Research Project Name: From perception to preparedness: Virtual reality simulations of flooded roadways in coastal communities (UPRM)	
Improving the Durability and Extending the Life of Transportation Infrastructure	

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Project Partners:
Municipality of Isabela, PR

Research Project Funding:

Federal: $ 50,005	Match: $ 50,482 (UPRM)
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Project Description: Coastal flooding regularly disrupts transportation networks, damages infrastructure, and limits access to essential services through storm surge, tidal inundation, and extreme precipitation. These events result in vehicle failures, stranded motorists, pavement damage, and delays in emergency response and daily mobility. Communities with aging infrastructure, limited resources, or constrained evacuation options face heightened vulnerability. The total annual economic burden of flooding in the U.S. ranges from $179.8 to $496.0 billion (US Congress JEC, 2024). In addition, the National Weather Service and the Centers for Disease Control and Prevention report that over half of all flood-related drownings occur when a vehicle is driven into hazardous floodwater. Understanding how drivers decide whether to cross or avoid flooded roads is essential for designing warnings, signage, and roadway treatments that reduce risky behavior and improve outcomes. The use of virtual reality (VR) and immersive 360° scenarios can let residents experience rising water, blocked routes, and mitigation measures without real-world risk, increasing realism and emotional stimulus. Scenario-based VR visualizations can help translate technical flood data into intuitive, actionable information for nontechnical audiences. Local resilience depends not only on infrastructure but also on household-level preparedness and decision-making, including how individuals interpret alerts and respond to flood risks. Chacon-Hurtado (2013) advocates for embedding community preferences and preparedness considerations directly into transportation decision-making frameworks, arguing that investments should be evaluated not only on engineering metrics but also on how they advance local capacity to act under hazard conditions.

This project will employ virtual reality (VR) simulations of flooded highways that are being developed by the UPRM team to study human behavior and perception in flood scenarios, with three main goals:

1) Enhance public understanding of flood risks by immersing participants in realistic coastal flooding scenarios,
2) Evaluate driver decision-making when encountering flooded roadways, analyzing how variables such as water depth, roadway conditions, and alert systems (e.g., signage, ADAS, in-vehicle alerts) influence choices, and
3) Assess community preferences for flood mitigation strategies, using immersive experiences to gather feedback on potential interventions.

Two VR approaches will be implemented. The first involves a driver simulator with 24–36 participants navigating flooded roadway scenarios to assess behavioral responses under controlled conditions. The second approach will engage community members from coastal municipalities like Isabela, Puerto Rico, in immersive 360° simulations to explore perceptions

of flood risk and mitigation strategies. Pre- and post-tests will measure changes in knowledge, perception, and behavioral intent. Insights from both simulations will inform the design of more effective alert systems and flood mitigation strategies that reflect community preferences and improve safety. The findings will support transportation and emergency planning professionals in developing human-centered solutions for flood-prone coastal areas.

US DOT Priorities: *Section left blank until USDOT's new priorities and RD&T strategic goals are available in Spring 2026.*

Outputs:
- Empirical data from VR driver simulations will assist in assessing how the contextual factors of roadway flooding events characteristics and driver warning modalities can influence decisions to cross or avoid flooded roads. Analyses will compare decision rates, response times, and changes in risk perception across experimental conditions and participant demographics.
- Methodologies and Processes: Development and validation of a dual-simulation framework integrating driving scenarios and community immersive experiences to evaluate human behavior under flood conditions that could be applied to other coastal communities in the US. Within this framework, different types of flood warnings can be experimentally tested and compared to determine which are most effective at deterring risky behavior.
- Partnerships and Practical Application: Collaborations with local and state transportation agencies, emergency management authorities, and community organizations to validate findings and support the implementation of the most effective warning modalities. These partnerships will facilitate the translation of research outcomes into operational practices and community risk communication strategies.

Outcomes/Impacts:
- Educational and Transferable Materials: A set of reusable VR scenarios and experimental protocols for training, community engagement, and emergency flood preparedness. Materials will include user guides, measurement instruments (pre/post questionnaires), and evidence-based recommendations for effective risk communication strategies.
- Improved Understanding of Driver Decision-Making: Empirical evidence on how flood length, water depth, flow conditions, and warning modalities (static signage, dynamic alerts, in-vehicle notifications) affect drivers' decisions to cross or avoid flooded roadways.
- Evidence-Based Risk Communication: Identification of the most effective driver warning types to influence safe driving behavior on roadway flooding scenarios, providing actionable insights for transportation agencies.

Policy and Educational Impacts: Findings can guide emergency management practices, community preparedness programs, and targeted educational interventions. It is anticipated that the research outcomes will be adaptable to other coastal communities.

Final Research Report: URL to final Report will be provided upon completion.