Research Brief
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Real-Time Prediction of Vehicle Locations in a Connected Vehicle Environment

Perspective Testing for the connected vehicle environment is under way around the nation. In this environment, vehicles equipped with advanced wireless communications, GPS and vehicle sensors will share their location, speed, direction and acceleration in real time with each other and with nearby infrastructure, such as traffic signals.

Likewise, the infrastructure will share information, such as traffic signal status and lane closures, with vehicles equipped with the technology. The information will be shared precisely and quickly within a secure network. Once connected vehicle technology is prevalent, its use is expected to reduce crashes, improve signal timing and allow more accurate measurement of how well traffic is flowing.

However, even if connected vehicle technology were to become standard equipment on all *new* vehicles, it likely would be more than a decade before *most* of the vehicles on the road were equipped.

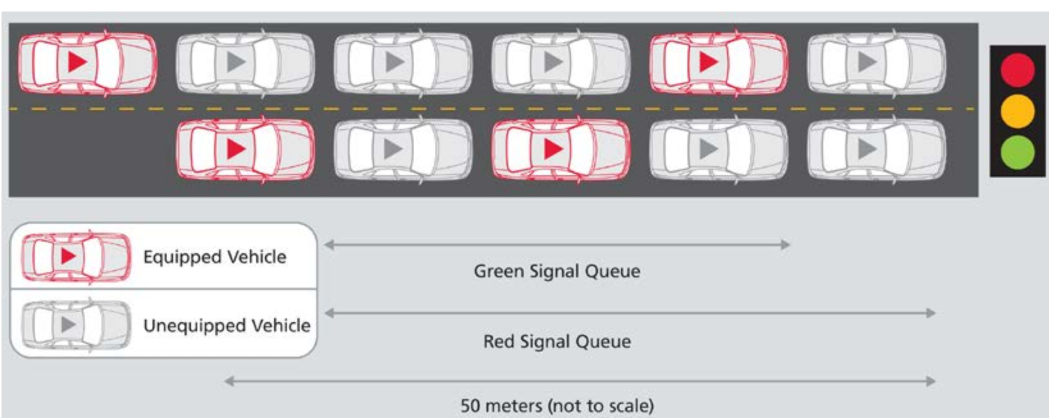
Until then, traffic will be a mix of equipped and unequipped vehicles, or those that can and cannot transmit their location wirelessly. When there are few equipped vehicles in the traffic stream, this translates to limited data being transmitted, which then restricts the infrastructure's ability to improve traffic flow, or mobility. But if a connected vehicle system could accurately estimate the behavior of unequipped vehicles, more drivers on the road would have a better chance to avoid traffic delays.

In this study by the Virginia Center for Transportation Innovation and Research (VCTIR), the research division of the Virginia Department of Transportation (VDOT), the researcher estimated real-time locations of unequipped vehicles in simulations of connected vehicle traffic. His work will help improve mobility in real traffic during the time that it takes for the developing environment to become commonplace. Better traffic flow has time, cost and ecological benefits.

Two objectives of the study were (1) to develop algorithms, which are step-by-step calculation procedures, to estimate the locations of a portion of unequipped vehicles in a simulated connected vehicle environment, based on the behaviors of equipped vehicles, and (2) to evaluate the performance of the algorithms, based on their accuracy and ability to improve the performance of software applications meant to keep traffic flowing well.

Background Virginia is a leader in preparing for connected vehicle technologies. VDOT's Operations Division supported this study as a means to develop a low-cost method to improve the benefits of connected vehicle mobility applications as soon as possible for the eventual rollout of the technology.

Several transportation software applications already are available that will use data from connected vehicles to improve mobility. These mobility applications — used, for example, to control traffic signals — have been tested in simulation because there have not been enough equipped vehicles to test them in the field.



An algorithm to estimate locations of vehicles not equipped with connected vehicle technology has calculated queue lengths during red and green signal phases on an arterial road.

For the full report, search 14-R4 at vtrc.virginiadot.org. For more information about the research, contact Noah J. Goodall, Ph.D., P.E., VCTIR research scientist, Noah.Goodall@vdot.virginia.gov

To mimic the expected gradual rollout of connected vehicle technologies, researchers run simulation models many times, using different assumptions of the percentage of vehicles in the stream of traffic equipped with communication devices. They observe how the different percentage estimates affect the impact of their connected vehicle applications on traffic mobility.

They often find that as they simulate an increase in the market-penetration rates of connected vehicle technologies, the performance of the application improves. Until more vehicles have connected vehicle technology, estimating the behavior of unequipped vehicles in the field could boost the benefits of mobility applications in the same way as if penetration rates had been increased.

Research and Recommendations The VCTIR researcher developed two location estimation algorithms, one for freeways and one for arterial roads, using car-following models. Both algorithms estimated locations for individual unequipped vehicles and modeled realistic vehicle behaviors. The arterial road algorithm also estimated unequipped vehicle movement through several successive intersections.

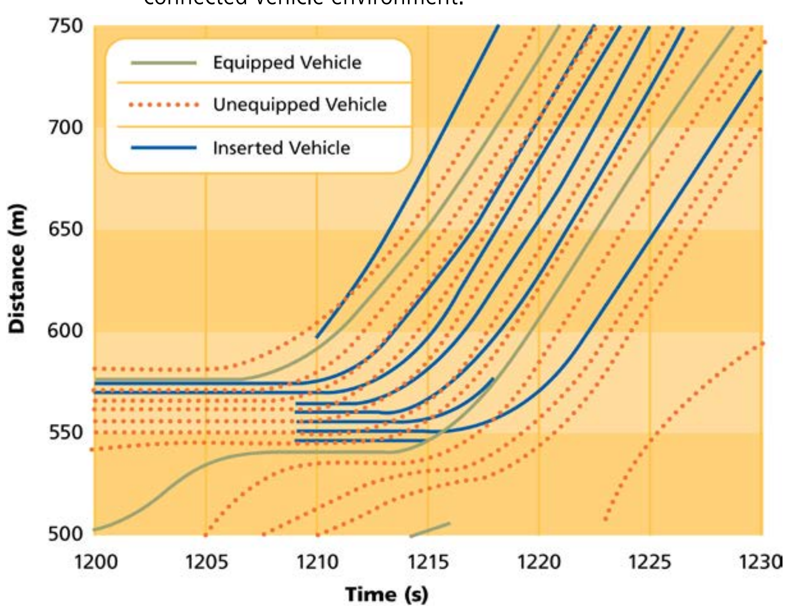
To test the freeway algorithm, the VCTIR researcher used vehicle trajectory data from the "Next Generation Simulation" project — in particular, a field-collected dataset of individual vehicle movements along a section of Interstate 80 in Emeryville, Calif. He tested the arterial algorithm on a calibrated model of four signals on U.S. 50 in Chantilly, Va. The researcher used the microscopic-simulation software VISSIM to simulate vehicle movements through the intersections. Both algorithms successfully estimated the locations of a portion of unequipped vehicles.

The researcher then used each algorithm with an existing connected vehicle application — ramp metering for the freeway algorithm and signal control for the arterial algorithm. He found that including the algorithms' estimates of the behavior of some unequipped vehicles produced small improvements in traffic performance in simulations with low percentages of vehicles equipped with connected vehicle technologies.

When compared to the use of connected vehicle data alone, the mobility applications were better able to do their intended jobs. There was up to an 8 percent reduction in delay for the ramp metering application and a 4.4 percent reduction in delay for the traffic signal control application when predicted data from unequipped vehicles were also taken into account.

By using known wireless vehicle data from equipped vehicles to calculate unknowns, such as unequipped vehicle behavior, existing and future transportation systems applications that use connected vehicle data will produce greater benefits sooner — for example, reduced emissions, travel time and fuel consumption.

The study recommends that VCTIR continue to assess the quality of data coming from connected vehicle pilot projects. As accurate data are identified, they can be used to test the ability of the algorithms developed in this study to improve the real-world performance of various connected vehicle applications at low actual penetration rates. This will help reduce delays and increase traffic flow on freeways and arterials when few vehicles are equipped to participate in a connected vehicle environment.



A sample of vehicle trajectories when 15 percent of the vehicles on a single lane are equipped with connected vehicle technology. The algorithm has estimated the locations of unequipped "inserted vehicles."

The Virginia Center for Transportation Innovation and Research (VCTIR) is proud to contribute to VDOT's reputation as a national transportation leader. VCTIR greatly appreciates the cooperation and support of VDOT and the Federal Highway Administration.

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