Review of Freeway Ramp Metering Strategies

By

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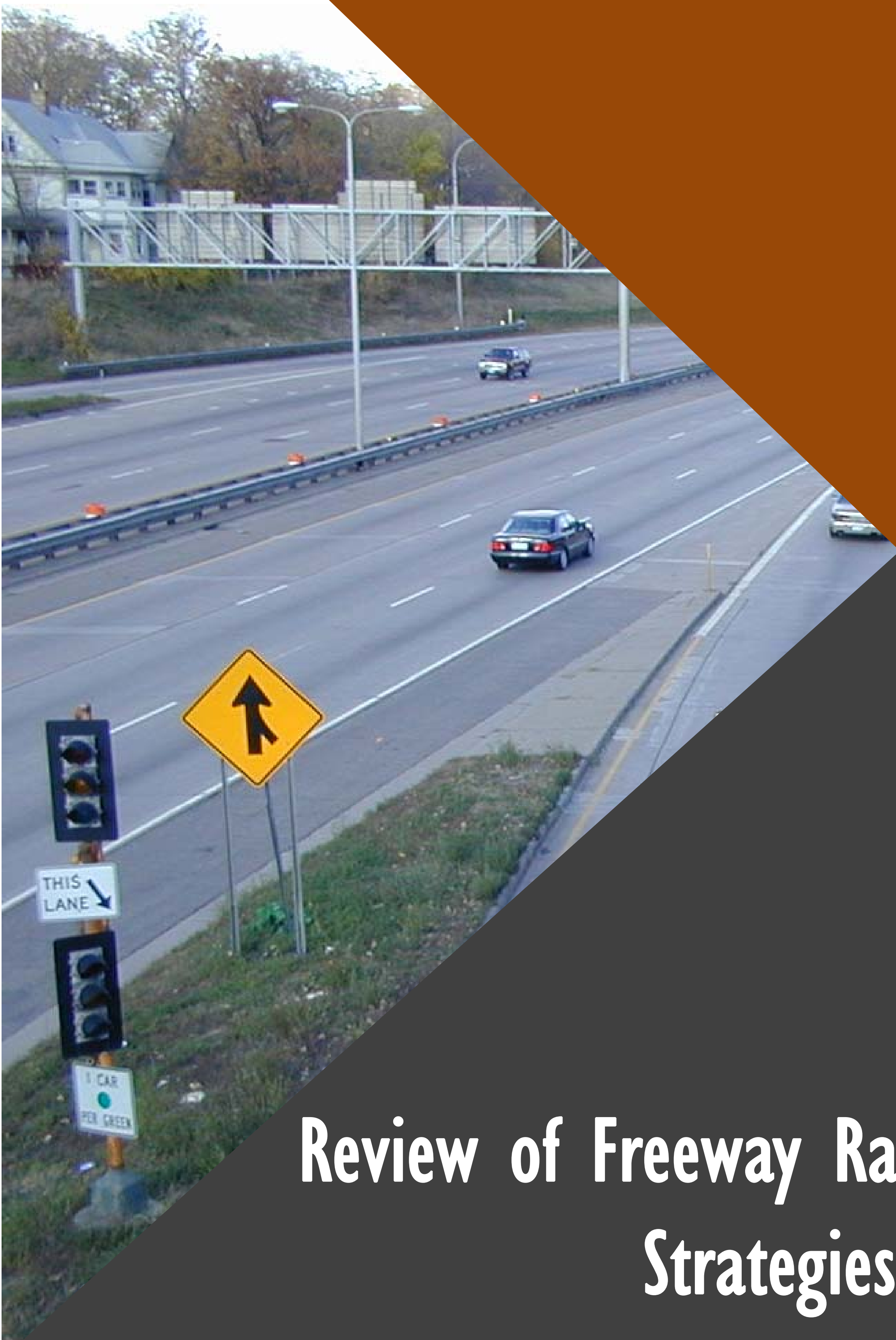

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Review of Freeway Ramp Metering Strategies

Abstract

Over a period spanning more than 30 years, several ramp metering strategies have been developed to improve the operation of freeways. Many of these strategies were deployed in several regions of the world, and field evaluations have shown their significance to improve traffic conditions on freeways and ramps. Previous reviews of ramp metering strategies focused more on the research outcomes and evaluations of traditional metering strategies developed in the early stage of ramp metering research. The purpose of this review is to cover the more recent developments in ramp metering in relation to the traditional metering strategies. Several local and coordinated ramp metering strategies were reviewed.

In summary, Asservissement Linéaire d'Entrée Autoroutière (ALINEA) was found to be the most widely deployed local ramp metering strategy. The algorithm is simple and requires less implementation cost. It also guarantees the targeted performance goals provided that the on-ramp has sufficient storage. Several extensions were proposed in the literature to fine-tune its performance. Among the coordinated metering strategies, zone based metering is simple to implement and easy to re-configure. System-wide adaptive ramp metering (SWARM) algorithm is more sensitive to calibrate for accurate prediction of traffic states. Heuristic ramp-metering coordination (HERO) algorithm can be useful if both local and coordinated control are desired particularly if the local control is using ALINEA. Fuzzy logic based algorithms are gaining popularity because of simplicity and the fast re-configuration capability. Advanced real time metering system (ARMS) seems theoretically a promising algorithm because of its proactive nature to prevent congestion; however, the performance is highly dependent upon accurate predictions. Finally, some guidelines were proposed for future research either to develop new proposals or to extend the existing strategies for guaranteed performance solutions.

Keywords: freeway operation; signal control; queue management; congestion management; algorithms; coordination strategy; traffic control

1 Introduction

Ramp metering is a ramp management strategy to control the number of vehicles entering a freeway using a traffic signal. They are programmed with a much shorter cycle time to allow a single vehicle or a small platoon of vehicles (usually two or three) per green phase. The metering rate is based on the traffic volume and speed on the freeway. On freeways, the goal is to increase throughput, speed, and capacity to maintain the optimum operation of the freeway. Ramp meters are usually employed to control vehicles at the on-ramp to enter the freeway (mainline) to mitigate the impact of the ramp traffic on the mainline flow. However, ramp meters can also be used to control traffic flow from the freeway to freeway and arterial to ramp and freeway. The selection of appropriate ramp metering strategy is based on the needs and goals of the regional transportation agency.

The simplest form of ramp meters works based on pre-set metering rates. The metering rates are either fixed or variable rates that are assigned on a defined schedule based on some historical traffic data. Fixed time or pre-timed metering addresses the recurring congestion problem but fails in case of non-recurring congestion. A better approach to ramp metering is adaptive or traffic responsive ramp metering where variable metering rates are allocated to ramps in response to actual traffic conditions. Traffic responsive metering uses present traffic conditions to adjust its metering rate. As shown in Figure , traffic data is collected using loop detectors or any other surveillance system in real time. The metering rate is either calculated based on some algorithms or selected from a pre-defined matrix. Traffic responsive control can be implemented in both local and coordinated fashion.

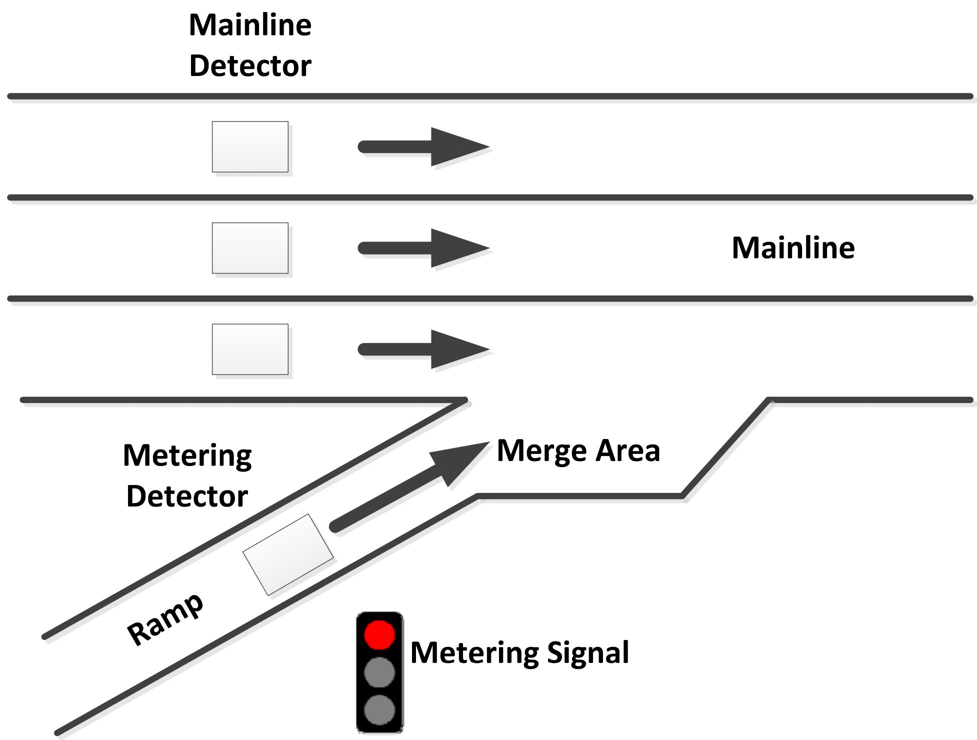

Figure 1: Ramp Metering Sketch

This review is divided into two main sections. The first section presents a review of adaptive ramp metering systems developed in the earlier stage and their evaluations. The second section provides a review of the recent developments in ramp metering.

2 Traditional Ramp Metering Strategies

This section describes the traffic responsive strategies that are developed in early stages. The working principles and control logics of these strategies are explained and compared in several aspects (Table 1).

2.1 Asservissement Linéaire d'Entrée Autoroutière (ALINEA)

ALINEA is a local traffic responsive feedback control algorithm for ramp metering developed by Papageorgiou et.al[1]. The algorithm takes freeway occupancy as input and computes the metering rate as a control variable that varies in response to changes in occupancy. ALINEA uses a single detector per lane of the freeway installed downstream at a distance of 40 meters or 400 meters. The downstream detectors measure the occupancy rate and send to the controller at regular intervals usually 40 seconds. The controller computes the difference between desired occupancy threshold and measured occupancy and determines the metering rate for the next interval (40 seconds). The algorithm also considers the previous interval metering rate while computing the metering rate for the next interval to avoid major variations in the metering rates for smooth operation. The goal of ALINEA is to set the metering rate at which the flow will not exceed the freeway capacity.

ALINEA performs well in maintaining a desired flow at the freeway. However, it creates long queues at the on-ramp that causes bottlenecks. Zhang et al.[2] proposed an extension to basic ALINEA to avoid the ramp traffic to exceed the capacity. Smaragdis and Papageorgiou[3] proposed three more modifications FL-ALINEA, UP-ALINEA and X-ALINEA/Q to the standard version for improving the performance in various scenarios.

FL-ALINEA uses the mainline flow from the downstream detectors instead of occupancy while UP-ALINEA uses occupancy values from the upstream detectors when the downstream detectors are not available. X-ALINEA/Q addresses the problem of long queue formation on the ramp when the freeway is saturated that causes restricted metering rates. Smaragdis et al.[4] proposed another extension AD-ALINEA, which addresses the issue of constant desired occupancy value that might change in real time due to weather conditions or traffic compositions.

Several field studies evaluate the performance of ALINEA. Chu et al.[5] evaluated ALINEA in a simulation environment over a stretch of the I-405 freeway in California where ALINEA shows good performance under both recurrent and non-recurrent congestion scenarios. Caglar and Hilmi[6] used ALINEA on Bosphorus Strait crossing bridges on State Road D100 and Europe Route E80 between Europe and Turkey. Field results showed that ALINEA regulates the ramp flow and keeps the mainline flow under capacity in the stable mode to prevent congestion. Zheng et al.[7] evaluated ALINEA on Shanghai Urban Expressway and successfully increased the mainline speed and reduced downstream congestion.

2.2 METALINE

METALINE[11] is an extension of ALINEA for coordinated control of ramp meters, proposed by Papageorgiou et al. (1990). The algorithm computes the metering rates using the list of occupancy values from several detectors on different ramps. The algorithm is similar to ALINEA in its response to the difference in the occupancy in two successive time intervals making it more sensitive to traffic variations. The disadvantage of METALINE is the complex calibration of the algorithm for multiple ramps. METALINE was deployed in Paris, France (1991)[11] on the three on-ramps of a six-kilometer freeway in Boulevard Périphérique. The results showed an increase in the mainline speed. In Milwaukee[10], METALINE was used on several freeways and showed improved performance in traffic. A field evaluation of METALINE in Netherlands, Amsterdam was conducted. However, the results are not published for organizational reasons.[9].

2.3 Bottleneck Algorithm

The algorithm was first developed by Washington State Department of Transportation by Jacobson et al.12. The algorithm works at both local and system-wide levels. At the local level, the algorithm compares the free demand at upstream of the ramp and capacity at the downstream of the ramp and thus optimum metering rates are computed that ensure that demand does not exceed capacity. At the coordinated level, the control algorithm is activated when the occupancy at a potential bottleneck area exceeds the threshold and the area upstream of the bottleneck is storing vehicles. The coordinated control determines the metering rates for all meters in the area or zone to reduce the volume of vehicles entering from the ramps to the bottleneck area equal to the volume in the upstream queue on the mainline. Once the two metering rates are computed for each ramp using local and coordinated control, the more restrictive rate is applied.

2.4 Zone Algorithm

Zone algorithms[13, 14] divide the freeway into multiple zones of various lengths from 3-6 miles with several metered and non-metered ramps. The algorithm maintains the density on mainline below a certain threshold by controlling the inflow and outflow in the zone. The collective metering rate is computed from the inflow and outflow values and then distributed among all ramp meters using the pre-defined ramp factor. One of the variants of zone metering is Stratified Zone metering[17] that uses density inputs obtained at real time on upstream of on-ramps, at mainline off-ramps, and on the mainline. The goal is to control the total volume of a segment of a freeway called a “zone”. The increase in the mainline density is balanced by lowering the metering rates in the particular zone.

2.5 HELPER Algorithm

Lipp et al.[18] proposed a local traffic-responsive algorithm with the added feature of central override control for system-wide implementation over the entire freeway corridor. All the on-ramps are divided into six groups. Six metering rates are defined that can be selected by individual ramp meters on the basis of local traffic conditions. If the queue on a ramp exceeds a specified threshold value for three consecutive time intervals, the central override feature is activated that reduce the metering rate by one level. This process continues until the problem is solved. If the queue persists, all the upstream ramps will be overridden and will operate with more restrictive metering levels. The algorithm was first deployed in the Denver area, Colorado in 1981 on I-10 freeway[19]. A comprehensive evaluation showed the significance of the central override feature in congestion reduction for low speeds (less than 90 km/hr) while less or no significance of the centralized control for speed greater than 90 km/hr.

2.6 System-Wide Adaptive Ramp Metering (SWARM) Algorithm

SWARM was developed by Paesani et al.[22] uses traffic forecasting to determine the metering rates. The algorithm works in two operational levels, a coordinated control (SWARM1) and local control (SWARM2). In SWARM1, traffic data is collected, and future state of traffic density is estimated using linear regression. For the non-linear relations between the data set, Kalman Filter is applied. The coordinated metering rates are computed using current and desired density values. In SWRAM2, metering rates are calculated based on density values computed locally from the distance headway measurements. Then the more restrictive metering rate (calculated in SWARM1 or SWARM2) is applied.

2.7 Fuzzy Logic Algorithm

The fuzzy logic algorithm is deployed in Seattle freeway by Taylor and Meldrum[24, 25, 26, 27]. This algorithms is well suited to situations where the accurate system model is not available. The fuzzy logic used in this algorithm takes real time measured values from detectors and convert them to different textual values based on the values of measured inputs. This is called fuzzification of inputs. Based on these fuzzified inputs the controller logic determines the control actions that are finally defuzzified to determine the real value of metering rates.

2.8 Linear Programming

The algorithm was first developed and implemented by Yoshino et al.[28,] on the Hanshin Expressway in Japan. The algorithm used detectors on all on and off ramps. The algorithm does not require any communication between ramp meters. The metering rates for all ramps are computed using complex functions.

2.9 Dynamic Ramp Metering

Dynamic control model of ramp metering was first proposed by Chen et al.[30] that include both local and coordinated control of ramps. The coordinated control is a kind of strategic control that uses a rolling horizon based predictive algorithm to minimize system travel time. The local control is a tactical control that sets its metering rates to maintain the traffic conditions that are provided by system-wide or coordinated control.

2.10 Advanced Real Time Metering System (ARMS)

ARMS, developed by Liu et al.[32,34] at Texas Transportation Institute, is a proactive metering algorithm that is designed to mitigate the risk of congestion. The algorithm predicts the traffic conditions and potential bottlenecks and resolves it using real time mainline flow information. ARMS is more complex relative to other ramp metering algorithms. However, the features are more appealing.

2.11 COMPASS

The Compass algorithm was first developed in Toronto Canada (1975). The details of this algorithm are explained in Michael et al. (1993)[34]. The metering algorithm allows both manual and automatic control of metering rates. The automated control function calculates metering rates at regular intervals of 30 seconds based on local mainline occupancy, downstream mainline occupancy, and upstream mainline occupancy. Each measured value of occupancy is compared to thresholds values stored in a look-up table to find the metering rates. If metering rates from the table for each parameter are different, the most restrictive rate is applied. The algorithm uses queue spillback detection to prevent queue formation on ramps.

2.12 Linked Algorithm

The algorithm, first developed by Tayler et al.[24] at Lancaster University, is based on the non-minimal state space (NMSS) approach of control design. The author proposed the use of proportional integral-plus linear quadratic (PIP-LQ) type of adaptive optimal controllers. The controller computes the metering rates as output by minimizing a linear-quadratic function. The inputs to the control function are ramp flows, occupancy values from detectors from the entire control area.

Table 1: Summary of Traditional Ramp Metering Algorithms

Algorithm	Year	Authors	Type	Control Inputs	Evaluations		
					Authors	Simulation	Field
ALINEA 1, 3, 4, 6, 7, 8, 11	1997	Papageorgiou et al.	Local w/Feedback	Occupancy	Papageorgiou et al.1, 7	✓	✓
					Chu et al.5	✓	X
					Zheng et al. 55	✓	X
					Caglar and Hilmi 56	✓	X
METALINE7 9,10, 11	1990	Papageorgiou et al.	Coordinated w/Feedback	Occupancy	Papageorgiou et al.11	✓	✓
					H.Talee et al. 9	✓	✓
					JHK Associates10	✓	X
Bottleneck12	1989	Jacobsen et al.,	Coordinated	Occupancy	WDOT, 198112	✓	X
Zone Algorithm 13, 14, 15, 16, 17	1989	Stephanedes,	Local or Coordinated	Flow rate	Minnesota DOT, 1989 14	✓	✓
HELPER 18, 19, 20, 21	1991	Lipp et al.	Coordinated	Occupancy	Corcoran et al., 1989 19	✓	X
					Colorado DOT, 1983 20	✓	X
SWARM 22, 23	1997	Paesani et al.	Coordinated (Prediction)	Density	Planned in California and Los Angeles 23	✓	X
FUZZY 24, 25, 26, 27	1998	Taylor and Meldrum	Coordinated	Multiple	WDOT, 1995 27	✓	✓
Linear Programming 28, 29	1995	Yoshino et al.	Coordinated	Not specified	Yoshino et al. 28	✓	X
Dynamic Ramp Metering [30]	1997	Chen et al.	Coordinated	Multiple	O Chen et al., 1997	✓	X
ARMS 31, 32, 33	1993	Liu et al.	Coordinated	Flow rate	Planned for Texas33	✓	X
COMPASS [34, 35]	1975	Canada DoT	Coordinated	Occupancy	Carroll et al., 1993	✓	X
Linked Algorithm [36, 37, 38, 39]	1998	Tayler et al.	Coordinated w/Feedback	Occupancy and flow	Banks, 199337, 38	✓	X

3 Recent Advancements in Ramp Metering

The main research challenge in ramp metering is to design a metering strategy that can maintain a good balance between two inversely proportionally parameters: freeway congestion and ramp queue[54]. This section presents the most-recent research trends in the development of ramp metering for local and coordinated control to overcome this challenge.

3.1 Heuristic Ramp-Metering Coordination (HERO)

The HERO algorithm was first developed by Papamichail et al.[40] and deployed at Monash Freeway in Australia. HERO is the extended version of ALINEA algorithm for coordinated ramp control. In HERO, the critical occupancy is measured at merge area of ramps. Each on-ramp is independently controlled using ALINEA, but all ramps are connected to each other via a central controller. When a bottleneck occurs on the mainstream near an on-ramp (queue length on an on-ramp (master) reaches a predefined threshold value), the central controller recruits the on-ramp in bottleneck segment as Master ramp and some of its upstream on-ramps as Slaves. The algorithms now try to increase the capacity of the master on-ramp.

3.2 Proportional Integral ALINEA (PI-ALINEA)

The PI-ALINEA proposed by Wang et al.[42] is an extended version of ALINEA to overcome one of its shortcomings. Basic ALINEA operates to reduce the mainline congestion at most a few hundred meters downstream of the merge point. However, if the bottleneck occurs further downstream from the location of ALINEA occupancy detectors, ALINEA will be unable to detect and thus respond to the congestion that can increase with time to form a bottleneck.

Simulations study[44] shows improved performance of PI-ALINEA as compared to ALINEA in both local and distant bottlenecks.

3.3 ALINEA with Speed Discovery

Rui et al.[45] proposed this algorithm to address the inherited problem with ALINEA with restricted metering rates that leads to longer queue at the on-ramp. Using queue management override feature with ALINEA, the queue can be discharged, but it again creates bottlenecks at merge area. Rui et al. proposed the concept of a mainline speed recovery with suspending queue management temporarily. However, when a potential breakdown is identified at the mainline, the algorithm gives control of the metering rate back to the standard ALINEA module. The study suggests that the mainline speed should be less than 45 Km/hr and suspension time 300 seconds for optimum operation of the control. Simulation results in AIMSUN show the improved speed and reduced travel time on mainline as compared to standard ALINEA. The results of this version of ALINEA should be compared with X-ALINEA/Q[3] to strengthen the idea.

3.4 Zippered Control Strategy (ZCS)

The ZCS proposed by Huadong et al.[46] used cellular automata based capacity model simulated in microsimulation software PTV VISSIM. The objective of the proposed strategy is to increase the capacity of the on-ramp junction. The model is based on a fair distribution of road priority between the mainline traffic and on-ramp traffic. The model has no field evaluations, and not enough details about simulation data are provided.

3.5 Genetic Fuzzy Logic Control (GFLC)

The idea of adaptive fuzzy logic control based on genetic algorithm was proposed by Amir et al.[47]. The fuzzy controller is used with the additional implementation of variable speed limits (VSLs) to control congestion and regulate the freeway traffic flow. The results of the fuzzy controller with and without VSLs were compared with no control and standard ALINEA implementation on the same network with same base conditions. The results showed that the genetic fuzzy logic based ramp metering results in smooth traffic states. The comparisons showed an increase in TTS (5% Without Using VSLs and 15.5% With VSLs) as compared to ALINEA. Fang et al.[48] proposed a genetic algorithm (GA) based tuning for the fuzzy logic controller for the isolated ramp. The GA-based tuning is repeated after 5 min intervals for any change in flow density on the on-ramp. The algorithm was tested in AIMSUN’s based simulation and the results showed improvement in total travel time as compared to the fuzzy logic controller without using the GA. In Jianxin et al.[49], the fuzzy logic controller is used with particle swarm optimization method to minimize the weighted total-time-spent (WTTS) on the freeway and ramp. The controlled logic was used for local ramp control and simulation results from microsimulation software PARAMICS showed a good balance between freeway and on-ramp traffic.

3.6 Dual Heuristic Programming Control (DHPC)

Dongbin et al.[50] proposed a DHPC method to solve recurrent and non-recurrent congestion using neural networks. The proposed algorithms were tested using mathematical models on a hypothetical freeway segment. The results of DHPC compared to ALINEA shows convincing improvements in freeway operation. The authors emphasized on the evaluation of DHPC method in microsimulation environments.

3.7 Iterative Local Control (ILC)

Zhongsheng et al.[51] proposed ILC based ramp metering control strategy that according to the authors has a simple learning approach, effective, inter-operable with ALINAE and other feedback-based control logics. The algorithm also requires less historical data as compared to fuzzy logic and neural networks based control algorithms. The use of ILC as an add-on to basic ALINEA is described as a complementary modularized approach to enhance the performance of ALINAE and ILC using a macroscopic simulation of the local ramp and freeway.

3.8 Additive Increase Multiplicative Decrease (AIMD)Algorithm

The AIMD algorithm is a coordinated ramp metering algorithm developed by Yinhai et al.[52] at Washington. The algorithm is inspired by the computer networks congestion control strategy. The algorithm reduces the on-ramp flow only to a fraction of ramp demand by limiting metering rates when congestion occurs and then gradually increase the metering rates to avoid queue spillover. The algorithm was evaluated using VISSIM simulation of Seattle's I-5 and I-90 freeways. The results compared with the fuzzy logic algorithm show a 28.2% reduction in travel time[52]. Table 2 provides a summary of most recent advancements in ramp metering.

Table 2: Comparison of Recent Ramp Metering Algorithms

Algorithm	**Year**	**Author**	**Type**	**Evaluation Methods**	**Description**
HERO [40, 41]	2010	Papamichail et al.	Local and Coordinated,	Field Implementation in Monash Highway, Australia	ALINEA based coordinated control metering, with master and slave on-ramps during congestion.
PI-ALINEA [42, 43, 44]	2014	Wang et al.	Local / Feedback-based	Simulation 42, 44 METANET 43	ALINEA extension for efficient detection and elimination of distant downstream congestion
ALINEA with Speed Recovery [45]	2012	Rui et al.	Local	Simulation/AIMSUN	Mainline speed recovery with suspending queue management temporarily.
ZCS [46]	2013	Huadong et al.	Local	Simulation/VISSIM	Cellular automata based capacity model for fair distribution of priority between mainline and ramp traffic
GFLC [47, 48, 49]	2012	X.F. Yu et al.	Local or Coordinated	Mathematical model47 AIMSUN 48 PARAMICS 51	Fuzzy Logic controller based on GA 47,48 and swarm optimization 49
DHPC [50]	2011	Dongbin et al.	Coordinated	Mathematical model	Neural network based dual heuristic programming model to solve recurrent and non-recurrent congestion
ILC [51]	2011	Zhongsheng et al.	Coordinated	Mathematical model	Iterative control of isolated ramp and integration with ALINEA for improved performance
AIMD [52]	2008	Yinhai et al.	Coordinated w/Feedback	Simulation/ VISSIM	Using computer networks congestion control policy to control congestion while preventing ramp queues

4 Discussion and Future Directions

Several local and coordinated ramp metering algorithms are discussed. Based on simulation results and field evaluations [1, 5 7 55, 56], ALINEA showed to be widely deployed local ramp metering strategy. Several extensions [3, 4, 42, 43, 44, 45] were proposed to fine-tune its performance in the diverse road and traffic conditions. Among the coordinated metering strategies, zone based metering is simple to implement and easy to re-configure. SWARM is more sensitive to calibrate for accurate prediction of traffic states. HERO algorithm can be useful if both local and coordinated control are desired particularly if local control is using ALINEA. Fuzzy logic based algorithms are gaining popularity because of simplicity, the fast re-configuration capability, and the integration of neural networks and genetic algorithms with fuzzy logic[47, 48, 49]. ARMS seems theoretically a promising algorithm because of its proactive nature to prevent congestion. Some guidelines are proposed for future research either to develop new proposals or to extend the existing algorithms for guaranteed performance solutions:

a. While developing a ramp metering strategy, it is crucial to understand the phenomenon of congestion occurrence, particularly the source of congestion and location of the bottleneck. The feedback based algorithms (e.g. ALINEA) ensure to eliminate downstream congestion if properly configured despite the distance from the on-ramp. However, it cannot detect upstream initiated congestion. The UP-ALINEA can detect upstream congestion only to a certain level. Future research should consider more fine-tuning of ALINEA. Some useful guidelines for configuring ALINEA can be found in Papageorgiou et al[57].
b. The success of achieving local ramp metering goals depends on the sufficient length of the on-ramp to store vehicles in the time of congestion on the freeway. If the ramp has limited

storage, the queues on ramps will extend to the arterial upstream. One possible approach to avoid this is the coordination of upstream traffic signal and ramp meter[59]. However, many ramp metering algorithms have not addressed this phenomenon.

c. Online simulation based metering can provide more realistic results, but the operational cost and acquisition of real-time traffic data in this method are a barrier for such implementations.

d. The genetic fuzzy logic metering algorithms has the potential to be the future choice for ramp metering. However, these algorithms usually require more inputs than any other method. The probe vehicle approach[54] based on cellular phones' data (e.g. speed, location) of road users should be considered to reduce the cost of traffic data acquisition in real time.

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Review of Freeway Ramp Metering Strategies - Quiz

Updated: 1/21/2019

1. Ramp metering is a ramp management strategy to control the number of vehicles entering ______________.

   a. a freeway.
   b. an arterial.
   c. a local road.
   d. a collector road.

2. Ramp meters are usually employed to control vehicles at the on-ramp in order to ________________________.

   a. mitigate the impact of the mainline flow on the ramp.
   b. increase the speed of the ramp traffic.
   c. mitigate the impact of the ramp traffic on the mainline flow.
   d. Increase the volume of the ramp traffic.

3. Ramp metering use a traffic signal with a ___________________________

   a. cycle time to allow all vehicles on the ramp to enter the mainline.
   b. cycle time to allow a single vehicle or a small platoon of vehicles to enter from the ramp.
   c. cycle time to allow ramp vehicles to enter the mainline and to stop the mainline traffic.
   d. cycle time to allow ramp vehicles to not exceed a specific queue.

4. The metering rate is based on ______________________

   a. the traffic volume on the freeway.
   b. the traffic volume and speed on the freeway.
   c. the traffic volume on the ramp.
   d. the traffic volume and speed on the ramp.

5. The purpose of ramp metering is to increase ___________________ on the main road.

   a. Throughput
   b. Speed
   c. Capacity
   d. All of the above

6. A simple ramp meter works based on pre-set metering rates. The metering rates are _________________

   a. fixed rates
   b. variable rates
   c. reduced rates
   d. either fixed or variable rates.

7. The main problem with fixed time or pre-timed metering ___________________.

   a. fails in case of recurring congestion
   b. fails in case of non-recurring congestion
   c. fails in case of long ramps
   d. fails in case of short ramps

8. Adaptive ramp metering use______________________________.

   a. present traffic conditions to adjust its metering rate.
   b. historical traffic condition to adjust its metering rate.
   c. fixed traffic values to adjust its metering rate.
   d. variable traffic values to adjust its metering rate

9. Adaptive ramp metering use traffic data is collected using __________________

   a. loop detectors.
   b. pneumatic tubes.
   c. origin-destination survey.
   d. GPS data.

10. In ALINEA, the downstream detectors measure the occupancy rate and send to the controller at regular intervals usually ____________ .

    a. 5 minutes.
    b. 40 seconds.
    c. 15 minutes.
    d. 1 hour.

11. Zone algorithms divide the freeway into multiple zones of various lengths from _______with several metered and non-metered ramps.

    a. 1-3 miles
    b. 3-6 miles
    c. 6-9 miles
    d. more than 10 miles

12. The Zone algorithm maintains the density on mainline below a certain threshold by

a. controlling the inflow and outflow in the zone.
b. controlling the inflow in the zone.
c. controlling the outflow in the zone.
d. Controlling the inflow and outflow downstream the zone.

13. In SWARM, traffic data is collected, and future state of traffic density is estimated using________

a. logistic regression.
b. linear regression.
c. polynomial regression.
d. stepwise regression.

14. The Linear Programming algorithm use detectors on__________

a. On-ramps
b. Off-ramps
c. Freeway
d. All on and off-ramps.

15. The Compass algorithm allows _______________.

a. both manual and automatic control of metering rates.
b. manual control of metering rates.
c. automatic control of metering rates.
d. coordinating control of metering rates.

16. In HERO, the critical occupancy is measured at _________________________.

a. upstream the ramps.
b. merge area of ramps.
c. downstream the ramps.
d. 400 m before the ramps.

17. In ALINEA with Speed Discovery, when a potential breakdown is identified at the mainline, the algorithm_______________________

a. gives control of the metering rate back to the standard ALINEA module.
b. gives priority to the mainline traffic.
c. gives priority to the ramp traffic.
d. balances the demand between the mainline and ramp traffic.

18. Dual Heuristic Programming Control is a method to solve recurrent and non-recurrent congestion using ________________

a. neural networks.
b. fuzzy logic.
c. decision tree.
d. neuro fuzzy.

19. Iterative Local Control strategy requires _______________________as compared to fuzzy logic and neural networks based control algorithms.

a. more historical data
b. less historical data
c. real life data
d. no historical data

20. The Additive Increase Multiplicative Decrease (AIMD) algorithm reduces the on-ramp flow only to a fraction of ramp demand by limiting metering rates when congestion occurs and then ___________________to avoid queue spillover.

a. direct traffic to another ramp.
b. gradually increase the metering rates.
c. immediately increase the metering rates.
d. maintain same metering rates.