demonstration phase, participants provided evidence showing that their DATP system was capable of accomplishing key safety-critical functions. The Operational Phase consisted of on-road operations and data collection.

V.A. DATP Pilot Request for Information: Summary

The RFI, issued by the FDOT Transportation Data and Analytics Office, invited expressions of interest in participating in a DATP pilot test. This document provided a proposed approach to the Pilot and sought comments, revisions, and alternative approaches that would make the Pilot attractive to industry while still attaining the State objectives. The RFI was open for several months during mid-late 2017. The full text of the RFI is provided in Appendix B.

V.A.i. Introduction and Objective

The Pilot aimed to highlight performance and safety considerations throughout a set of operational scenarios. More specifically, the pilot aims were to:

- Evaluate impacts on surrounding traffic of DATP, in terms of safety and traffic flow.
- Evaluate impacts of DATP on infrastructure.
- Evaluate feasibility of conducting enforcement responsibilities when DATP trucks are operating.
- Evaluate administrative aspects of permitting DATP systems.

V.A.ii. Administrative Requirements for the DATP Pilot

Per statute (F.S. 316.0896), participants were required to submit to the Department of Highway Safety and Motor Vehicles (DHSMV) an instrument of insurance, a surety bond, or proof of self-insurance acceptable to the DHSMV in the amount of $5 million. Along with evaluation of other information provided, this would enable the Department to issue a permit allowing truck-following distances less than 300 ft.

V.A.iii. Demonstration Phase

For the Demonstration Phase, the RFI sought a full description of system operation provided to the State of Florida by the participant. The demonstration phase centered on Florida officials gaining confidence in the ability of the DATP system to perform safely on public roads by seeking demonstrations on a closed test track. The closed course location for the demonstration was intended to be within the Central Florida Automated Vehicle Proving Ground. Plans called for the Florida Department of Highway Safety and Motor Vehicles (DHSVM) and the Florida Highway Patrol (FHP) to also provide input and support of this pilot project

The State sought for participants to show the procedures for forming and dissolving platoons, the ability of the rear platooning vehicles to respond safely to cut-in by light vehicles and hard braking by the lead vehicle, as well as operational factors such as system robustness to weather, complex interchanges, and system component failures.

Rather than closed-course demonstrations, participants were also provided the option to submit data or video from prior testing that demonstrated the key areas of performance.

The RFI stated that, based on the Demonstration Phase, FDOT, FTE, DHSMV, and FHP would make a determination as to whether the DATP system demonstrated these capabilities at an appropriate performance and safety level. If so, activities with the participant would proceed to the Operational Phase.

V.A.iv. Operational Phase

The Operational Phase was envisioned to be conducted during a period determined by the Department and based on discussions with the participants. Operations would comply with a Safety Management Plan developed by FTE.

The RFI expressed a goal of one week or more of on-road operations observing approximately 1,000-2,000 miles of DATP operation, across conditions including day/night, dry, wet/rainy, and foggy, as available. Regular highway traffic would operate normally.

The RFI-specified operations would occur on portions of the Florida Turnpike that provide the desired traffic conditions and infrastructure configurations. Trucks equipped for DATP had the option to operate in these selected road segments in regular revenue service.

The operational scenario was outlined as follows:

1. Trucks equipped for DATP operate in selected road segments in regular revenue service.
2. The fleet operator (along or with a third party) organizes equipped vehicles to rendezvous on road, providing guidance to drivers as needed.
3. Drivers use HMI provided by technology developer to "link up."
4. The fleet sets gap and speed, based on conditions and their safety protocols. Gaps and speed will vary based on conditions.
5. DATP vehicles operate within normal traffic stream, changing lanes as desired (via manual steering).

The RFI noted that DATP operations were intended for runs over a consistent route. Data and video was to be collected by the participant and analyzed with emphasis on the following:

1. All cut-ins are noted and truck spacing adjustments are noted.
2. All hard braking events noted, to include GPS and video data, for possible later analysis.
3. How interchanges or geometric changes affect DATP operations

The RFI noted that, with full video coverage of the entire Turnpike, video of interactions between platooning trucks and other vehicles would be captured by FTI and analyzed to assess any traffic impediments or improvements. FTE would collect data regarding bridge loading as DATP platooning cross. FTE would be responsible for public education regarding DATP testing.

V.A.v. Report Generation

The RFI stipulated that participants in the Operational Phase would be required to provide a monthly high-level performance / operational report for the duration of the pilot project, which would provide high-level analysis of data and information collected,

The RFI noted that the State would generate a report based on the data and results of the demonstration phase and the operational phase of the pilot project, with the report being delivered to the Florida legislature.

V.A.vi. Application Procedure to Participate in Pilot Program

Those interested in participating in the pilot project were asked to provide responses to the following:

1. Would you like to present a demonstration, or both a demonstration and pilot testing?
2. What type of operations (long haul, short haul) are of interest?

3. What area / highway segments are desired?
4. What dates are preferable to do the testing?
5. What duration / mileage is desired?
6. Would you be willing to operate in varying conditions, including but not limited to sunny, dry, wet/rainy, foggy, and dark conditions?
7. With what range of traffic conditions (light, medium, heavy) and infrastructure configurations (urban highway, rural highway, etc.) would you like to conduct the test? Do you seek a police escort or other methods to "cushion" your operations from regular traffic?
8. How would you suggest handling the question of "signing" of platooning; e.g., a placard on the truck tractor indicating a DATP-capable vehicle, an indicator for when platooning is active, etc?
9. What type of trailer configurations would you use?
10. What aspects of DATP would you like to evaluate?
11. What data would you be willing to provide at the conclusion of the operational phase?
12. Are you willing to have selected data become part of an FDOT report?

V.B. Summary and Commentary Regarding RFI Responses

V.B.i. Peloton Technology Inc. RFI Response

Peloton Technology (Peloton) expressed interest in participating in both the Demonstration Phase and Operation Phase (Peloton RFI Response, 2017). In the Demonstration Phase, Peloton preferred to submit data or video from prior testing and/or participate in a closed-course activity.

In the Operation Phase, Peloton noted that two sub-phases of participation could be possible during Q4 2017: Subphase I, in which Peloton would operate its own trucks with its own drivers, and Sub-phase II, in which Peloton would operate with a fleet partner. Peloton would consider operating for approximately two days, targeting more than 500 miles total, stating their belief that such duration and mileage would sufficiently demonstrate platooning operations to a broad variety of on-road conditions. Peloton would use single 53-ft trailers, single 28-ft trailers, or twin 28-ft "pup" trailers with ABS brakes.

Peloton's interest was in certain short, regional, and long-haul freight operations, and for the Operations Phase these roadways were noted:

a. The Florida Turnpike
b. I-95 from Jacksonville to Savannah
c. I-75 from Tampa to Atlanta
d. I-4 from Tampa to Orlando

In terms of specific aspects of DATP they would like to evaluate, Peloton noted "we are conducting extensive testing and safety validation of its platooning system in coordination with OEMs and Tier 1 supplier partners, and in approaching commercial deployment of the Peloton platooning system. This testing includes functional testing on tracks, hardware in the loop testing, and road mileage accumulation. In the Operation Phase of this Pilot Project, therefore, Peloton evaluation would focus on the particular platooning conditions in the state of Florida. In particular, Peloton would evaluate the traffic, construction, weather, and topography conditions of Florida roadways."

Peloton noted that they "would consider sharing data such as vehicle miles traveled and speed, as well as data referenced in the RFI, such as cut-ins and hard braking events," adding that their platooning system "continuously logs this type of data – including truck acceleration, braking (including hard braking events), forward radar sensor data (including vehicle cut-ins), forward-facing camera data, and other information available on the J1939 CAN bus. Additionally, they noted that "data deemed high priority is sent continuously to the Peloton Network Operations Center via 4G LTE, and a larger set of data can be retained on the truck and downloaded via WiFi for analysis."

Based on Peloton's high interest in proceeding, several planning calls were held with Florida state officials, resulting in a DATP Pilot event in December 2017, as described in Section V.C.

V.B.ii. Volvo Technology of America RFI Response

Volvo Technology expressed an interest in engaging with FDOT in both the demonstration and operational phases of the DATP pilot but emphasized they needed additional information in order to make the necessary arrangements (Volvo Technology of America RFI Response, 2017). In particular, they noted that "the involvement of the Volvo Group and our research and development partners is subject to available external financial support and clear definition of the mission."

Volvo Group's interest was in both long- and short-haul operations, on interstates, freeways, and expressways, including dedicated lanes if available. Their interest in evaluating DATP centered on:

a. system performance in marginal weather conditions (various rates of rainfall and wind)
b. acceptability of different time gap settings to truck drivers with a variety of levels of driving experience
c. evaluating driver effects and performance in follower trucks

In terms of data sharing, Volvo Group was not definitive given their desire for more information. However, they noted, "In general, we welcome the idea of sharing results from field trials and other pilot testing to support technology standards (e.g., SAE) and policy development. It must be noted, however, in the event real fleet operators are involved, some of the data would be the property of the fleet operators and any sharing of data is very much subject to their consent."

Follow-up calls focused on the potential for state funding to support Volvo activities. This was not possible and discussions did not proceed further.

V.B.iii. Society of Automotive Engineers RFI Response

SAE noted that they are routinely active in forming "industry cooperative research projects and technology consortia for research, development, and testing" (SAE RFI Response, 2017). They noted that they had been in discussion "with Volvo Technology North America and others, regarding the potential of having interoperability demonstrations and testing in Florida." They stressed that "interoperability is a major element in any new technology deployment" and they echoed Volvo Group's responses to the RFI.

V.B.iv. Martin-Brower RFI Response

Freight carrier Martin-Brower's RFI response noted they are "one of the largest distribution companies in the world, providing trucking carrier services to industry leading customers with a strong focus on cold chain delivery of food products" (Martin-Brower RFI Response, 2017). They expressed their interest in investigating and implementing "highway truck platooning as well as automated local delivery." Their interest in the DATP Pilot centered on their daily hamburger bun shuttles from Orlando to Pompano Beach via Florida's Turnpike, "subject to finalizing agreements with key technology and test partners." They were interested in both long- and short-haul operations, elaborating by saying, "We are very interested finding new ways to improve the way that we move product from our Orlando DC [distribution center] to our Pompano DC. We shuttle four trailers a day, seven days a week during normal volume; this number increases when we experience spikes in our business. Future focus would include our daily routes from the Pompano DC to each of the 325 individual stores that we currently service."

Martin-Brower was interested in initiating pilot testing "as soon as possible based on availability, Q4 of 2017 or Q1 of 2018 at the latest" testing at all hours of the day as they run a 24/7 operation. Three hours of platooning at a time was seen as seen as a good initial trip length, as this is the time it takes to travel between the Pompano and Orlando distribution centers. However they also noted that "our shuttle routes currently take 14 hours each, driving a total of 514 miles each, 7 days a week; this takes 4 drivers to cover.
Our longest delivery route to our customer is to Key West which rolls in at about 378 miles round trip and takes about 13 hours."

Martin-Brower was willing to operate in varying conditions (traffic and weather) as this "would most closely match what we currently do and would be very important to us as it should ensure the most valuable data/results."

They further noted that they currently use refrigerated 48' and 32' "pup" trailers. Their shuttles are two 48' refrigerated trailers "with a dolly pulled by one tractor with a single driver," adding that "the shuttles are broken down to singles at a staging area at each end and each trailer is then taken to the DC on surface streets. Daily routes encompass all types of legal roadways which includes highways and surface streets with all types of traffic from highly congested stop and go to very light traffic depending on the time of day."

Martin-Brower's interest in the DATP Pilot focused on investigating:

a. fuel economy as a function of truck separation distance and speed.
b. conduct testing in a variety of conditions such as road topography and weather conditions
c. the utility of the network operations center concept for platooning in terms of effectiveness, timeliness, accuracy, etc.

d. cost effectiveness of DATP compared to current operations

In terms of data sharing, Martin-Brower was open to “provide all data that is not proprietary to our unique operations” plus “would not cause any issues with our business partners.”

Discussions with Martin-Brower have continued since their RFI response and their interest remains high in launching DATP operations in Florida once they have finalized plans with system suppliers.

V.C. Summary of DATP Pilot Conducted with Peloton Technology

Based on discussions with RFI respondents, FDOT, FTE, and FHP coordinated with Peloton Technology, Inc. to conduct a DATP Pilot on the Florida Turnpike during December 18-19, 2017. Peloton Technology provided written and video documentation of the system safety approach for highway driving to fulfill the Demonstration Phase requirements, providing a sufficient basis to proceed with on-highway pilot operations.

Two routes were run multiple times. The “Long Route” was a 295 mile round trip from FTE HQ at Turkey Lake to Route 706 (near Jupiter). The “Short Route,” used for demonstrations to public officials and fleet representatives, was a 16 mile round trip from FTE HQ at Turkey Lake to Route 50 (near Oakland). Several days of testing preceded the Demo Days on December 18-19, such that a total distance of 1,215 miles were driven while platooning in low to moderate traffic conditions during daylight as well as dusk. Data, photo and video documentation was generated for later analysis.

As agreed with state officials prior to the Pilot, Peloton provided data generated by the DATP systems during the runs. This data revealed that, while no system-initiated hard braking events occurred, the DATP system successfully handled a “cut-in” by another vehicle in front of the forward truck by automatically activating braking. Additionally, in a small number of cases, the rear truck driver detected impending cut-ins between the two platooning trucks and manually initiated braking to accommodate the merging traffic.

FHP experienced Peloton DATP system operations and and observed no clear safety concerns during the three-day pilot phase. During this time, six members of the FHP rode inside commercial DATP-equipped motor vehicles engaged as both the lead and rear commercial motor vehicle at separation distances averaging 66 feet. Each commercial motor vehicle was a truck tractor semi-trailer combination which operated on the Turnpike (limited-access facility) primarily during clear daylight conditions, with some minor fog conditions interspersed during one morning.

Additionally, FHP had its Aircraft Pilot observe the long run demonstration. From the pilot’s perspective it was clear the CMV’s were travelling close together and within the 300 foot allowable distance and there were no observed traffic related problem during the testing. Similarly, state traffic officials observing operations in the Pilot did not observe any instances of the platoon interfering with traffic or inconveniencing other motorists. Demo participants observed platoon drivers accommodating merges and lane changes for other traffic. The FTE Traffic Management Center monitored the 1,215 miles of testing and recorded no impacts to daily operations.

VI. Summary and Recommendations

VI.A. Study Overview

Current Florida statute (316.0895) prohibits truck drivers from following closer than 300 feet based on an assessment that following at shorter distances is unsafe given the nature of truck braking systems and reaction times for human drivers. DATP technology now being commercialized is designed to safely achieve shorter following distances, which would reduce fuel use due to aerodynamic drafting effects. Significant fuel economy benefits from platooning (on the order of 7% improvement for the truck pair) have been documented through extensive test track evaluations, motivating major trucking fleets to deploy platooning. If current law is revised to allow shorter following distances while trucks platoon, Florida will see enhanced safety and reduced environmental impacts (emissions and energy use) from trucking operations while maintaining its standing as a tech-forward state. At the same time, the cost of goods movement will be reduced for freight carriers, with savings potentially passed on to Floridians.

In 2016, the Florida legislature directed the Florida Department of Transportation (FDOT), in consultation with the Department of Highway Safety and Motor Vehicles (DHSMV), to study the use and safe operation of DATP for the purpose of developing a DATP pilot project (Florida House Bill 7027 (2016-81)). In response to this legislative mandate, FDOT requested the University of Florida to conduct this study.

With DATP having the potential to lower the cost of freight transport and the footprint of trucks on the road, it was important to first address these questions:

a. Will DATP trucks be more likely to crash, or increase the severity of a crash?
b. Will DATP trucks impede other traffic, particularly at interchanges?
c. Will DATP trucks damage infrastructure due to intensified loading or aerodynamic effects?
d. What administrative processes to allow DATP operations would best serve State interests?

The study approach centered on a thorough literature review relating to automated vehicles generally and DATP specifically. The findings of the literature review, combined with the results of the DATP Pilot, were then applied to key questions and issues raised by the Florida DATP Working Group.

VI.A.i. Regulatory Aspects of DATP

Ten states (Arizona, Arkansas, Georgia, Michigan, Nevada, North Carolina, Ohio, South Carolina, Tennessee, and Texas) currently allow truck platooning on their highways. Additional states are expected to join this group in 2018. Of these states, some allow for platooning operations "carte blanche" while others require a "platooning plan" or a notification. Currently no permits are required in states with platooning commercial allowance laws.

Across states allowing platooning, self-certification of safe operations and practices is the norm.

VI.A.ii. DATP Safety Measures and Risk Assessment

FHP officers reviewed the Peloton safety design approach plus videos of system operation prior to moving from the Demonstration Phase to the Operational Phase of the DATP Pilot. During the on-road portion of the Pilot, FHP officers experienced Peloton DATP system operating at 66 feet inter-vehicle gaps and and observed no clear safety concerns.

VI.A.iii. DATP Traffic Interactions

Traffic must not be impeded by DATP trucks in merging and de-merging at freeway interchanges. This is addressed by proper share-the-road behavior on the part of truck drivers in today's world, and the same applies to DATP operations. Both the Daimler and Peloton approaches accommodate any need to open up the inter-vehicle gap for traffic situations so that other vehicles may safely merge or change lanes. When traffic is merging, the leader truck driver assesses the situation, keeping in mind the overall length of the two truck platoon, and the driver judges whether to brake for merging traffic or to maintain speed so that merging traffic can come in behind the platoon.

While limited evaluation of platooning traffic effects have been conducted via simulation and observed in field demonstrations in the U.S. and Europe, no detailed public road data have been published to date. Qualitative observations from the days-long 2016 European Truck Platooning Challenge indicated that passenger car traffic was not disrupted.

Traffic interactions during the recent Florida Platooning Pilot operational demonstration, which included interchanges, bridges, toll plazas, Service Plazas, etc., did not raise concerns. An FHP aircraft observed the long run demonstration; from the pilot's perspective it was clear the CMV's were travelling close together and within the 300 foot allowable distance and there were no observed traffic related problem during the testing. Similarly, state traffic officials observing operations in the Pilot did not observe any instances of the platoon interfering with traffic or inconveniencing other motorists. Demo participants observed platoon drivers accommodating merges and lane changes for other traffic. The FTE Traffic Management Center monitored the 1,215 miles of testing and recorded no impacts to daily operations.

VI.A.iv. DATP Interactions with Bridge Structures

A 2017 FDOT analysis found that well less than 1% of bridges on interstate and turnpike mainlines could be subject to stresses exceeding bridge design specifications with trucks platooning at a 30-foot spacing. First generation platooning systems are expected to operate at spacings over 30 feet.

It would be straightforward for the State to notify system providers and fleets regarding any locations/areas where platooning should be restricted, due to specific infrastructure elements or other factors. Data provided by the State can be used by platooning system providers and fleet users to update geofencing and driver usage of platooning.

VI.B. Conclusions and Recommendations

The DATP Pilot plus the University of Florida DATP Study have given state officials a degree of confidence that platooning can be done safely without disruption to surrounding traffic. Based on discussions with DATP vendors and early-adoption fleets, only a small number of DATP-equipped vehicles are expected to be deployed on Florida highways during the first year after DATP following distances are allowed. This gives the State the opportunity to evaluate the approach to DATP deployment and coordinate with manufacturers and trucking fleets to develop best legislative and operational approaches as the technology continues to mature, in addition to defining optimum approaches to communicating with the public. Florida has the opportunity to take a leadership position in creating an approach that accelerates early deployment.

Table 8 in the main report addresses key parameters summarizing study findings in terms of the roles of State agencies and the private sector.

VI.B.i. Safe Operation and Enforcement

Responsibility for safe operations of trucks on the roads today lies with the vehicle operator. Based on the above discussion and the in-depth findings in this study, the same paradigm can be extended to DATP operations.

Because DATP builds upon proper brake operation, current inspection protocols are sufficient for DATP. Given the safety best practices described above, DATP vehicles can be expected to operate well above minimum standards. This approach can be evaluated during the initial phase of deployment.

Because FHP troopers and other law enforcement agencies may pull over trucks as a normal part of their duties in enforcing the 300-foot minimum following distance for non-DATP trucks, some means is valuable for enforcement officers to understand the DATP status of trucks. Options considered for this were a decal indicating the tractor is DATP-capable, an active indicator showing when platooning is underway, and various electronic means including methods that would provide information to existing systems on law enforcement vehicles. During discussions of the Florida DATP Working Group, only a state-issued decal was considered practical for initial deployment of DATP. While other approaches are straightforward technically, there are numerous practical hurdles. The decal protocol is seen as a simple approach for the early phase of DATP deployment; the effectiveness of this approach will be evaluated after the initial phase of DATP operations.

Recommendations

a. Enforcement personnel on the road can be informed that tractors are DATP-capable via a state-issued decal (issued based on the recommended permitting process). This is seen as a simple initial approach for the early phase of DATP deployment, in which relatively few DATP-equipped trucks are expected to be operating in Florida.
b. Evaluate the effectiveness of the DATP decal approach during the first phase of DATP deployment.
c. Enforcement operations would benefit from evaluating the degree to which "copycat" behavior (non-DATP vehicles closely following behind a platoon) is occurring, if at all. This can be augmented by discussions with early deployment fleets. If this appears to be an issue, develop training and methods for troopers to detect and respond to such instances.

Planning

Potential planning measures could include capacity change considerations with higher truck platooning penetration. Although capacity increases can be theorized for rural highways, these are typical road segments in which there is spare capacity. To the degree platooning is deemed appropriate on urban or suburban highways, a net benefit may occur.

MPO policies could address the creation of "truck platooning opportunity corridors. However, based on the literature and discussions with stakeholders, DATP operations would not require dedicated lanes.

Recommendations

a. Planning processes would benefit by adapting travel demand models to include DATP operations to support future planning studies.
b. Traffic simulations incorporating DATP behavior would be useful to understand the potential effects of extensive DATP operations.
c. It will take time after initial DATP deployment to gain a sense for operating parameters (inter-vehicle gaps preferred by fleets, for instance) and adoption rates. Therefore, any assessments of the need for dedicated lanes and/or environmental impacts should be deferred for the time being.

VI.B.ii. Traffic Operations/Interactions

Operations activities do not require any specific actions at the outset of DATP deployment. DATP, being limited to two trucks, is expected to be a benign presence on the road in general. Surrounding traffic will find it preferable to pass two closely spaced trucks rather than two trucks with today's typical spacing. Traffic interactions during the 1,215-mile DATP Pilot did not raise concerns.

Regarding merging and diverging, the trucker road etiquette for merging traffic that has long been in place also encompasses DATP operations.

Driver judgment regarding when to platoon appears to be a better approach than road segmentation or placing restrictions upon DATP use based on traffic / interchange density.

Recommendations

a. Allow DATP operations on any limited access, multi-lane, divided highway, with decisions to platoon on a particular road segment based on driver and system assessment of conditions (traffic, topography, work zones, weather), plus any guidance from road authorities.
b. Allow DATP operations on any lane currently allowable for trucks. Based on an assessment of the immediate traffic situation and consistent with existing state guidance and practices, allow drivers to choose which lane is best.
c. As DATP operations begin to proliferate in certain corridors, this provides an opportunity to evaluate any occurrences of traffic disruptions (near interchanges or other areas), as well as assess any detrimental behavior of other traffic near the platoon.
d. Given that no data have been published to date of DATP operations on public roads, as DATP comes into use in Florida and across the nation empirical data should be collected to understand any impacts more thoroughly.
e. If any restrictions need to be applied, the State should develop an approach to notifying platooning operators of such areas and what operating parameters should be observed by platoons.

f. Platoons of greater than two trucks may be beneficial to both the public and private sector in certain situations, such as roads that are dominated by truck drayage services near seaports. This could be a unique innovation opportunity for the State and should be examined.

VI.B.iii. Infrastructure

Within Florida, no bridges would be of concern with legally loaded two-truck platoons operating at 60-foot spacing, and less than 1% of bridges would be of concern at 30-foot spacing. First generation DATP systems are expected to operate at spacings over 30 feet.

Recommendations

a. Identify structures that should be geo-fenced as restricted platooning zones, if any.
b. Devise a process to notify DATP permit holders of any locations for which platooning should be restricted, due to specific infrastructure elements or other factors. Platoons would be required to cease platooning when traversing these locations.
c. Conduct modeling, simulation, and empirical studies to gain a more complete understanding of bridge effects from various DATP configurations and following distances.

VI.B.iv. Administrative Processes

Changes in licensing, registration, and titling processes for DATP are not required. With regard to licensing, DATP drivers are fully engaged in the driving task and report that use of DATP is quickly learned and not significantly different from regular driving.

Of the states that now allow commercial deployment of DATP, the "notification form" approach that Tennessee has established may be a good model for Florida, as it provides opportunity for a two-way process with applicants. Based on an applicant submitting a notification form, state agencies can receive key information specified by the state (such as approaches to system safety design and validation), seek further information if needed, and disallow an entity from proceeding if they determine there are concerns.

Note however that in discussions during the preparation of this study, DATP developers and fleet industry comments have stressed the importance of keeping the requirements and mechanism for issuing permits relatively simple so as to not create a state-specific burden on industry.

Recommendations

If Florida statue is modified to allow DATP operations, the research team recommends to implement a process to issue DATP-specific permits on a per-vehicle basis.

In the permit application process, fleets (possibly working jointly with DATP suppliers) could be required to provide information such as the following (based on results of the DATP Study, manufacturer's recommendations, and discussions with stakeholders):

a. Fleet name and contact information
b. Supplier of DATP system and contact information (fleets may rely on the supplier to provide some of the information below)
c. Truck VIN

d. Type of trailers to be pulled plus configuration (single, tandem)
e. Routes and general timeframes for DATP operations
f. Operational Design Domain of system (includes number of vehicles in platoon, minimum inter-vehicle gap used)
g. Equipment (self-certify):
    a. Tractor: disc brakes on all tractor axles, forward collision avoidance and mitigation system, plus any other equipment applicant notes as further enhancing safety
    b. Trailers: ABS-equipped
h. Description of Safety Validation Procedure
i. Description of operational practices to enhance safety while platooning (examples specific to Peloton: intelligent ordering, role of Network Operations Center)
j. Description of operational practices to accommodate nearby traffic while platooning

As part of the process to approve an Application, FDOT may request a demonstration of system capability on a closed-course track.

Related recommendations are:

a. DATP-capable trucks affix a state-issued decal(s) to the vehicle at locations specified by DHSMV and FDOT. Input from freight carriers would be useful in defining these locations.
b. Equipped vehicles carry documents showing the tractor is equipped with the platooning and supporting safety systems
c. Drivers carry a document showing they have completed an industry-provided DATP training.
d. Hauling of placarded hazardous materials using DATP would not be allowed.
e. Seek input on implementation of these recommendations from stakeholders including the Florida Trucking Association, leading fleets exploring platooning, and others as appropriate.

VI.B.v. State Liability

For DATP, having engaged drivers in both trucks serves to keep the liability questions very similar to those for regular driving. State liability relates to well-marked and -maintained infrastructure, as is the case now.

VI.C. Summary

The questions motivating this study (as posed in Section I) addressed the safety of DATP trucks, their effects on other traffic, their effects on infrastructure, and administrative processes to allow DATP operations.

The study has brought to light the extensive body of literature regarding truck platooning in general. Much of this literature is focused on research and simulations. The literature review provided a solid basis for planning the DATP Pilot in December 2017. The Pilot provided state officials with real world experience with traffic and safety relevant interactions on public roads, leading to confidence that deployment of DATP could go forward based on a permitting process focusing strongly on industry best safety practices.

Specifically, state officials did not observe safety factors or traffic interactions of concern during the Florida DATP Pilot. This, coupled with a deeper understanding of the equipment and practices supporting DATP, led to the platoon permitting approach that the research team is recommending. Initial evaluation of impacts on structures led to no significant concerns even though more in-depth research would be useful.

In the initial phase of DATP deployment, ongoing evaluation of DATP operations could be useful. Because DATP is likely to be operating across multiple states, FDOT and DHSMV can work with other states to monitor traffic and safety measures of truck platooning and further evaluate system effects.

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Appendix A: 2016 FDOT DATP Task Force Meetings – Key Issues

Consolidated Meeting Notes

High-Level Points

a. Develop a goal: play on what is important to FDOT, namely the Mission: Supporting the initiative of truck platooning and planning for the development on the transportation system to enhance mobility of people and goods.
b. Recommendation to bring in someone from the Office of General Counsel for legal review.
c. How will this be extended to other states long term? Florida's goal should be to set the standard for other states.
    a. Interoperability between states; it can be done but how do we do it?
d. Federal agencies are looking for states for deployment projects and potential policies and regulations.

Benefits

a. Can road capacity be enhanced with platoons? Simulation estimates that 60% saturation would return capacity benefits, but 20% has no net effect.
b. The acceleration and deceleration setting should be carefully reviewed in a micro-simulation model, if funding allows, to predict anticipated operational and environmental benefits.
c. Establish benefits to state, beyond just for truckers:
    a. Increased business
    b. Increased capacity
d. Consider cost/benefit of overall economy as a result of truck platooning.

Carriers / Users

a. Make sure to not create a scenario which creates a single proprietor situation.
b. Should motor carriers have a minimum Safety Fitness score?
c. Companies must ensure vehicles are fully operative and must ensure brakes are in good condition.
d. Only want best of the best companies (in terms of safety practices) participating.
e. DATP operations should be limited to reputable freight operators
    a. Consider CSA scores
    b. Carrier requirements
    c. Fleet size
    d. Driver experience/driving record
    e. Vehicle inspection protocols
f. Florida Power & Light could be a potential user of DATP technology.

Safety

a. DHSMV's concern about safety is the primary reason for much of the legislation language. DOT and DHSMV legislative affairs met and agreed that they are not comfortable allowing platoons without knowing what safety ramifications.
b. Consider risk of cars coming in between platooning trucks; what are safeguards?
c. Need to understand how Lead Vehicle emergency braking impacts the Following

Vehicle and vehicles behind the Following Vehicle. Does this impact minimum safe following distances between the Lead Vehicle and Following Vehicle?

d. Will the study consider acceptable inter-vehicle gap ranges vis-a-vis a potential incident?
e. Technology exists to ensure that the trailing vehicle adjusts the headway in the event of a rogue vehicle sneaking between the two trucks in the train. Will this pilot help with (a) the advance vehicle "knowing or sensing" the presence of an intruder while the lagging vehicle monitors for such an entry and adjusts accordingly?
f. How will the vehicle respond to other obstacles that cut in-between platooning trucks, such as deer, etc.,?
g. What are inter-vehicle gap distances guidelines for vehicles engaged in truck platooning?
h. Does the lead vehicle have to comply with safe travel distances for other vehicles?
i. Will systems provide lane departure and similar warnings?
j. What happens when there are radar and similar system failures? Does the platooning system disengage, other?

DATP Drivers

a. Changes in the Driver's Handbook to discuss platooning are anticipated. Is there other information material?
b. What driver training should occur? Are there certifications for lead versus following vehicle drivers?
c. How much experience should a driver have to engage in platooning?
d. Who should be the lead driver? Should this be based on vehicle weight, vehicle design and driver capability?
e. Should we look at driver motor vehicle reports and crash history to determine eligibility?
f. Will platooning increase driver fatigue and distraction issues? Should following drivers' hours of service be changed?
g. Will systems manage speed or stop drivers from speeding?
h. How does the system ensure against driver sabotage and potential for terrorism?
i. Driver-to-Driver communications (voice, VoIP, cellular, CB radio, etc.)?
j. Does the Following Vehicle driver need to read road signage while DATP is engaged? If so, what is the ability of Following Vehicle driver to read road signage if it is spaced closely behind Lead Vehicle?
k. What communications should be established between drivers while not violating 392.80 and 392.82?

Vehicle Equipment and Maintenance

a. What types of vehicles—truck tractors, straight trucks, TT-ST, TR-ST, Doubles, etc.—should be allowed to engage in platooning?
b. Natural gas powered trucks are OK for platoons. (DHSMV)
c. Participating trucks must be automatic transmission, therefore only newer trucks can participate.
d. Will not have vehicles that are over height or dimensioned except for FTE doubles (28' doubles). (system provider)
e. 3rd party should define system requirements, that would include SMS, CSA, hours of service, maintenance, etc., for vehicle and driver eligibility (need to limit liability to

the State agencies).

f. Should there be standards on screen display for platooning so it does not violate F.S. 392.60? How do we ensure the display does not obstruct vision?
g. What will be the human to machine interface requirements? What types of display will platooning vehicles have?
h. Should there be a requirement for annual, quarterly, etc. diagnostics for brakes and system components?
i. How often does the manufacture, 3rd party installer, or vehicle owner/operator have to come in to verify the equipment?

DATP Operations

a. What speeds should platooning have?
b. Should platooning trucks be allowed to overtake slower vehicles while engaged in a platoon?
c. Speed differential requirements when platooning trucks pass slower vehicles? (addressing the possibility of limiting queue lengths if trucks are in 2/2 lanes while passing)
d. One of the major field-level issues is about the merge and diverge points; in particular, the impact of decelerating vehicles (as they head to a rest area or exit the freeway) and merging/acceleration (from rest areas or freeway entry) are areas of traffic operations concern, especially during truck platooning.
e. Similarly, merging between lanes due to construction or road closures.
f. What are lane change protocols – disengage during maneuver?
g. Consider which lane platoon runs in. If traffic disruptions are expected to occur, consider running pilot in the middle of a 3 lane segment.
h. The pilot project should have a vehicle platooning identifier; sign, light, ID. GPS, Bluetooth, RFID chip and could allow distance, location, and labeling measures. An electronic identifier might be preferred. (FHP)

DATP Restrictions / Allowance

a. On which roads should platooning be allowed?
b. Consider limiting DATP to limited access facilities (4-lane divided highways with driveways would be prohibited)
c. Should rural 4-lane divided highways with a specified (low) driveway/ intersection density (for example, below 2/mile) allow DATP?
d. Should transportation of Hazardous Materials or other cargo be limited from platooning? Consult the Emergency Response Guidebook.
e. Identify 'lowest common denominator' when identifying areas that DATP should/should not be allowed.
f. Identify simplest way for drivers/DATP systems to identify where platooning is not allowed. For example, if urban areas (high density of interchanges) should be excluded from DATP, which results in a posted speed limit of 55 mph, then consider prohibiting platooning anywhere with a posted speed limit of less than 55 mph (this would, in effect, only allow platooning if the posted speed limit is equal to or greater than 60 mph). Additionally, optimal benefits (fuel efficiency) are generally attained at higher speeds.
g. A potential pilot project could limit locations to those 55 mph and higher. (DHSMV)
h. For hazardous materials, loads requiring a placard, refer to the Emergency

Response Guidebook. Which commodities should be excluded from platooning? Which combination of commodities should be excluded? For example, H2O-activated chemicals should not platoon with H2O tankers. (DHSMV)

i. Reference the federal rules on explosive commodities. (FHP)

Infrastructure

a. What electronic or physical infrastructure is needed?
b. Should there be minimum roadway design for platooning?
c. Are there size and weight concerns for highway infrastructure and vehicle conditions. Should permitted vehicles be allowed to engage in platooning?

Traffic Operations

a. What are risk factors? How do you mitigate risk?
b. Consider time of day, day of week, and weather restrictions. How does inclement weather impact platooning operations?
c. Look at MUTCD for sight distance and advance warnings (work zones).
d. Examining potential operational impacts from multiple vehicle trains (more than 2-truck platoons) should be considered.
e. Consider possible impacts to other vehicles in the traffic flow streams, meaning, will other vehicles slow down and behave differently when they see a platoon of, say, 4 or more trucks in the train?
f. The study may provide clarity for readers on the fact that truck platooning is not the same as, and in fact quite different from, cooperative adaptive cruise control (CACC). In fact, it is worth noting the way CACC functions and look for commonalities with DATP as regards traffic flow characteristics.
g. Should there be limitations on traffic density for platooning? How does platooning affect traffic density?
h. How will platooning affect traffic flow?
i. Can there be more than two combinations in a sequence?
j. Should platooning trucks be allowed to overtake slower vehicles while engaged in a platoon?
k. Should transportation of Hazardous Materials or other cargo be limited from platooning? Consult the DHSMV Emergency Response Guidebook.

Enforcement / Inspection

a. How do FHP and other state agency staff verify that a vehicle is equipped with certified DATP technology on the roadside?
b. Regarding 316.0895 – following too closely, should it be stated that the Lead Vehicle of a platoon cannot follow within 300' of another vehicle? (address the concern of multiple 2-truck platoons forming a series of (2+) 2-truck platoons, essentially creating a 4+ truck platoon. This could also address 2 trucks simulating a DATP, even though the 2 trucks are not equipped with DATP technology.)
c. Should DHSMV establish an "Approved Products List" (potentially based on FDOT's model) for aftermarket DATP devices? If so, should standards be set by a 3rd party for DATP devices to be added to an Approved Products List?
d. Should braking, communications, detection devices, etc., that are necessary for DATP operation be inspected annually to ensure safe operation?

e. What are the best methods for training to law enforcement?

Tolling

a. Should DATP trucks disengage through tolling gantries? (FTE)
b. Should there be a minimum distance between LV and FV through gantries so as to not obscure the license plate of the LV by the FV? (for tolling by plate facilities) (FTE)
c. Can existing tolling technologies 'capture' both the LV and FV transponders if DATP is engaged? Consider quantifying the minimum following distance and maximum speed necessary. (FTE)

Bridge Structures

a. Florida bridges are designed for 80,000 lbs., NY's are designed for 100,000 lbs. so rules may vary from state to state.
b. State has heavy freight corridor study; this one should coordinate with that.
c. Many bridges can take legal loads only.
d. There are 12 structures that are concerning with weight limits. All are in urban areas.
e. Establish signal to driver that bridge is approaching? In cab warning/ connected vehicle device?
f. Prolonged use/heavy saturation rate of DATP could decrease life of structures.
g. Consider identifying a saturation rate of DATP in use on public roadways that could lead to a decrease in lifespan.
h. Consider a cost/benefit analysis of increased freight movement vs. cost to replace structures (repair/replace intervals)
i. Consider establishing (and maintaining) a geo-fence app/layer that identifies structures that could pose issues for DATP (deficient bridges, dense interchange areas, construction zones, etc.)

Aerodynamic Effects

a. Ensure stability of roadside and overhead structures, if platooning results in additional turbulence. (FTE)
b. Assess the impact of turbulence and aerodynamic drag created by a platooning train on the adjoining non-truck traffic.
c. Is wind shear compounded by 2 trucks following within 30'-120'?

Communications / Data

a. Can V2I be tested during platooning testing as well?
b. Should we identify minimum data requirements for ad hoc truck platooning? (i.e., braking characteristics, load type, vehicle/trailer weight, power/weight ratio, DATP technology specifications, v2v system requirements, etc.)
c. FDOT does not want to broker platooning but plug/pull data into system.
d. Define specific standards for V2V and V2I communication
e. What cybersecurity standards should be established?

Registration / Certification

a. Only AV trucks registered in FL would be identified, as other states likely do not have a field within a vehicle's title to be identified as 'autonomous'

b. If vehicles aren't registered as autonomous can they still participate in study?
c. Aftermarket applications will be majority of possible candidates for pilot. Aftermarket devices are not identified on a vehicle's title.
d. To a large degree, aftermarket devices have not altered safety critical functions of a vehicles (steering, braking, and acceleration). Aftermarket products (larger brake rotors, improved brake pads, etc.) are on the market, but they have not impacted 'decisions' by the vehicle on behalf of the driver.
e. Does the alteration of the vehicle require a new specification certification? How do they prove it was done? Would this requirement come up in administrative code?
f. Manufacturer installation (OEM) vs 3rd party aftermarket. 3rd party installation requirements? Certificate to install?

Permitting

a. Florida is an easy permit state, $5 for 36 months; a special permit for platooning trucks is preferred.
b. It is recommended that the pilot project not include dump trucks, concrete trucks, or single unit trucks.
c. It is also recommended that the pilot project not include overweight vehicles (permitted).
d. Trucks could have RFID so trucks could be identified for weight enforcement.
e. FHWA's only guidance is with convoys which recommends 60', but is in military convoy context.

Planning

a. Consider the amount of truck traffic and percent of trucks on the roadway.
b. Reference FDOT strategic plans and understand how this is addressed and if the plans need to be amended to include impacts from DATP (Florida Transportation Plan, Freight Plan, and the Emerging Motor Carrier System Plan).

Public Perception

a. Need to be cautious of public perception and address as needed.
b. What are the best methods for communicating to the motoring public?

Insurance

a. Review the amount of liability. Is $5M the appropriate level of insurance?
b. Who should pay for insurance and who should have the insurance?

Industry Standards

a. Are there specific industry standards that should be established?

Federal Standards

a. How does Automated Vehicles and DATP fit into Federal Motor Vehicle Safety Standards (FMVSS)?
b. Are there limitations/constraints with the FMVSS that would preclude the use of DATP on public roadways? Should FMVSS be updated to address specific points, and how might that impact state governments?

Information Sources

a. The study may extract operations challenges from such studies as (a) SARTRE, a European platooning project; (b) PATH, a California traffic automation program that includes platooning; (c) GCDC, a cooperative driving initiative, and (d) Energy ITS, a Japanese truck platooning project.
b. Worth evaluating this report titled, "Results of initial test and evaluation of a driver-assisted truck platooning prototype." Abstract of the document refers to "a range of technical and non-technical issues, including assessing real-world business and operational issues within the trucking industry."

Appendix B: DATP Pilot Request for Information

This invitation is provided to the heavy trucking industry to seek expressions of interest in participating in a pilot test of Driver Assistive Truck Platooning (DATP).   This document provides a proposed approach to the Pilot, for which we seek comments, revisions, and alternative approaches that would make the Pilot attractive to industry while still attaining the state objectives.

Introduction and Objective

The goal of the pilot project is for trucking industry firms and/or technology developers to demonstrate Driver Assistive Truck Platooning (DATP) technologies to State of Florida transportation stakeholders.

DATP is defined in Florida statute 316.003 as "*Vehicle automation and safety technology that integrates sensor array, wireless vehicle-to-vehicle communications, active safety systems, and specialized software to link safety systems and synchronize acceleration and braking between two vehicles while leaving each vehicle's steering control and systems command in the control of the vehicle's driver in compliance with the National Highway Traffic Safety Administration rules regarding vehicle-to-vehicle communications.*"

The pilot project will highlight performance and safety considerations throughout a set of operational scenarios. More specifically, the pilot project will:

- Evaluate impacts on surrounding traffic of DATP, in terms of safety and traffic flow.
- Evaluate impacts of DATP on infrastructure.
- Evaluate feasibility of conducting enforcement responsibilities when DATP trucks are operating.
- Evaluate administrative aspects of permitting DATP systems.

The pilot project will be comprised of two components; i.e., a demonstration phase and an operational phase. In the demonstration phase, participants will show the procedures for forming and dissolving platooning operation as well as the ability of the platooning vehicles to respond to cut-in by light vehicles. The closed course location for the demonstration will be selected by the Florida Department of Transportation (FDOT) and the Florida Turnpike Enterprise (FTE) from within the Central Florida Automated Vehicle Proving Ground (CFAVPG) (as designated by USDOT) resources, in consultation with private sector participants. The Florida Department of Highway Safety and Motor Vehicles (DHSVM) and the Florida Highway Patrol (FHP) will also provide input and support of this pilot project

The Operational Phase is envisioned to be conducted during a period determined by the Department and based on discussions with the participants; it will include an intensive review at a minimum of one week observing approximately 1,000-2000 miles of DATP operation. DATP operations will be reviewed in varying conditions available, including but not limited to, sunny, dry, wet/rainy, foggy and dark conditions.

In coordination with CFAVPG, operations will occur on portions of the Florida Turnpike which provide the desired traffic conditions and infrastructure configurations, as well as being relevant to regular freight runs conducted by participating fleets. In the Operational

Phase, trucks equipped for DATP will operate in these selected road segments in regular revenue service. Industry firms may participate in the Demonstration Phase alone, or in both the Demonstration and Operational Phases of the project.

Freight carrier applicants may partner with technology providers and participate as a team. In addition, FDOT is open to participation from multiple teams.

Administrative Requirements for Pilot Program

1. Per statute (F.S. 316.0896), before the start of the pilot project, participants must submit to the Department of Highway Safety and Motor Vehicles (DHSMV) an instrument of insurance, a surety bond, or proof of self-insurance acceptable to the DHSMV in the amount of $5 million.

2. A minimal cost permit will be issued to each participant for the operational phase of the pilot project. The Department will assist the participant in obtaining the necessary permit.

3. Any legal trailer types are allowed.

4. Vehicles will be labeled so that other vehicles and monitoring staff can readily identify the trucks as being capable of DATP operation.

Demonstration Phase

The Demonstration Phase will begin with a full description of system operation provided to the State of Florida by the participant. Particular items of interest are:

1. How does the system select which truck is to be in the lead?
2. How does the DATP system react if communication is disrupted between the vehicles?
3. What operational restrictions exist with regard to weather conditions, evacuation orders, traffic density, etc., if any?
4. How is DATP operation handled through interchanges, geometric changes, operational differences (curve ahead, speed limit changes), etc.?

The closed course portion will demonstrate the following capabilities:

1. <u>Procedure that establishes communication link between vehicles</u>. Participants will show how information is provided to drivers about procedures needed to establish platooning and how drivers are notified when platooning is in effect.
2. <u>Ability of follower truck to maintain commanded separation distance as lead truck varies velocity</u>. Participants will measure and report separation distances.
3. <u>Ability of driver of follower truck to adjust the separation distance</u>. The participant will demonstrate how the separation distance is established and maintained, plus the capability of the drivers of the trucks to set the separation distance, if any.
4. <u>Ability of either driver to disengage DATP</u>. The participant will demonstrate what actions either driver can take to disengage DATP operations.

5. Ability of follower truck to rapidly apply braking in response to lead vehicle sudden deceleration. The participant will show how the following vehicle responds when a large braking effort is applied to the lead vehicle. A large braking event is defined as approximately 50% of braking effort applied by the lead truck (this threshold may be refined based on discussions with participants).
6. Ability of system to notify other drivers that DATP operation is ongoing. The participant will show how other motorists on the highway can be notified that the two trucks are actively performing DATP operation, if this feature exists.
7. Ability of follower vehicle to adjust following distance appropriately when a car cuts in to the space between the trucks. The car will be driven by a professional test driver. The participants will demonstrate how their DATP system responds to this situation to maintain safety.
8. Safe response of both trucks if communication link is corrupted/interrupted and not yet reestablished after a period of time designated by the participant. The participant will demonstrate how their DATP system reacts if communication is disrupted between the vehicles. They will also report what length of time constitutes a disruption of communication.
9. Procedure for ending platooning operation. The participant will show how DATP operation is terminated allowing both trucks to return to manual operation.

Procedures and actions will be documented by video recording and/or other data collection methodologies.. This data collection is intended to have no impact on the normal DATP operations of the Demonstration Phase participant; any concerns regarding proprietary data can be discussed further with RFI respondents.

Based on the Demonstration, FDOT, FTE, DHSMV and FHP will make a determination as to whether the DATP system demonstrated has demonstrated these capabilities at an appropriate performance and safety level. If so, activities with the participant will proceed to the Operational Phase.

In addition, participants are welcome to provide any data or video from prior testing that demonstrates the performance items listed above. The State of Florida, after carefully evaluating this information, may waive the requirement for a participant to perform the demonstration phase prior to proceeding to the operational phase.

Operational Phase

DATP operations will be conducted during daytime and/or nighttime on limited access highway segments of the Florida Turnpike, to be identified by the State of Florida and FTE in collaboration with industry partners. The roads will have either two or three lanes in the travel direction. Highway traffic will not be restricted.

A Safety Management Plan developed by FTE will be implemented; participants will have an opportunity to review the plan and discuss any changes with FTE.

The operational scenario is outlined as follows:

1. Trucks equipped for DATP operate in selected road segments in regular revenue service.
2. The fleet operator (along or with a third party) organizes equipped vehicles to rendezvous on road, providing guidance to drivers as needed.
3. Drivers use HMI provided by technology developer to "link up".
4. The fleet sets gap and speed, based on conditions and their safety protocols. Gaps and speed will vary based on conditions.
5. DATP vehicles operate within normal traffic stream, changing lanes as desired (via manual steering).

DATP operations are intended for runs over a consistent route. Data and video will be collected by the participant and analyzed with emphasis on the following:

1. All cut-ins are noted and truck spacing adjustments are noted.
2. All hard braking events (see Section 3) are noted, to include GPS and video data, for possible later analysis.
3. How interchanges or geometric changes affect DATP operations

FTE has full video coverage of the entire Turnpike. Video of interactions between platooning trucks and other vehicles will be captured and analyzed to assess any traffic impediments or improvements. FTE will collect data regarding bridge loading as DATP platooning cross. FTE will be responsible for public education regarding DATP testing.

Report Generation

Participants in the Operational Phase will be required to provide a monthly high-level performance/operational report for the duration of the pilot project. This report will provide high-level analysis of data and information collected as listed in Section 4. The format of this submission will be coordinated with the Department. This report should be free of any proprietary or identifying information not related to the testing purposes.

The State of Florida will generate a report based on the data and results of the demonstration phase and the operational phase of the pilot project. The report will be public and delivered to the Florida legislature.

Application Procedure to Participate in Pilot Program

The contact person representing the State of Florida for this pilot project is Mr. Ed Hutchinson of FDOT.

For those interested in participating in the pilot project, please provide responses to the following:

13. Would you like to present a demonstration, or both demonstration and pilot testing?
14. What type of operations (long haul, short haul) are of interest?
15. What area / highway segments are desired?
16. What dates are preferable to do the testing?

17. What duration/ mileage is desired?
18. Would you be willing to operate in varying conditions, including but not limited to sunny, dry, wet/rainy, foggy, and dark conditions?
19. With what range of traffic conditions (light, medium, heavy) and infrastructure configurations (urban highway, rural highway, etc.) would you like to conduct the test? Do you seek a police escort or other methods to “cushion” your operations from regular traffic?
20. How would you suggest handling the question of “signing” of platooning, i.e. a placard on the truck tractor indicating a DATP-capable vehicle, an indicator for when platooning is active, etc.?
21. What type of trailer configurations would you use?
22. What aspects of DATP would you like to evaluate?
23. What data would you be willing to provide at the conclusion of the operational phase?
24. Are you willing for selected data to be made part of an FDOT report?

Appendix C: NCHRP Truck CV AV Report Critique

In late 2016, the National Academies Press published the results of a study conducted by the National Cooperative Highway Research Program, titled "Challenges to CV and AV Applications in Truck Freight Operations" (Fitzpatrick, 2016).

The authors of this University of Florida study find key points and observations in this NCHRP report to be unsupported or not well informed. With due respect to the professional work of the authors, here we note and discuss areas of concern with the findings of this report.

Summary
p. v
"Truck platooning in particular is an exciting development that will see small-scale testing throughout the decade. Though business cases and safety cases are not fully defined, and a national-scale legal environment is not in place, opportunities over the next several years for testing and eventual limited deployments are quite present. Federal regulators currently lack sufficient data to validate safety. But the lack of a national-scale legal environment can be overcome with particular states that are actively setting their own environments; thus initial testing might not cross state lines."

a. "Federal regulators currently lack sufficient data to validate safety." Note that NHTSA hasn't collected data or "validated" many other Level 1 systems as well, such as adaptive cruise control or automated emergency braking.
b. "Truck platooning in particular is an exciting development that will see small-scale testing throughout the decade." This statement is not accurate, based on the literature, which indicated that deployment (not testing) will occur in the very near term. Ten states have already enacted legislation authorizing the deployment of Level 1 truck platooning systems. In 2015, the ATA TMC Future Truck Automated Driving and Platooning Task Force predicted that truck platooning deployment would be likely to begin in 2016-2017. Even though the end point of the NCHRP project was in 2016 and some of these recent developments could not have been included, the TMC Task Force prediction is a significant source, in addition to the NACFE Confidence Report on Platooning (NACFE Confidence Report, 2017), which is not referenced in the report at all.

Chapter 3: Research Findings
Legal Regulatory and Policy Topics
p. 40
"One important policy issue for vehicle platooning is existing legal restrictions on signage and lights on platooned vehicles. Currently the only flashing lights that can be placed on vehicles are for emergency vehicles and they require standardized indicators. There are exceptions to this, which include tow trucks and school buses. Platooning vehicles need an indicator light of some kind, and this issue is regulated at the state level. For wide scale adoption it would be desirable to have standardization of requirements for indicators, perhaps at least on the National Highway Freight Network."

a. "Platooning vehicles need an indicator light of some kind…" -- The authors do not provide support for the assertion that an indicator light is a "need." This is an active area of debate subject to a wide range of pros and cons and it does a disservice to the larger community for an unsupported assertion such as this to be published by NAS/TRB. The argument for an indicator when platooning is active centers on this information being valuable to other drivers near the platoon so they can make maneuvering decisions for merging and exiting the highway. A counter-view is that drivers could be distracted by additional lighting information to process or could "take advantage" of the technology to enter a small gap, knowing the trucks will respond to make space. Both of these arguments rely on other drivers knowing what platooning is in the first place. Another view is that DATP operations are not significantly different from regular truck operations in the view of other road users. Indicators of platooning operations may confuse or alarm other drivers, particularly if they have misconceptions that the trucks are fully automated. At this time, no results of objective testing or evaluation concerning this question have been published. Notably, none of the states that have authorized deployment of L1 truck platooning require the use of active platooning indicators, although some have called for signage particularly so that law enforcement can recognize trucks that are equipped for platooning. More appropriate language would be "It may be useful for platoon-capable vehicles to provide some means to indicate when platooning is underway, if this is determined to be useful information for nearby motorists."

Chapter 3: Research Findings
Application Scenarios
p29

"Truck platooning holds a promise of improving safety through the reduction in frontal collisions, the most common highway accident type for heavy trucks in the U.S. Additional testing is needed to both validate this assertion and look more holistically at how highway safety might be affected by platooning deployments. Conceptually, the automated control of a truck's movements, whether lateral control is included or not, should reduce accidents as the driver reaction time is eliminated as a concern. Even if the platooning function is not engaged in a platoon-ready truck, the radar and CV technologies can at least shorten the driver awareness of a situation. Improved safety affects a business case via higher system productivity and fewer injuries and damage costs."

a. "Additional testing is needed to both validate this assertion." – Platooning systems build upon and integrate with commercially available Forward Collision Avoidance and Mitigation Systems (FCAM). NTSB has estimated that FCAM systems could reduce ~80% of rear-end crashes (NTSB, 2015). The NTSB study referenced an internal study performed by early adopter Conway Trucking (now XPO/Conway), which found that, in over 30 months with FCAM systems operating on 12,600 tractors, a 71% reduction in rear-end collisions occurred along with a 63% reduction in unsafe following behavior. A study addressing the effectiveness of these CAS was published by NHTSA in June 2016 (Grove, et. al., 2016). Surely these results, and others like them, validate the safety aspects of platooning.

Chapter 3: Research Findings
Freight Planning Topics
p. 56
"Adoption of automation technologies will create mixed traffic situations where drivers in non-automated vehicles are next to platoons of heavy vehicles with short time headways. Although truck automation promises to improve safety issues at full market penetration, it may adversely affect the safety of non-automated vehicles under mixed traffic conditions consisting of both human driven vehicles and automated vehicles especially trucks. In addition, driver behavior will be impacted while operating in a mixed CV and AV environment. For example, drivers in the vicinity of platoons may demonstrate behavioral adaptation by reducing their own time headways (Gouy et al., 2014).

Therefore, transitional periods of technology adoption may decrease safety for conventional vehicles. The expectation for zero fatalities is unrealistic for any type of self-driving vehicle (Sivak and Schoettle, 2015) due to reasons such as mechanical failure or software failure.

Such incidents, if they occur, may result in more fatalities involving heavy vehicles.

The focus on truck platooning has been largely concerned with energy savings (Shladover 2012) but safety impacts of truck automation require attention. Historically many projects have been approved on the basis of improving safety. Although, at this point it is difficult to quantify safety benefits due to CV and AV freight applications, it is likely to have significant impacts on project evaluation and selection."

d. As a general comment on this excerpt, these broad statements seem to emphasize negative safety outcomes based on a generic form of automation during the transitional period. It is certainly true that crashes can still occur with automated systems; however, these outcomes must be compared to today's outcomes with only human responses (this comparison is neglected, for example, in the assertion that incidents caused by truck automation "may result in more fatalities"). Plus, system developers are strongly focused on fail-operational and fail-safe designs as part of the commercialization process. In Level 1 DATP in particular, a human driver is always in the loop. All that can be said at this time is that safety outcomes are an unknown, but with a recognition that significant engineering and testing is underway to create a net safety benefit.
e. "Although truck automation promises to improve safety issues at full market penetration, it may adversely affect the safety of non-automated vehicles under mixed traffic conditions consisting of both human driven vehicles and automated vehicles especially trucks" -- ….or it may beneficially impact safety in mixed traffic..
    a. The following may be useful: As a key concern to truck fleet operators, the TMC Information Report (TMC Information Report, 2015) addressed this topic, noting that truckers routinely experience other vehicles on the highway cutting them off, requiring immediate braking by the driver or automatic braking systems. These systems assist the truck driver in braking as quickly as possible in response to such a vehicle with a speed differential that may cause a forward collision. These systems respond to a developing crash situation as quickly as possible (and significantly faster than a human driver could) to either avoid the crash or slow the vehicle speed to reduce the energy in a crash. Importantly, automated

and platooning trucking systems build upon these CAS systems, creating a basis to at least assert this safety benefit as AV and platooning proliferate on our roadways.

b. Furthermore, as an example, Peloton addresses traffic issues as follows (Peloton FAQ, 2017): "Do truck platoons get in the way of traffic? Before two trucks form a platooning link, the Network Operations Center must authorize the platoon based on several safety parameters. For starters, platooning only occurs on multi-lane divided highways, ensuring that traffic will always have the opportunity to pass the platoon. The Peloton system's forward radar also allows the platooning trucks to recognize vehicles cutting in between the trucks, for example, to exit the highway. To make way for cut-ins, the following distance between the trucks is increased and then reduced again once the trucks are clear of the other vehicle."

c. Also concerning this item, the USDOT Volpe Center used data from previous safety field testing to extract following distances between highway vehicles (Nodine, et. al. , 2016). A key finding was that cut-ins by passenger vehicles are uncommon with inter-vehicle distances of 100 feet or less (typical platooning inter-vehicle distances will be well under 100 feet). Because the analyzed data set was limited, further analyses and testing would be useful to assess the likelihood of such events for various platooning following distances.

f. "driver behavior will be impacted while operating in a mixed CV and AV environment." -- The referenced Gouy et al. study provided interesting insights regarding shorter headways adopted by drivers adjacent to platoons, but it is not definitive enough to make this "will be" statement. The Gouy et al. study team noted that "further work needs to investigate whether behavioral adaptation of non-platoon drivers to short time headways in platoons is the result of a combination of social and perceptual mechanisms or if one of the mechanisms is predominantly influencing behavioral adaptation. Trucks were selected in this study as their salience was meant to increase the visual attention directed to the platoons. However, drivers are perhaps more likely to reproduce behavior from other drivers that are similar to themselves. Therefore, the employment of cars to form platoons actually enables to investigate the social mechanisms of behavioral adaptation of non-platoon drivers whereas trucks enable to investigate perceptual mechanisms. Further work is required using this factor to investigate the underlying mechanisms of behavioral adaptation of unequipped vehicle drivers to short time headways."

g. "safety impacts of truck automation require attention" – this statement ignores a large existing body of research conducted by the vehicle industry and academic community.

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Freight Planning Topics
p. 56

"Although the basic infrastructure requirements for the operation of automated vehicles in the form of better road infrastructure such as better ride quality and visible road markings will be dictated by both passenger and freight vehicle segments, the efficient operation of automated trucks will require additional dedicated freight facilities. This is particularly important for interstate highways where truck platooning is likely to be most effective. As the trucks will be entering and exiting in the form of platoons from interstate highways, even though with small headways, they will necessitate longer on and off ramps than what exists today. The uninterrupted entry and exit of truck platoons will also require better geometric design such as smoother curves for on ramps and off ramps, and gentle vertical curves."

a. These points seem to be based on assumptions that do not align with current commercial activity to deploy platooning. Tech developers are focusing on platoon operations only on mainline high speed road segments, not ramps – only at highway speeds do the aerodynamic effects occur that reduce fuel usage. There is no need for DATP vehicles to be platooned before entering the highway; the platoon will be formed once the trucks are on the main roadway, aided by software and connectivity that will help the trucks to "find each other." Similarly, it will be the normal case to dissolve platoons on-highway prior to exiting ramps for local streets. To platoon on entry/exit ramps between two divided highways may be possible in many cases unless the curvature is extreme; if the curvature is too great, the platoon will simply be dissolved until both vehicles are on the new highway. Therefore, for platooning, no "additional dedicated freight facilities" are "required." This excerpt could be put in context of a long term vision of platooning, but does not apply to the first wave of deployment. The configurations of platoons will be flexible; they will adapt to the high configurations. True, one could speculate that infrastructure "could" change to make platoons more efficient in the long term after a very high deployment rate is reached, but the benefits of doing so for low speed operations are questionable.
b. At minimum, no statement should be made that these infrastructure changes "will be required."

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Freight Planning Topics
p. 57

"Further, to harmonize freight traffic operation and to improve safety issues, some dedicated freight corridors need to be constructed or some existing roads may be designated for trucks only use. This will necessitate digitization of available freight routes for CV and AV equipped trucks, preparation of digital maps and interfacing protocols with truck operation."

a. "dedicated freight corridors" should be stated as possible measures rather than "needs," given that the authors did not provide a basis for this statement.

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Freight Planning Topics
p. 58

"In addition, for a truck platoon to move seamlessly from freeway to arterial or to rural roads or to navigate a corridor with intersections without speed reduction will require improved geometric design. For example, gentle curves for exit ramps, longer exit ramps, and curved right turns at intersections as compared to perpendicular right turns may be some of the desired characteristics. In addition, in order to accommodate the high truck volumes with small headways will necessitate better surface quality of roads and thicker pavements. In essence, new improved infrastructure might be needed. Acquiring additional land for building improved infrastructure may be costly and difficult. This is especially so in urban areas, though the impact of highly automated trucks in urban environments may be at least several decades away. The new infrastructure can be built sequentially in the same place where the existing infrastructure exists. The major consideration is that the focus of infrastructure investments will need to shift from largely road widening to better geometric design, road markings and improved thicker pavement. Further, as infrastructure interventions to improve the surface quality and geometric design cannot be taken simultaneously for the entire transportation network. Therefore, staged or prioritized road infrastructure improvements needs to be implemented.

a. The assertion that "high truck volumes with small headways will necessitate better surface quality of roads and thicker pavements" is not supported by research to date. Any studies at this point would be speculative, since the market penetration and operational characteristics (such as number of platooned trucks) of platooning will evolve based on market factors. For the first wave of platoon deployment, there are no basic requirements for surface quality or thicker pavements at the introduction stage.

b. Also, suppliers of L1 DATP systems are limiting their use to multi-lane, divided, limited access highways. As a result, a number of the possible design changes noted above for non-highway roads are not needed.