Washington State Transportation Center
RESEARCH REVIEW

New ramp metering algorithm improves system-wide travel time

In its continuing effort to smooth traffic flow, the Washington State Department of Transportation (WSDOT) has sponsored research for several years to improve its algorithm for determining ramp metering rates. The resulting new algorithm has proved so successful that it recently began metering over 100 ramps in the greater Seattle area (Interstates 5, 405, 90, and SR 520).

On-line testing showed that the new algorithm noticeably decreased mainline congestion on I-90 while increasing flow. On I-405, ramp queues decreased significantly while mainline congestion increased only slightly. Overall, the new algorithm appears to reduce total travel time system-wide, with an overall increase in flow in comparison to WSDOT's previous metering algorithms.

The algorithm was developed by Cynthia Taylor, research engineer, and principal investigator Deirdre Meldrum, associate professor, with the University of Washington's Department of Electrical Engineering. It is based on fuzzy logic control, which emphasizes qualitative information over quantitative information. Rather than absolute answers such as *yes/no* or *on/off*, fuzzy logic can handle ambiguities in between. This makes it well-suited for ramp metering in important ways.

Handles data better

Loop detector data are often missing or inaccurate because of communication problems, hardware failures, construction, and poor calibration. For this reason, a ramp metering algorithm that does not require perfect data is highly desirable. Because the new algorithm preprocesses data rather than calculating rates directly from raw data, it is better suited to handle imprecise data.

Balances conflicting objectives

An inherent difficulty with ramp metering is that it is intended to meet two conflicting objectives: reduce mainline congestion by restricting metering rates and reduce the ramp queue by increasing metering rates. WSDOT's previous algorithms often oscillate between these opposing objectives.

These algorithms are prone to oscillation because they are activated by a congestion threshold, which is either on or off. Thus they respond to existing problems rather than preventing them. Unfortunately, once the problem exists, meeting the threshold necessary to activate the algorithm, it is difficult to correct. So the goal for ramp metering is not to wait until mainline congestion and excessive ramp queues occur but to prevent or delay them.

The new algorithm eliminates the time lag between problem detection and corrective action because of important new capabilities. It can consider data not only from the local mainline traffic stream and ramp queues but also from downstream bottlenecks. In addition, it can balance several performance objectives simultaneously. Thus, rather than waiting for on or off threshold activation, the algorithm provides graduated activation for smoother, faster, and more preventive control.

Paul Neel, flow engineer with WSDOT's Traffic Systems Management Center, has witnessed the changes the new algorithm has produced, both in the traffic control room and on the freeways. An example of its usefulness is the Montlake on-ramp for eastbound SR 520, where balancing between mainline congestion and on-ramp backup has always been particularly tricky. Because of various factors, engineers at the TSMC have had to watch the progress at that ramp and manually alter the metering equation as traffic has changed, not always successfully. Now, however, engineers can confidently allow the algorithm to adjust the metering rate automatically, with smoother results. Said Neel, "It is much more responsive to the demands of both freeway and queued traffic."

Works more intuitively

Other reasons the new algorithm is appropriate to ramp metering is that it does not require extensive system modelling and is easy to calibrate. Freeway systems are difficult to model accurately because traffic conditions can change so unpredictably. By using congestion indicators as its controller inputs rather than a system flow model, the new algorithm can expertly handle poor data, incidents, special events, and bad weather without requiring that control parameters be modified.

The ability to calibrate a ramp metering algorithm easily is valuable because performance objectives are not uniform. In some areas, local politics may dictate shorter ramp queues, while in others, freeway flow may be paramount. Traffic patterns can also change with construction, urban growth, and seasons, which may require a new balance of performance objectives. The previous WSDOT algorithms are difficult to calibrate because an operator has to follow a series of adjustments to the metering rate. The new algorithm, on the other hand, mimics the way an operator thinks about ramp metering and is thus easier to understand and calibrate to achieve the desired performance.

Neel said, "It is much more intuitive to tune. When we see a problem we want to adjust, it's easier to know what to change to produce the desired effect."

For further information about WSDOT's new fuzzy logic control ramp metering algorithm, contact Cynthia Taylor at <taylorc@isdl.ee.washington.edu> or Paul Neel at 206-440-4464.

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