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

Technology Transfer Final Report

STRIDE Project M2

Comparing and Combining Existing and Emerging Data Collection and Modeling Strategies in Support of Signal Control Optimization and Management

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1. Project Overview

For decades, traffic signal management agencies have used signal timing optimization tools combined with fine-tuning of signal timing based on field observations in their updates of time-of-day signal timing plans. These traditional signal optimization methods and tools use very limited amount of data and depend on default values in the signal timing optimization/simulation tools to estimate network performance under different signal optimization strategies. In recent years, new data collection technologies are emerging including high resolution controller data, more advanced detection technologies such as video image detection that are based on vehicle tracking and possible integration with microwave detectors, automatic vehicle-based identification technologies, third party crowdsourcing data, connected vehicles, and connected automated vehicles data.

This project proposed methods and algorithms to combine data collected from existing and emerging sources with enhanced models and optimization algorithms to optimize and manage signal operations. A method for the calibration and validation of microscopic simulation models of arterial networks was developed utilizing high-resolution controller data combined with a two-level unsupervised clustering technique and multi-objective optimization for simulation model calibration. Based on the results from this calibration, the study compared the performance of two signal timing optimization methods based on macroscopic simulation and microscopic simulation with and without fine-tuning their parameters based on high-resolution controller data. A combination of two artificial intelligence approaches, namely Recursive Partitioning and Regression Decision Tree (RPART) and Fuzzy Rule-Based System (FRBS), was used to recommend modifications to signal timings during non-recurrent events such as incidents, construction, surge in demands, and device malfunctions.

The performance of the resulting plans from the above methods was compared with those obtained using a simulation-based optimization method to select the signal timing parameters during non-recurrent conditions. The use of clustering analysis, multi-resolution modeling (MRM), and optimization techniques in the development of plans on alternative routes was also investigated to accommodate diverted traffic during freeway incidents. The utilized mesoscopic simulation-based MRM was calibrated based on the increase in demands and travel times on alternative routes using data from third party vendors. Microscopic simulation-based optimization of signal timing was used in the project utilizing a multi-objective optimization that jointly minimizes the delays and maximizes the throughputs considering the whole intersections as well the specific impacted movements on the alternative routes.

2. Research Goals

The goal of this research is to propose and evaluate methods and algorithms to combine data collected from existing and emerging sources with enhanced models and optimization algorithms to optimize and manage signal operations. The results from applying the developed methods and algorithms are compared with traditional signal timing and optimization methods currently used by transportation agencies.

3. Findings

The findings of the survey conducted in this study shed light on current signal timing practices and software resources used for signal control optimization and management and document types and sources of data used for evaluating signal performance along with stated preferences related to the value of the investment in emerging technologies for signal optimization and the adequacy of resources. The study provides a different perspective on the use of HRC data and highlights the usefulness of the HRC data in signal timing optimization. This study also demonstrated the benefits of the use of HRC data in the calibration of signal timing optimization tools over traditional calibration using turning movement counts only. The simulation results indicate that changing the green times based on the output of the fuzzy rules decrease the delays due to lane blockages or demand surge. The evaluation of the methodology developed in this study showed that the optimized signal timing plan improved the intersection and overall corridor performance in terms of queue length, overall throughput, intersection delay, and corridor travel time. The evaluation of the signal timing plans resulting from the multi-objective signal timing optimization indicates that the derived special signal timing plans can reduce the delays and increase the throughputs in the network, particularly for the traffic movements utilized by the diverted traffic.

4. Performance Metrics

Metric	# Completed
OUTPUTS	
Products: Number of new or improved tools, technologies, products, methods, practices, and processes created or improved	2
Technical Report: Number of client-based technical reports published	2
OUTCOMES	
Body of Knowledge: Number of trainings for transportation professionals	2
Professionals Trained: Number of professionals participating in trainings	44
IMPACTS	
Stakeholders: Number of stakeholders you met with to encourage adoption or implementation of product(s)	4
Adoption/Implementation: Number of incidences outputs of research have been implemented or adopted	0

5. Products

a) Non-Technical Description

1) Developed a hybrid machine learning and fuzzy logic model for signal timing selection under non-recurrent conditions.

2) Developed multi-objective optimization methods to select signal timing plans under congestion conditions.

b) Technical Description

Method 1: This project investigated and assessed automating the process of updating the signal timing plans during non-recurrent conditions by capturing the history of the responses of the traffic signal engineers to non-recurrent conditions and utilizing this experience to train a machine learning model. The project used a combination of Recursive Partitioning and Regression Decision Tree (RPART) and Fuzzy Rule-Based System (FRBS) to deal with the vagueness and uncertainty of human decisions. Comparing the decisions made based on the resulting fuzzy rules from applying the methodology to previously recorded expert decisions for a project case study indicates accurate recommendations for shifts in the green. The simulation results indicate that changing the green times based on the output of the fuzzy rules decrease the delays due to lane blockages or demand surge.

Method 2: Method 2 uses multi-objective optimization problem to optimize signal timing plans for non-recurrent conditions. The signal timing optimization problem is solved via a simulation-based optimization utilizing the Non-Dominated Sorting Genetic Algorithm (NSGA-III) algorithm to find a set of Pareto optimal fronts. The Pareto optimal fronts allow trade-offs among various objectives of the simulation. Microscopic simulation models are developed and calibrated using high-resolution controller data to better replicate real-world conditions.

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

State and local transportation agencies that operate various-sized traffic signal systems can use the methods developed in this study to design signal timing plans during non-recurrent events such as incidents and surges in demands.

7. Body of Knowledge & Professionals Trained

1. **STRIDE webinar**: Mohammed Hadi, Ph.D., PE, Florida International University and Virginia P. Sisiopiku, Ph.D., University of Alabama at Birmingham (UAB) presented “Combining Emerging Data Collection and Modeling Strategies in Support of Signal Control Optimization” on May 19, 2021 (44 attendees, 33 YouTube views). Participants in the webinar represented universities, state DOTs, and consulting companies. Eleven participants completed the survey after the webinar. 100% of respondents indicated the webinar quality was either “above average” or “excellent.” Seven respondents indicated they planned to use the information presented in the future.
2. **STRIDE Product Showcase**: Mohammed Hadi, Ph.D., PE, Florida International University, will present the technology transfer products at the STRIDE Product Showcase on November 17, 2021.

8. Stakeholder Engagement

MEETING DETAILS		NARRATIVE DESCRIPTION
Date of Activity	May 2019	
Type of Activity	in-person meeting	

Location	FDOT D4 Regional TMC	Meet with FDOT Signal Consultants to discuss automating the signal timing updates in special events.
Stakeholder(s)	Giri Jeedigunta Aidin Massahi	
Date of Activity	September 2019	Meet with Dr. Alex Haiden (UA) to discuss data sharing and potential collaboration on implementing project findings
Type of Activity	phone meeting	
Location		
Stakeholder(s)	Dr. Alex Haiden (UA)	
Date of Activity	January 2020	Discuss the potential for applying the product from this project.
Type of Activity	in-person meeting	
Location	Fort Lauderdale	
Stakeholder(s)	Dan Smith and Nicole Forest (FDOT), Giri Jeedigunta (AECOM), Aidin Massahi (Eland engineering)	
Date of Activity	May 2020	Continue discussing automating the signal timing updates in special events and the tournament participation.
Type of Activity	phone meeting	
Location		
Stakeholder(s)	Giri Jeedigunta Aidin Massahi	

9. Adoption/Implementation

Met with FDOT District 4 and their consultant for possible implementation of a product from this project. The product has not been implemented.

10. Broader Impacts

When implemented, the products of this project can be used by agencies to design and implement signal timing plans for activation during non-recurrent conditions like arterial incidents, diversions due to freeway incidents, and surges in demands. This is expected to improve the mobility and reliability of the transportation systems.