ARIZONA DEPARTMENT OF TRANSPORTATION SR-51 ADAPTIVE RAMP METERING

By: Arizona Department of Transportation and the University of Arizona

IN THIS CASE STUDY YOU WILL LEARN:

1. How adaptive ramp metering can maximize existing freeway infrastructure to save commuters time and money.
2. About the major challenges of reaching the next level of adaptive ramp metering.
3. About the cost, process and rollout of adaptive ramp metering.

BACKGROUND

Many large cities in the U.S. use ramp metering to reduce traffic congestion and increase freeway service levels. Commonly, fixed discharge rate and time of day scenarios for ramp metering are used. An increasing number of regions have upgraded their systems using responsive ramp metering automatically reacting to changing roadway conditions. The major challenges of reaching the next level of innovative, adaptive ramp metering, are the higher costs and the difficulty of documenting its effectiveness in a timely manner. Improving mobility on freeways is one of the major goals of the Arizona DOT (ADOT). ADOT's Transportation Systems Management and Operations (TSMO) Division developed an innovative adaptive ramp metering strategy area. The developed strategy includes two parts:

1) **an adaptive ramp metering algorithm, named "MaxFlow," which was developed in-house by ITS engineers in TSMO** and

2) **a real-time ramp metering evaluation tool developed by the University of Arizona (UA).**

These two parts combine to form an innovative and cost-effective adaptive ramp metering solution that maximizes the existing freeway infrastructure to save Phoenix area commuters time and money.

TSMO PLANNING, STRATEGIES AND DEPLOYMENT

ADOT's TSMO engineering staff developed the adaptive ramp metering algorithm, MaxFlow, which is based on the idea that freeway capacity is lowest or becomes constrained where vehicles enter the freeway from the on-ramp. By controlling the number of vehicles entering the freeway from the on-ramps, the freeway is kept under capacity as traffic increases, thus maximizing the output of the freeway segment/corridor. While a responsive ramp metering system is limited to a local view of this approach, the adaptive system looks at both upstream and downstream freeway segments and adjusts the ramp metering rate in order to utilize the freeway on-ramp storage, which leads to a higher flow rate of the segment or corridor. The system in turn balances the storage on the ramps, for example, if the traffic demand of a ramp surpasses its storage capacity, the ramp metering rate will be increased, but at the same time the system will decrease upstream ramp metering rates that have excess storage capacity. MaxFlow uses coding functionality within existing controllers to create a virtual detector based on local right lane conditions and ramp flows compared to the downstream conditions. The standard metering rate table used for responsive metering in the ramp metering controller is then used with this virtual detector to control ramp flow rates. Therefore, each ramp can be metered according to both local and upstream/downstream conditions on a real-time basis without the need for additional hardware or software.

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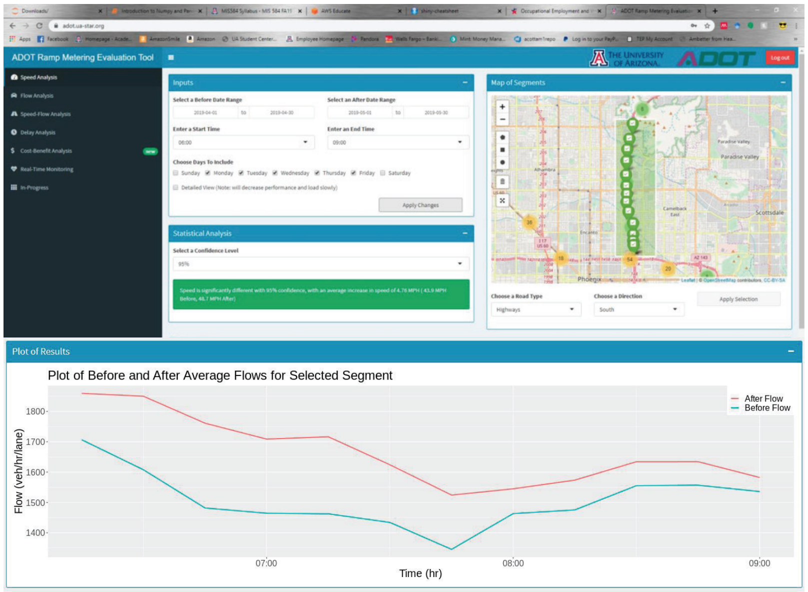

The Ramp Metering Evaluation Tool (RMET) was developed to evaluate and quantify the performance improvements of ADOT's MaxFlow ramp metering algorithm used along SR-51. The UA's Smart Transportation Lab developed software to collect, pre-process, and archive data from three sources: INRIX, cabinet event-based data, and loop detector data. These three data sources were used to provide various performance metrics via RMET. RMET was developed as a web-based visualization platform built with the open-source language R. It provides before and after comparisons of speed, flow, capacity, delay, and delay cost, as well as showing real-time values for system fine tuning. For the speed and flow before and after comparisons, statistical methods were used to quantify changes, and to determine whether the change was a result of random noise, or if it was a statistically significant change. RMET is capable of conducting a series of analyses for multiple locations. This tool can also be used for highways and arterials throughout Arizona for speed data analysis. The figure below shows the RMET dashboard used for quick and user-friendly analysis of specified roadway segments and time intervals.

COMMUNICATIONS PLANNING AND EXECUTION

The success of this project relied upon the commitment of both ADOT and UA to innovate and develop a breakthrough tool that will allow ADOT to optimize the performance of their transportation system. As the algorithm was being developed by ADOT staff, the UA research team requested input and feedback through bi-weekly meetings to ensure that the RMET tool would meet ADOT's expectations and would be capable of evaluating the effectiveness of the MaxFlow algorithm. The UA research team worked onsite to help ADOT's TSMO staff tune up RMET to meet project specific needs, and the team held quarterly meetings with the TSMO division leadership to ensure the project stayed on track and had no overlapping effects with other initiatives.

OUTCOMES, BENEFITS, AND LEARNINGS

The final product from the team was the implementation of the MaxFlow algorithm along SR-51, and the development of RMET to evaluate the improvement yielded by the implementation of an adaptive ramp metering system. RMET looked at speeds during weekdays in the month before and after deployment of MaxFlow to determine its effectiveness. The results showed that the speed increased considerably at a significance level of 95 percent, with an average increase of over 4.8 mph during morning peak hours (6:00 a.m. to 9:00 a.m.) when the ramp metering was active. The graph to the left shows the change in median speeds for the before and after periods along the selected corridor. Furthermore, as seen to the left, a before and after flow rate comparison was conducted using RMET for the same time periods as the speed comparison. The average increase during the morning peak hours was 152 vehicles per hour, per lane.

The RMET tool is able to quantify the benefit of MaxFlow implementation by estimating the average delay and the average delay cost in a before and after comparison. It was found that on average, the delay cost before MaxFlow was implemented was approximately $10,946 per weekday, whereas the after delay cost was approximately $6,474 per weekday during the morning peak hours. The costs were estimated with the value of an hour of delay being the average wage for Phoenix, $24.29 per hour, as reported by the Bureau of Labor Statistics (U.S. Bureau of Labor Statistics, 2018). These weekday savings will amount to approximately a million dollars in savings for the morning peak hours under the assumption that the conditions stay relatively constant throughout a year (at least one year of data will need to be collected in order to begin assessing the seasonal variance in the traffic demand).

The positive outcome of this project was achieved through the collaboration and innovation between ADOT and the UA, enabling the development of a revolutionary strategy integrating an innovative adaptive ramp metering algorithm with a real-time ramp metering evaluation tool to optimize the performance along SR-51. The strategy has proven to be a cost-effective solution and was deployed for pennies on the dollar when compared to a consultant proposed adaptive ramp metering system on this same segment. The total cost to ADOT, not including staff time, was just over $200K and this included the contract cost to the UA for RMET.

FURTHER INFORMATION

NOCoE Knowledge Center: https://transportationops.org/knowledge-center