U.S. Department of Transportation
Federal Highway Administration
Office of Operations
Research and Development

MITIGATING OVERSATURATION WITH COOPERATIVE AUTOMATED DRIVING SYSTEMS

Applying Bundled Speed Harmonization, Cooperative Adaptive Cruise Control, and Cooperative Merging Applications to Managed Lane Facilities

INTRODUCTION

Traffic congestion is typically caused by oversaturation, poor weather, vehicle crashes, work zones, poor signal timing, and special events. Over saturation occurs when more vehicles use a road than the road is designed to accommodate. The resulting congestion leads to unstable traffic flow, which instigates breakdowns and bottlenecks.

The Federal Highway Administration (FHWA) has investigated how automated vehicles could improve traffic performance and reduce congestion. This research suggests the potential value of combining evolving communication and automated control systems into a cooperative automated driving technology to increase the capacity of roadways. Cooperative Automated Driving Systems use radar and other communication systems to control the throttle and brake systems of vehicles. Vehicles that cooperate with each other while using automation can operate much more effectively with shorter headways and improved response to other vehicles' movements. These cooperative automated driving systems can operate even more efficiently when they benefit from traffic management systems that can coordinate traffic movements, including desired vehicle speeds, and smooth traffic flow. Our research has focused primarily on concepts that require driver engagement and steering at all times (Society of Automation Engineers [SAE] Level 1 for driving automation), however, automated vehicles that incorporate communication would also benefit when they become available.

OBJECTIVES

The project objective was to develop and assess the potential of cooperative automated driving systems toward reducing traffic congestion on freeways. The study addressed a promising scenario where cooperative automation was applied to a hypothetical managed freeway system (illustrated in figure 1) in order to improve the capacity and reliability of the roadway. The managed lane scenario was selected because initial deployment of cooperative automated vehicles may be expected on managed lane facilities that can limit access to automated vehicles, resulting in improved capacity and performance. The opportunities to encourage driver use of these emerging technologies have been noted in prior research studies.

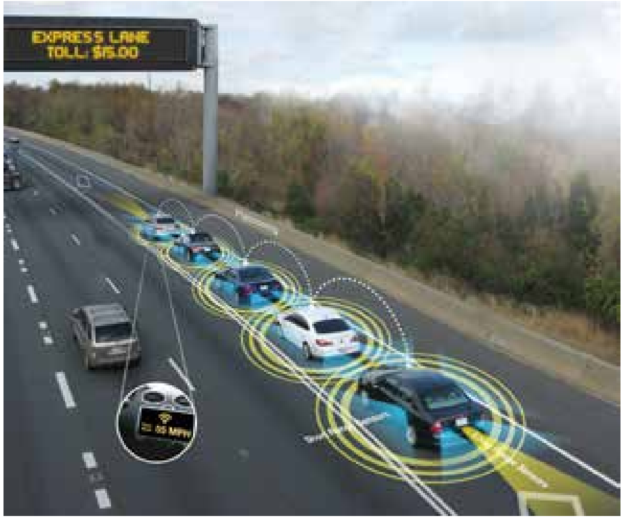

Figure 1. Illustration. Data exchange during platooning. (Source: FHWA).

SYSTEM CONCEPTS AND VEHICLE PLATFORM

The cooperative automation systems integrated three automation applications: (1) speed harmonization; (2) vehicle platooning; and (3) cooperative merge. These systems comprised the Integrated Highway Prototype (IHP) and were incorporated onto the FHWA Saxton Transportation Operations Lab's fleet of Cooperative Automation Research for Mobility Applications (CARMA) vehicles. This fleet uses a robot operating system (ROS) framework for testing and evaluating cooperative automation applications. The speed harmonization concept allows vehicles to follow speeds that will maintain optimal traffic flow and reduce speed variations; the platooning allows vehicles to follow more closely, but also safely, to improve highway throughput and capacity; and the cooperative merging allows vehicles in platoons to cooperate with each other to accept merging vehicles and keep traffic flowing smoothly.

METHODOLOGY

The project scope included both microscopic traffic simulation and field testing. The testing presumed a simple freeway network where vehicles enter a one-lane managed lane facility, additional traffic enters from an entrance ramp, and then the combined traffic proceeds to the end of the managed lane facility.

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First, a traffic simulation model was used to assess how the IHP systems might improve traffic performance for the illustrative network. Both normal traffic conditions and an experimental case *n* which traffic incorporated the IHP applications were modeled to assess the impacts on traffic performance. Since the IHP systems are intended to increase capacity and performance, the tests included varying percentages of vehicles equipped with IHP systems.

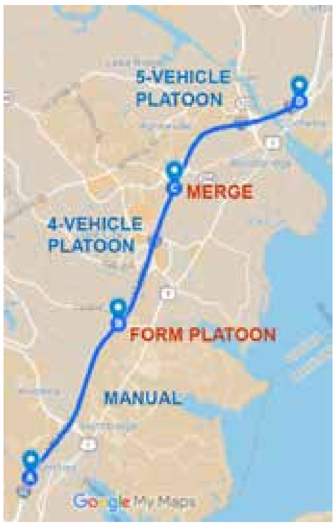

Figure 2. Map. Map of key points along testing route. (© 2018: Google Maps, Altered by: FHWA.)

Second, field tests were conducted using the FHWA research vehicles on the I–95 Express Lanes, owned by the Virginia Department of Transportation and operated by Transurban. The test network is illustrated in figure 2 for the northbound tests. Because field testing was conducted primarily with the roadway closed to other traffic, the lead vehicle in the platoon (or the lead vehicle in the string in the baseline case) followed speed profiles derived from the simulation study so that the effects of other traffic could be reflected in the tests. Prior to the testing, a mobile data collection trailer with cellular and Dedicated Short Range Communication transceivers was temporarily installed to track test vehicles and to allow communication with the vehicles. The experimental IHP systems were pretested off-road at the Army's Aberdeen Test Center to ensure they were safe and ready for testing on actual roadways and with other traffic. Again, testing was conducted both for the baseline normal conditions and then experimentally using the IHP equipped vehicles. The proof-of-concept tests were initially conducted when the roadway was closed to other traffic, but later in light traffic conditions so as to minimize the impacts on customers. More than 20 runs were made in baseline and experimental IHP conditions. Figure 3 illustrates the cooperative merge with the IHP platoon.

RESULTS

The simulation results suggest that roadway capacity can be significantly increased and traffic performance improved. As expected, roadway capacity and performance increased as the proportion of vehicles equipped with IHP systems increased. With all vehicles equipped with the experimental IHP systems, the capacity of the managed lane increased by more than 50 percent (2073 vehicles per hour per lane [vphpl] base to 3190 vphpl experimental). The impacts on traffic performance were substantial; when vehicle demand equaled the capacity enabled by the IHP systems for both the baseline and experimental cases, the IHP systems reduced average delay by more than 80 percent *n* addition to increasing capacity.

The field tests confirmed that the performance of the IHP vehicles on the I–95 Express Lanes closely matched their performance in the simulations, with much closer following distances and higher speeds in the IHP case than in the baseline case. Detailed statistical analyses of the field data also confirmed the stability of the vehicle speeds and spacings in the IHP case that support the significant capacity and traffic flow improvements. The field tests demonstrated a platoon of closely spaced vehicles that maintained a throughput equivalent to more than 3600 vphl over an extended section of an actual managed lane facility.

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REFERENCES

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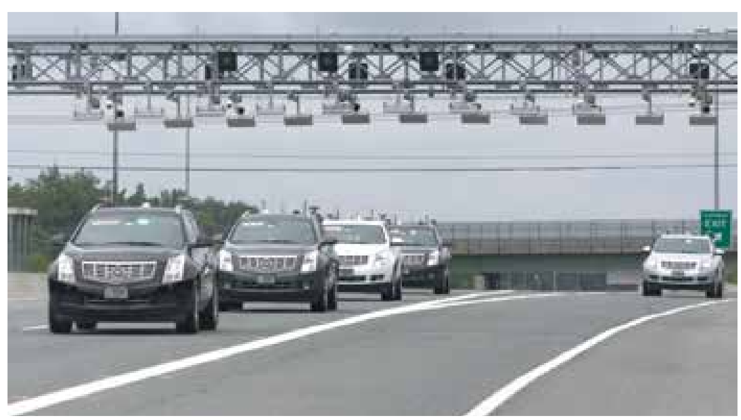

Figure 3. Photo. A car approaches to merge with a 4-car platoon. (Source: FHWA).