DATA DRIVEN MODELING OF PAVEMENT CONDITIONS FOR FLOOD-PRONE ROAD NETWORKS USING MACHINE LEARNING AND GIS TECHNIQUES

From Flood Exposure to Maintenance Priorities

SOUTHEAST TEXAS
URBAN INTEGRATED FIELD LAB

WHY NOW?

Urban road networks in flood-prone regions deteriorate faster due to repeated exposure to standing water, saturated subgrades, and extreme rainfall. Traditional pavement management systems often treat road condition as a function of age and traffic alone, overlooking the compounding effects of flooding and climate exposure. As a result, agencies may underestimate deterioration rates in vulnerable neighborhoods, misallocate maintenance funds, and struggle to prioritize repairs that improve long-term resilience and equity.

WHAT WE DID

This work integrates pavement condition data, flood exposure information, climate variables, and infrastructure characteristics into a unified, map-linked dataset to support data-driven modeling of roadway performance. Road segments were spatially defined using GIS and linked through a unique identifier to pavement condition surveys (PCI, IRI, distress metrics), maintenance and rehabilitation records, traffic and design attributes, precipitation and temperature data, flood depth and frequency indicators, terrain-based indices, and ground deformation measures. Machine learning models—including Random Forest and XGBoost—were trained to predict pavement condition changes over time, with model interpretation performed using explainable AI techniques to identify the most influential drivers of deterioration and improvement. Spatial analyses were used to identify clusters of accelerated degradation and recovery across the roadway network.

WHO WAS INVOLVED?

This work was developed in close coordination with local and regional partners in Southeast Texas. The City of Beaumont provided pavement inspection data and maintenance histories through its pavement management system. Flood exposure layers and environmental datasets were assembled with support from academic researchers and students working through Lamar University's Center for Resiliency. The resulting data products and modeling framework are designed to directly support local agencies, emergency managers, and transportation officials responsible for maintaining flood-exposed roadways and ensuring safe mobility during and after high-water events.

FINDINGS

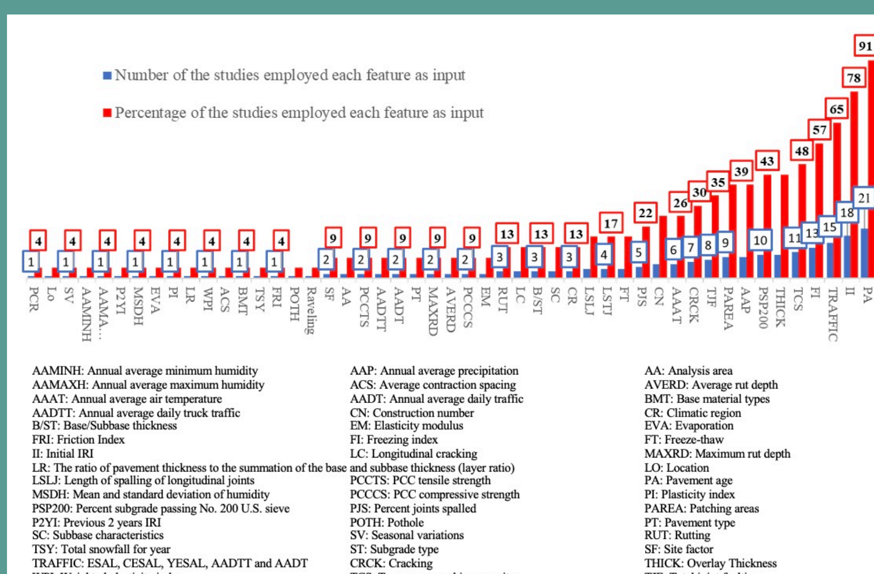
• Pavement performance in flood-prone urban networks is controlled by a combination of initial structural condition, maintenance history, and hydrologic exposure, rather than age and traffic alone.

• Initial condition indicators, particularly PCI and IRI, remain dominant predictors of future pavement performance, but flood-related stressors such as inundation depth, flow intensity, flood frequency, and terrain-driven water accumulation are observed to significantly accelerate deterioration.

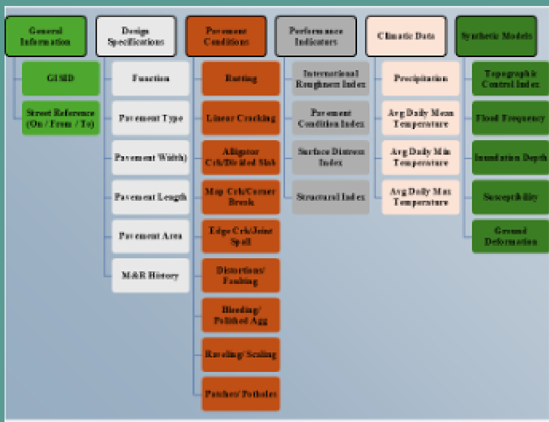
• Machine-learning-based models provide superior predictive capability compared to traditional statistical approaches by capturing nonlinear interactions among pavement characteristics, climate, maintenance treatments, and flood exposure.

• Spatial analysis reveals that pavement deterioration is spatially clustered in low-lying, flood-susceptible corridors, while condition improvements align strongly with segments receiving timely and appropriate maintenance or rehabilitation.

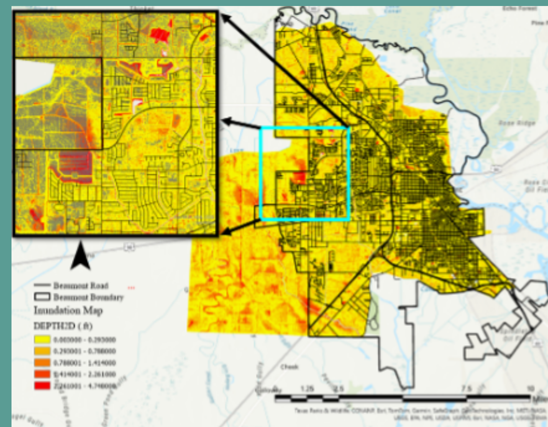
• Integrating flood exposure and environmental context into pavement performance modeling improves maintenance prioritization, supports proactive asset management, and enhances roadway resilience in communities experiencing recurrent flooding.



Most common inputs for predicting roughness: pavement age and starting roughness appear most frequently across existing studies.



Dataset Organization



Estimated floodwater depth across Beaumont road segments to show where streets may face deeper water.

MORE ABOUT SETX-UIFL

The Southeast Texas Urban Integrated Field Lab (SETx-UIFL) is one of four projects funded in 2022 by the U.S. Department of Energy to study how climate, environment, and urban changes affect cities. A team of over 80 researchers from UT, Lamar University, Texas A&M, Prairie View A&M, Oak Ridge National Lab, and Los Alamos National Lab has collected data and conducted modeling across hazards including flooding, hurricanes, heat stress, and air quality. Our Why: Southeast Texas faces numerous hazards, yet smaller communities like this one have often felt forgotten compared to larger cities. The SETx-UIFL was designed to explore the complex dynamics of disaster vulnerability for this economically and culturally vibrant region. We believe Southeast Texas is a bellwether for the entire Gulf Coast, and an exemplar for strategies that protect people and places. We hope this effort supports your path toward lasting resilience.

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