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Recommendations Regarding Further Development of Truck Platooning Technologies

Developed by the Technology & Maintenance Council's (TMC)
S.18 Automated Vehicle Study Group Platooning Task Force

ABSTRACT

The Technology & Maintenance Council's (TMC) S.18 Automated Vehicle Platooning Task Force examined the current state of truck platooning commercialization by examining a variety of use cases, trials, and current efforts towards product introduction. The Task Force found that, despite intense activity over the last decade, current commercial activity to introduce platooning in longhaul operations is minimal, even as it is gaining a foothold in off-highway niche markets. To the degree that commercialization becomes relevant, TMC provides herein several recommendations that system developers should address to best serve the interest of trucking fleets.

INTRODUCTION

The Technology & Maintenance Council's (TMC) S.18 Automated Vehicle Study Group, as part of its scope to study all types of automation in medium- and heavy-duty trucks, established a Task Force to study and make recommendations regarding Truck Platooning Technologies.

Accordingly, S.18's Platooning Task Force examined the current state of truck platooning commercialization by examining a variety of use cases, trials, and current efforts towards product introduction. The Task Force found that, despite intense activity over the last decade, current commercial activity to introduce platooning in longhaul operations is minimal, even as it is gaining a foothold in off-highway niche markets. To the degree that commercialization becomes relevant, TMC provides herein several recommendations that system developers should address to best serve the interest of trucking fleets.

In the course of its work, the Task Force reviewed information regarding the technologies used in platooning systems and various trials and demonstrations, and in limited fleet deployments. At the time of publication, platooning has seen only limited adoption in on-road

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fleet operations. The following findings and recommendations to system developers are presented as follows:

I. Truck Platooning Overview
- Platooning Function
- Platooning Levels of Automation
- Platooning Benefits
- Platooning Application Areas

II. Technical Approach and Key Functions
- Key Functions of a Platooning Systems
- Factors in Short Headway Platooning

III. Commercialization of Platooning
- Relevant Public-Private Projects
- Past Commercial Development
- Current Commercial Deployment
- Road Fuel Economy Testing Results

IV. Regulatory Factors

V. Recommendations

I. TRUCK PLATOONING OVERVIEW

Platooning Function

Truck platooning refers to a human-driven lead truck transmitting driving-relevant information to one or more compatriot following trucks to synchronize braking and acceleration for both trucks, enabled by radar and cyber-secure vehicle-to-vehicle communications. This technique enables closer following distances than human drivers can safely accomplish. In some implementations, steering is synchronized as well. Commercial platooning efforts have focused on two- and three-truck platoons.

Platooning Levels of Automation

Figure 1 described the levels of automated driving, as defined by SAE International [1].

L1/L1 platooning systems rely on actively involved drivers in all platooning trucks, where longitudinal control for follower trucks is automated and follower truck drivers are responsible for steering.

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	SAE LEVEL 0™	SAE LEVEL 1™	SAE LEVEL 2™	SAE LEVEL 3™	SAE LEVEL 4™	SAE LEVEL 5™
What does the human in the driver's seat have to do?	**You are driving** whenever these driver support features are engaged – even if your feet are off the pedals and you are not steering			**You are not driving** when these automated driving features are engaged – even if you are seated in "the driver's seat"		
	You must constantly supervise these support features; you must steer, brake or accelerate as needed to maintain safety			When the feature requests, you must drive	These automated driving features will not require you to take over driving	
	These are driver support features			**These are automated driving features**		
What do these features do?	These features are limited to providing warnings and momentary assistance	These features provide steering **OR** brake/ acceleration support to the driver	These features provide steering **AND** brake/ acceleration support to the driver	These features can drive the vehicle under limited conditions and will not operate unless all required conditions are met		This feature can drive the vehicle under all conditions
Example Features	• automatic emergency braking • blind spot warning • lane departure warning	• lane centering **OR** • adaptive cruise control	• lane centering **AND** • adaptive cruise control at the same time	• traffic jam chauffeur	• local driverless taxi • pedals/ steering wheel may or may not be installed	• same as level 4, but feature can drive everywhere in all conditions

Figure 1: SAE J3016 Levels of Driving Automation

L1/L4 platooning systems completely automate the driving of following trucks, combining fuel savings with labor savings. A driver is not required in the following truck.

Platooning Benefits

Platooning can provide the following benefits:

- ***Fuel savings*** — The aerodynamics of all trucks in a platoon benefit if following truck(s) are running at a short following distance relative to the truck ahead; thus, improving fuel economy. Typical following distances in commercial system development have been 40-50 feet.
- ***Labor savings* —** L1/L4 platooning enables a single driver in the front truck to operate two tractor-trailers.

Platooning Application Areas

Commercial development of platooning encompasses:

- longhaul applications on limited-access highways,
- resource extraction, carrying material from source to processing/shipping depot, typically running on unimproved or rural roads, and;
- agricultural hauling, carrying harvested items from harvest area to processing plant, typically running on unimproved or rural country roads.

Platooning is compatible with L4 solo driverless trucks. At some future time when there are many driverless trucks in operation, operators of individual driverless trucks may choose to platoon with other driverless trucks to draft on one another and save additional fuel.

II. PLATOONING TECHNICAL APPROACH AND KEY FUNCTIONS

Platooning trucks exchange data, with one or more trucks following the leader in automated mode. Vehicle-to-vehicle (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.

Truck platooning depends on V2V communications between the linked pair of trucks. It does not depend on V2V communications from other nearby vehicles.

Key Functions of a Platooning System

The on-highway platooning system should:

- allow the driver to control throttle, braking, gear selection, and steering at any time;
- control engine torque, gear selection (for automated manual transmission-equipped vehicles), and braking — including engine brakes/ retarders as well as foundation brakes,
- be adaptable to varying levels of brake performance (within specified bounds), as well as uncertainty as to real-time braking ability,
- use data from all platooning vehicles to continually calculate optimum inter-vehicle distance to maintain a safe stopping distance in an emergency braking situation,
  maintain integrity of communications and effectively handle degradation/loss of communications,
- react in a safe manner to other vehicles cutting into the space between the platooning trucks. Specifically, if a passenger vehicle cuts-in between two platooning trucks, the rear truck must respond and brake appropriately to attain a safe following distance behind the encroaching vehicle;
- be designed in a "fail operational" manner to ensure driver and vehicle safety, and;
- operate across a defined set of weather conditions; operations shall be adjusted based on weather conditions as needed to maintain safety. System developers should clearly specify limitations relating to weather.

Factors In Short Headway Platooning

When platooning is used for close following, it is important that the inter-vehicle gap setting take into account several factors to set a safe gap. Key factors are:

- driver acceptance,
- traffic conditions,
- engine horsepower,
- estimated mass of each vehicle,
- ability to cool engine with adequate air flow,
- road configuration (including tight curvature and/or dense entry/exit sections), and;
- estimated braking ability of each vehicle (measured in real time). Factors affecting braking performance include estimated mass of each vehicle, weather conditions, brake condition, and road conditions.

III. COMMERCIALIZATION OF PLATOONING

Relevant Public-Private Projects

In a trial funded by the German government in 2018 [2], MAN Level 1 platoon trucks logged 34,000 kilometers running freight on the A9 motorway from Munich to/from Nuremberg, working with the trucking firm DB Schenker. Even though European Union (EU) rules made these results not completely transferable to other markets (truck speed limits significantly lower than car traffic, plus restricted to the right lane), results included the following:

- Although only four percent fuel economy improvement was measured, MAN said they could reach 10 percent with closer following.
- Technology uptime was 98 percent, and the vehicles experienced no critical safety events.
- Drivers were initially skeptical of the system but during pre-testing training their reaction shifted to strongly favorable.
- Drivers preferred the shortest inter-vehicle gaps to reduce cut-ins.
- Physiological studies showed no degradation of driving ability (monotony, stress) compared to regular truck driving
- A DB Schenker executive noted that operationally “40 percent of our network is a ‘fit’ for platooning.”

The European Commission ENSEMBLE Project [3], which ran from 2018 to 2022, aimed to stimulate inter-operability between platooning systems from different original equipment manufacturers (OEMs). Participating OEMs were DAF, Daimler, IVECO, MAN, SCANIA, and Volvo Group. Together they developed engineering requirements and specifications for both L1/L1 and L1/L4 systems. The project culminated in 2021 with a one-day demonstration near Barcelona, in which trucks from each OEM ran together in a seven-truck platoon in L1/L1 mode. The trucks ran at headways of approximately 1.5 seconds at the European truck speed limit of 54 mph.

The US Army Ground Vehicles Systems Center [4] contracted with Robotic Research to field 60 platooning systems, which are termed as “Optionally Manned Leader–Followers.” The vehicles were deployed to U.S. Army bases in 2021. The vehicles have the capability to be driven independently, remotely, or follow a lead vehicle.

In 2021, the Japanese government [5] conducted testing in which a convoy of three semi-trailer trucks drove down an expressway in Shizuoka Prefecture with the two trailing vehicles never veering off the lead vehicle's path by more than 50 centimeters. The trucks traveled about 15 kilometers at a speed of 80 kph (50 mph) while maintaining an approximate nine-meter following distance down the Shin-Tomei Expressway. At the time, the government said that a project was underway aimed at realizing an automated truck for highway use.

In 2021, the U.S. Department of Transportation (DOT) awarded a four-year, $8.8 million project to a team consisting of the Ohio Department of Transportation (ODOT), the Indiana

Department of Transportation (INDOT), and the Transportation Research Center Inc. (TRC) [6]. The project aims to advance the adoption of truck automation technologies in the logistics industry by integrating these technologies into truck fleets' daily revenue service operations to deliver products across Ohio and Indiana. The project focuses on demonstrating truck automation technology in revenue service on the “I-70 Truck Automation Corridor” between Columbus and Indianapolis. Truck platooning, SAE Level 2 automation, and SAE Level 4 automation (with a safety driver), are being deployed. Based on an RFP issued in late 2022, truck platooning will be implemented by EASE Logistics partnering with technology provider Kratos. A 2023 RFP will seek fleets and tech providers to implement L2 and L4 trucking.

Past Commercial Development

Truck platooning has been in active commercial development for since approximately 2012. Those developing and demonstrating such systems include startups Locomation and Peloton, Hexagon, Kratos, RRAI, as well as truck-makers Daimler, Ford-Otosan, Traton, and Volvo Group. Following are short summaries of these activities.

Peloton Technology, founded in 2011, focused on L1/L1 platooning for its initial product while developing a L1/L4 system in parallel. Peloton planned to make the system available to fleets via 3rd party up-fitters who will add the platooning components to a pre-wired truck straight from the factory. Extensive on-road testing was done with fleet partners, including UPS. Peloton aimed to be the first company to offer a commercial platooning system, with plans to introduce an initial system for use by truck fleets in 2017.

Due to various delays, this was pushed back several times, with a definitive release set for 2020. However, the COVID-19 pandemic and other factors delayed this process. Peloton ceased operations in 2021 [7].

Locomation was founded in 2018 and developed capable platooning trucks which were tested by partner fleets. The product under development was L1/L4. According to press statements, the company had three customer contracts to deploy more than 2,600 trucks. Locomation ceased operations in early 2023 [8].

Starting in 2016, Freightliner/Daimler had an extensive platooning development program focused on L1/L1 platooning. Pre-commercial prototypes were evaluated on-road. Daimler stepped away from first generation platooning in 2019 [9].

In 2018, Volvo Trucks partnered with FedEx to demonstrate L1/L1 platooning with three trucks on the North Carolina Turnpike [10].

In 2018. Ford Otosan, co-owned by Ford and Koç Holding Otosan demonstrated a pre-commercial L1/L1 platooning system on a test track in Turkey. Ford Otosan Assistant General Manager Burak Gökçelik noted that “long term we aim to develop SAE-Level 4 autonomous driving features and realize hub-to-hub autonomous highway transportation [11].”

Current Commercial Development and Deployment

In 2022, Kratos Defense & Security Solutions, Inc. began running L1/L4 truck platoons to haul harvested sugar beets between piling stations and a granulated sugar processing plant in Wahpeton, North Dakota, a 30-mile trip.

The lead truck of a pair is human-driven, with the follower truck wirelessly receiving navigation data from the leader to follow closely behind. The focus is on the niche, short-haul trucking routes which can be deployed today via retrofitting the customer’s trucks.

Kratos is supporting the Minn-Dak Farmers Cooperative (MDFC), which is owned by 500 shareholders and growers who collectively grow more than 100,000 acres of sugar beets.

At harvest time, driver shortages are a severe problem. An expanded fleet is expected to support harvests in 2023 and into the future [12].

Working with mining entity Mineral Resources, Hexagon will deploy fully autonomous road trains in Western Australia, where 30 percent of the world's iron ore is located. Extracted ore must be transported from the mine site to the port on the northern west coast of Australia on a paved closed road, a 62-mile route.

The first phase of deployment occurred in early 2022. Each road train included one tractor and three trailers, each carrying about 300 tons of iron ore. One road train platooned behind a leader road train traveled 62 miles from mine to port with safety drivers.

A subsequent phase with fully autonomous road trains is planned. Taking into account savings from driverless operations, the project participants assert that a 100-truck fleet could see savings of up to $236 million (USD) per year using the autonomous platooning system. Mineral Resources expects to have more than 120 automated trucks by mid-2024 [13].

In 2021, FPInnovations, a Canadian private non-profit research and development center supporting the forest industry, began a project with Robotic Research, LLC to develop a Class 8 truck platooning system for the forestry industry. In forestry operations, these driverless follower trucks must handle conditions and situations such as non-line-of-sight turns, vehicles with heavy loads, vehicles with high centers of gravity, as well as adverse weather conditions present in northern Canadian environments.

Furthermore, FPInnovations notes that "most of the testing and commercial operations will occur on very rural low volume public roads" which means that other vehicles and pedestrians may be present and must be safely handled. The development team is currently doing advanced field testing with the initial systems and pilot vehicles will be delivered to Canadian sites in October 2023. FPI is targeting pre-commercial operations in 2025 [14].

On-Road Fuel Economy Testing Results

Platooning has shown significant fuel economy benefits due to close-headway following, based on trials with pre-commercial systems.

A 2013 test of an early platooning implementation showed significant fuel economy improvements on the order of 4.5 percent for the lead truck and 10 percent for the following truck, when traveling at 64 mph at 33-foot spacing. The USDOT-funded research was conducted by Auburn University and Peloton Technology [15]. In 2014, a similar test performed by DOE's National Renewable Energy Laboratory (NREL) conducted tests of platooning systems implemented by Peloton Technology, which produced similar results [16].

Peloton Technology extensively trialed L1/L1 platooning during 2016-2020, moving over 1,500 tons of freight. Running at interstate highway speeds, intervehicle gaps were in the range of 60 feet. Across seven major fleets running in Texas, typical fuel economy improvements showed four percent for leader and 10 percent for the follower at 60-foot separation at 60 mph. There were no hard braking or critical safety events [17].

In 2016, Daimler said that their Highway Pilot Connect platooning system running a three truck platoon provided a seven-percent fuel economy improvement (two-percent improvement for the lead truck, 11 percent for the second truck and nine percent for the third truck), with an inter-vehicle gap of 15 meters at 50 mph [18]. Volvo Trucks performed on-road platoon testing with FedEx in 2018, running three-truck platoons. The company reported that, at highway speeds with a 30-foot inter-vehicle gap, a 10-percent fuel economy improvement can be achieved [see reference 10].

In 2016, the North American Council on Freight Efficiency (NACFE) published a Confidence Report on Two-Truck Platooning. This was a very thorough survey of the results above plus others. NACFE concluded that, given uncertainty in traffic congestion and other factors, real-world fuel economy improvements would be in the range of three percent for the leader truck and 7.5 percent for the follower truck [19].

IV. REGULATORY FACTORS

State regulations focused on tailgating behavior for trucks have been updated in many states to accommodate L1/L1 platooning. Currently, commercial deployment of L1/L1 platooning is allowed in 28 U.S. states. These states encompass more than 80 percent of U.S. truck freight traffic annually. L1/L4 platooning has been allowed in three states [see reference 7].

V. RECOMMENDATIONS

If and when commercial deployment of truck platooning proceeds for use cases relevant to the industry, TMC offers the following recommendations to guide system developers.

A. Driver Factors (L1/L1)

Technology developers must create intuitive driver interfaces that allow driver to cooperate with nearby vehicles to establish a platoon. Key interfaces include:

- Following-vehicle request to join
- Lead-vehicle accept to join
- Headway adjustment
- Disassociate from platoon
  - Notification of disassociation
  - Request for disassociation
  - Acceptable frequency
- Other Vehicle intrusion (cut-ins)
  - Notification to platoon
  - Resolution

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.

Drivers must be trained to be fully aware of the capabilities of the vehicle they are driving and the mode of automation which is active (and the system itself should clearly indicate the current mode of operation).

B. Maintenance

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; therefore, systems should be designed with this in mind. Ideally, maintenance protocols and diagnostic tools already used for advanced technology systems (such as adaptive cruise control and lane detection) can be used with only minor adaptations. Techniques for maintaining dedicated short range communications-based V2V communications should be developed if/when truck platooning comes to market for longhaul operations.

C. Benefits

There is a need to establish an expert consensus on the potential of fuel savings for various operating conditions.

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