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RESEARCH
SERVICES SECTION

TECHNICAL SUMMARY

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PROJECT COST:
$140,139

Inaccuracies in on-ramp meter algorithms can lead to long ramp queues and waiting times. Minnesota law prescribes a maximum waiting time of four minutes.

Improving Minneapolis/St. Paul's Ramp Metering System for Smoother Traffic Flow

What Was the Need?

To help prevent traffic congestion in highway bottlenecks, Mn/DOT operates more than 400 traffic signals at highway on-ramps to approximately 210 miles of freeway in the Twin Cities metropolitan area. These ramp meters control the rate at which vehicles merge onto busy freeways during peak periods. When properly implemented and operated, ramp metering can benefit the freeway system by smoothing the overall flow of traffic, decreasing travel times and increasing safety. The objective of the ramp metering system is to improve mainline conditions while maintaining acceptable ramp queue delays and avoiding backups onto adjacent roadways.

To operate its ramp meters, Mn/DOT uses the Stratified Zone Metering strategy. SZM employs traffic detection stations to subdivide highways into zones based on traffic density. It applies a complex algorithm to prevent traffic inflow from exceeding outflow for each zone, while keeping delays for the drivers waiting on ramps below a predetermined threshold in accordance with Mn/DOT's ramp metering policy. The SZM algorithm needed to be modified to improve its ability to balance the goals of minimizing both freeway congestion and on-ramp delays.

What Was Our Goal?

This project aimed to optimize the effectiveness of the current SZM algorithm for controlling Minnesota ramp meters by refining the parameter regulating the minimum rate at which cars are released onto the highway and improving its methods for estimating vehicle queue length.

What Did We Do?

Researchers first developed strategies for improving the performance of more than 20 existing SZM parameters, including the minimum release rate into the traffic stream and the estimation of entrance ramp vehicle queue lengths. Queue size estimation is critical to determining on-ramp waiting times; any inaccuracies caused by detection errors can lead to significant increases in waiting times or a reduction in mainline traffic flow.

Researchers then tested the effectiveness of these strategies using computer-generated simulations as an alternative to trial-and-error field experimentation. These simulations applied several mathematical models for different levels of traffic volume to site-specific data from two representative sections of the metro area freeway.

After using these simulations to refine the site-specific parameters, researchers performed an analysis of four representative freeway sections to generalize these parameters into a common set of optimum values applicable to the entire Twin Cities metropolitan area. Then they tested the relative effectiveness of existing, new site-specific and optimized common parameters by inserting them into the SZM algorithm. Measures of effectiveness included total freeway mainline delay, total freeway mainline travel time and travel speed.

What Did We Learn?

Results indicate that compared to the existing SZM algorithm, the new SZM strategy significantly improves total system performance. Both the site-specific and optimized

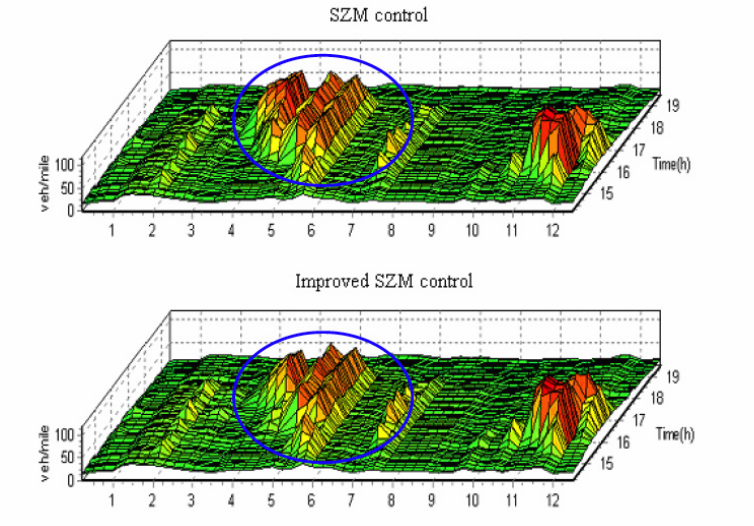
continued

"The optimized Stratified Zone Metering strategy provides more accurate estimates of release rates and queue lengths on entrance ramps than the current system."

–Henry Liu,
Assistant Professor,
University of Minnesota
Department of Civil
Engineering

"Making improvements to the ramp metering system on Twin Cities freeways will reduce travel time, save fuel and improve safety on the mainline while maintaining acceptable delays at the ramp."

–Todd Kramascz,
Operations Supervisor,
Mn/DOT Regional
Transportation
Management Center



Plots of freeway traffic density controlled by existing and improved SZM algorithms show that while bottleneck periods (circled) remain the same, the duration of congestion lessens.

SZM parameters are more effective in postponing or decreasing freeway congestion and improving freeway traffic flow. Total travel time was reduced by nearly 5 percent, and system average speed increased by as much as 5.27 percent. Also improved were the system average total stops, ramp delays, ramp total travel time, energy consumption and pollutant volumes. These improvements are due largely to an increase in the effectiveness of the minimum release rate parameter as a consequence of increased accuracy in queue size estimation.

While the optimized common parameters do not improve the existing SZM algorithm as much as site-specific values, the difference in relative effectiveness is small; both improve upon the current SZM strategy. Most significantly, the optimized parameter strategy is both suitable to the entire Twin Cities metropolitan area and consistent with Mn/DOT's ramp metering policy, which specifies a maximum ramp waiting time of four minutes.

What's Next?

Mn/DOT is postponing a decision on the implementation of the optimized SZM algorithm until it can evaluate the results from research in progress to test the effectiveness of a density-based algorithm for controlling traffic flow. If implemented, the optimized SZM algorithm may be further enhanced through more detailed analysis of individual parameters. There is some concern that implementing the current study's recommendations would make the SZM algorithm more complex, which would make monitoring and analyzing the ramp metering system more difficult.

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This Technical Summary pertains to Reports 2007-13, "Employment of the Traffic Management Lab for the Evaluation and Improvement of Stratified Metering Algorithm—Phase III," and 2007-51, "Employment of the Traffic Management Lab for the Evaluation and Improvement of Stratified Metering Algorithm—Phase IV," published May 2007 and December 2007, respectively. The full reports can be accessed at http://www.lrrb.org/PDF/200713.pdf *and* http://www.lrrb.org/PDF/200751.pdf, *respectively.*