STRIDE | Southeastern Transportation Research, Innovation, Development and Education Center

Technology Transfer Final Report

STRIDE Project ID: B4

Project Title: Integrated Corridor Management: Cooperative Signal Control with Freeway Operations and Ram Metering

Project Grant Period: 8/16/2020 to 1/16/2024

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THE STRIDE CENTER

The STRIDE Center is the 2016 USDOT Region 4 (Southeast) University Transportation Center (UTC) housed at the University of Florida Transportation Institute (UFTI). Our mission is to develop novel strategies for Reducing Congestion. The Center has nine partners, representing seven states in the Southeastern U.S. The UFTI and its partners in the STRIDE Center are recognized leaders at state, regional, national, and international levels. The STRIDE Center is focused on assembling and integrating research projects throughout the region in a way that maximizes contributions to solving current and future transportation problems as well as strengthening expertise and developing new technologies. For more information see https://stride.ce.ufl.edu/.

DISCLAIMER

ACKNOWLEDGEMENT OF SPONSORSHIP AND STAKEHOLDERS

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1. Project Overview

Integrated corridor management offers great potential to improve traffic operations on both freeway facilities and intersecting arterial streets. Coordinating ramp metering rates on on-ramps and signal timing plans for the interchanges and upstream intersections of the arterial street can improve both freeway and arterial operations. This research introduced three methodologies for integrated corridor management. The three methodologies can be used together in an integrated management framework to predict congestion before it occurs, then use this information to either activate a special signal plan from a library of plans or switch to a real-time signal control strategy to reduce the impacts of congestion. The first methodology aimed to reduce queue spillbacks from on-ramps to lessen their impacts on arterial roads. Based on the capacity of freeway and on-ramps, signal timing plans and ramp metering rates were adjusted off-line to improve the overall corridor performance. In the second methodology, an integrated control framework was developed where all signal controllers and ramp metering rates were optimized jointly to improve the overall traffic condition of the corridor. In the third methodology, machine learning techniques were applied to predict capacity reduction of arterial roads due to queue spillbacks from freeway on-ramps to the arterial streets that result in lane blockages.

2. Research Goals

The goal of this project is to reduce traffic congestion on freeway corridor networks by developing integrated corridor management methodologies that cooperatively coordinate the control decisions of the signalized intersections and ramp flows from the on-ramps. This project aims to reduce congestion along both the freeway facility and the arterial facility in an integrated corridor management (ICM) operation. Two different approaches are followed to achieve this:

- Rules-based optimization approach: Develop a signal control methodology that considers freeway operations in order to time the interchange and/or adjacent arterial traffic signals such that they can meter the traffic entering the freeway through on-ramps.
- Cooperative optimization-based approach: Develop a traffic-responsive methodology that integrates signal timing plans and ramp metering controls to improve traffic operations of both the arterial corridor and the freeway.

In addition to these two approaches, the research team developed a machine-learning-based prediction methodology for use as part of real-time decision support tools for integrated corridor management to allow the recommendation of the activation and implementation of the appropriate signalization plans to achieve the integrated management of the freeways and arterial streets. In real-world applications, the predictive methodology can be used to continuously predict the potential for queue spillbacks from the ramps before they occur. Once a potential spillback is predicted, then a decision support software at the traffic management center will direct the controller to activate a special plan from a library of plans developed off-line using one of the two signal control approaches mentioned above (the mathematical optimization-based approach and the heuristic optimization based approach)

3. Performance Metrics

Metric	# Completed
OUTPUTS	
Product(s): Number of new or improved tools, technologies, products, methods, practices, and processes created or improved	3 new methodologies 2 presentations at TRB, 1 presentation at INFORMs, 2 journal papers submitted, 1 journal paper will be submitted.
Technical Report: Number of client-based technical reports published	STRIDE Final Report
OUTCOMES	
Body of Knowledge: Number of trainings for transportation professionals	One webinar
Professionals Trained: Number of professionals participating in trainings	25 attendees participated in the webinar
IMPACTS	
Stakeholders: Number of stakeholders you met with to encourage adoption or implementation of product(s)	0
Adoption/Implementation: Number of incidences outputs of research have been implemented or adopted	0

4. Product(s) – New/improved tool, technology, product, method, practice, or process

We report the product names and descriptions directly to USDOT.

*Provide a non-technical description for **each** product that was created or improved during your. Please use easily accessible language for the public (ex. a legislator or USDOT program officer) that includes*

a) Name of the product

Integrated corridor management methodology

b) Description – 5-10 sentences describing

The product reduces traffic congestion in freeway corridors. This is done in three ways:

(a) by optimizing the timing of traffic lights at intersections on arterial streets upstream on freeway on-ramps
(b) by jointly optimizing traffic light and ramp metering signal timing, and
(c) by predicting the onset of congestion on on-ramps

Computer simulation results show that the average delay can be reduced by up to 30% compared to the existing conditions. This method can be used by traffic engineers at State and Local DOTs to retime traffic lights at arterial streets upstream of on-ramps and metering signals.

c) Additional Information (if available)

- link to where the product can be accessed (may include a link to a publication)
- graphic about the product (ex. a process diagram, table, image of a simulation or GIS map)

5. Who benefits/will benefit from your product(s)?

Travelers

6. Body of Knowledge & Professionals Trained

For each training that was completed, please provide the following

- *Type: Webinar.*
- *Title: Integrated Corridor Management*
- *Date: November, 15, 2022*
- *Presenters: Ali Hajbabaie, North Carolina State University, Mohammed Hadi, Florida International University, Lily Elefteriadou, University of Florida*
- *Organizer: STRIDE*
- *Attendees: 25*
- *N/A*

7. Journal Publications, Conference Presentations, & Posters

Journal papers:

Farabi A.[*], R. Mohebifard[*], R. Niroumand[*], **A. Hajbabaie**, M. Hadi, L. Elefteriadou. Integrated Corridor Management by Cooperative Traffic Signal and Ramp Metering Control. *Computer-Aided Civil Infrastructure Engineering*, Under First Round of Review 2023.

Jabin A., H. Mata, M. Hadi, A. Hajbabaie, and L. Elefteriadou. Impact of Ramp Queues on the Capacity of Upstream Signalized Intersection using Machine Learning. IEEE Transactions on Intelligent Transportation Systems, Under First Round of Review.

Presentations:

A. Farabi, R. Mohebifard, R. Niroumand, A. Hajbabaie, M. Hadi, and L. Elefteriadou. Integrated Corridor Management by Cooperative Traffic Signal and Ramp Metering Control. The 102nd Annual Meeting of the Transportation Research Board, Washington, DC, 2023 (Poster).

Hajbabaie A., A. Farabi, R. Mohebifard, and R. Niroumand. Cooperative Traffic Signal and Ramp Metering Control in a Fully Connected Corridor Network. INFORMS Annual Meeting, October 16-19, 2022 (Lectern).

Jabin, H. Mata, M. Hadi, A. Hajbabaie, and L. Elefteriadou. Machine Learning Models for Predicting Capacity Reduction Rate Resulting from Queue Spillback Due to Ramp Metering. The 102nd Annual Meeting of the Transportation Research Board, Washington, DC, 2023 (Poster).

8. Stakeholder Engagement – We did not have this activity.

9. Adoption/Implementation

N/A

10. Broader Impacts

The products developed in this project, when implemented properly, could lead to significant reductions in travel times in corridor networks. The improvements were observed in computer-based simulations and can be observed in the field by conducting before/after studies. In the short term, reduced travel times, increased throughput, and reduced fuel consumption and emissions are some of the main impacts. In the long term, a better driving experience and a more environmentally friendly corridor network are expected.