DRISI
Caltrans Division of Research, Innovation and System Information

Research Notes

Advanced Research

FEBRUARY 2023

Project Title:
Cooperative Adaptive Cruise Control (CACC) for Partially Automated Truck Platooning

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Federal Highway Administration (FHWA) Truck Platooning Early Deployment Assessment Phase 2

Test and evaluate cooperative adaptive cruise control equipped trucks in close-spaced platooning operations along the I-10 corridor

WHAT IS THE NEED?

Traffic volumes and vehicle miles traveled continue to increase. Constructing new highway facilities is becoming more problematic and mitigating the environmental, societal and economic impacts becomes more difficult and less sustainable. Partial or fully automated vehicle control systems in conjunction with vehicle-to-vehicle (V2V) communications, have the potential to reduce fuel use and emissions while improving highway and commercial vehicle operations and safety without the expense and impacts of constructing new highways. While fully automated vehicles are years and possibly decades away from widespread commercial deployment, partially automated driver-assist technologies are currently available and when combined with V2V communications, they have the potential to realize those benefits sooner.

V2V communications between the platooning trucks has two significant effects 1) it reduces reaction time allowing the trucks to be safely operated with smaller gaps between platooning trucks and 2) it supports coordinated movements among the vehicles in the platoon so the truck can operate more like a train. Smaller gaps and coordinated movements lead to aerodynamic benefits such as reduced fuel use and the ability to move more vehicles through a segment of highway which increases existing highway capacity.

This is the second of two federal grant projects examining the benefits and impacts of integrating V2V communications with commercially available adaptive cruise control (ACC) to create cooperative adaptive cruise control (CACC) and then using the CACC to safely perform close-spaced truck platooning operations.

Caltrans

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Under the first grant project Caltrans partnered with UC Berkeley, Volvo, and Cambridge Systematics. PATH with, with Volvo support, integrated vehicle-to-vehicle (V2V) communications into Volvo's commercial ACC to create CACC on three Volvo trucks. CACC development continued throughout the project in tandem with testing, demonstrations, driver acceptance and fuel-consumption experiments on a test track. Modeling and simulation work based on test results looked at how wide-spread adoption and use of CACC systems can increase highway capacity and smooth traffic flow leading to significant improvements to highway operations and safety in addition to reductions in fuel use and emissions

The current project will pick up where the first project left off by upgrading the CACC system developed in the first project and integrating that system into four new trucks and performing tests and examining how truck platooning operations impacts commercial fleet operations, highway operations, truck drivers and other roadway users.

WHAT ARE WE DOING?

This is a complex project bringing together a diverse team with subject matter experts in a number of fields including: vehicle control, communications, , human factors, big data collection and analysis, simulation and modeling and trucking fleet operations and logistics.

After developing the scope for the project, the initial project team recruited Westat (a company with expertise in human factors) and Roly's Trucking a freight transport firm that makes weekly multiple truck trips along a 1,400 mile stretch of the I-10 between the Los Angeles region in California and the Dallas-Fort Worth metro area in Texas. The team then put together various project documents including plans for: project management, concept of operations, CACC adaptation and refinement, testing and evaluation, risk management, partnership development, and driver recruitment and training.

PATH is leasing four new Volvo trucks equipped with Volvo's latest adaptive cruise control system. They will integrate dedicated short-range communications (DSRC) to create Cooperative Adaptive Cruise Control (CACC). The team will install a suite of data collection and communication equipment on the four trucks.

CACC is a level 1driver-assist driving automation system that controls braking and acceleration to maintain proper separation between the trucks while the CACC is engaged. The driver still steers and is responsible for operating the vehicle. The lead truck will always drive in Adaptive Cruise Control (ACC) mode. The other drivers can decide when to drive in CACC mode and set a desired time gap between trucks. The trucks will be limited to driving at 65 mph or less in platooning mode – 55 mph maximum in California. Roly's Trucking will integrate the four trucks into their daily fleet operations between terminals in Rancho Cucamonga, California and Fort Worth, Texas (see map below). Up to three of the trucks will operate in platoon formation and the fourth will drive separately to serve as a reference truck for comparison during each run. The field test will run weekly for 50 consecutive weeks and data will be continuously collected and shared with USDOT and their Independent Evaluator (IE) during the test.

Once the data is collected, the performance measures will be updated and the data will be prepared for analysis in three major areas: 1) driver behavior, 2) vehicle control and platooning operations and 3) energy consumption and emission. The results will be developed into outreach materials such as presentations, videos, posters, papers, and brochures and a final report will be prepared. Outreach materials will be shared with stakeholders and others.

WHAT IS OUR GOAL?

The overall goal of the project is to gain a better understanding of how CACC based truck platooning works on a real-world highway environment and the impacts from those operations.

Specific project objectives include:

- Determine truck driver preferences for automatic following gap size and implications for fuel savings;
- Assess impacts on driver performance and alertness over an extended period of usage in traffic;
- Better understand the impacts of truck CACC or platooning on safety, fleet operation logistics and truck operating costs in typical long-haul trucking;
- Assess interactions between platooning trucks and other vehicles.
- Understand how platooning operations affects fuel use and emissions.

WHAT IS THE BENEFIT?

Caltrans supports the continued development and testing of freight transportation technologies, such as cooperative adaptive cruise control (CACC). In the long-term these types of technologies offer the potential to lead to transformational changes and advances in freight and highway operations. The potential benefits include increased safety and capacity, and reductions in fuel use and emissions, reducing the need to build new costly infrastructure.

It's hoped that the data and results from Phase 2 work may help:

- Accelerate the deployment of CAV technologies for freight
- Assess the integration of truck platooning into fleet operations
- Gain a better understand the impacts of truck platooning on:
    - Truck driver performance and attitudes
    - Operational logistics
    - Traffic operations, and
    - Public policy

WHAT IS THE PROGRESS TO DATE?

The existing CACC control system was modified and adapted for the four new Volvo trucks. Task 6 was partially accomplished under joint funding with FHWA. The system was initially tested and demonstrated to the Independent Evaluator. However, coordinated emergency braking was not tested on the track. FHWA's decided to stop the project as issues between PATH research team and Volvo team could not be resolved. The lowerlevel control actuation was the strategy that was used in the previous FHWA EARProgram Project with Caltrans Match Funding. However, this approach was not accepted by Volvo. Research team and Volvo collaborated to implement the control actuation approach that was preferred by Volvo based on its safety considerations. The main difficulty was that, once the service brake was applied, whether automatically or manually, the engine torque control (for Adaptive Cruise Control) would be disabled, so the driver would have to reactivate it, which is also true for the manufacturer's production Adaptive Cruise Control feature. To resolve this problem, it would be necessary for Volvo and Bendix, the provider of the service brake control Electronic Control Unit (ECU), to work closely to change the hardware and/or software, which the project team was not be able to do. A whole year was spent trying to come up with multiple solutions, including shipping a truck to Volvo US in Greensboro. But a successful solution could not be found in the expected timeframe. This unexpected process significantly delayed the project. This was the main reason for FHWA to stop the project.

All three trailers have been unloaded and returned to the vendor. All the instrumentations that were installed on the 4 Volvo VNL760 trucks has been removed. All the trucks have been restored to the manufacture's condition, after working with the Volvo technician in TECH. All the trucks have been returned to Roly's Trucking. A 508 compliant report on Comprehensive Deployment Plan has been submitted to both FHWA and Caltrans. A 508 compliant report on Test and Evaluation Plan has been submitted to FHWA and Caltrans. The following white papers have been submitted:

1. System Refinement Report
2. Report on driver recruitment and training considerations
3. Hazard Analysis Plan/Report
4. Real-time monitoring System Development
5. Data Collection System Development
6. Brief Report on Driver Monitoring System
7. Lesson Learned

Final presentation was held on December 17, 2022.

IMAGES

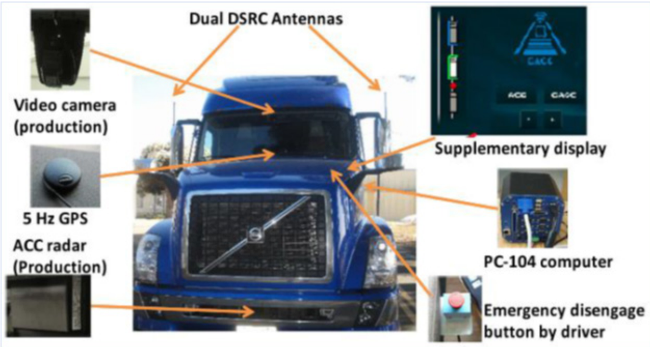

Image 1: Overall Cooperative Adaptive Cruise Control (CACC) Systems Components