Research Project Name: Integrating Machine Learning and Optimization with Spatiotemporal Techniques to Develop a Methodology for Assessing Rural Resilience

Recipient/Grant (Contract) Number: Florida A&M University; Florida State University

Center Name: Rural Safe, Efficient, and Advanced Transportation (R-SEAT) Center

Research Priority: Preserving the Existing Transportation System

Principal Investigator(s): Eren Erman Ozguven, Ren Moses

Project Partners: Apalachee Regional Planning Council

Research Project Funding: $134,274 (Federal request); $67,935 (Non-Federal cost share)

Project Start and End Date: 6/1/2023 to 5/31/2024

Project Description: The objective of this project is to develop a methodology to assess the resilience of rural communities against natural disasters such as hurricanes by integrating Geographical Information Systems-based spatiotemporal analysis with machine learning and optimization techniques.

Research into urban resilience has dwarfed the very limited disaster resilience research in rural settings. Because of their different characteristics, a resilience solution in an urban city may not work in a rural environment. This gap between urban and rural readiness became more apparent after catastrophic events such as Hurricane Michael. Adding complexity are the populations at risk, such as the aging population, the most rapidly growing population segment in the State of Florida, and disproportionally the most adversely affected people from storms. As such, there is a clear need to develop novel methodologies along with improvements to the resilience of existing and future infrastructure that can better fit the distinct needs of these rural communities.

Moreover, the performance of physical infrastructure systems – whether intact or damaged – is a function of their interaction with social systems. Therefore, there is a need to identify this interaction to fully comprehend the impacts, coping strategies, and barriers to recovery of hurricane victims, particularly differential effects on vulnerable groups such as low-income households, minorities, outdoor workers, the elderly, and the chronically ill. With a focus on Florida's Panhandle as a test bed, this project will develop a methodology to assess the resilience of these communities using machine learning, optimization, and spatiotemporal techniques based on historical and real-life infrastructure status with data on the environment, socioeconomic, demographic, and health-related characteristics of the population.

US DOT Priorities: The use of proposed advanced technologies is critical as outlined in the USDOT RD&T Strategic Plan 2022-2026, specifically under the themes of Climate and Sustainability on reducing the impacts of climate change by developing methods to assess and mitigate the risks to transportation system performance, and Advanced Asset Management on improving the resilience of transportation assets. It is also clearly indicated as part of USDOT Innovation principles, enabling adaptability and resilience in transportation systems towards the digital age.

Outputs: The proposed methodology will be used to assess this vulnerability at multiple levels and develop an effective remedial action scheme to (a) identify the impacted rural communities in varying population densities with respect to the hurricane-induced frequency and duration of service disruptions, (b) characterize the spatial and temporal patterns in infrastructure and environment-related disruptions within these communities, and utilize those patterns to provide future situational awareness and decision support, (c) hierarchically prioritize the restoration of rural transportation systems, and (d) provide these services with awareness of those rural communities (i.e., aging populations).

Outcomes/Impacts: Developing the proposed integrated methodology will extend our knowledge of community-scale limitations of rural areas in planning for catastrophic storms and provide critical insights into the risks and constraints associated with them. We will carefully test and validate the methodology using the Panhandle rural communities and identify the barriers and limitations in the context of data availability, model accuracy, and scalability. We will leverage the research findings to inform governments and communities towards developing strategic adaptation and

implementation plans and to articulate efficient strategies in utilizing these findings in the preparedness, response, and mitigation operations.

Three papers were presented at 2025 TRB Conference.

- Takyi, S., Antwi, R., Ozguven, E. E., Okine, L., & Moses, R. (presented 2025, January). Assessing the Impact of Hurricanes on Roadway Closures and Accessibility: A Machine Learning–Based Case Study of Hurricanes Ian and Idalia in Florida. Paper presented at Transportation Research Board's 2025 Annual Meeting, Transportation Research Board, Washington, DC.
- Kaya, M., Alisan, O., Karaer, A., & Ozguven, E. E. (presented 2025, January). Assessing Tornado Impacts in the State of Kentucky with a Focus on Demographics and Roadways Using a GIS-Based Approach. Paper presented at Transportation Research Board's 2025 Annual Meeting, Transportation Research Board, Washington, DC.
- Antwi, R., Lawson, P., Ozguven, E. E., & Moses, R. (presented 2025, January). Post-Tornado Roadway Debris Detection from Satellite Images: An Integrated GIS and Image Processing Approach on Florida's Public Roadways. Paper presented at Transportation Research Board's 2025 Annual Meeting, Transportation Research Board, Washington, DC.

Six papers have been published:

- Antwi, R., Takyi, S., Karaer, A., Ozguven, E. E., Kimollo, M., Moses, R., Dulebenets, M., & Sando, T. (in press). Automated Geographic-Information-System-Based Framework for Detecting Crosswalk Changes from Bi-Temporal High-Resolution Aerial Images. Transportation Research Record, 20 pages.
- Takyi, S., Antwi, R., Ozguven, E. E., Okine, L., & Moses, R. (2025). Towards Sustainable and Resilient Infrastructure: Hurricane-Induced Roadway Closure and Accessibility Assessment in Florida Using Machine Learning. Sustainability, 17(9), Article 3909.
- Sevim, A., Guo, Q., & Ozguven, E. E. (2025). A Simulation-based Framework for Leveraging Shared Autonomous Vehicles to Enhance Disaster Evacuations in Rural Regions with a Focus on Vulnerable Populations. Journal of Infrastructure Preservation and Resilience, 6, Article 10.
- Antwi, R., Lawson, P., Kimollo, M., Ozguven, E. E., Moses, R., Dulebenets, M., & Sando, T. (2025). Automated Detection of Pedestrian and Bicycle Lanes from High-Resolution Aerial Images by Integrating Image Processing and Artificial Intelligence (AI) Techniques. ISPRS International Journal of Geo-Information, 14(4), Article 135.
- Antwi, R., Lawson, P., Ozguven, E. E., & Moses, R. (2025). Post-Tornado Roadway Debris Detection from Satellite Images: An Integrated GIS and Image Processing Approach. Remote Sensing Applications: Society and Environment, 37, Article 101439.
- Yang, J., Kocatepe, A., Alisan, O., & Ozguven, E. E. (2024). Geographical Information Systems-Based Assessment of Evacuation Accessibility to Special Needs Shelters Comparing Storm Surge Impacts of Hurricane Irma (2017) and Ian (2022). Geographies, 5(1), Article 2.

Final Research Report: https://cdn.prod.website-files.com/656f7c66bed80d5266213809/6812b54a9745c64a991e70db_UTC%20REAT%20Final%20Report_FAMU%20Project%201_First%20Year.pdf