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

Technology Transfer Final Report

STRIDE Project N2

Data Fusion for Signalized Arterial Performance Measurement

Shoaib Samandar, PhD

ITRE at North Carolina State University

March 2023

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

The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the information presented herein. This document is disseminated in the interest of information exchange. The report is funded, partially or entirely, by a grant from the U.S. Department of Transportation's University Transportation Centers Program. However, the U.S. Government assumes no liability for the contents or use thereof.

ACKNOWLEDGEMENT OF SPONSORSHIP AND STAKEHOLDERS

This work was sponsored by a contract from the Southeastern Transportation Research, Innovation, Development and Education Center (STRIDE), a Regional University Transportation Center sponsored by a grant from the U.S. Department of Transportation's University Transportation Centers Program.

1. Project Overview

There are currently more than 330,000 signalized intersections across the United States. In the past, measuring the efficiency of these intersections relied heavily on manual observations and floating travel time runs. However, with new sources of data like high-resolution vehicle detection and probe vehicle fleets, agencies can now combine these disparate data sources to obtain better performance measures. This study aimed to develop a data fusion framework, apply it to multiple test cases, and provide recommendations for public agencies on how to use the framework to improve their networks.

The first application of data fusion tested various methods with multiple data sources to predict travel time on an urban signalized arterial in Atlanta. The study found that the fusion algorithms reduced errors, and neural network based algorithms produced the lowest errors compared to other algorithms considered.

The second data fusion application evaluated and compared the Automated Traffic Signal Performance Measure (ATSPM) against two alternative methods for control delay estimation at a signalized intersection equipped with high-resolution sensors in Salt Lake City, Utah. The two algorithms provided better estimates of delay compared to the ATSPM approach. A separate validation effort confirmed the findings.

Finally, the study examined the validity of probe vehicle data for estimating link speeds on a signalized arterial. High-resolution trajectory data from a site in Los Angeles, CA, was used to assess the accuracy of probe sample speed reports from third-party providers. The study found that a minimum market penetration rate of 10% and broadcasting frequency in the 15-30 seconds range met most of the performance criteria.

2. Research Goals

1) Develop data fusion framework to incorporate data with different spatiotemporal resolutions including synthetic data sources.
2) Prototype and test signalized arterial performance measures using the data fusion framework.
3) Evaluate effectiveness and accuracy of the framework and the new performance measures compared to single-source performance measures.

3. Findings

The project focused on developing a framework for integrating data from different sources with varying geospatial and temporal resolutions for signalized arterials. Three main applications of this framework were explored: predicting travel times, improving Automated Traffic Signal Performance Measures' approach delay, and obtaining link speeds using probe vehicle data. Various data sources were used, including Bluetooth sensors, loop detectors, signal timing plans, and probe vehicles. The study found that data fusion improved travel time predictions, and two new delay estimation methods were introduced to address the limitations of the current ATSPM approach. The project also examined the impact of market penetration rate, broadcasting frequency, and aggregation level on the accuracy of reported speeds using probe vehicle data fusion.

4. Performance Metrics

Metric	# Completed
OUTPUTS	
Product(s): 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	STRIDE Final Report
OUTCOMES	
Body of Knowledge: Number of trainings for transportation professionals	2
Professionals Trained: Number of professionals participating in trainings	94
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	2

5. Product

Data Fusion Framework for Signalized Arterials and Improved Delay Estimation Methodology for Signalized Intersections

Agencies dealing with signalized intersection corridors often have access to multiple data sources with varying quality and complex data relationships. To integrate these disparate data sources, improve their quality, and support decision-making, a data fusion framework is necessary. This project aimed to address this need by developing a comprehensive data fusion framework that utilizes functional data fusion process models for geospatial and temporal fusion of traffic data. The framework allows public agencies to obtain enhanced performance measures of their network, helping to mitigate congestion and improve efficiency. Additionally, this project has developed two alternative algorithms for more accurate estimation of approach delay at signalized intersections. These algorithms not only help with identifying problematic nodes but also improve the congestion and efficiency of the entire network. While the products of this project have not been adopted yet, they offer significant potential benefits for transportation systems.

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

- Public agencies such Departments of Transportation
- Academics
- Researchers
- Consultants
- Traffic analysis tool/software developers

7. Body of Knowledge & Professionals Trained

1) October 2018: Thomas Chase participated in the STRIDE Workshop at the ITS 5C Meeting in Jacksonville, Fl. A dozen attendees participated in learning concepts and joined in a Q&A for each project. Thomas Chase introduced the STRIDE project motivation and objectives. Attendees from Florida DOT and Georgia DOT expressed interest in use of the products and offered data sharing for their existing arterial datasets. (12 Attendees)

2) In October 2021, Shoaib Samandar presented the developed framework and algorithms at the NCDOT's Research and Innovation Summit held in Chapel Hill, NC. Over 50 attendees, including representatives from NCDOT, NCSU, UNCC, UNC, and other academic institutions participated in the session. The presentation covered the motivation, objectives, and outcomes of the STRIDE project. Attendees expressed keen interest in adopting the framework and algorithms for their existing arterial datasets and offered data sharing. The session also included a Q&A where attendees could learn more about the project and its potential impact on transportation performance metrics. (50 Attendees)

3) STRIDE Webinar: "Data Fusion for Signalized Arterial Performance Measurement" presented by Data Fusion for Signalized Arterial Performance Measurement on March 8, 2023. (32 Attendees) Recording: https://youtu.be/0FebtCtjEOQ

8. Journal Publications, Conference Presentations, & Posters

Date	Type of Accomplishment	Detailed Description
10/18	Conference Presentation	*ITS5C STRIDE Workshop:* ATSPM and other Data Sources for Performance-based Prioritization of NCDOT's Statewide Signal Retiming Program, Thomas Chase
10/18	Conference Presentation	*6th Annual UTC Conference for the Southeast Region*: Making Sense of Arterial Data: Pilot Testing and Data Fusion, Thomas Chase
1/19	Conference Presentation	*STRIDE Poster Competition, TRB*: AN INTEGRATED DATA FUSION FRAMEWORK FOR SIGNALIZED ARTERIAL PERFORMANCE MEASURES, Shoaib Samandar, Thomas Chase, Nagui Rouphail
5/19	Publication	*Report*: IMPROVING ATSPM'S APPROACH DELAY CALCULATION, Ishtiak Ahmed, Shoaib Samandar, Sumit Toshniwal, Pravek Dwivedi, Taehun Lee, Thomas Chase, Nagui Rouphail
8/19	Conference Presentation	*TRB Traffic Signal Systems Committee Midyear Meeting:* Improving ATSPM's Approach Delay Calculation, Shoaib Samandar
1/20	Conference Presentation	*STRIDE Poster Competition, TRB*: Alternative Algorithms for Improving ATSPM's Approach Delay Estimation, Shoaib Samandar, Thomas Chase, Nagui Rouphail
10/21	Conference Presentation	*NCDOT's Research and Innovation Summit:* Multi-Sensor Data Fusion for Signalized Arterial Travel Time and Delay, Shoaib Samandar
03/23	Conference Presentation	*NCDOT's Research and Innovation Summit:* Multi-Sensor Data Fusion for Signalized Arterial Performance Measurement, Shoaib Samandar

9. Stakeholder Engagement

MEETING DETAILS		NARRATIVE DESCRIPTION
STRIDE rep	Thomas Chase	Thomas Chase met with NCDOT to closeout a separate NCDOT research project. As the
Date of Activity	8/2018	

Type of Activity	in-person meeting	NCDOT and STRIDE projects had very similar NCDOT stakeholders, the STRIDE project was introduced and NCDOT committed to sharing data for use in the project. A future discussion was planned to coincide with another NCDOT research meeting in May.
Location	Raleigh, NC	
Stakeholder(s) – Name, title, affiliation	Matthew Carlisle, NCDOT State Signal Systems Engineer Mohd Aslami, NCDOT State ITS & Signals Management Engineer	
STRIDE rep	Thomas Chase	Thomas Chase met as planned with NCDOT to discuss the preliminary findings of the STRIDE project. NCDOT mentioned plans to utilize ATSPM statewide with a stage implementation. NCDOT recognized the contributions of the STRIDE research project and the research team plans to submit a RNS for NCDOT's Research Program for implementation of the methods into NCDOT's future ATSPM platform.
Date of Activity	5/2019	
Type of Activity	in-person meeting	
Location	Raleigh, NC	
Stakeholder(s) – Name, title, affiliation	Matthew Carlisle, NCDOT State Signal Systems Engineer Mohd Aslami, NCDOT State ITS & Signals Management Engineer	

10. Adoption/Implementation

Although the products of this research have not been put into use, they are now available for adoption by public agencies. The researchers have been in talks with NCDOT to assist them in integrating the developed framework and enhanced delay estimation algorithms into their everyday operations. The framework, if accepted, will enable the fusion of various data sources with different spatial and temporal resolutions. Additionally, adopting the developed algorithms will enhance the estimation of transportation performance metrics, resulting in better efficiency and safety. Therefore, the potential adoption of the framework and algorithms will bring significant benefits in terms of improving transportation operations.

11. Broader Impacts

The data fusion framework for signalized arterials has the potential to positively impact the transportation system in several ways. By combining multiple data sources, the framework can provide more accurate and performance metrics, which can help transportation agencies better manage traffic flow and reduce congestion. This, in turn, can improve safety by reducing the likelihood of accidents caused by stop-and-go traffic and congestion-related incidents. In terms of costs, the data fusion framework can help transportation agencies optimize their resources by providing better information on traffic patterns and congestion. This can help agencies make more informed decisions about where to invest in roadway infrastructure and transportation services, reducing overall costs and improving the efficiency of the transportation system.

Overall, the data fusion framework has the potential to improve the safety, reliability, durability, and cost-effectiveness of the transportation system, making it a valuable tool for transportation agencies looking to improve their operations and services.

The short-term impact of the developed data fusion framework and algorithms could include more accurate and reliable real-time traffic information for drivers, which could improve safety and reduce travel time. In the long-term, the framework could be used to inform transportation planning and infrastructure decisions, leading to more efficient and cost-effective transportation systems. Additionally, the development of more advanced data fusion techniques could lead to further improvements in the accuracy and reliability of traffic data, potentially allowing for the implementation of new technologies such as connected and autonomous vehicles. However, the full impact of the framework and algorithms will depend on their widespread adoption and implementation in transportation systems.