

Performance Evaluation of Adaptive Ramp Metering Algorithms (ATMS TESTBED PHASE III FINAL REPORT)

Why was this Research Undertaken?

Adaptive ramp metering has undergone significant theoretical developments in recent years. However, the applicability and potential effectiveness of such algorithms depend on a number of complex factors that are best investigated during a planning phase prior to any decision on its implementation. A field operational test is one way to evaluate metering operation. The method can provide the ultimate fair evaluation of the actual performance of a ramp metering system as applied in the real world, but they are usually very expensive and time-consuming to conduct. Moreover, without prior testing, such tests have the potential to adversely impact traffic conditions, and such uncontrollable factors as incidents or variations of demand patterns often make it difficult to fairly compare algorithms or even before-after results. As an alternative, this project studied a microscopic simulation based evaluation method.

For more in depth discussion and technical analysis, refer to [TTR3-14 \(Testbed Technical Report\)](#).

What was done?

Three well-known adaptive ramp-metering algorithms, ALINEA, BOTTLENECK and ZONE were selected for evaluation. ALINEA is a local feedback control algorithm and the other two are area-wide coordinated algorithms. Paramics was adopted as the simulation platform for further evaluation of these metering algorithms. Several Paramics plugin modules, including loop detector data aggregation (used for on-line data collection), ramp metering control (used to mimic ramp signal operations), and ramp metering algorithms (metering logic implementations of ALINEA, BOTTLENECK and ZONE), were developed to build a simulation based ramp metering evaluation framework. The evaluation was then conducted over a stretch of the I-405 freeway in California. The performances of these metering algorithms were compared with respect to different demand patterns under both recurrent congestion and incident scenarios.

As an alternative to the difficult task of fine-tuning them in real-world testing, a hybrid Genetic

Algorithms (GA) simulation method was developed to optimize four operational parameters of a particularly effective algorithm, ALINEA, including the update cycle of the metering rate, a constant regulator, the location and the desired occupancy of the downstream detector station. In the hybrid method, GA-simulation was used for parameter optimization, and micro-simulation (i.e. Paramics) was used for performance evaluation. The objective of the study was to achieve system optimum for all metering freeways and ramps. Simulation results showed that the genetic algorithm was able to find a set of parameter values that can optimize the performance of the ALINEA algorithm for the whole controlled system.

What can be concluded from the Research?

Simulation results showed that adaptive ramp-metering algorithms can reduce freeway congestion effectively compared to the fixed-time control. ALINEA shows good performance under both recurrent and non-recurrent congestion scenarios. BOTTLENECK and ZONE can be improved by replacing their native local occupancy control algorithms with ALINEA. Compared to ALINEA, the revised BOTTLENECK and ZONE algorithms using ALINEA as the local control algorithm are found to be more efficient in reducing traffic congestion than ALINEA alone. The revised BOTTLENECK algorithm performs robustly under all scenarios. The results also indicated that ramp metering becomes less effective when traffic experiences severe congestion under incident scenarios.

Since our simulation network does not contain arterial routes, traffic diversion to alternative routes is not considered and thus the performance improvement through ramp metering control is not fully revealed.

Ideally, one should consider a corridor network and integrate a variety of control measures, including ramp metering, traffic diversion, and signal timing, to combat traffic congestion. We should also note that all of the algorithms evaluated in this study are reactive, rather than proactive, control strategies. Algorithms with state estimation and/or Origin/Destination (OD) prediction

capabilities are desirable. The development and evaluation of these integrated control strategies will be left to future studies.

Because of the good performance and easy implementation of ALINEA metering algorithm, ALINEA was identified as a good algorithm that can be potentially implemented in the field. The ALINEA algorithm was implemented together with a typical queue override strategy in Paramics as a plugin. The queue override strategy was used to avoid vehicles to spillback to arterials during ALINEA operation with low metering rate.

It was found that the system performance is not sensitive to the variation of the constant regulator under ALINEA control. When the updated cycle ranges between 30 to 60 seconds, mainline detector is placed between 120~140 meters downstream of the on-ramp nose, and the desired occupancy is set to 19% to 21%, the ALINEA control produces the best system performance with most stability in our testing network.

The desired occupancy is the most sensitive parameter among all four selected operational parameters in our study. Choosing a suitable value for the desired occupancy was essential to optimize the performance of ALINEA control. Simulation results show that the occupancy at capacity at the mainline downstream detector station is the best value to be selected. If less on-ramp delay is expected from metering control, a higher desired occupancy (around 30%) could be used.

What do the Researchers recommend?

This study showed that micro-simulation with genetic algorithm can be used to calibrate and optimize the operational parameters of ramp metering control algorithms, as a necessary part of successful implementation. Potentially, micro-simulation and genetic algorithm may also be used to fine-tune various other ITS strategies.

The study provides a parameter setting guideline for the ALINEA ramp metering control. Practitioners can use the recommended parameter values as a basic operational reference when they setup ALINEA control in the field.

Implementation Strategies

Ramp metering control involves balancing the interests of local (arterial) and through (freeway) traffic, and thus its applicability, onsite deployment and operation continue to face political challenges that call for the cooperation of related parties. Because of the complexity of these coordinated ramp metering systems, their successful implementation depends both on such hardware (or

ITS infrastructure) as communication system and loop detectors installed at specific locations and on software (such as the algorithm logic, the design and operational calibration of a ramp metering algorithm on the target freeway network). Studies show that significant benefits can be obtained from ramp metering only when implemented correctly and operated effectively (Pearce 2000). Therefore, questions related to whether ramp metering is warranted, which kind of ramp metering algorithm is suitable and how to calibrate and optimize the operational parameters, ought be investigated during a pre-implementation phase in order to ensure the success of the implementation.

List of Contacts

Principle Investigator:

Dr. Will Recker
Institute of Transportation Studies
University of California
Irvine, CA 92697-3600
Tel.: (949) 824-5642
Fax: (949) 824-8385
Email Address: wwrecker@uci.edu

Contract Manager:

Fred Yazdan
Caltrans, Division of Research and Innovations
Office of Technology Applications
Advanced Testbed Program Branch
6681 Marine Way, Irvine, CA. 92618
Tel.: (949) 936-3462
Fax: (949) 936-3461
Email Address: fred.yazdan@dot.ca.gov