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Freeway – Arterial Interactions: Strategies and Impacts

David Kan, Alexander Skabardonis[1]

Department of Civil and Environmental Engineering, University of California, Berkeley, CA 94720 USA

ABSTRACT

Several efforts are underway for integrated corridor management (ICM) of highway facilities comprised of freeways and adjacent arterial streets. One of the main obstacles toward an efficient management of a travel corridor is the coordination of the various subsystems that it comprises. The divisions between these subsystems are drawn along jurisdictional boundaries which often have little to do with travel patterns.

A guide published by FHWA describes the challenges for arterial–freeway coordination and suggests procedures to facilitate integration with emphasis on non-recurring (incident related) congestion [1]. The document focuses mainly on planning, institutional issues and data dissemination, and less on the development of control strategies. Existing research has focused on developing control algorithms for independent operation of freeways and arterials [2-3]. Other approaches focus on control strategies for freeway interchanges [4].

The objective of the study described in this paper is to develop and test a simple and readily implementable control strategy for an integrated operation of arterial signals and freeway ramp meters with emphasis on a) control strategies that prevent overflow on metered ramps that adversely affect arterial operations under recurrent congestion [5], and b) guidance on traffic diversion from freeway to arterials in the case of non recurrent (incident related) congestion [6].

1. Recurrent Congestion

The objective of freeway on-ramp metering is to regulate the entry of vehicles to prevent congestion on the freeway mainline [7,8]. Several ramp metering algorithms have been developed and implemented worldwide [9]. Most of the operational ramp metering systems employ a "queue override" feature that is intended to prevent the on-ramp queue from obstructing traffic conditions along the adjacent surface streets. The override is triggered whenever a sensor placed at the entrance of the on-ramp detects a waiting queue of the on-ramp vehicles, and increases the metering rate to its maximum value, to empty the queue into the freeway. However queue override reverses the objective of on-ramp metering, which protects the freeway discharge rate and avoid congestion at merge bottlenecks. Recent empirical evidence [10] suggests that the freeway bottleneck discharge rate drops by approximately 10 percent when queue override is activated.

1 Corresponding author. Tel.: +1-510-642-9166
E-mail address: skabardonis@ce.berkeley.edu

We developed a control algorithm to manage the entry of vehicles on the on-ramp through signal control changes at the adjacent intersection(s). The proposed strategy adjusts the signal settings (cycle length, green times and offsets) on the arterial traffic signals with the objective that on-ramp queues do not exceed the on-ramp queue storage. The constraints that must be satisfied include i) minimum green times at each signal phase, ii) fixed cycle time, and iii) available storage on the arterial links.

The proposed algorithm was tested on a real-world freeway segment and parallel arterial in the city of San Jose, California. The test site is a 4 mile section of the I-680 freeway in the northbound direction, and a parallel arterial Capitol Avenue with three signalized intersections. The on-ramp meters operate under the local responsive demand-capacity strategy, and the arterial traffic signals operate with time of day coordinated actuated timing plans. The proposed freeway-arterial coordination strategy was tested using the AIMSUN microscopic simulation model [11]. The results indicate that the proposed strategy improved the performance of the freeway; the delay was reduced by 15%, and the throughput was increased by 4%. On the arterial, the delay was reduced on travel directions/movements that do not intend to access the freeway on-ramp, and increased on the approaches serving the on-ramp traffic. However, the delay increase did not create operational issues on those links. On the average, the delay on arterial through traffic was reduced by 15%, and the delay for the on-ramp serving traffic was increased by 5%.

2. Freeway Non-Recurrent Congestion

A commonly recommended strategy for freeway/arterial coordination in ICM projects is the use of parallel arterial(s) as reliever route(s) to the freeway travelers whenever there is a capacity reducing incident on the freeway. In this situation, drivers may be instructed to divert on the parallel arterial(s) and return to the freeway past the incident location. The signal settings on the arterial are set to facilitate the movement of the diverted freeway travelers ("flush plans"). Several models have been developed to provide alternative routes and estimate the benefits of diversion. However, there is no empirical evidence yet on the effectiveness of such strategies, and there is no clear understanding of the issues involved in the development and implementation of these strategies. The FHWA freeway-arterial coordination handbook provides mostly information on interagency coordination but not technical guidance on estimating allowable diversion volumes and associated impact.

The effectiveness of diversion strategies largely depends on accurate prediction of the diverted volume on the parallel arterial and deployment of signal settings on the arterial to accommodate the diverted traffic. Critical considerations for diversion strategies include but are not limited to freeway operating conditions, incident location, severity and duration, characteristics of the traveler information system, surveillance and control system in place, and characteristics of the parallel arterial.

We developed a straightforward analytical procedure to estimate the amount of diverted traffic to the parallel arterial depends on the available (spare) capacity at the critical intersection along the arterial. The diverted volume can be thought as a gain in the reduced capacity of the freeway due to the incident, i.e., less reduction in remaining freeway capacity. The proposed approach provides a planning level methodology on the potential of diversion at selected corridors given the characteristics of parallel arterials before investing in detailed simulation analyses and implementation scenarios. This approach provides guidance for selecting candidate facilities for possible diversions and estimates of associated impacts. he approach is currently extended to cover different incident characteristics (multilane blockages), freeway characteristics and adjacent surface street networks (e.g., multiple alternate routes).

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