RESEARCH SUMMARY

NOVEMBER 2024

Refining Max-Pressure Traffic Signal Control to Improve Traffic Flow

Effective traffic signal control technologies facilitate optimal traffic flow and travel time. Building on previous research, this project made significant progress toward field implementation of a novel adaptive signal control technology. This research phase demonstrated the max-pressure traffic signal algorithm can successfully integrate into Hennepin County traffic signal hardware and respond to changing traffic conditions in real time, providing confidence to test the system in the field.

What Was the Need?

Signal timing at intersections significantly impacts traffic congestion and travel time. Current traffic signal control involves actuated timed settings based on time of day volume profiles and adaptive signal control methods, which use detection data to accommodate unexpected traffic demand fluctuation from special events, incidents or weather. But current adaptive signal control methods have limited performance when traffic volumes are high. Max-pressure is a novel adaptive traffic signal control algorithm that detects the quantity of cars—or queue length—in real time at one or several intersections to determine signal timing that is proven to maximize throughput for the entire city. Simulations have shown that increasing throughput also reduces delays.

In a previous LRRB project, microsimulations were used to investigate the use of max-pressure signal control strategy on seven Hennepin County intersections. Driver delay was substantially reduced, vehicle throughput increased and the controller adapted to traffic demand changes.

However, these microsimulations didn't test the max-pressure algorithm on actual roads. Before modifying real-world traffic signal hardware, Hennepin County wanted to explore the compatibility of the max-pressure traffic control algorithm with this hardware before testing the system in the field.

"This long-term research highlights the potential benefits of a max-pressure traffic signal control system. Moving forward, we aim to further validate the system's safety, functionality and operation through real-word field deployment to gather valuable insights and lessons learned that will benefit Hennepin County and other public and private agencies."

—BEN HAO, TRAFFIC OPERATIONS ENGINEER, HENNEPIN COUNTY

What Did We Do?

Despite the successful performance of the max-pressure traffic signal control strategy in simulations, investigators needed to ensure the algorithm could operate safely in conjunction with traffic signal controllers and traffic detector input before testing at actual intersections. The main components of a testbed included the max-pressure algorithm applied in a traffic simulation model generating realistic traffic scenarios, a traffic signal controller used by Hennepin County and a laptop that served as a virtual signal display.

To further demonstrate the efficiency and test the interaction of the max-pressure traffic control algorithm in a realistic traffic setting, researchers needed to translate the data from the simulation model to a format consistent with the video data collected by the county to determine queue lengths at intersections.

Implementing max-pressure control hardware in the testbed setup required establishing parameters and aligning the operation of the components with a generic four-leg intersection design with defined major and minor road traffic flow. Researchers simulated an actual Hennepin County intersection using intersection geometry and traffic data.

A video shows the testbed hardware setup and demonstrates the simulation of the max-pressure firmware operating signal timing through the traffic signal controller in a selected Hennepin County intersection.

What Did We Learn?

The max-pressure traffic signal control algorithm was successfully integrated with a Q-Free MaxTime traffic signal controller. As in the first phase of research, simulations illustrated the max-pressure system's ability to respond to real-time variations in traffic demand as an alternative to signal timing based on historical or average demand levels.

Unlike many adaptive traffic signal timing systems, max-pressure uses one timing algorithm that responds to all traffic demand levels instead of separate algorithms for different time periods. Rather than maximizing throughput—or volume—one cycle at a time, the mathematical properties of the algorithm intend to result in maximum traffic throughput moving through one or several traffic signals over time along major corridors without compromising the travel time to the crossing streets.

In addition to the successful testing and simulations, the test method researchers devised can be used to safely test other traffic signal controllers and detection technologies before implementing in the field.

What's Next?

Project results provide confidence in planning for testing max-pressure signal control strategy and firmware in the field. To implement the research findings, a Phase III project would include additional testing on the traffic signal test cabinet at the Hennepin County Traffic Management Center to ensure the max-pressure signal control system can accommodate various traffic signal operating conditions in the field, including flashing yellow arrows, pedestrian signal calls, emergency signal preemption and all red flashing.

Following successful deployment of the system on a single traffic signal in Hennepin County, max-pressure signal control would be implemented on a corridor with three to five traffic signals.

About This Project

REPORT 2024-26
"Towards Implementation of Max-Pressure Control on Minnesota Roads—Phase 2."
Find it at mdl.mndot.gov.

CONTACT
research.dot@state.mn.us.

TECHNICAL LIAISON
Ben Hao, Hennepin County, Ben.Hao@hennepin.us

INVESTIGATOR
Raphael Stern, University of Minnesota, RStern@umn.edu

PROJECT COST
$140,034

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