Washington State Department of Transportation

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NEW RAMP METERING ALGORITHM IMPROVES SYSTEMWIDE TRAVEL TIME

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In an ongoing effort to smooth traffic flow, the Washington State Department of Transportation (WSDOT) has sponsored research since 1994 to improve its ramp metering algorithm. After lengthy development, careful modeling, and online testing, a new algorithm has proved so successful that WSDOT is using it in the greater Seattle area to meter more than 100 ramps on Interstates 5, 405, and 90, and on State Route 520 (Figure 1).

Problem

Ramp metering improves operations on a freeway by restricting and evenly spacing the traffic volume entering a freeway. Although more advanced than many used around the country, WSDOT's previous ramp metering algorithms still had limitations. First, the data from loop detectors—the in-pavement sensors—were often missing or inaccurate because of communication problems, hardware failures, and poor calibration. The former algorithms calculated metering rate adjustments directly from raw loop-detector volumes and were limited therefore by the accuracy of the mainline volume data.

Second, ramp metering has the inherent difficulty of balancing two conflicting objectives: to reduce mainline congestion by decreasing entry rates and to reduce ramp queues by increasing entry rates. WSDOT's previous algorithms often oscillated between these opposing objectives. As a result, they responded to congestion rather than preventing it—and correcting the congestion was difficult.

Third, freeway systems are difficult to model accurately because traffic conditions can change abruptly or gradually, and a small event can have a large effect. WSDOT's previous algorithms depended on the accuracy of a system-flow model, and flaws in that model hampered the metering.

Finally, the previous WSDOT algorithms were difficult to calibrate. Ease of calibration is important because of variations in the desirable balance between mainline congestion and ramp queue length. In some areas, local politics may dictate shorter ramp queues, but in others, freeway flow may be paramount. Traffic patterns also can change as a result of urban growth, construction, time of year, or other conditions, requiring a new balance of performance objectives.

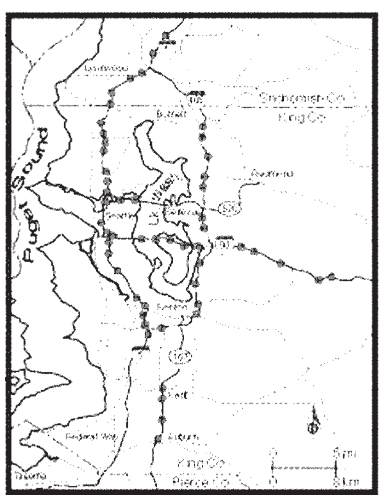

FIGURE 1 Seattle-area sites of ramps metered with fuzzy logic controls.

Solution

To address these problems, researchers at the University of Washington's Department of Electrical Engineering developed a ramp metering algorithm based on "fuzzy logic" control. Fuzzy logic emphasizes qualitative over quantitative information, and inputs and outputs are descriptive (e.g., "no congestion," "light congestion," and "medium congestion"), which is appropriate for imprecise or incomplete information. It also uses rule-based logic to incorporate human expertise; in this way, it can balance several performance objectives simultaneously and consider many types of information, such as traffic conditions downstream. These capabilities allow fuzzy logic to anticipate a problem and take temperate, corrective action before congestion occurs.

Application and Results

The fuzzy logic algorithm (FLA) was tested online within two corridors along I-405 and I-90 for a 4-month period beginning March 1999. The sites were chosen for their recurrent congestion, absence of construction, adequate loop detection, full closed-circuit television (CCTV) coverage, and metered ramps geographically isolated from corridors controlled by a different algorithm. The FLA's performance was compared with that of two previous WSDOT algorithms, dubbed "bottleneck" and "local." The evaluation balanced several objectives at the study sites: to decrease mainline congestion, increase mainline flow, and maintain acceptable ramp queues.

At the I-90 study site, the FLA produced lower mainline congestion than the local algorithm (Figures 2 and 3). The 8.2 percent change in mainline congestion was visible on CCTV. The FLA also prevented significant regular bottlenecks; the local algorithm did not. Overall, the FLA produced a 4.9 percent increase in throughput. With the combination of lower mainline congestion and higher throughput, the FLA controlled the mainline more efficiently than the local algorithm.

However, the effects of the FLA on ramp queues were mixed. Some ramp queues decreased, while others increased slightly. Nonetheless, these ramps had sufficient storage space, and given the mainline benefits, slightly longer ramp queues were acceptable.

The I-405 site, congested for hours each day, offered a more difficult challenge. Test results showed that mainline congestion was 1.2 percent worse with the FLA than with bottleneck metering. Vehicle throughput was nearly identical, with the FLA producing an increase only 0.8 percent more than the bottleneck algorithm. However, the FLA excelled at trimming the I-405 ramp queues, reducing the time each ramp was congested by an average of 26.5 minutes. These shorter ramp queues were politically preferable for I-405, since no acceptable level of metering would have reduced mainline congestion significantly.

Benefits

Limited by the accuracy of loop detectors and complicated by nonuniform traffic conditions, the online test results were mixed. Travel times, diversion to alternative routes, demand, and queue delay could not be measured directly. However, the tests showed that on I-90 the new algorithm decreased mainline congestion noticeably and increased flow. On I-405, the ramp queues decreased significantly but mainline congestion increased only marginally.

In addition to these operational advantages, the FLA was easier to use. With congestion indicators as inputs, the FLA can handle poor data, incidents, special events, and adverse weather without modifying the control parameters. It also mimics the way that operators approach ramp metering, making it easier to understand and calibrate for desired performance.

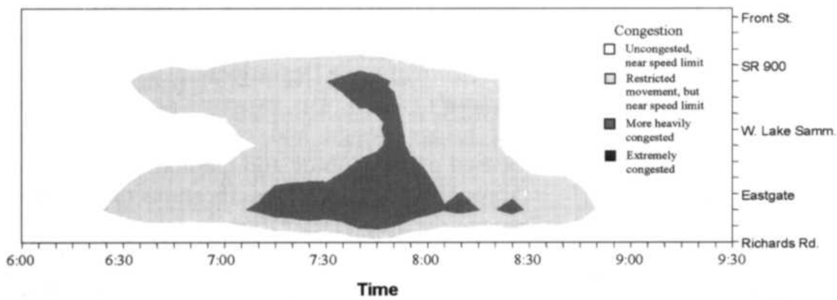

FIGURE 2 Contour map of location and duration of congestion on I-90 during morning peak period with ramps metered using the local algorithm; congestion is heavy from 7:10 to 8:10 a.m.

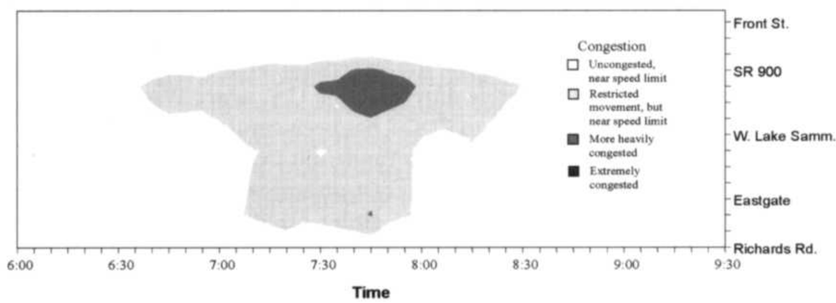

FIGURE 3 Contour map of the effects of fuzzy logic metering on I-90 during morning peak period; congestion is reduced, particularly near the Richards Road and Eastgate on-ramps.

Overall, the FLA appears to reduce total travel time systemwide, increasing flow in comparison with WSDOT's previous metering algorithms. Given these results and the other benefits of the new algorithm, WSDOT is applying the FLA to meter all of the ramps in the greater Seattle area.

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EDITOR'S NOTE: *Appreciation is expressed to B. Ray Derr, Transportation Research Board, for his efforts in developing this article.*

Suggestions for "Research Pays Off" topics are welcome. Contact G. P. Jayaprakash, Transportation Research Board, 2101 Constitution Avenue, NW, Washington, DC 20418 (telephone 202-334-2952, e-mail gjayapra@nas.edu).