Wisconsin Ramp Metering Operations and Implementation

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ABSTRACT

With the objective of improving wise deployment and efficient operations of ramp meters, the Wisconsin Department of Transportation (WisDOT) has undertaken a comprehensive evaluation project comprising several elements.

Already completed components include two evaluations of metering impacts on major corridors in the Milwaukee metropolitan area and on the freeway beltline in Madison. A third component was an evaluation of the timing and retiming strategy used by WisDOT. The most recently completed component is the *Statewide Ramp Metering and Control Plan*, which emphasizes applying consistent implementation criteria for potential installations.

WisDOT reviewed algorithms and metering practices used throughout the country. Each algorithm was evaluated against its benefits, relative costs, and concerns related to implementation and operation. Discussions were held with selected states, to aid in understanding other states' experiences with ramp metering algorithms. This effort has resulted in valuable insight into the widely varied practice of ramp metering nationwide.

Tasks currently underway include a revisit of metering benefits for existing deployments and the Statewide Freeway Surveillance and Ramp Control sketch planning activity, which is one component of the broader sketch planning project for statewide traffic operations. Preliminary results of a prototype implementation planning tool should be available late 2007.

Lastly, with a focus on improving metering operations in Wisconsin, WisDOT is utilizing microsimulation models, as well as simpler techniques, to improve their existing ramp meter algorithm. The initial effort is applied to five metering locations in Milwaukee and Madison to determine whether more optimal plans are achievable for low cost.

Key words: algorithm—meter—operations—ramp—Wisconsin

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INTRODUCTION

Ramp metering is a critical component of Wisconsin's intelligent transportation systems (ITS) program, which applies advanced technologies for traffic management and traveler information. Ramp metering has been relied upon in Wisconsin since 1969 and there are now over 120 meters in operation in Milwaukee and Madison.

Ramp meters are traffic signals on freeway entrance ramps that break up clusters of vehicles entering the freeway. Doing this reduces disruptions that clusters cause to freeway flow and improves merging safety. The *2005 Urban Mobility Report* estimated that there were 938,000 hours of delay saved in 2003 alone through the use of ramp meters in Milwaukee (TTI 2005). Furthermore, ramp metering evaluations have been completed in Wisconsin for the US-45 corridor in the Milwaukee area and also for the beltline freeway in Madison.

The benefits of ramp metering are well established in the literature, but much work remains in the area of operations, especially in an environment of substantial fiscal constraints and political pressure. The Wisconsin Department of Transportation (WisDOT) is confronted with competing pressures to deploy additional meters where they may or may not be warranted, to improve operations at existing meters or decommission them, and to maintain the ongoing ramp metering and broader ITS program without additional funding or staffing.

With the objective of improving wise deployment and exploring more efficient operations, WisDOT has undertaken a comprehensive ramp metering evaluation project, comprising several elements. This paper briefly summarizes the parts already completed and their key findings, describes ongoing and upcoming efforts, and discusses results, benefits, and next steps.

Components of this project that are already completed include deployment evaluations from Milwaukee and Madison, an evaluation of the timing/retiming procedure, a survey of practices nationwide, including interviews with selected system operators, and a statewide ramp control plan. Components that are underway include the Statewide Freeway Surveillance and Ramp Control sketch planning project, a revisit of the benefits of existing meter installations, a forthcoming evaluation of key metering locations utilizing microsimulation, and ongoing project-related ramp metering considerations throughout the five WisDOT regions.

Given the prohibitive time and expense needed to implement an entirely new algorithm in Wisconsin, the objective of the latter phase of this project is to increase economic efficiency through an exploration of opportunities to streamline deployment decisions and improve operations through low-cost modifications. The results of the research will collectively lead to a more reliable and consistent methodology for new ramp metering deployments throughout the state and for more efficient operations of meters, whether a new algorithm is implemented or not.

BACKGROUND AND RECENTLY COMPLETED RESEARCH COMPONENTS

In this section, three recently completed evaluations are discussed. The first is a before and after evaluation of a deployment in 2000 of additional meters on the US-45 corridor in Milwaukee. The second evaluation is from the beltline freeway in Madison, and third is an evaluation of the current retiming practice used by WisDOT.

The other recently completed task is a survey of practices and algorithms used around the country. This work included several interviews with ramp meter operators in other states and an initial pass at whether other strategies may be applied in Wisconsin for low cost.

Recently Completed Evaluations

The documents for the three evaluations discussed in this section are available on the Sketch Planning Workgroup page: http://www.topslab.wisc.edu/workgroups/sketchplanning.htm#ramp. The Sketch Planning project is further discussed later in this document.

Ramp Metering on US-45 in Milwaukee

Roughly 15 miles of southbound US-45 entering the Milwaukee metropolitan area is metered (Figure 1). In early 2000, seven ramps were furnished with meters. This was in addition to the six currently metered southbound on-ramps. WisDOT pursued a before and after evaluation of this installation. The report on this evaluation, *Evaluation of Ramp Meter Effectiveness for Wisconsin Freeways, A Milwaukee Case Study*, was published in October 2004.

The study was completed jointly by personnel at Marquette University and the University of Wisconsin, Milwaukee (2005a), and it covered several facets of operations and safety effects of ramp metering. The final report includes discussion of the following:

- Traffic diversion, primarily spatial diversion because of little evidence of modal or temporal diversion, utilizing cutlines crossing two parallel arterials. The data collected included 18 hours of operation during the before condition and 18 hours during the after condition.
- Origin-destination trip length changes based on license plate video survey. However, the original data was not available to the project team. Without knowing the sample size, collection times, or capture rate, meaningful conclusions are difficult to draw.
- Potential modeling approaches to evaluating ramp meter effects, including microscopic, mesoscopic, and macroscopic approaches.
- Traffic operations effects, including speeds and delays.
- Safety effects.

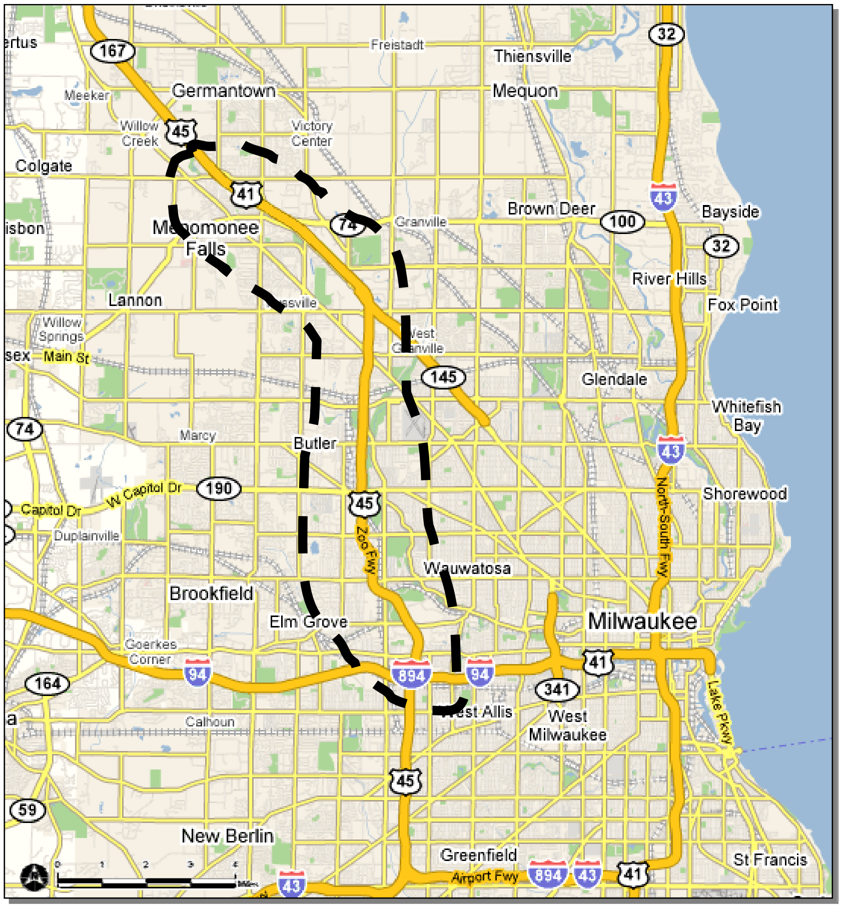

Figure 1. US-45 location map

The “with ramp metering” data collection for the diversion evaluation began three weeks after the additional meters were activated. Evidence from the Twin Cities ramp meter shutdown indicates that even eight weeks may not be sufficient to reach equilibrium after a system shock, although that was a larger change to the system (Mn/DOT 2001). Furthermore, only 18 hours of data were evaluated in each condition. With historical loop data readily available via the recently developed WisTransPortal transportation data hub, additional data will be incorporated and a validation of these results completed.

Among the key findings were increased mainline speeds and reduced crashes. Overall, vehicle hours of travel decreased by 2% following meter installation. It is noted in the report that much of the corridor was not congested during the evaluation times, so as traffic volumes continue to grow, this travel time savings is expected to grow. The existing meters were primarily deployed in the southern, more congested portion of the corridor.

A stated preference survey indicated that drivers would respond to delays at metered ramps. Where traffic volumes were heaviest or ramp queues longest, a significant number of drivers would divert their travel away from the freeway or from a specific ramp. If a metered ramp had waiting vehicles, 82% of surveyed drivers said they would take an alternate route.

Following meter deployment, an origin-destination survey indicated that drivers may be less likely to use the freeway for very short trips, which would cause less entering and exiting and less disruption to traffic flow. However, the original data from origin-destination license plate video survey was not available to the project team. Without knowing the sample size, collection times, or capture rate, any conclusions drawn from that information may not be reliable.

Travel speeds in the most congested south portion of the corridor increased by as much as 13% during the afternoon peak period. The average speed on the entire southbound US-45 section evaluated increased by 4% during the afternoon peak. New ramp meter operation, in conjunction with relatively minor geometric improvements in ramp merging areas and mainline resurfacing, resulted in a 21% crash rate reduction.

Ramp Metering on Madison Beltline

In July 2001, WisDOT implemented ramp metering along the US-12/18 Beltline freeway in Dane County. The evaluation analyzed the impact of ramp metering on the Madison Beltline from five metering locations, including qualitative and quantitative impacts such as travel time, traffic flow, safety, public perception, and air quality. The report was published in January 2005.

The findings showed a crash reduction. While the entire Beltline from Stoughton Road to Old Sauk experienced a 57% reduction in crashes, the area identified as the eastbound ramp meter influence zone near Whitney Way experienced an even greater reduction in crashes during metered and non-metered periods: 86% for both periods. The westbound ramp meter influence zone near Park Street and Fish Hatchery Road showed a 50% reduction in crashes during metered time periods and an overall reduction of 27%.

Ramp metering improved WisDOT’s ability to mitigate effects of traffic incidents. About 96% of public safety agency representatives surveyed for the study found the time to clear crashes has improved because of the introduction of ramp meters along the Beltline, while approximately 64% of the agency respondents found that the time to respond to accidents has improved with ramp metering.

Despite significant growth in traffic volumes, travel times increased only slightly during three of the four metering periods, with a slight reduction in the westbound a.m. metering period. Three out of the four travel periods experienced a lower variability in travel speeds, which translates to improved travel time reliability, an increasingly prominent economic consideration. During the westbound morning peak period, the variation of travel times was reduced from +/- 10.9 seconds down to +/- 3.8 seconds after ramp metering.

Although the Madison Beltline has relatively few alternative routes, results from the ramp counts indicate that motorists at some locations are seeking alternative routes to avoid congested ramps.

Evaluation of Ramp Meter Retiming Procedure

Many ramp meters were added to the Milwaukee freeway system in the 1990s. After initial adjustments, many of these meters were not retimed for several years. By early 2000s, a standard retiming approach was developed, and in 2003 and 2004, all meters were retimed and based on this approach as well as feedback from operators. The need to balance quality freeway operations with the negative effects of ramp queue spillback was paramount.

A December 2005 report (UW Madison 2005b) documented a review of retiming process developed in southeast Wisconsin and evaluation of whether the process is effective in minimizing delay and crashes in the southeast Wisconsin freeway system. After the 2003–2004 retiming, no significant change in traffic flow was observed. Surveyed operators generally agreed with the approach of the retiming procedure, but field observations and adjustments based on experience are necessary. This is consistent with traffic signal retiming practice.

The evaluation recommended four key improvements. First, there needs to be a better understanding and accommodation of temporal variations in traffic flow and its effect on ramp meter timing. Second, although resource-intensive, simulation may provide valuable insight into alternative timing plans. Third, WisDOT operates their meters as local-responsive only (not systemwide), but relative to other states, meter operation is “quite sophisticated.” And fourth, there remains a longer-term need to move forward with systemwide or corridor-based algorithms.

National Experience

According to the Federal Highway Administration, evaluations from across the country show that ramp metering reduces collisions on freeways and ramps from 15 to 50%. Ramp management strategies often increase travel speeds while reducing travel time and delay. Freeways that have metered entrance ramps usually carry more traffic than they did before metering began while attaining the improvements mentioned previously. Table 1 below provides a brief summary of common measures of effectiveness for ramp metering in other places.

Table 1. National ramp meter benefits (WisDOT 2006)

City	Study road	Speed increase	Travel time reduction	Crash reduction	Flow increase	Program initiation
Minneapolis	I-35	26%	-	- 27%	25%	1970
Portland	I-5	61%	12 min	- 43%	-	1981
Seattle	I-5		11.5 min	- 39%	62%-86%	1981
Long Island	Multiple	9%	-	- 15%	2%	1989
Detroit	I-94	8%	-	-50%	14%	1982
Austin	I-35	60%	-	-	7.9%	Late 1970s
San Francisco	I-80	-	- 1 min	-	14%	1974
Denver	I-25	57%	37%	-5%	-	1981
Milwaukee	US-45	6%–13%	5%	-16%	-	1969

Nationwide Ramp Meter Algorithms

In late 2006, WisDOT reviewed many ramp metering algorithms used throughout the country. Each algorithm was evaluated against its benefits, relative costs, and concerns related to implementation and operation. Furthermore, discussions were held with selected states, including Oregon, Colorado, and New York, to aid in understanding other states’ experiences with ramp metering algorithms. This effort has resulted in valuable insight into the widely varied practice of ramp metering nationwide.

Below is a list of many diverse ramp meter algorithms (Scariza 2003; Zhang et al. 2001). Traffic-responsive ramp meters use local and/or coordinated ramp meter algorithms. This is an abbreviated and descriptive list that includes neither interview material nor the initial assessment of feasibility and benefits.

Local Ramp Meter Algorithms

Local control is a process of selecting ramp meter rates based solely on conditions present at an individual ramp. In some cases, congestion problems at the ramp may appear to be fixed, when in reality problems are transferred to or uncovered at upstream or downstream locations.

- **ALINEA.** The control input is based on the system output. The goal of ALINEA is to sustain near maximum flow downstream of the on-ramp by regulating the downstream occupancy to a target value, which is set a little below the critical occupancy at which congestion first appears.
- **ALINEA/Q**. This algorithm calculates two metering rates. The first rate is calculated exactly the same as ALINEA. The second rate that is calculated is the minimum rate needed to keep the ramp queue at or below the maximum allowable queue length.
- **FL-ALINEA**. FL-ALINEA uses flow measurements from downstream detectors rather than occupancy measurements.
- **MALINEA**. MALINEA addresses a shortcoming of ALINEA by measuring the upstream occupancy.
- **UF-ALINEA**. It simply uses the sum of the upstream flow and the ramp flow to estimate the downstream flow.
- **UP-ALINEA**. Uses occupancy measurements, but from upstream detectors, and estimates the downstream occupancy.
- **X-ALINEA/Q.** This is where any of the modified ALINEA algorithms are used with queue control. All of these algorithms, except for X-ALINEA/Q are less efficient than the traditional ALINEA algorithm but are useful when various occupancy measurements are not available.
- **Demand-Capacity**. This traffic responsive algorithm measures the downstream occupancy. If it is above the critical occupancy, congestion is assumed to exist. The metering rate is then set to the min rate. Otherwise, the volume is measured upstream of the merge, and the metering rate is set to the difference between the downstream capacity and the upstream volume.
- **Fixed-Rate or Time-of-Day**. Ramp meter timings are adjusted automatically by specified time-of-day parameters. This algorithm does not afford flexibility for changing traffic conditions.
- **Percent-Occupancy.** This strategy uses only upstream sensor occupancy measurements to identify and measure congestion. The critical occupancy is measured using historical data.
- **RPMS (Ramp Metering Pilot Scheme).** The heart of the algorithm is the function that cycles through each of the following conditions: determines if ramp metering needs to be switched on or off using mainline smoothed flows and speeds downstream of the ramp, determine if a new cycle length needs to be calculated, determine if queue adjustment is necessary, and determine the technical issues related to the ramp meter signals.

Systemwide Coordinated Ramp Meter Algorithms

This is a process of selecting metering rates based on conditions throughout the entire length of the metered corridor. This makes systemwide control more flexible in handling reductions in capacity that occur as a result of congestion or non-recurring incidents.

- **ARMS (Advanced Real-time Metering System)**. ARMS works on two levels. In the first level, a systemwide control policy is to maintain free flow conditions. A prediction and pattern recognition algorithm is also developed to predict in real-time the potential occurrence of recurrent congestion. In the second level, the algorithm works to resolve congestion once it develops. It does this by minimizing the congestion clearance time and queues on the controlled ramps.

- **BEEX (Balanced Efficiency and Equity).** BEEX seeks to minimize the total weighted travel time, which involves weighting both the freeway mainline travel time and the ramp delays.
- **Fuzzy Logic.** It can balance several performance objectives simultaneously, such as occupancy, flow rate, speed, and ramp queue. The performance objectives are divided into finite categories and then rules are developed with different weighting factors to relate traffic conditions with metering levels. Fuzzy logic can anticipate a problem and take temperate, corrective action before congestion occurs. With congestion indicators as inputs, the Fuzzy Logic can handle poor data, incidents, special events, and adverse weather without modifying the control parameters.
- **Linear.** The linear algorithm maximizes the weighted sum of ramp flows. It also computes a real-time capacity for each road segment. The drawbacks of this algorithm are (1) its performance is heavily dependent on accurate origin-destination data, and (2) it is static, i.e., it neglects the variation of travel time in its computation of ramp metering rates.
- **METALINE**. The metering rate of each ramp is computed based on the change in measured occupancy of each freeway segment under METALINE control and the deviation of occupancy from critical occupancy for each segment that has a controlled on-ramp.
- **Metering model for non-recurrent congestion**. It has a dynamic traffic flow model to describe the traffic flow process, explicitly links control with a clear set of objectives, takes into account systemwide physical and environmental constraints and projected traffic conditions, and uses a rigorous yet straightforward solution procedure to obtain real-time metering rates.
- **MILOS (Multi-Objective, Integrated, Large-Scale, & Optimized System)**. The areawide coordinator assigns target ramp metering rates to maximize freeway throughput, balance ramp queue growth rates, and minimize queue spill-back into the adjacent surface street interchanges.
- **SZM (Stratified Zone Metering)**. Effective in reducing ramp delays and queues, reducing freeway travel time and delay, increasing freeway speed, smoothing freeway flow, as well as reducing the number of stops.

Local and Systemwide Coordinated Ramp Meter Algorithms

The following algorithms have both local and coordinated capabilities.

- **Bottleneck.** For each ramp, the more restrictive of the two rates is chosen. <u>Local</u>: A control strategy compares the upstream demand with the downstream supply, then takes the difference of them as the locally determined metering rate. <u>Systemwide</u>: A coordinated control strategy first identifies bottlenecks, decides the volume reduction for the bottleneck based on flow conservation, and then distributes the volume reduction to upstream ramps according to predetermined weights.
- **Compass**. The most restrictive of the following two rates is selected. <u>Local</u>: Determines the metering rates from an ad-hoc lookup table, which has multiple levels for each ramp, determined by the local mainline occupancy, the downstream mainline occupancy, and the upstream mainline volume. <u>Systemwide</u>: Coordinated control use of off-line optimization to generate metering rates based on systemwide information. Compass addresses spillback through overriding restrictive rates. If the occupancy at a ramp queue detector exceeds its threshold value, the metering rate is increased by one rate level until the detected occupancy is back below the threshold level.
- **Dynamic metering control**. Local control attempts to maintain traffic conditions close to the target traffic conditions that are provided by area-wide control. It obtains metering rates through minimizing the total system travel time that includes travel time on freeway and delay on ramps, subject to demand and queue capacity constraints.
- **FLOW**. FLOW tries to keep traffic at a predefined bottleneck below capacity and works best at very high traffic volumes. The most restrictive of the following two rates is chosen. <u>Local</u>: The

metering rate associated with each upstream occupancy is the difference between the capacity and volume associated with the occupancy on the fundamental diagram. Systemwide: For the bottleneck metering rate, bottleneck locations on the freeway must be determined. The bottleneck metering rate for each ramp is then calculated by subtracting the bottleneck metering rate reduction from the measured on-ramp flow during the previous interval.

- **Helper (or incremental)**. A freeway corridor is divided into six groups consisting of one to seven ramps per group. Local: In the local traffic responsive metering component, each meter selects one of six available metering rates based on localized upstream mainline occupancy. Systemwide: If a ramp grows a long queue and is classified as critical, its metering burden will be sequentially distributed to its upstream ramps.
- **Linked**. Local: It is separated into a number of local traffic responsive controllers. This algorithm is based on the demand-capacity concept, and the local metering rate is determined based on upstream flow measurement at each location where the metering rate is equal to the target flow rate minus the upstream flow rate. Systemwide: Whenever a ramp's metering rate is in one of its lowest three metering rates, then the upstream ramp is required to meter in the same rate or less, and, if necessary, the further upstream ramps are also required to do so.
- **Neural Control**. Local: This algorithm uses feedback regulation to maintain a desired level of occupancy, or the target occupancy, which is usually chosen to be the critical occupancy. Moreover, the neural control algorithm is limited in adaptive control if on-line tuning is not implemented. Systemwide: This uses artificial neural networks to learn and memorize the metering plans generated by a traffic simulation model and a ramp control expert system.
- **RAMBO (Ramp Adaptive Metering Bottleneck Optimization)**. Local: RAMBO I evaluates plans generated based on ramp metering specifications. Systemwide: RAMBO II evaluates ramp metering rates based on forecasted traffic conditions along an extended section of freeway containing up to 12 metered on-ramps and 12 exit ramps. RAMBO II develops ramp metering rates using capacity and merge constraints for the entire freeway segment specified by the user.
- **SWARM (System Wide Adaptive Ramp Metering)**. SWARM has to stay within a TOD max and min range. The most restrictive rate is selected for each ramp. Local: The local control decides ramp metering rates based on local density. Systemwide: When a bottleneck is detected, a new set of ramp metering rates are determined. Downstream ramp meters will be shut off and upstream ramp meters will have a more restrictive timing. SWARM has the potential to be proactive, rather than reactive. It has a built-in failure management module to clean faulty input data from detectors. It also allows further adjustment to accommodate queue spill-back handling. It automatically adjusts timing for incidents and holidays.
- **ZONE**. Local: Zone provides for local control by using the occupancy control philosophy. Systemwide: ZONE divides a freeway into several zones of three to six miles in length. The upstream end of a zone is a free-flow area, whereas downstream end of a zone is a critical bottleneck. ZONE calculates metering rates based on volume control in each zone. To accomplish this, ZONE relies on proper division of zones, accurate estimates of bottleneck capacity, and accurate measurements of all in- and out-flows from a zone.

STATEWIDE RAMP METERING INITIATIVES

With the need to consider new ramp meter deployments around the state on an equal basis, WisDOT is developing high-level screening procedures. These new deployments must be evaluated on an equal basis not only with competing ramp meters around the state but also with other capacity improvements and other ITS strategies. There are two current components to this effort: the Statewide Ramp Control Plan and the Sketch Planning activity.

Wisconsin Statewide Ramp Control Plan

This effort laid the groundwork for an institutional and procedural plan for integrating the implementation criteria for ramp control strategies into statewide planning and programming processes. This project encompassed not only ramp meters but also ramp control gates. The focus was on implementation guidelines or warrants, and this part concluded with the issuance of a report *Statewide Ramp Metering and Control Plan* in July 2006 (WisDOT 2006).

The study cautioned that it is not appropriate to make final implementation decisions based on a high-level scan and that metering success is highly dependent on local conditions. The report presents a methodology for deployment considerations that could be applied statewide with minimal data input. This was key because of the limited resources available for additional data collection. The methodology was incorporated into a spreadsheet tool, the Wisconsin Ramp Analysis Tool, and piloted on select corridors.

Wisconsin Statewide Freeway Surveillance and Ramp Control Sketch Planning

Currently underway is the Statewide Freeway Surveillance and Ramp Control sketch planning activity, which is one component of the broader sketch planning project for statewide traffic operations. The other two components are traveler warning / information systems and traffic signal systems.

Each component will apply the overarching corridor planning methodology across the state to identify potential areas or corridors that may benefit from various ITS deployments. The second application will aid in prioritizing deployments subject to the considerable financial constraints facing the state. The criteria are based on readily accessible data such as traffic volumes, heavy vehicle volumes, forecast growth, and crash history.

Preliminary results of a prototype implementation planning tool should be available later in 2007. More information is available on the Sketch Planning workgroup page: http://www.topslab.wisc.edu/workgroups/sketchplanning.htm.

RAMP METERING OPERATIONAL EVALUATION

The current ramp metering evaluation project focuses on two aspects of ramp metering in Wisconsin. First is an across the board evaluation of before and after traffic flow and safety for each metering installation. This builds in part on the previous evaluations already completed on corridors in Milwaukee and Madison. The operations and safety data availability has been tremendously enhanced since those studies through the development of the WisTransPortal, a transportation data hub containing all loop detector data, crash data, and other information from the last ten years or more. See http://transportal.cee.wisc.edu for more information on this resource.

The second aspect is an in-depth look at low-cost alternatives for improving metering operations. WisDOT currently utilizes a time of day local ramp metering algorithm, and there has never been a comprehensive study of the effectiveness of this ramp metering algorithm in Wisconsin and whether or not the algorithm could be improved.

The existing ramp meter algorithm will be modeled at each of five locations, along with different ramp metering timing schemes to determine whether more optimal plans are achievable for low cost. Simple examples of possible improvements include modifying the volume to capacity thresholds currently in use and gradual quickening of the metering rate at the end of the metering time period so that the residual queue does not flood the freeway all at once.

It is expected that the results of this evaluation will lead to more efficient operations of meters utilizing the existing algorithm or a low-cost modification of it.

The five proposed ramp metering locations for evaluation include the following, which are intended to provide a meaningful cross section of operating conditions.

1. I-894 Northbound Corridor, Milwaukee. This corridor has five ramp meters and is delayed in both the AM and PM peak periods. This series of ramps will provide an opportunity to explore corridor-based metering operations.
2. I-94 Westbound at Moorland Road, Milwaukee. This ramp has very high volumes that back up onto Moorland Road during the afternoon peak, and the mainline volumes are relatively high.
3. I-94 Eastbound at 35th Street, Milwaukee. This ramp enters into a very dense central business district and has insufficient storage.
4. I-894/43 Westbound at 60th Street, Milwaukee. This meter has relatively sufficient storage with minimal delays on the mainline downstream.
5. US-12/14 Eastbound at Whitney Way, Madison. This location has both high ramp and mainline volumes, and the ramp has insufficient storage.

All controllers in use in these locations are type 170 except in Madison; it is a type 2070.

CONCLUDING REMARKS

This paper intentionally covers a broad spectrum of ramp metering issues and activity in Wisconsin. This was done in part because of the parallel needs for a synthesis of recent evaluation work, to draw together the statewide deployment planning efforts and to reiterate the emerging policy implications.

With increasingly scarce operating funding comes an increasing need to carefully and economically justify new ramp metering installations. Furthermore, with perennial political and public pressure to reconsider existing installations and their operations, the state is compelled to revisit the justification for ramp metering. Fortunately, the disparate needs for greater scrutiny point to the same three-fold solution: developing a defensible strategy for identifying and prioritizing ramp metering deployments statewide, revisiting the operations and safety benefits of recent installations, and evaluating low-cost yet effective ways to improve metering operations.

Related to that last part, the recommendations from preceding research and evaluations invariably include the need for further in-depth analysis of metering operations, utilizing microsimulation. The current objectives of the remaining research include finding and applying those solutions that will lead to improved metering operations.

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