RATING RAMPS
EVALUATING PORTLAND, OREGON’S ADAPTIVE RAMP METERING SYSTEM

Although ramp metering is becoming an accepted and popular strategy for reducing congestion, a long-term deployment is needed before the results and benefits of this form of traffic management can be accurately assessed.

Ramp metering is a common traffic management strategy used to control the flow of vehicles joining a freeway. The theory behind the technique is to balance increased ramp delay and mainline performance. As one of the few freeway corridor management tools available, ramp meters are usually implemented to achieve two main goals: to limit the amount of traffic joining a freeway to prevent flows from reaching capacity, and to break up the platoons of vehicles discharged from an upstream arterial traffic signal. Effective ramp metering has the potential to improve traffic flow, traffic safety and air quality. It can reduce congestion and fuel consumption, and manage demand by discouraging short trips.

In the state of Oregon, USA, ramp meters have been in use since the early 1980s, originally deployed along a six-mile stretch of I-5. The implementation combined inductive loop detectors and CCTV cameras with a pretimed metering plan. This strategy was based on limited analysis of historical patterns. Since that time — and with the advances in more robust freeway surveillance, communications and improvements to traffic-responsive metering algorithms — Oregon has transitioned to using the system-wide area ramp metering (SWARM) system as a replacement for the pretimed strategy.

In May 2005, the SWARM system was implemented in stages and is currently operational on all freeway corridors, apart from a small section connecting two main corridors near downtown Portland. SWARM was developed by the National Engineering Technology (NET) Corporation, now known as Delcan, under a contract with the California Department of Transportation (Caltrans). The algorithm was first implemented in Orange County (District 12) and later in Los Angeles and Ventura Counties (District 7) in the late-1990s.

THE STUDY
Optimal ramp metering strategies are often debated, but all involve trade-offs between imposing delay on those vehicles already on the freeway and those attempting to join. The amount of delay that can be imposed on vehicles at on-ramps is often constrained by physical limitations for queue storage.

Early ramp metering systems were designed to cope with typical traffic conditions and unable to incorporate real-time variations in freeway conditions. Consequently, the effectiveness of the fixed-time system deteriorated substantially with large variations in freeway conditions, or when non-recurrent conditions (such as incidents) occurred on freeways.

In conjunction with a team of researchers from the Portland State University ITS Lab, the Oregon Department of Transportation (ODOT) recently conducted an in-depth analysis relating to the impacts of the SWARM implementation in the Portland, Oregon region.

The objective of the research was to compare selected freeway and ramp performance metrics under SWARM versus pretimed operations. To facilitate this comparison, the ramp meters were operated for two consecutive weeks under each configuration. The corridors studied are shown over the page in Figure 1.
"Optimal ramp metering strategies are often debated, but all involve trade-offs between imposing delay on those vehicles already on the freeway and those attempting to enter."

or data quality issues, and these days were subsequently excluded from the study. Weather information, incident logs, and communication error reports were taken from the PORTAL archive.

PERFORMANCE METRICS
Vehicle miles traveled (VMT), vehicle hours traveled (VHT), and delay were selected as the three primary measures of mainline freeway performance. The metrics were then calculated for each 20-second observation with the assumption that each detector station was representative of traffic conditions until the next downstream detector station.

The change in ramp delay is a key performance metric that requires data on both ramp demand (vehicles entering the ramp) and outflow to be computed. Although nearly all of the ramps in the study corridors had detectors placed at the ramp entrance used to capture entering volumes, counts at these detectors were not set up by ODOT to be archived (the detector only serves to inform the local controller of potential queues). Using a programmable logic controller (PLC), input signals from the entering and departing vehicles were collected and aggregated over the peak analysis period. Ramp outflow was contained in the archived data. A combination of the known outflow
combined with the application of simple queuing theory for demand estimates was used to calculate ramp delay.

The final performance metric captured by the study was the ability of the existing communication infrastructure to handle the data-intensive nature of the adaptive metering system. The SWARM algorithm requires consistent and accurate data from the advanced traffic management system (ATMS), as well as the ability to send new commands (metering rates) to the controllers on a frequent basis. In pretimed operation, the ATMS system polled each ramp controller to obtain each 20-second data packet. In normal operations, some of these communication polls failed and were flagged in the archived data. To estimate the overall impact of SWARM on corridor communications, the percentage of 20-second readings missing or corresponding to communication failures for each station was calculated.

Visualization through the use of contour plots was an invaluable tool in the detailed analysis of the study. By constructing plots of the fundamental traffic flow relationships coupled with time-space speed contour plots to determine the spatial extent of congestion — each day could be characterized. Much of the performance information was visually summarized by constructing speed contour plots from the 20-second archived data. Additional information was presented by overlaying the activation and deactivation times of metering. A sample of this plot type is shown in Figure 2.

The plots clearly showed corridor congestion and communication failures — represented as ‘zero’ speed readings where congestion was not likely (in the lower left of the plot region near the Clackamas station from 06.00-10.00h). As an example, the scale of communication failures can be seen rather dramatically in Figure 3, which showed the failures for each station and day in the corridor. It was clear that SWARM operation impacted data quality.

Additional contour plots were constructed to further analyze changes in vehicle hours of delay. Figure 4 was constructed to show the changes in moderately congested average delay under SWARM in the time-space plane. Green colors indicated that SWARM operation resulted in less delay, while red colors revealed the opposite. The figures communicated the spatial and temporal variability in the comparisons; further plots were used to delve into the trends.

**CONCLUSIONS**

The SWARM system in the Portland, Oregon metropolitan region produced mixed results. For one of the corridors (I-205), the results were generally positive. In the morning peak period, SWARM operation resulted in decreased mainline delay and decreased variability in the delay. For the afternoon peak period, improvements were also found with the exception of moderately congested days, which resulted in an increase in mainline delay. On OR-217, however, significant increases were found in overall average delay. Reliability also decreased under SWARM for this corridor.

The contrasting results for SWARM performance between the two freeway corridors can partially be explained by the general differences between the two facilities. OR-217 is a relatively short freeway (seven miles) bounded on both ends by freeway-to-freeway interchanges. The ramp spacing is generally short (0.75 mile average) and the freeway contains numerous auxiliary lane drops and adds. In the afternoon, the unmetered merge with a busy arterial and northbound freeway (I-5) traffic resulted in recurrent congestion. The I-205 freeway corridor is unbounded, has greater ramp spacing (one mile average), and maintains three through lanes. Only one auxiliary lane add/drop is present. Peak period mainline lane flows are generally higher on OR-217 than on I-205.

It was confirmed from the empirical evidence that in all cases evaluated, the SWARM algorithm as configured by ODOT allowed more vehicles to enter the freeway mainline. The higher per lane flows combined with less desirable geometry on OR-217 may explain why higher metering rates produced a significant increase in mainline delay.
IMPROVING RAMP METERING
To improve system operations, tunable SWARM parameters that distribute the volume reduction (or excess if local density is smaller than the required density) to upstream on-ramps based on demand and queue storage of each on-ramp should be evaluated. The conclusions from the study must be tempered due to lack of ramp demand data. If an assumption is made that ramp demand changes correspond with the measured freeway VMT changes, it is likely that ramp delay decreased under SWARM operation (that is, more vehicles were allowed on the freeway, which would equate to lower delay for vehicles on the ramps).

Another important finding was that implementation of the SWARM algorithm resulted in significantly more data communication failures. Although this outcome is specific to the ODOT communication infrastructure and hardware, it was not anticipated. These failures have the potential to impact other traveler information programs that depend on the freeway surveillance data as well as the SWARM algorithm. Following the study, ODOT investigated and implemented measures to improve communications.

Finally, the results of the project have encouraged ongoing evaluation and continuous improvement of the ramp metering system, and in general the overall freeway management system. It is clear from the analysis that meter activation times and rates are necessary to evaluate system performance. Incorporating additional logging capabilities into the SWARM system would make it easier to automatically evaluate the system operations on an ongoing basis. In addition, the freeway surveillance system should be modified to incorporate vehicle counts from the ramp queue loop detectors. If data is appropriately collected, applying simple queuing theory should allow ramp delay to be calculated.

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References

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