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Proactive Congestion Management

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POLICY BRIEF

BACKGROUND AND OBJECTIVES

Congestion management is an area of traffic research aimed towards reducing the impact of various forms of congestion. Typically, most congestion management solutions focus on reactive rather than proactive approaches. Proactive approaches to congestion management, unlike reactive, seek to apply algorithms and mathematical models to identify early indicators that might potentially lead to traffic congestion using available data sources such as radar sensors, loop detectors, probe or connected vehicles (CVs), and appropriately deploying mitigation strategies to optimize traffic flow and reduce delays.

This project is applicable to congestion management on corridors, both with and without managed lanes. The project utilizes data fusion between traditional sources, such as radar and loop detector data, with newer sources, such as Bluetooth and CV data, to identify conditions that signal impending congestion. The main goal is to establish a data driven methodology to signal the likely occurrence of both recurring and non-recurring congestion, irrespective of the data source. Traffic and other-relevant data from two states, Texas and Florida, in the United States are collected and analyzed. Big data and signal processing techniques are explored to understand and differentiate various levels of recurring and non-recurring congestion within the collected data.

The overall aim of this project is to utilize aggregate data available from traditional traffic monitoring sources coupled with CV data and other geospatial information to build a more robust congestion detection algorithm for freeways. The robustness and proactive capabilities of the algorithm are prioritized to effectively test and deploy congestion mitigation strategies in the study area. More specific objectives of this project are to:

- Conduct a thorough literature review on existing measures of congestion and near real-time congestion management/mitigation strategies.
- Develop a congestion detection methodology applicable to both traditional (i.e., radar, loop detectors, Bluetooth) and CV-based data sources, originating from different geographic locations.
- Utilize the depth of low penetration CV-data along with traditional measures of traffic congestion to develop and validate a congestion detection algorithm.
- Highlight the versatility of CV-based infrastructure even at low market penetration, when compared to other traffic data sources.
- Use TransModeler to simulate recurring and non-recurring congestion, and potential mitigation strategies (based on algorithm output) on the Tampa Hillsborough Expressway Authority (THEA) Selmon Expressway in Tampa, FL.

METHODOLOGY

To achieve the overall aim, data compatibility checks, facility/corridor matching, and data fusion of various traffic and environmental variables are performed. Compatibility check is initially performed to ensure travel time estimates generated from Basic Safety messages (BSMs) and Bluetooth detectors can be used interchangeably for the development and validation of the congestion detection algorithm. A criteria matching tool was developed to identify freeway facilities from the pooled databases of the project research teams, with similar traffic and geometric properties across the two states, Florida and Texas, in United States. Data from the two geographic locations were used to introduce variability and improve robustness of the congestion detection algorithm. Data fusion is then applied to merge travel times, average speeds, incident and planned lane closure records, and weather elements.

A universal parameter, b1 metric, is established to compute change in travel time index (TTI) intensity between two successive time-steps to unify congestion indicative variables across segments (independent of geometric and traffic properties). The Butterworth infinite impulse filter, derived from signal processing, is tested to smooth the variability observed in the b1 metric and proactively signal potential congestion along with its intensity.

 DOI: doi.org/10.5038/CUTR-NICR-RR-2022-4-2

RESEARCH FINDINGS

This project sought to develop a robust proactive congestion detection algorithm. Mitigation strategies applicable to selected study areas are simulated under recurring and non-recurring congestion to explore any improvements to traffic flow and roadway safety. The methodology applied to the preparation and fusion of the datasets, especially CV data, prove to be efficient in generating the same level of travel time data quality as other more common sources such as Bluetooth, even at low CV market penetration. The versatility of BSM data provides great flexibility for travel time estimation in more aggregate/shorter segment lengths.

The validated congestion detection algorithm shows a mean prediction error of 30.2% and is relatively effective in proactively predicting the onset of congestion and its intensity levels (i.e., normal, recurring/weather-related, other non-recurring, and incidents). However, the process followed to compute the prediction error heavily penalizes the algorithm especially in instances where the ground truth cannot be fully verified to the nearest 5-minute time period (i.e., time logs from incident reports could be filed as a derivation of officer arrival time and not actual crash time). The algorithm is expected to have an overall lower prediction error in real-world applications.

Microsimulation was applied to replicate real-world congestion scenarios and test feasible strategies applicable to the Selmon Expressway in Tampa, FL. A previously unexplored method to calibrate microsimulation models using real-world CV data more realistically by employing virtual sensor-based segment division was utilized and found to be successful in simulating various (normal, recurring, and non-recurring) traffic conditions, with normalized root mean square errors of less than 30% per individual section of calibration. Two congestion mitigation strategies were simulation tested. Combining speed harmonization and dynamic rerouting was observed to provide the most benefit, in terms of traffic flow and roadway safety, within the congested sections and across the entire facility.

POLICY AND PRACTICE RECOMMENDATIONS

The developed congestion detection algorithm is robust enough to function using either traditional or CV travel time datasets, thus addressing earlier identified research gaps from the literature such as the current focus on complex data sources and analytics in favor of existing, and still valuable, infrastructure and datasets. This robustness makes the implementation of the methodology relatively more efficient for transportation agencies using traditional infrastructure or those already transitioning to more advanced data sources such as CV technology. To deploy the algorithm, transportation agencies only require access to live travel time estimates of the roadway segments, preferably two miles or shorter in length depending on agency-specific precision requirements for identifying the congestion location and progression. For effective deployment of the congestion detection algorithm in specific locations, optimization of the congestion thresholds can be performed using historical travel time data of the facility, where available.

This project also demonstrated the advantage of using CV-based travel time estimates to calibrate simulation models over fixed point-based derivations of travel time from spot speeds or limited probe vehicle estimates. While TransModeler was the microsimulation tool used in the study, the calibration process utilized universal driver behavioral models of car-following and lane changing to ensure replicability across other microsimulation platforms. The ability to calibrate simulation models based on individual sections of shorter lengths (less than or equal to 0.5 miles) allows for a more detailed replication of real-world conditions including potential impacts of deploying mitigation strategies to combat congestion.

For more information on this project, download the entire report at nicr.usf.edu or contact **nicr@usf.edu**

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