Abstract

This project is to evaluate the benefits of the System-Wide Adaptive Ramp Metering (SWARM) system implemented in the Portland Metropolitan area as compared to a pre-timed system. The results presented here are drawn from a two-week pilot study of the southbound Oregon highway 217 corridor in June, 2006. The freeway corridor for the pilot study was carefully selected based on a number of criteria that were developed. For the selected corridor, data quality and on-ramp conditions were further investigated in order to come up with a data collection plan that conformed to our objective given the resources available.

Objectives

The objective of this study was to quantify system-wide benefits in terms of savings in delay, emissions and fuel consumption, and safety improvements on and off the freeway due to the implementation of the SWARM system. The pilot study was part of an effort to develop a strategic design for a future regional-level study.

Background

The freeway system in the Portland metropolitan region serves local commuters, through traffic, and freight trucks from/to the Portland International Airport and the Port of Portland. Starting in 1981, the Oregon Department of Transportation (ODOT) implemented pre-timed ramp metering to manage traffic congestion during the morning and afternoon peak periods.

The SWARM system was first implemented in Southern California and was adapted for use in Portland. It has been implemented in stages since May 2005 and is operating on six of the seven metered freeway corridors.

Results

We found that the VMT exhibited a marginal increase under the SWARM operation. However, the total delay on the freeway increased with SWARM, and empirical evidence suggests that this increase resulted from higher metering rates at most of the on-ramps. These higher metering rates under SWARM resulted in lower travel times on several major on-ramps, indicating a trade-off between increase in freeway delay and lower on-ramp delays. However, whether the increase in the total freeway delay was solely caused by the higher merging rates remains an open question since the bottleneck discharge rate could not be measured from the data. Moreover, delays could not be quantified at all on-ramps due to the limitations on data collection efforts, and hence, it was not feasible to analyze the system-wide trade-offs between the freeway and on-ramp delays.

Next Steps

The lessons learned from the pilot study are being used to design a regional-level study, and the results of this research will assist ODOT in fine-tuning the deployment of the SWARM system and in reporting its benefits to decision-makers and the public.

Acknowledgements

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SWARM Ramp Metering Algorithm

Traffic responsive ramp-metering algorithms such as SWARM determine metering rates and activation/deactivation times in response to real-time freeway conditions along corridors.

SWARM computes metering rates under a local mode with respect to conditions near each ramp and a global mode operating on an entire freeway system, and applies the more restrictive rate. The densities around the bottleneck are forecasted by performing a linear regression on a set of data collected from the immediate past and applying a Kalman filtering process to capture non-linearity. The excess density, the difference between the forecasted density and a threshold density (saturation level at the bottleneck), is converted to the required density to avoid congestion within a forecasting time span (Tcrit).

The corresponding volume reduction (or excess) is distributed to upstream on-ramps within the system according to pre-determined weighting factors.

Freeway Corridor Selection

ORE 217 southbound contains 12 on-ramps, 10 of which are controlled by ramp meters. The ramp-metering system is supported by 36 loop detectors, spaced 0.75 miles apart on average (minimum of 0.31 miles and maximum of 1.23 miles), and nine CCTV cameras. SWARM was implemented on this corridor in early November 2005.

In addition to the selection criteria in the table below, construction schedules and stability of the SWARM system were taken into account.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Notes</th>
</tr>
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<tbody>
<tr>
<td>Level of congestion</td>
<td>Large temporal and spatial extent of congestion</td>
</tr>
<tr>
<td>Spatial extent of queues</td>
<td>Head and tail of a queue isolated within the corridor</td>
</tr>
<tr>
<td>Loop detector spacing</td>
<td>Spacing between loop detectors should be small</td>
</tr>
<tr>
<td>Data quality</td>
<td>Loop detector quality, communication failures</td>
</tr>
<tr>
<td>Corridor length, # on-ramps</td>
<td>Five to ten mile corridor considered manageable</td>
</tr>
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Evaluating the Benefits of a System-Wide Adaptive Ramp-Metering Strategy in Portland, Oregon

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Analysis

Basic performance measures computed from loop detector data from 6 to 9 AM for four days each under pre-timed and SWARM operations:

<table>
<thead>
<tr>
<th></th>
<th>VMT</th>
<th>VHT</th>
<th>Travel-Time</th>
<th>Delay (vehicle-hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-Timed</td>
<td>65,871</td>
<td>1,337</td>
<td>8.8</td>
<td>210</td>
</tr>
<tr>
<td>SWARM</td>
<td>66,426</td>
<td>1,416</td>
<td>9.2</td>
<td>283</td>
</tr>
<tr>
<td>% Change</td>
<td>0.8%</td>
<td>6.0%</td>
<td>5.1%</td>
<td>34.7%</td>
</tr>
</tbody>
</table>

VHT and the average travel-time increased under SWARM, corresponding to an increase in total freeway delay.

Temporal and spatial changes in freeway delay were plotted to help determine the cause of the delay.

The yellow/orange shading on the speed contours below shows the extent of congestion. The darker orange area on the right-hand plot identifies slower speeds under SWARM operation.

In the morning peak period, a recurrent bottleneck is located between Scholls Ferry Rd. and Greenburg Rd., and the resulting queue propagates over 4–5 miles upstream. The bottleneck activates due to large inflow from the on-ramp at Scholls-Ferry Rd.

The cumulative curve for SWARM lies above the one for the pre-timed strategy, and the vertical separation between the two curves increases over time. This indicates that the SWARM strategy admitted consistently higher flows to the freeway.

Most on-ramp flows were slightly larger when SWARM was in operation. The increases in flow (except at Hall Blvd.) were between 3% and 9%.

These moderate increases in flow decreased travel time on the on-ramps. at Beaverton-Hillsdale Highway and Scholls-Ferry Road on-ramps, sampled once every five minutes.

Communication failures experienced under SWARM were much larger, exceeding 10% in some locations.

Communications

The SWARM algorithm requires a large amount of data to compute metering rates and send adjustments to the ramp metering system in real-time. ODOT is completing an upgrade of its data network to remedy the higher rate of communication failures experienced under SWARM operation.