Texas A&M Transportation Institute

PROJECT SUMMARY

Texas Department of Transportation

0-7131: Leveraging Artificial Intelligence (AI) Techniques to Detect, Forecast, and Manage Freeway Congestion

Background

Enhancing the quality and efficiency of the Texas surface transportation system necessitates reliable predictions about the initiation and dispersion of prolonged congestion, as well as effective tracking of atypical events and their potential evolution. Artificial intelligence (AI) offers a unique avenue for achieving these goals, presenting an opportunity to accurately estimate congestion measures by utilizing data from various sources, including agency-owned sensors, third-party providers, and extensive enterprise databases. The Texas Department of Transportation (TxDOT) 0-7131 project aims to bridge the current research gap through the implementation of two main project phases. The first phase seeks to verify the reliability of commercial data sources for transportation planning and operations. The second phase focuses on identifying the most effective AI models or algorithms to meet the Agency's needs, considering specific use cases and data availability. Additionally, it is crucial to conduct an in-depth analysis of the requisite data models and workflows to determine the long-term sustainability of training, testing, and validating the proposed AI methodologies.

What the Researchers Did

In this research project, researchers designed a comprehensive survey to understand the freeway congestion reduction practices state departments of transportation employed by using big data. This survey addressed topics such as data collection methods, data analysis techniques, big data platform usage, report creation practices, and future needs.

Subsequently, the researchers developed AI models to predict congestion measures in Texas. These models considered three congestion indicators: average operating speed, standard deviation of operating speed, the 85th percentile operating speed, and percent variation in travel time. To build these models, the team utilized a variety of machine learning techniques, including Random Forest, Gradient Boosting, K-Nearest Neighbors, Support Vector Regression, Artificial Neural Networks, and CatBoost. The team explored scenarios both with and without crash data as independent variables, utilizing a dataset comprising 28,684 rows of freeway segments for this analysis. Separate models were created for rural and urban land-use types. The researchers also incorporated explainable AI methods, specifically Shapley Additive explanations, to interpret the outcomes of the modeling process.

Finally, the team developed a prototype decision support tool based on geographical information system technology. This tool is designed to estimate and visually illustrate freeway congestion, allowing transportation authorities and planners to identify congestion hotspots. This identification process assists in prioritizing infrastructure

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improvements or targeted traffic management interventions. By analyzing congestion measures for various segments, authorities can more effectively allocate resources and implement measures aimed at mitigating congestion and improving overall traffic flow.

What They Found

The research findings provide valuable insights into freeway congestion and its influencing factors. The study reveals that major urban areas, such as Houston and Dallas, experience significant congestion due to high population densities, extensive transportation networks, and economic activities. Congestion levels vary across different segments within urban areas due to factors like road network design, traffic demand, and ongoing construction or maintenance projects. Additionally, posted speed limits (PSLs) have a significant impact on congestion measures, with different segments exhibiting unique congestion patterns based on their respective speed limits. The study highlights the importance of considering speed limits when assessing congestion levels and developing effective mitigation strategies.

For rural freeways, the prevalence of districts with varying PSLs raises the need to investigate influencing factors such as geographic location, population density, economic activities, and transportation infrastructure development. Most rural freeways, regardless of the PSL, are designed with only two lanes, which can lead to limited capacity and potential congestion during peak travel times or periods of high traffic demand.

Similarly, urban roadways' capacity to handle traffic volumes is greatly influenced by the number of lanes they have. Although a greater number of lanes generally indicates higher capacity and smoother traffic flow, urban roadways are not immune to congestion. Factors like merging points, interchanges, and bottlenecks can still contribute to travel time variability and congestion.

What This Means

The research findings highlight the importance of targeted congestion mitigation strategies and infrastructure improvements, particularly in urban areas with significant congestion like Houston and Dallas. Transportation authorities and planners should prioritize resources effectively to address the specific characteristics and congestion patterns of different roadway segments. Implementing dynamic traffic management strategies, such as variable speed limits and ramp metering, can help adapt to the spatial and temporal variations in congestion. Additionally, based on the distinct congestion dynamics associated with higher and lower speed limits, a careful review and adjustment of speed limits in different segments is necessary. On rural freeways, it may be beneficial to consider adding lanes or creating bypasses to enhance capacity and alleviate congestion during peak travel times. For urban roadways, identifying and improving problematic areas like merging points, interchanges, and bottlenecks is crucial to reduce travel time variability and congestion, even with multiple lanes in place. By implementing these recommended strategies, transportation authorities can effectively address congestion and improve overall traffic flow in both urban and rural areas. The findings provide valuable guidance for decision-makers to prioritize resources, allocate funding, and implement specific measures tailored to the unique characteristics and congestion patterns of different freeway segments. Ultimately, these efforts can lead to a more efficient and reliable surface transportation system in Texas.

For More Information

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