Safety and Human Factors of Adaptive Stop/Yield Signs Using Connected-Vehicle Infrastructure

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Introduction

In the United States, intersection crashes, especially those occurring at stop-controlled intersections, are a great safety concern. In past vehicle and infrastructure treatments that have been identified with the intention to inform the driver to correct poor or distracted driving behavior. But all past treatments have merely provided supplemental information, not active in-vehicle information that will act in a preventative manner, instead of only serving as a warning. It has been proposed that by using connected vehicle (CV) technology, the traffic control sign may be varied between "stop" and "yield" to help mitigate intersection collisions, improve traffic flow, and positively impact the environment. However, to complete a full evaluation of CV technology, the human factors and driver perceptions must be considered to ensure that implementation will be easy for drivers to understand and will not be a detriment.

A closed-course study is proposed to test the effectiveness of adaptable stop/yield signs. Drivers will be run through multiple scenarios to determine how the signs affect their driving and to test worst-case scenarios to verify drivers will react properly. Data will be collected through pre- and post-drive surveys completed by participants and through the collection of video and kinematic information from the vehicle. From these data, an analysis will be conducted to measure driver acceptance and potential safety benefits of adaptable signs. Conclusions will be drawn, and a report will be drafted to discuss the findings.

Problem Statement

Adaptable stop/yield signs have been proposed by some traffic professionals to improve travel time, reduce air pollution, increase fuel economy, and adjust to different traffic conditions such as peak hours, weather, or emergency vehicles. While adaptable signs have great potential, they must be properly designed and tested to ensure that:

1. The net safety benefits are positive,
2. Drivers interpret and respond correctly to the signs,
3. Drivers pay appropriate attention to the signs without adaptation in the form of relying on past history (e.g., the sign may be different than the prior 10 times the intersection was crossed),
4. There are no other unintended consequences when signs are deployed, and
5. Driver acceptance of the technology is high.

Example of an Electronic Stop Sign

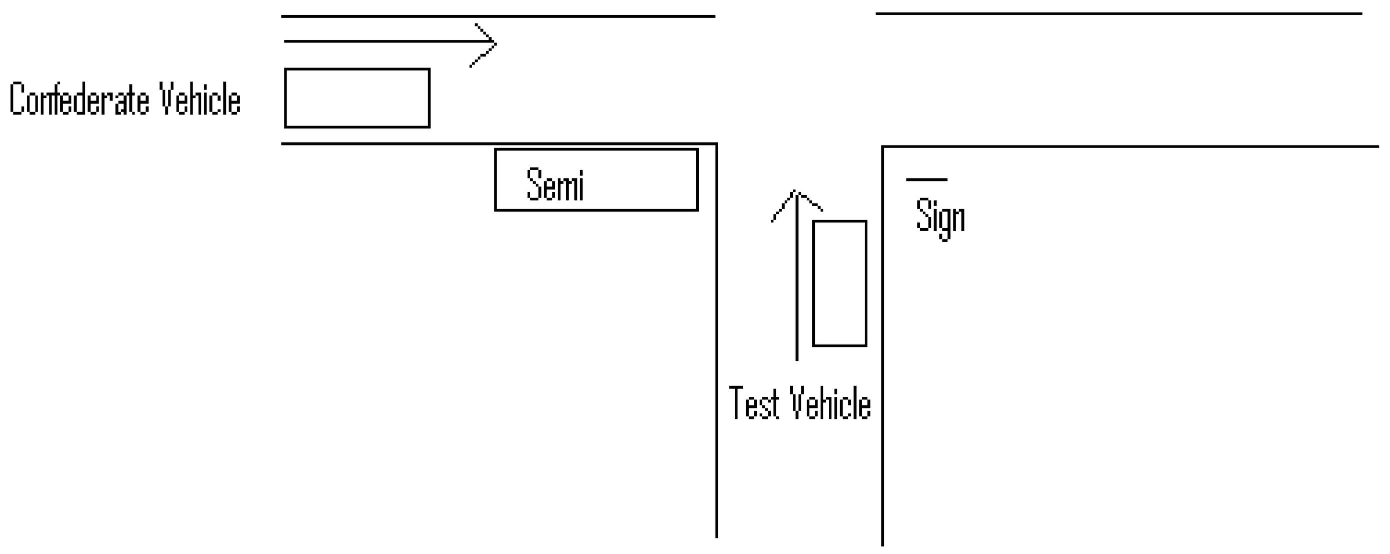
Experimental Design

During this study, safety and human factors aspects of using adaptable systems will be examined. Multiple designs and scenarios will be tested on the Virginia Smart Road using a working CV system and participants of different age groups. A sign with adaptable stop/yield control will be erected to direct traffic movements. This sign will be electronic and will have the capability of showing a "stop" or "yield" directive in a black field so that the shape of the sign may be preserved. The sign will be pole mounted and will be placed in accordance to all standards that the inadaptable stop or yield sign must follow. It will also be capable of broadcasting its status to the vehicle using the CV system.

During tests, different traffic scenarios will be presented with the adaptable sign set to either "yield" or "stop" mode with different timings of the change based on driving characteristics and different algorithms of when to have the driver to stop or proceed with caution. The default setting of the sign will also vary during testing to determine what role the default setting has on driver behavior. All testing will occur on dry roadways with fair weather (e.g., no rain, fog, snow, etc.).

Instrumented Intersection on the Smart Road

One of the tests (a worst-case scenario) will be a "blind" intersection at which the sign changes before the driver can see an approaching vehicle. To keep the vehicle out of sight of the driver, an obstruction will be established (e.g., a tractor trailer that makes seeing approaching vehicles difficult). The image below illustrates the general setup for all of the tests, with test vehicles driving on the minor approach and confederate vehicles using the major approaches.



Example of an experimental scenario that demonstrates an obstructed view

Data Collection and Analysis

Data will be collected in two ways:

1. Surveys filled out by the participant, and
2. Vehicle instrumentation.

One pre-survey and two post-surveys will be developed by researchers to measure driver self-evaluation. Drivers will fill out surveys before testing while presented with a hypothetical system. This survey is designed to collect demographic data and any experience with CVs or similar systems. Two types of in-vehicle surveys will be employed during the study: 1) Immediately following completion of a scenario to obtain initial impressions and 2) After all testing is complete to gauge drivers' perceptions of the overall system concept. These surveys will comprise both open-ended questions to allow for participants to expound upon their thoughts about the system and qualitative questions where participants will rate a question and provide their responses on a numeric scale. These questionnaires will be modeled on those used during other CV projects conducted in part by VTTI, although specific questions will be tailored to this project. Questions will be similar for all runs and will be able to be compared to determine what differences in opinions are found based on ongoing tests. This will help identify any concerns with the sign and quantify whether drivers react positively to the sign or not. These surveys are subject to further refinement and editing as the project progresses.

Each car will be instrumented to collect vehicle kinematic, driver performance, and behavioral data, including: video of the driver and forward roadway, in-cabin audio, reaction time, brake force, and any errors (false negatives and false positives). Collection will be accomplished using the standard data acquisition system (DAS) at VTTI. The DAS is specifically designed from the ground up to support transportation research and boasts a number of unique data collection capabilities:

- Up to six cameras that provide driver behavior and driving context;
- Wide field-of-view forward radar (self-calibrating);
- A machine-vision-based, head pose/eyes-forward monitor (self-calibrating);
- A machine-vision-based lane tracker (self-calibrating);
- A variety of vehicle data bus information for most light- and heavy-vehicles such as acceleration (lateral, longitudinal), yaw rate, and speed; and
- Global positioning system (GPS).

An Example of an Installed VTTI Data Acquisition System (DAS Unit)

CVI UTC | MORGAN STATE UNIVERSITY | VirginiaTech Transportation Institute | University of Virginia