

# An Evolutionary Fuzzy System for Coordinated and Traffic Responsive Ramp Metering

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## Abstract

*This paper proposes a nonlinear approach for designing traffic responsive and coordinated ramp control using a self adapting fuzzy system. The traffic responsive metering rate is determined every minute by an adaptive fuzzy logic algorithm. The coordination between multiple on-ramps is ensured by the integration of a common input into all ramp controllers upstream of a bottleneck and a periodically update of the fuzzy system every 15 min. by a evolutionary tuning process. The objective of the genetic tuning of the fuzzy parameters is to minimize the total time spent in the system. Therefore a modified Payne traffic flow model is used. For testing the developed system a section of 25 km of the A9 Autobahn was simulated with the *FREQ* model. The results of the simulation of the adaptive fuzzy algorithm are very satisfying and an implementation of the ramp metering system is planned in the very near future.*

## 1. Introduction

Ramp metering, considered in the context of traffic management systems, offers several operational features for improving freeway flow, traffic safety and air quality by the regulation of input flow to a freeway. Ramp meters are traffic signals placed on freeway entrances and controlled by a traffic strategy. In the "metering" mode, ramp meters operate to discharge traffic at a measured rate based on real-time conditions, thereby protecting the sensitive demand-capacity balance at the ramp merge or at a downstream bottleneck. As long as mainline traffic demand does not exceed capacity, throughput is maximized, speeds remain more uniform, and congestion related accidents are reduced. If well controlled, metering can significantly increase speeds and reduce travel times. While ramp delays may increase, system wide delay reductions can be large. Smoother flow on the freeway by preventing the occurrence of bottlenecks through ramp metering can lead to substantial reduction in fuel consumption and air pollutants. Ramp meters also

regulate the ramp traffic in order to break up platoons of vehicles that have been released from nearby signalized intersections. The mainline, even when traffic flow nears capacity, can usually accommodate merging vehicles one or two at a time. On the other hand, when platoons of vehicles attempt to force their way into the mainline traffic, this action creates turbulence that can cause the mainline flow to break down. Reduced turbulence in the merge zones also leads to reduced sideswipe and rear-end accidents that are associated with unrestricted ramp access during high volume conditions.

Under conditions of heavy, prolonged demand on the freeway facility, the principal mechanism by which ramp metering can also improve the situation is by encouraging diversion to alternate routes. If enough vehicles divert to alternate facilities, the reduced demand will reduce, or even eliminate, freeway congestion. However, since the freeway is part of a larger traffic system, this diversion is truly beneficial only when the alternate routes have sufficient capacity available to carry the diverted traffic and when this diversion is part of an integrated traffic policy. Otherwise, the only effect will be to move congestion from the freeway to the surface streets, but not actually improve overall traffic conditions. For ramp metering to have a significant effect in shifting traffic demand over time, it would be necessary for vehicles to spend a similar amount of time in the on-ramp queue. This may be technically possible in some situations, but not acceptable.

Ramp metering was first successfully introduced and applied within the Chicago and Los Angeles area traffic control system and is considered as an important component of freeway traffic control and intelligent transport systems.

Historically, there have been three control approaches in developing ramp metering strategies: pre-timed, local traffic responsive, and coordinated traffic responsive. Each of these three control approaches are briefly described in the following three paragraphs.

Pre-timed ramp metering control was first implemented in the 1960's and is in operation in several locations today. A local or system-wide pre-timed ramp metering plan is