Research Project Name: Link Disruption Scenario Generation for Transportation Network Criticality Analysis	
Recipient/Grant (Contract) Number: Florida A&M University; Stony Brook University	
Center Name: Rural Safe, Efficient, and Advanced Transportation (R-SEAT) Center	
Research Priority: Improving Mobility of People and Goods	
Principal Investigator(s): Anil Yazici	
Project Partners: -	
Research Project Funding: \$89,618 (Federal request); \$45,768 (Non-Federal cost share)	
Project Start and End Date: 6/1/2024 to 12/31/2025	

Project Description: Policy makers need the criticality ranking of transportation network links so that they can act to suggest investment/improvement strategies. The criticality of transportation networks links is calculated through utilizing selected criticality metric(s) for various disruption scenarios. The disruption scenarios generally include link failure scenarios that can correspond to one link removal/degradation at a time (the most common) or simultaneous removal/degradation of multiple links. The common approach is to utilize singular component degradation/failure to calculate the individual criticality, i.e., run traffic assignment for each link removal scenario, calculate the difference of the network performance function (e.g., total system travel time) between the unaffected network and the failure scenario, and rank the links based on this functionality loss difference, i.e., the highest the difference, higher the ranking of the link. However, it is more likely that multiple links fail simultaneously, especially when considered within disaster conditions such as hurricanes and snowstorms. As shown in the literature, single link removals do not reveal the actual criticality of link(s) due to network dependencies, e.g., a link that may not create a large network performance change to be deemed critical, yet can cripple the system when fails in conjunction with others. In other words, the network dependencies make it difficult to isolate each link's individual criticality. Multiple simultaneous link removal scenarios can capture the network interactions; however, the calculated criticality scores indicate the criticality ranking of scenarios than individual links, e.g., the links in scenario-1 is more critical than the links in scenario-2. In addition, running multiple link failure scenarios can be computationally infeasible due to the combinatorial nature of scenario creation. For example, for a medium size network with 100 links, the number of scenarios to include all simultaneous two-link removals are 4,950 (combinations of 2 links out of the total 100). For triple link removal, the number of scenarios increase to 485,100, and for quadruple removals, the total number of scenarios is 2,352,735. Considering that simultaneous quadruple link removals in a network size of 100 cannot reveal the network flow interdependencies, such multi-link failure analysis lead to impractical computation times.

In this context, there are two main research questions: 1) How to calculate criticality of individual links based on scenarios that include multiple simultaneous failures? and 2) What is the optimal scenario generation approach that reveals the network flow dependencies while it is computationally tractable? For the first problem, PI Yazici has developed an approach that calculates individual link criticality based on a given number of scenarios.

The approach utilizes the distribution of the criticality scores for each link, i.e., the criticality score distribution for link #X is composed of the criticality scores of scenarios that include link #X. The criticality ranking for each link is calculated based on its criticality score distribution's mean, coefficient of variation and skewness. The approach was tested on real-life networks and it was shown that it provides robust link criticality rankings that account for network interactions. Hence, this project focuses on the optimal scenario generation strategy that will provide a systematic approach to select a smaller subset of all link failure scenarios that enables transportation criticality analysis that account for network flow interaction patterns with reasonable computation times. The developed procedure will also account for the network size and topology that affect network flow dependencies, thus the criticality of individual links.

US DOT Priorities: This project aligns with the USDOT the strategic objective of "Infrastructure Resilience"

Outputs: A scenario generation procedure that takes the network size into account and provide a methodology that creates a set of failure scenarios with high accuracy on providing link criticality rankings with reasonable runtime.

Outcomes/Impacts: The anticipated procedure will help researchers avoid the heavy computational burden of running extensive number of scenarios and provide "just enough" number of scenarios to account for the network flow dependencies in transportation link criticality analysis.

Final Research Report: N/A