Naturalistic Study of Warning Device Equivalency

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Equivalency Analysis

As demonstrated in the analysis that follows, the Alternative Warning Device[1] tested by Aurora Operations, Inc. (Aurora) performs equivalently to the placement of bidirectional emergency reflective triangles[2] (Warning Triangles) around a commercial motor vehicle (CMV) when required by federal regulation at 49 CFR § 392.22(b).

1. Objective

The purpose of this study was to determine whether deployment of the Alternative Warning Device performs equivalently to the Warning Triangles required by federal regulation to be placed on the highway at the specific locations prescribed by 49 CFR § 392.22(b)(2)(iv)-(v), based on the metrics evaluated. Specifically, this study compares the effect on driving behavior of other road users who encounter an Aurora CMV parked on the right shoulder of a highway with either Warning Triangles or the Alternative Warning Device deployed.

2. Methodology

2.1. Overview

To evaluate whether the deployment of the Alternative Warning Device performed equivalently to the deployment of Warning Triangles, Aurora sought to determine whether each warning device induced certain driver behavior. Aurora collected data on public roads using a sample of drivers traveling at highway speeds who encountered an Aurora CMV parked on the right shoulder of the highway and who were unaware of the study. The data was collected using sensors, located on the Aurora CMV, that are capable of detecting vehicles in the vicinity of the Aurora CMV; calculating their velocities and accelerations; and tracking their locations from approximately 300 meters behind to 300 meters in front of the Aurora CMV. A variety of lighting conditions and interstate roadway geometries were selected to evaluate the effectiveness of the warning devices in eliciting either a reduction in passing vehicle speed or an increase in lateral separation between a passing motorist and the stopped Aurora CMV. This curated variety of scenarios allows for the equivalence claim to extend to as many operating modalities as possible.

[1]The Alternative Warning Device tested for this study consists of two Elemental 4 TIR LED Grille and Surface Mount Lights (produced by Extreme Tactical Dynamics). Each light features four 3W LEDs that are amber in color and meet the class 1 photometric requirements described in SAE J595. One light is temporarily mounted for this study on each side of the cab at a point approximately one foot behind the sideview mirror (closer to the rear of the cab) and approximately four inches above the top of the sideview mirror. The flash pattern used for this study was called “triple flash,” consisting of a burst of 3 flashes with a 1 second pause between such bursts.

[2] The Warning Triangles tested are three bidirectional emergency reflective triangles that conform to 49 CFR § 571.125, as required by 49 CFR § 393.95(f).

2.2. Evaluation Metrics

In this naturalistic driving behavior study, the driving performance and responses of approaching motorists were collected and evaluated to determine the overall effectiveness of the Alternative Warning Device and Warning Triangles. Aurora expected that an effective warning device, when deployed, would elicit a reduction in passing vehicle speed or an increase in lateral separation between a passing motorist and the stopped Aurora CMV.

Aurora selected these metrics based on past studies performed to evaluate the effectiveness of warning devices. In the 1982 National Highway Traffic Safety Administration (NHTSA)-sponsored study,[3] similar metrics were selected because "[t]he relationships of these measures to a safety benefit was postulated to lie in the fact that the main elements of the regulation can be viewed as intended to enhance the conspicuity of the disabled vehicle and motorist setting, with this enhancement improving driver detection of the scene and bringing about vehicle courses and anticipatory responses which would increase the lateral separation of passing vehicles."[4] Similarly, increased lateral separation and reduction in passing speed are discussed throughout a September 1994 NHTSA Notice of Proposed Rulemaking regarding warning devices and analogous conspicuity studies referenced therein.[5]

To qualitatively assess how motorists responded to each warning device, Aurora evaluated the proportion of vehicles in the right lane leading up to the Aurora CMV parked on the right shoulder. This assessment is summarized in Section 3.1. A second, more quantitative assessment was then conducted using two additional metrics: 1) the proportion of vehicles that responded, if at all and 2) the distance-at-response (DAR) value. The DAR is the distance behind the rear of the trailer at which a vehicle responded. This assessment is summarized in Section 3.2. For this assessment, a response was defined as:

- A lane change to a further lateral distance;
- For vehicles in any lane, a speed reduction to 95% of the speed when first perceived by data collection equipment; or
- Any lane change described above and a speed reduction to 95% of the speed when first perceived by data collection equipment.

The DAR metric allows for a direct comparison of the responses elicited by the different warning devices. It cannot be concluded in this study why a motorist responded but it is reasonable to expect that one or more of the responses described above could be due to the presence of the truck on the shoulder.

Using this metric, warning devices that perform equivalently would bring motorists' attention to the Aurora CMV parked on the shoulder of the highway and elicit a response around the same distance leading up to the rear of the trailer.

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[3] "Analysis of the Dismounted Motorist and Road-Worke Model Pedestrian Safety Regulations" (Ulmer et al., 1982).
[4] See *id*. at iii and 15.
[5] See Federal Register Volume 59, Number 188 (Thursday, September 29, 1994).

By specifically evaluating changes to motorists' driving behavior as it relates to the metrics above, Aurora could assess whether the Alternative Warning Device performed equivalently to the Warning Triangles required to be placed on the roadway by federal regulation today.

2.3. Data Collect Configurations

Aurora acquired and evaluated on-road data using two configurations:

- **Configuration 1:** Tractor-mounted Alternative Warning Device with activated hazard warning signal flashers.
- **Configuration 2:** Warning Triangles with activated hazard warning signal flashers.
    - Warning Triangles were placed at the specific locations described in 49 CFR § 392.22(b)(2)(iv) or (v), depending on the roadway type on which the CMV was stopped.

2.4. Data Collect Scenarios

Data was collected for the two configurations noted above under different scenarios to encompass a significant portion of conditions in which a CMV may require warning devices. Specifically, data was collected for four roadway geometries: straight, curve left, curve right and beyond the crest of a hill. Data was collected for these roadway geometries under both daylight and nighttime lighting conditions. Daylight collections were performed between the hours of 8:00 a.m. and 5:00 p.m. and nighttime collections were performed between the hours of 9:00 p.m. and 4:00 a.m.

All data collections were performed in Texas on Interstate 45 between Exits 258 and 249. To ensure that on/off ramps did not impact the results, stopping locations were all at least a half mile away from all ramps. See Appendix A for locations and coordinates of the above roadway geometries used for data collection. All locations are on areas of Interstate 45 that have three lanes of travel and speed limit of 75 mph.

2.5. Collection Duration and Procedures

Warning Triangles, one of the three warning devices explicitly permitted by regulation today, are required to be placed at specified locations within 10 minutes of a CMV stopping on a highway or shoulder thereof for any cause other than a necessary traffic stop.[6] As such, each data collection was limited to an approximately eight minute interval. In most cases, a single pull-to-shoulder event would encompass two-8 minute data collections using the two different configurations detailed in Section 2.3. A typical data collection occurred as follows:

- CMV (tractor and trailer) is driven to the desired shoulder location.
- CMV's hazard warning signal flashers are activated and Configuration 1, the Alternative Warning Device is activated.
- Vehicle operator performs an 8-minute data collection on Configuration 1.

[6] 49 CFR § 392.22(b).