Request for Research Funding for FY 2023-2024			
Project Number (Research Center Use Only): TEO-24-05			
Requesting Office	D6 Traffic Operations	**Priority** High	5 of 11
Proposed Title	Resilience Assessment and Real-time Adaptation for Roadway Networks in Florida Coastal Cities under Extreme Rainfall Events		
Justification	**Background** Global climate change is increasing the likelihood of extreme events, such as flooding, particularly in low-lying coastal areas. Flood risk will also increase due to the rapid urbanization, given the growing concentration of population and assets in cities and the clustering of cities along coastlines. Due to its low elevation, large coastal population, and frequent storm events, Florida experiences significant economic losses from floods. Recent estimates from the National Centers for Environmental Information (NCEI) indicate that from 1990 to 2022, Florida suffered more than $10 billion (in current US$) in losses. Based on a composite risk score accounting for floodplain area and the number and value of households, Florida ranked as the state with the highest risk for flooding. Floods can lead to substantial direct damage to transportation infrastructure assets and cause significant indirect losses to communities that rely on transportation networks. This damage could further result in several disruption scenarios to the transportation system. For example, certain trips will not occur as flooded roadway links have made it impossible for vehicles to get from one place to another. Many trips will require longer travel time due to flooding. Vehicles are forced to take alternative routes to avoid impassable links, or as a result of traffic congestion on passable links that is caused by the diversion of traffic away from impassable links. These disruptions have significant economic costs due to the cancellations of trips or longer travel time. How to effectively manage the risks of floods by deploying adaptation strategies to improve the resilience of road networks is a question that constantly concerns many agencies. This issue has become increasingly urgent with the likely increase in the frequency and intensity of floods in the South Florida area. While many jurisdictions and traffic engineers have extensive experience coping with weather disruptions, they are confronted with the emerging challenge of identifying and developing appropriate real-time adaptation strategies to address greater risk and uncertainty associated with extreme rainfall events. **Research Gap** Currently there are no high-resolution frameworks (detailed 2D flooding inundation) that can identify the nodes and links of road networks (and their areas of influence) that become impassable due to excessive flooding, prior to extreme flooding events. These forecasted maps could be created days before extreme flooding events and updated every few hours as more weather information becomes available, and they would provide jurisdictions with the ability to identify affected links or node for road networks under various flooding scenarios. With the aid of forecasted maps to distinguish the network links or nodes that become impassable, the vehicle flow and the amount of travel time can be obtained by running the Urban Transportation Modelling System (UTMS). These results can be compared with the normal circumstance that provide baseline values of traffic flow and system travel time to determine how many lost trips and how much extra travel time may be attributed to the weather event. **Research Objectives** The goal of this project is to develop an integrated system that produces forecasting maps for identifying links or nodes (and their areas of influence) that will be made impassable due to excessive flooding. The integrated system will consist of three interdependent components: the road network component that generate dynamic traffic flow when identifying problematic links of nodes of road network and areas of influence; the hydrology component that uses real-time information from the NOAA/NWS's National Water Model (NWM) for rainfall-runoff modeling and routing; the hydraulics component that simulate predicts inundation. The system will be tested and validated in Miami-Dade County and Broward County through pilot studies. The specific research objectives of this project include: a. The existing tools for resilience assessment, risk management, and adaptation planning will be synthesized.		

b. Flood risk assessment will be provided for Miami-Dade County and Broward County based on historical events considering small, medium and large rainfall events with a focus on hurricane-induced flooding events in the last two decades.
c. Real-time flood conditions will be monitored and the impact areas on the road network will be identified.
d. Traffic models will be developed considering the dynamics of travel choice behavior for motorists from different traffic analysis zones under various storm weather scenarios.
e. Adaptation strategies will be developed to account for the various storm weather scenarios.
f. Visual analytics will be used to evaluate the robustness of road network and provide jurisdictions and traffic engineers with real-time responsiveness to identify the optimal adaptation strategies.

Benefits and Impacts

This system will provide a more accurate assessment on the potential impacts of extreme storm events on road network in terms of better estimates of the time window (when it will happen), the magnitude of impacts (how large are the inundation depths much rainfall is expected), and the impact areas (where flooding is expected). Knowledge of the impacts of floods on road network and information on how best to respond to the challenge is critical for jurisdictions to ensure the mobility they provide and the safety of passengers during extreme storm weathers and evacuations.

Intended Implementation of Research

The following supporting implementation plans will be performed to achieve the stated objectives:

Task 1: Flood risk assessment will be conducted according to the historical data. A scoring system was used to rate each road and road link in the region with respect to their resilience to permanent sea level rise inundation and periodic inundation from storm surge and heavy rainfall. The following Figure 1 outlines the workflow for the technical analysis for the flood risk assessment.

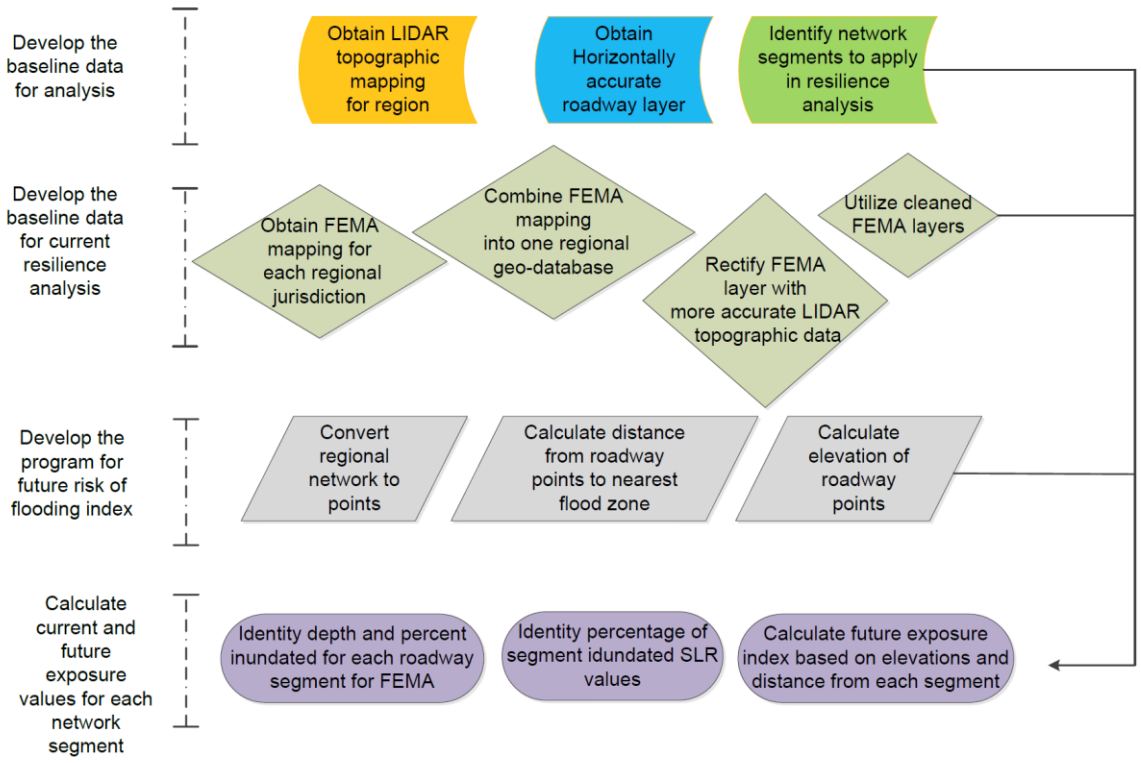

Fig. 1. Flood risk assessment for roadway networks

	Task 2: High-resolution frameworks (detailed 2D flooding inundation) will be generated to determine when roadway segments may flood; how high floodwaters may get; how much lead time we have to prepare; and what resources are needed. Task 3: Flood early warning system will be developed by identifying types if warning alerts and recommending flood forecasting for "hotspot" areas. The flood early warning will be put out by the traffic management center (TMC) through variable message signs (VMS) and 511 systems for immediate deployment. Task 4: Pilot studies will be conducted to validate the forecasted maps. Two counties in south Florida, namely Miami-Dade and Broward Counties, will be selected to conduct the pilot studies. A unique aspect of the metropolitan area is that with the Atlantic Ocean on the east and the Everglades on the west, the Miami urbanized area is approximately 110 miles long and at most 20 miles wide, making it one of the most densely populated urbanized areas in the U.S. This geography also results in a transportation system that is very concentrated in north-south corridors. **Anticipated outcome of Implementation** A major outcome of this project is evaluation of the performance of road networks in Florida during recent flooding events in order to meet transportation departments' goals and objectives of transportation safety in urban areas. The detailed 2D flooding inundation can provide better predictions on flooding for first responders, and it provides the efficient way to compare radar rainfall estimates with on-the-ground measurements. Color-coded links and nodes and real-time legend representations will provide easily distinguishable information to distinguish traffic flow pattern under typical operating conditions from those of a flooded network. This project will provide jurisdictions and stakeholders with real-time responsiveness to identify the optimal adaptation operational strategies under extreme conditions.
Impact	This project will provide the FDOT with a much-needed tool for creating near real-time maps for identifying links and nodes (and their areas of influence) that will be made impassable due to excessive flooding. Color-coded links and nodes and real-time legend representations will provide easily distinguishable information to distinguish traffic flow pattern under typical operating conditions from those of a flooded network. These models will provide jurisdictions and traffic engineers with real-time responsiveness to identify the optimal adaptation operational strategies under extreme conditions. If this project is not performed, FDOT might not have a tool or method for determining the boundaries of inundation in Florida road networks. This in turn will limit FDOT's capabilities of having accurate information for making optimal adaptation strategies before and during extreme weather conditions.
Affected Offices	State Traffic Engineering and Operations, District Traffic Operations
Existing Work	Two major studies significantly advanced the transportation adaptation to extreme weather events field: BD548-05, Framework for Modeling Emergency Evacuation, 2005, Florida Department of Transportation. Traffic Engineering and Operations. BC096-17, Post-Disaster Dynamic Routing of Emergency Vehicles, 2003, Florida Department of Transportation. Traffic Engineering and Operations. Even though some work has been done coupling weather, inundation and transportation engineering models, all of the applications used statistical return periods for the precipitations and were intended for planning purposes. Furthermore, the resolution of the inundation modeling in most existing work was relatively coarse and most of the models used one-dimensional modeling, which is not suitable for relatively flat areas such as Florida. What we propose in this problem statement is that we use weather forecasts (using Weather Research and Forecasting Model) with a lead time of 7 days, so the product can be used in near real-time. Furthermore, the inundation modeling would be very detailed and use a 2D model.

Keywords Used In Existing Work Search **(Cannot leave blank)**	2D flooding inundation, Resilience assessment, Road network, Hurricane-induced flooding events		
Related Contracts (Give contract numbers)	N/A		
Funding Request	$270,000	**Anticipated Duration**	18 months
Project Manager	Javier Rodriguez, D6 Edith Wong, STEO, Co-PM	**Contracting Method**	Direct contract FIU, Dr. Guo
Equipment			
Urgency	Score - 1	Florida is particularly vulnerable to extreme weather conditions and excessive flooding events, which cause major financial losses, road network operations, damage to transportation infrastructures, and ultimately threats to public safety and human lives. As the probability of extreme storm events is projected to rise under the global warming scenarios, this project addresses this urgent issue by providing a more accurate tool to monitor flooding conditions real-time monitoring and road network operations.	
Implementability	Score - 1	The integrated system can be applied to the entire state. The visual analytics tool will be directly implementable by the district offices. This will be implementable given that we currently don't have a system that can identify areas prone to flooding. Flooding has been an operational challenge historically.	

Project Benefits (Succinct, complete explanation)

This project will provide the FDOT with a reliable tool to create near real-time maps for identifying road network links and nodes (and their areas of influence) that will be made impassable due to excessive flooding, which allows more accurate assessment on the potential impacts of extreme storm events on transportation networks. This tool will inform the development of evacuation and management plans and provide agencies and stakeholders (e.g., Josiel Ferrer-Diaz from DTPW from Miami-Dade County) with real-time responsiveness to improve the robustness of road network, enhance safety efforts, and improve system efficiency in response to extreme storm events.

Project Benefits **(Select all that apply and explain)**	**Quantifiable Benefits (units, dollars, etc…if applicable)**	**Methodology or Data Sources Used to Determine Quantifiable Benefits. If not applicable, please give justification of project benefits**
○ Materials Enhancement		
○ Materials Savings		
○ Time Savings	More accurate response plans can be developed in advance to reduced economics loss	The developed tool will provide accurate information on the flooding and expected impacts on roadway networks prior to the extreme storm events, which provides significant time savings for transportation system operators and safety

		officials to develop management and operations plans in response to the storm events.
○ Lives Saved/Injuries Prevented	More efficient rescue and evacuation responses	Accurate and timely information provided by the tool will lead to better planning, management, and operation decisions in response to extreme storm events, which would help save lives and prevent injuries.
○ Other (Explain)		

*Comments should explain and support urgency, financial benefit, and implementability scores