Title

Variable Speed Limit Control to Reduce Traffic Congestion in the Face of Uncertainty

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RESEARCH BRIEF

Variable Speed Limit Control to Reduce Traffic Congestion in the Face of Uncertainty

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Research Question

Highway bottlenecks caused by traffic incidents, lane drop, ramp merging or slow vehicles negatively impact traffic mobility and safety. Traffic regulation techniques, such as adjusting speed limits, providing lane-change recommendations, and restricting on-ramp vehicle inputs with traffic signals in response to an incident, have been found to mitigate congestion from these types of bottlenecks. However, most existing research assumes that traffic models and measured traffic data are accurate and that vehicle drivers always comply with recommendations from the infrastructure. These assumptions are rarely true in the real world and can lead to inconsistencies between the theoretical benefits and the actual benefits obtained in field tests. To address this issue, traffic models need to be modified to accommodate these sources of uncertainty, and traffic management approaches need to be designed to account for these uncertainties and modeling errors.

Researchers at the University of Southern California developed, analyzed, and evaluated an innovative approach to alleviate highway bottleneck congestion. The approach includes issuing variable-speed advisories and lane-change recommendations when needed to the upstream vehicles, as well as ramp control to manage incoming traffic, while accounting for inaccuracies in traffic data and road information and the complex behavior of human driving. The researchers ran simulations to test the system's potential mobility and emissions benefits.

Key Research Findings

The distance between variable speed limit signs has a significant impact on the effectiveness and performance of variable speed limit control. The distance between the two variable speed limit signs furthest upstream from the bottleneck affects how quickly vehicles slow down. Signs that are placed closer together achieve a faster convergence to steady-state traffic densities and much better benefits compared to ad hoc distances used in past research. Moving the signs closer together is an effective design tool for tuning and improving the performance of variable speed limit control.

Concentrating most speed control efforts farther upstream from the bottleneck and minimizing speed variations closer to the bottleneck improve the performance of variable speed limit control. Classic variable speed limit algorithms distribute the control effort evenly among road sections leading to the bottleneck, which may lead to significant speed differences between successive sections, create shockwaves, and deteriorate the control performance. An effective solution to this issue is to concentrate most control efforts farther from the bottleneck by matching the upstream traffic volumes with the bottleneck throughput. Then the remaining road sections closer to the bottleneck only need to maintain a consistent flow, which reduces the speed variations and shockwaves.

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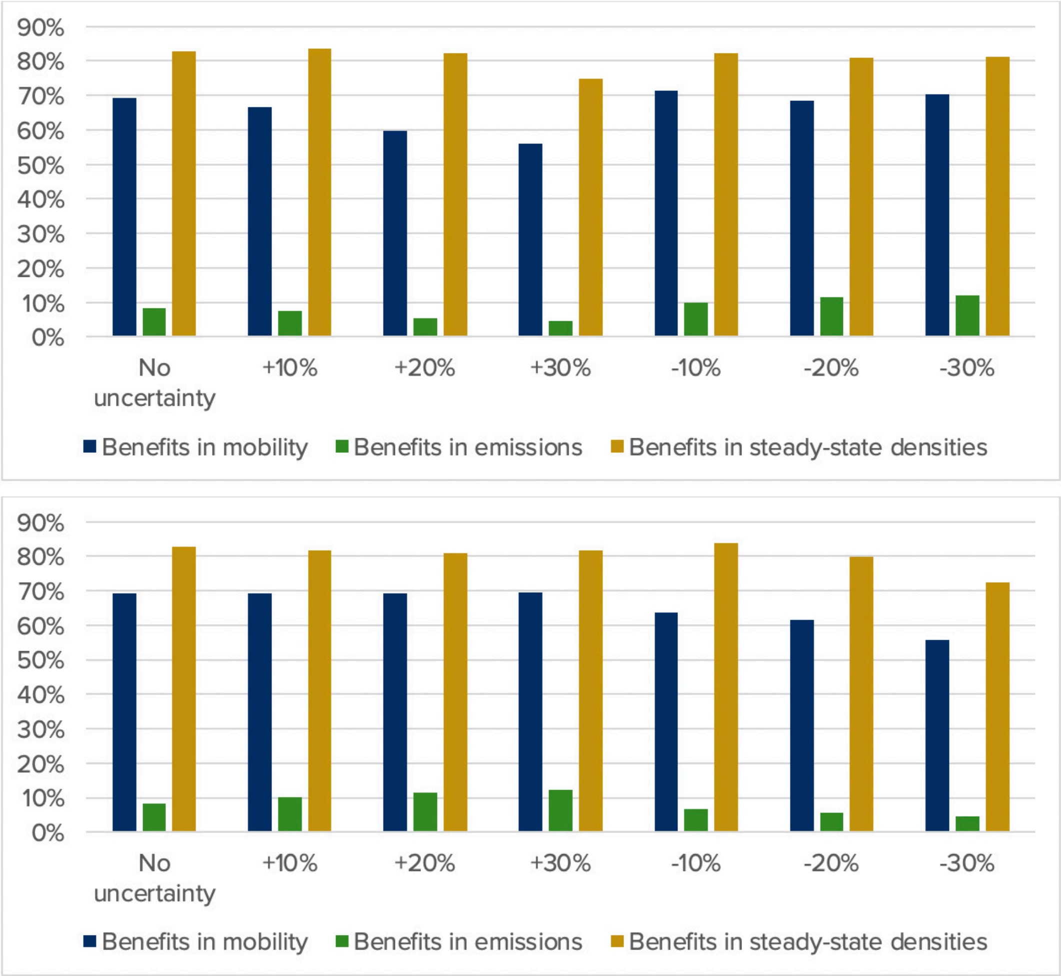

Figure 1. Benefits over no-control scenario under various levels of uncertainties in measured traffic flows (top) and densities (bottom). The percent improvement over the no-control case is plotted against the percent error in flow and density measurements.

The proposed approach can tolerate 20% uncertainty levels in sensitive measurements, such as mainstream traffic flows and densities, without losing too many benefits in terms of mobility, emissions, and steady-state traffic densities (Figure 1). Measured mainstream flows and densities are the most sensitive uncertainty sources among all the model parameters and measurements. Overestimating the traffic flow or densities due to uncertainties in measurements does not have a significant impact on the benefits when compared with the no-control case.

More Information

This research brief is drawn from "Robust Design, Analysis and Evaluation of Variable Speed Limit Control in a Connected Environment with Uncertainties: Performance Evaluation and Environmental Benefits," a report from the National Center for Sustainable Transportation, authored by Tianchen Yuan, Faisal Alasiri, and Petros Ioannou of the University of Southern California. The full report can be found on the NCST website at https://ncst.ucdavis.edu/project/robust-design-analysis-and-evaluation-variable-speed-limit-control-connected-environment.

For more information about the findings presented in this brief, contact Tianchen Yuan at tianchey@usc.edu.

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