Exhibit D

Research Project Requirement Template

Enhanced Network Models for Multimodal Resiliency

Recipient/Grant (Contract) Number: The University of Texas at Austin/Grant # 69A3552344815 and 69A3552348320

Center Name: Center for Understanding Future Travel Behavior and Demand (TBD)

Research Priority: Improving Mobility of People and Goods

Principal Investigator(s): Stephen Boyles

Project Partners: N/A

Research Project Funding: $120,000 (Federal + non-Federal funding)

Project Start and End Date: 9/1/2023 - 5/31/2025

Project Description: This project will develop next-generation multimodal network resilience models. We will examine the performance of networked transportation systems in disrupted conditions using field data, generate mathematical models to describe system performance and user behavior, and develop mitigation strategies based on this model. This project is distinguished from previous efforts in this space by explicitly considering multiple travel modes. We specifically will consider road transport, freight waterways, and port terminals as the transportation systems in our scope. The primary disruption we will consider is a natural disaster, such as a hurricane, which can disrupt both transportation supply (closing roads, damaging port or waterway infrastructure) and demand (evacuation, closed businesses).

Task 1 - Literature review. The research team will review the state-of-the-art in disrupted network operations, focusing on evacuations and disruptions to freight. The review will include both case studies and theoretical models, and identify the key assumptions, modeling tools, and data sources used for calibration and validation. The primary emphasis will be hurricane impacts, although other natural and anthropogenic disruptions will also be reviewed to gain a broad perspective.

Task 2 - Identify data sources. Based on the findings of the literature review, the research team will identify relevant data on both the supply side (network topology, capacity, etc.) and on the demand side (travel origins and destinations, expected compliance with evacuation instructions, etc.) This data will form the basis of the subsequent investigation.

Task 3 - Construct multimodal network models. Using the data collected in Task 2, the research team will construct one or more network models representing land transportation, waterways, and port terminals. In this work, the research team may build on models they have developed in preliminary research, including a discrete-event agent-based simulation for the Port of Port Arthur, TX. This network model will incorporate a congestion model on the supply-side (at this point we anticipate a point queue model will be appropriate, although other choices may emerge after Tasks 1 and 2 are complete), and a behavioral model for the demand-side. As hurricane disruptions are rare, we do not believe the traditional user equilibrium assumption will hold either for evacuation or for freight, and we will explore route choice models based on a combination of real-time information, historical data, and route guidance systems. This network model will be implemented in a common programming language and used for the subsequent project tasks.

Task 4 - Develop optimization models for mitigation strategies by identifying critical links. Using the network model from Task 3, the research team will identify strategies for improving the resilience of the network. In particular, our analysis will focus on identifying critical "bottleneck" links, that is, links that can reduce overall throughput of the network if disrupted. Our main hypothesis is that the critical links in the multimodal network will be different than those seen in a network corresponding to a single node.

Task 5 - Technology transfer. The research team will document research findings and share them with the larger research and practitioner community through conference presentations, manuscripts submitted for peer review in journals, and technical reports.

US DOT Priorities:
p. 50: "I**ntegrated System-of-Systems**: System Architecture: Develop technologies and consensus standards to support interoperability, data-sharing, and security across the transportation system-of-systems to produce an integrated multimodal user experience".

p. 64: "To further encourage the adoption of innovations, U.S. DOT agencies publish technical papers and guides; present webinars and deliver presentations to stakeholders; create websites; develop and deliver training courses and workshops; engage in standards development activities, and distribute newsletters and other outreach materials highlighting research results".

Outputs: The anticipated outputs of the project are novel multimodal network models and optimization models for resource allocation. These will be reported in a project report; in presentations at center workshops, professional conferences, and/or invited lectures; and in one or more peer-reviewed articles submitted for publication in a premier venue such as *Transportation Research Part B* or *Transportation Science*. These publications will be accompanied by code implementing these algorithms, and data used for analysis, as described in the data management plan.

Outcomes/Impacts: The anticipated outcomes of the project are increased understanding of the interdependence between different transportation modes as related to resiliency, and eventual improvements in resiliency by more targeted strategies to enhance network capacity and resistance to disruption.

The anticipated impacts are improved allocation of network investments to improve resiliency. By viewing the transportation systems as an integrated multimodal network, rather than a collection of independent modal networks, we will provide a more holistic notion of critical links that leads to a more efficient use of resources.

Final Research Report: A URL link to the final report will be provided upon completion of the project.