

Request for Research Funding for FY 2023-2024

Project Number (Research Center Use Only): D4-24-01

Requesting Office	FDOT District 4	Priority	1 of 1 (projects may not have the same ranking – no ties)
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Proposed Title Integrated Management and Decision Support of Arterial Street Operations

Justification

A major constraint to advancing traffic signal control strategies and practices has been the lack of data and data analytics that allow the assessment and prediction of system performance and the support of decisions based on this assessment and prediction. However, in recent years, detailed data start to be available from multiple sources including advanced sensors, traffic control equipment, probe and connected vehicles, and third part vendors. The availability of the data have allowed the derivation of Automated Traffic Signal Performance Measures (ATSPMs). Increasingly, agencies have utilized high resolution controller data (signal control timing and detection events) and some of them have explored advanced sensing technologies that have only become available in the market in recent years. These sensors include more advanced versions of video image detectors, microwave detectors, and LIDAR detectors that provide additional data that can be used to assess the system performance in both off-line and real-time environment. Agencies are also accessing detailed data from third party vendors based on probe vehicles. This data includes in addition to traditional travel time measurements, more detailed data and measures such as vehicle trajectory data (e.g., Wejo data) and intersection performance dashboards (e.g., using Inrix data). Connected vehicle technologies will also provide additional high-resolution data that can be used to support of traffic management and operations.

The availability of data creates an opportunity for major advancements in traffic management and operations on arterial streets. Data-enabled arterial management strategies can better support the operations during recurrent conditions as well as non-recurrent events, such as lane blockage incidents or demand surge due to traffic diversion or rerouting during freeway incidents. However, there are questions that need to be answered on how best to use the data from multiple sources and what additional value can be obtained from using data from each of the new source of data considering that the data vary in their types, qualities, resolutions, details, and costs. There are a number of methods that can be used to support transportation agency decisions based on data. These methods range from simply reporting and visualizing summary statistics of system performance to advanced machine learning (ML) and artificial intelligence (AI), traffic flow theory and analysis, and simulation techniques. In recent years there has been an increasing interest in using AI/ML as part of decision support systems of transportation system management and operations (TSM&O). AI/ML can be used for the monitoring/categorization, diagnosis, and prediction of system performance; in addition to providing recommendations for the setting and activation of strategies, tactics, and plans. These systems can be classified supervised, unsupervised, and reinforcement learning. Supervised learning uses training data, which involves feeding paired inputs and outputs to the model. Examples of supervised learning are statistical regressions, neural networks, support vector machine, decision trees, and tree ensembles. With unsupervised learning, the input data is not associated with outputs. Examples are clustering, visualization, and association rules. Reinforcement learning can observe the conditions and select the best actions for a given situation.

This project will:

- Identify management strategies that can be enabled and enhanced by advanced data collection and analytics techniques based on the needs and requirements of transportation agencies
- Assess the performance measures that can be derived from different technologies in their ability to support data-enabled arterial traffic management strategies
- Identify and evaluate the data analytics technique to support the monitoring, diagnosis, prediction, and recommendation strategies for the enhancement of system performance as part of the data-enabled strategies
- Demonstrate and evaluate the benefits of using the data-enabled strategies to support the operations and management of signalized arterial streets

It is anticipated that the demonstration and evaluation of the data-enabled strategies will be conducted using case studies in the City of Boca Raton. The City of Boca Raton have installed and assessed various types of emerging traffic sensing technologies and have access to data from multiple sources and will work closely with the FDOT and the project team on this project.

The deliverables of this research will include:

- A report that summarizes the needs and decisions of traffic management/signal control agencies that can be met by data-enabled decision support systems and the associated analysis processes and techniques
- A report that summarizes and assesses the existing data sources and data collection technologies and the performance measures that can be estimated based on these technologies

	<ul style="list-style-type: none"> • A report that assess the use of different data analytics including AI/ML to support traffic management/signal control agency operations and decisions • A report that summarizes the results from demonstrating the utilization of data analytics to support the operations of the City of Boca Raton traffic coNtrol center • A draft final report and final report that summarizes all project activities and results
Impact	<p>Arterial management/signal control agency decisions have been made using a small amount data with limited analysis of the impacts of the implemented strategies during recurrent and non-recurrent conditions, resulting in suboptimal decisions. This have decreased the agency capabilities in meeting their performance targets in terms of mobility, safety, and other agency objectives. This research will allow transportation management agencies to select and refine arterial and signal control strategies, tactics, and operation plans based on information derived from the collected data in real-time and off-line decision making processes, significantly improving system performance.</p>
Affected Offices	<p>The District 4 Traffic Operations Office will need to be involved in the scoping of the research as well as its execution. The Traffic Operations Office will also be affected by implementation of the results and will need to participate in the implementation process.</p>
Existing Work	<p>In a recent study for Federal Highway Administration (FHWA), Hadi et al. (forthcoming) proposed an integrated management support system (IMSS) framework that addresses and supports all levels of decisions in an integrated manner based on business intelligence. This framework addresses the strategies, performance measurement, people, processes, platforms, and data to support the decision-making processes. Iqbal and Hadi (2017) developed a model to predict the breakdown probability on urban arterial streets utilizing ITS data collected from detectors located along Glades Road in Boca Raton, FL. Hadi et al. (2022) developed and evaluate a proactive traffic responsive plan selection (TRPS) strategy that uses ATSPM measures as input to supervised and unsupervised machine learning algorithm, and select the signal timing plans for implementation based on traffic flow parameters predicted for the near-term future. Another study by Azizi and Hadi (2021) utilized a combination of unsupervised (clustering) and supervised learning for the prediction of the traffic states based on connected vehicle data.</p> <p>Hadi et al. (Hadi, Saha, and Tariq in various papers) also investigated the use of supervised and unsupervised machine learning to support arterial signal control decisions during non-recurring events. This included arterial incidents and diversion of freeway traffic during freeway incidents. The study used a combination of two artificial intelligence approaches, namely Recursive Partitioning and Regression Decision Tree (RPART) and Fuzzy Rule-Based System (FRBS) to recommend modifications to signal timings during non-recurrent events such as incidents, construction, surge in demands, and device malfunctions. These studies also investigated the use of clustering analysis, multi-resolution modeling (MRM), and optimization techniques in the development of plans on alternative routes to accommodate diverted traffic during freeway incidents. The studies combined the use of high-resolution controller data and travel time measurements in a two-level clustering technique using the k-means algorithm to identify the traffic patterns in the network.</p> <p>Several studies explored the use of clustering for the identification and classification of traffic states based on traffic measurements. Xia (2012) used clustering method to identify congestion levels based on traffic characteristics such as flow, speed, and occupancy measures. Azimi and Zhang (2010) investigated pattern recognition methods using three clustering approaches to categorize freeway traffic conditions. Wu and Liu (2011) evaluated the impacts of signal operations on the Arterial Fundamental Diagram (AFD) by analyzing signal-based occupancy data from point detectors located on a major arterial. Kianfar and Edara (2013) studied the application of diverse clustering techniques for the categorization of traffic flow data into free-flow and congested regimes. ,Yang et al. (2017) utilized a spectral clustering algorithm to analyze the traffic state variations at the network level based on speed data. Another study by Theofilatos (2017) implemented an expectation maximization clustering algorithm to classify the traffic into multiple regimes in urban arterials for safety analysis. Gu et al. (2016) employed a k-means clustering algorithm to analyze arterial traffic flow. The study utilized high-resolution controller data and video images from multiple intersections.</p> <p>Hosseini et al. (2019) utilized time-space diagrams constructed from connected vehicles data in combination with a convolutional neural network (CNN) for the prediction of the traffic state which was defined based on the density flow relationship. Li and Ban (2019) developed a deep learning-based method for short-term traffic volume prediction of all movements at signalized intersections. Adu-Gyamfi and Zhao (2018) introduced a methodology for traffic speed prediction in urban arterials using a combination of LSTM Neural Network with an Empirical Mode Decomposition (EMD) algorithm.</p> <p>REFERENCES</p> <p>Adu-Gyamfi, Y. a. (2018). Traffic Speed Prediction for Urban Arterial Roads Using Deep Neural Networks. International Conference on Transportation and Development.</p>

	<p>Azimi, M. a. (2010). Categorizing Freeway Flow Conditions by Using Clustering Methods. Transportation Research Record, Vol. 2173, No. 1. pp. 105-114.</p> <p>Azizi, L., and M. Hadi. Utilizing Traffic Disturbance Metrics to Estimate and Predict Freeway Traffic Breakdown and Safety Events. Transportation Research Record, Journal of the Transportation Research Board, DOI: 10.1177/03611981211012422, Washington D.C., May 2021.</p> <p>Elfar, A. T. (2018). Machine Learning Approach to Short-Term Traffic Congestion Prediction in a Connected Environment. Evanston, IL: Civil and Environmental Engineering. Northwestern University.</p> <p>Gu, Y. Q. (2016). An Unsupervised Learning Approach for Analyzing Traffic Impacts Under Arterial Road Closures: Case Study of East Liberty in Pittsburgh. Journal of Transportation Engineering, Vol. 142, No. 9, p. 401.</p> <p>Hadi, M. and D. Hale. Integrated Management Support System. Developed for FHWA by Leidos, Forthcoming.</p> <p>Hadi, M. et al. Real-Time Data-Based Decision Support System for Arterial Traffic Management. STRIDE USDOT University Transportation Center Final Report, 2022.</p> <p>Hosseini, M. a. (2019). Traffic Prediction Using Time-Space Diagram: A Convolutional Neural Network Approach. (T. R. Record, Ed.) Journal of the Transportation Research Board. Retrieved from https://journals.sagepub.com/doi/pdf/10.1177/0361198119841291</p> <p>Iqbal, M. S., Hadi, M., & Xiao, Y., Predicting Arterial Breakdown Probability: A Data Mining Approach,” Journal of Intelligent Transportation System. Volume 21, Issue 3, 2017.</p> <p>Kianfar, J. a. (2013). A Data Mining Approach to Creating Fundamental Traffic Flow Diagram. Procedia-Social Behavior Science, Vol. 1934, No. 1, pp. 430-439.</p> <p>Li, W. a. (2019). A Deep Learning Approach for Lane-Based Short-Term Traffic Volume Prediction at Signalized Intersections. Seattle, USA: University of Washington.</p> <p>Saha, R., M.T. Tariq, and M. Hadi, “Deep Learning Approach for Predictive Analytics to Support Diversion during Freeway Incidents,” Transportation Research Record, Journal of the Transportation Research Board, Washington D.C., DOI: 10.1177/0361198120917673, June 3, 2020 Research Article</p> <p>Tariq, M.T., R. Saha., and M. Hadi, “Combining Machine Learning and Fuzzy Rule-Based System in Automating Signal Timing Expert’s Decisions,” Transportation Research Record, Journal of the Transportation Research Board, DOI: 10.1177/0361198120918248, Washington D.C., May 2020. J. N. Hutton, C. D. (2010). Evaluation of an adaptive traffic signal system: route 291 in Lee’s Summit, Missouri.</p> <p>Theofilatos, G. Y. (2017). Modeling the Effect of Traffic Regimes on Safety of Urban Arterials: The Case Study of Athens. Journal of Transportation Engineering (English Edition), Vol. 4, No. 3, pp. 240-251.</p> <p>Xia, J. H. (2012). A Clustering Approach to Online Traffic State Identification Using ITS Data. KSCE J. Civil Engineering., Vol. 16 No. 3, pp. 426-432.</p> <p>Yang, S. W. (2017). Analysis of Traffic State Variation Patterns for Urban Road Network Based on Spectral Clustering. Advanced Mechanics and Engineering, Vol. 9, No. 9, p. 168.</p>		
<p>Keywords Used In Existing Work Search (Cannot leave blank)</p>	<p>Signal Control, Data Mining, Machine Learning, Artificial Intelligence, Decision Support Tools</p>		
<p>Related Contracts (Give contract numbers)</p>			
<p>Funding Request</p>	<p>\$160,000</p>	<p>Anticipated Duration</p>	<p>18 Months</p>
<p>Project Manager</p>	<p>Daniel Smith</p>	<p>Contracting Method</p>	<p>Direct Contract with Florida International University (PI: Dr. Mohammed Hadi)</p>
<p>Equipment</p>	<p>Estimated equipment cost (or N/A)</p>	<p>N/A</p>	
<p>Urgency</p>	<p>Score 1-5 1= highest, most immediate need</p>	<p>Score = 1. Data are becoming available for arterial management agencies, but this data has not been fully utilized and there is a potential for much more effective use of the data. There is a critical need for development of decision support tools that use AI/ML to support agency operations based on the data.</p>	

Implementability	Score 1-5 1=greatest likelihood of and proximity to implementing results	Score = 1. The project research team will work closely with the FDOT, City of Boca Raton, and potentially the Counties in FDOT District 4 and District 6 in ensuring that all products are immediately implementable to support traffic management enter decisions.
<p>Project Benefits (Succinct, complete explanation)</p> <p>Ineffective traffic management and signal control is one of the major reason for the unreliability, congestion, and safety risks of the transportation system. The utilization of data and data analytics to support the transportation management decisions in real-time and off-line operations will significantly improve system performance reducing the delays and crashes during recurrent congestion and non-recurrent events such as incidents on the arterials and adjacent freeways and bad weather.</p>		
<p>Project Benefits (Select all that apply and explain)</p>	<p>Quantifiable Benefits (units, dollars, etc...if applicable)</p>	<p>Methodology or Data Sources Used to Determine Quantifiable Benefits. If not applicable, please give justification of project benefits</p>
<p><input type="radio"/> Materials Enhancement</p>		N/A
<p><input type="radio"/> Materials Savings</p>		N/A
<p><input type="radio"/> Time Savings</p>		<p>Significant improvement in travel time is expected. For example, Hadi et al. (forthcoming) estimate that a proactive traffic responsive traffic control strategy improves the travel time by 4% and 17%. Another study by Hadi et al. (2020) estimated that activating traffic signal control strategies to accommodate diversion during non-recurrent events reduced delay by 85 seconds to 130 seconds per vehicle per intersection depending on the severity and type of the event.</p>
<p><input type="radio"/> Lives Saved/Injuries Prevented</p>		Crashes are expected to decrease as estimated by near misses with improved signal control.
<p><input type="radio"/> Other (Explain)</p>		<p>An automated traffic signal performance measures (ATSPM) maintenance program implemented by Utah DOT was projected to save \$108 million in reduced agency labor costs and improved operations over 10 years.</p>

*Comments should explain and support urgency, financial benefit, and implementability scores