Expanded Research and Development of an Enhanced Rear Signaling System for Commercial Motor Vehicles

In 2010, the National Highway Traffic Safety Administration (NHTSA) found that heavy trucks were three times more likely than other vehicles to be struck from behind during two-vehicle fatal crashes. The Federal Motor Carrier Safety Administration (FMCSA) has been working to develop and refine an Enhanced Rear Signaling (ERS) system to address these types of crashes. There were three phases of ERS research performed prior to the current project (as seen in Table 1). This report focuses on refining the developed Phase III prototype system in preparation for a Field Operational Test (FOT).

Table 1. ERS Phases I, II, and III project descriptions.

Phase I (2004)	Phase II (2006)	Phase III (2010)
Performed a crash data analysis to determine causal factors of rear-end truck crashes and identify auditory and visual countermeasures.	Development of a prototype system that incorporated auditory and visual countermeasures identified in Phase I.	Analyzed characteristics of rear-end truck crashes; explored benefits of auditory and visual countermeasures from Phases I and II in static and dynamic environments; developed a plan for a large-scale ERS FOT.

Findings from the current study indicate that the ERS system, using either of the tested activation systems described below, is ready for further evaluation in an FOT.

BACKGROUND

The primary visual warnings currently installed on the rear of all commercial motor vehicles (CMVs) are the stop lamps, or brake lights. These brake lights have limited effectiveness across varying operational conditions. Because these brake lights are activated only with the service brakes, the visual warning is only provided during conditions where the lead vehicle is decelerating using the braking system. The brake lights may not be activated during other important conditions that are unique to CMVs wherein rear-end collisions can occur, such as when the CMV is stopped, is traveling slower, or is decelerating using an engine retarder. The purpose of the ERS system is for CMVs to provide following-vehicle drivers with a supplemental visual warning of an impending collision with the rear of a CMV.

PROCESS

Three ERS system development efforts were undertaken during this project. The first effort involved the modification of the ERS system into a unit designed for simple truck and trailer installation. The second effort involved refinement of the radar target identification firmware to reduce the likelihood of false alarms in lower speed, high-traffic-density scenarios and to transfer the activation processing mechanism from the research team's test device to the radar itself. The third effort involved testing different nighttime brightness levels in order to select the one with the best balance between attention-getting and discomfort-glare characteristics.

Prior to beginning expanded development efforts, the research team completed a concept of operations (ConOps) and a design failure mode and effects analysis (DFMEA). The purpose of the ConOps was to provide a conceptualization from the user's perspective of the daily conditions and functions of the system during implementation. The research team employed a DFMEA process to systematically explore the potential failure modes of the ERS system based on prior system testing and engineering experience with similar technologies. The findings of this analysis helped engineers and researchers prioritize and address potential design deficiencies early during the development process.

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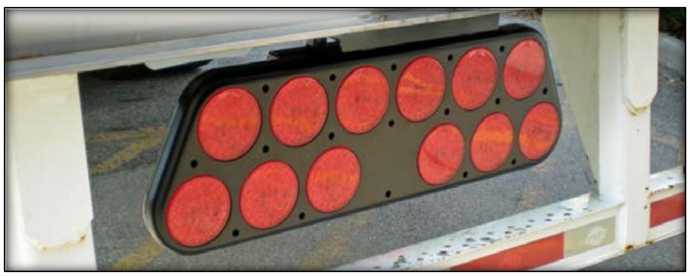
System Modification for Simple Installation

It was deemed necessary to modify the ERS for improved truck and trailer installation, prior to an FOT. The goal was to reduce the numerous components of the Phase III design (see Figure 1) and to reduce the potential for unnecessary failure modes. The research team was successful in designing a simpler ERS system that is easier to install (as seen in Figure 2).

Figure 1. Photo. Phase III prototype ERS system.

Figure 2. Photo. Final ERS System.



In addition to reducing the number of components of the physical lighting system, the research team also worked with a private radar company to transfer the collision warning system processes to the radar (which was mounted on the installed apparatus). This eliminated the need for a separate data acquisition system, which was used during Phase III testing.

Improving Following-Vehicle Tracking Firmware

The system included two light activation subsystems: open-loop and closed-loop. An open-loop system requires no measurements associated with the following vehicle; only measurements associated with the lead vehicle (i.e., the vehicle equipped with the ERS system) are available. This open-loop system activates the rear lighting when a CMV is heavily decelerating. A closed-loop system includes the measurement of the closing rate (velocity) and closing distance to the following vehicle (using radar), along with lead-vehicle velocity and deceleration. The closed-loop system requires more technical components. Therefore, implementation costs would be greater.

Efforts were undertaken to improve the vehicle tracking firmware for the closed-loop system. The research team performed multiple tests on the Virginia Smart Road using the Phase III prototype system in low-speed, high-density scenarios. Data from these tests were used to refine the firmware until testing indicated improved tracking performance. After this process, the ERS system was formally tested using the Virginia Smart Road and real-world testing on public roadways.

STUDY FINDINGS

During the formal Smart Road testing, the open-loop activation system correctly detected 100 percent of all conditions that could result in a rear-end collision (causing the system to light up and provide a warning) and correctly rejected 100 percent of all conditions that would not result in a rear-end collision (preventing the system from lighting up). The closed-loop activation system correctly detected 100 percent of all conditions that could result in a rear-end collision, and correctly rejected 95 percent of all conditions that would not result in a rear-end collision. During the real-world testing, no open-loop system activations occurred (i.e., there was no hard braking), so no data could be collected. However, the closed-loop activation system correctly detected 100 percent of all conditions that could result in a rear-end collision and correctly rejected 85.43 of all conditions that would not result in a rear-end collision, across all roadway types.

Nighttime Warning-Light Brightness Testing

Two studies were performed to evaluate the ERS system during nighttime conditions. The first study used following-vehicle drivers to provide ratings on discomfort glare and “attention-getting” effectiveness for multiple nighttime brightness levels. The second study used the brightness level candidate identified during the ratings study as the most effective and comfortable, and included the collection of real-world data on public roadways. During this real-world testing, no following-vehicle unintended consequences were found.

CONCLUSIONS

Over the course of this project, the research team successfully modified the ERS system. The updated system is simplified and easier to install, has improved following-vehicle tracking firmware, and has improved nighttime warning-light brightness levels. FMCSA will make these research findings available to trailer manufacturers and other interested CMV industry members.

For more information, please visit: http://www.fmcsa.dot.gov/safety/research-and-analysis/publications?keywords=&title=&author=&year=&to=&page=0

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