Exhibit D

Research Project Requirement Template

Investigation of Emerging Sensing and AI/ML Technologies to Enhance the Safety of Vulnerable Roadway Users at Signalized Intersection

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): Yiqiao Li, Co-PIs: Camille Kamga, Jie Wei

Project Partners: N/A

Research Project Funding: $371,410 (Federal + non-Federal funding)

Project Start and End Date: 6/1/2024 - 5/31/2026

Project Description: Accurately identifying and analyzing vulnerable roadway users (VRUs) such as pedestrians, bicyclists, and other non-vehicle occupants, are a crucial yet difficult undertaking. VRUs' behavior is influenced by localized factors such as land use, and their movements are not confined to predefined paths. This study will investigate the use of emerging technologies such as LiDAR, network cameras, and AI/ML algorithms to capture the movements and behaviors of vulnerable road users (VRUs). By evaluating pedestrian demand, including the volume and characteristics of pedestrian traffic, this research aims to assess and improve the safety of intersections.

This project will start with a comprehensive study of the state-of-the-art methods of VRU data collection, image- and LiDAR-based VRU object detection and classification, and dynamic VRU trajectory estimation methods. Next, a candidate study intersection will be reviewed and selected for the sensor installation and data collection. The LiDARs and Cameras will be synchronized with the field processing unit and the retrieved data will be transferred and saved to be further analyzed.

In the model development process, three traffic data collection framework will be designed: a roadside LiDAR-based VRU data collection, video-based VRU data collection, and an integrated framework.

<u>Standalone LiDAR- and video-based Method:</u>

1) ML/DL-based LiDAR/video object detection methods will be designed to better accommodate the task of infrastructure-based data collection, especially on small objects such as VRUs. These methods will segment out VRUs and vehicle objects from the background scene of the intersection into different classes. In this task, a data annotation process is required to provide the ground truth, which will be used to train/fine-tune the detection ML/DL models.
2) Data association methods will be applied to align objects from multiple frames of LiDARs and cameras to yield a complete picture of the VRUs and scenes.
3) Develop a LiDAR/Video-based VRU trajectory reconstruction method using sequential ML/DL models to capture dependencies and patterns to predict further trajectories. DL sequence models such as Recurrent Neural Networks, diffusion models, visual transformers, will be investigated and exploited. VRU safety-related essential metrics such as the VRU flow direction, speeds, and volumes will be extracted from the reconstructed trajectories.

Sensor Integration to Improve the Accuracy of VRUs Monitoring:

LiDAR sensors can generate PCD with rich 3D spatial information of the detected objects. However, PCD's sparsity means that small objects may not be adequately represented or even missed entirely when distances are too large. Cameras, with a higher resolution, can capture more detailed visual information to compensate for the sparsity in LiDAR data. However, cameras rely on visual cues and lack the direct distance measurement capabilities, a deficiency that cannot be resolved by this data modality alone. The proposed multi-modal research will provide promising data-fusion technology to accurately determine the position and distance of objects from both data modalities, resulting in improved detection and tracking of small VRUs and other objects of interest. After extracting the VRU safety-related metrics, this project will explore multiple quantitative safety assessment methods to evaluate the safety perspective of intersections. This will further facilitate intersection design and signal planning.

US DOT Priorities: The proposed project is capable of addressing the following Transformation Research Priorities:

- Research Priorities: Data-Driven Insight (Page 50):
    - Data Science: Harness advanced data collection and data processing capabilities to create timely, accurate, credible, and accessible information to support transportation operation and decision-making.
- New and Novel Technologies: Automation
    - Harness advanced data collection and data processing capabilities to create timely, accurate, credible, and accessible information to support transportation operations and decision-making.
- Adaptive and Dynamic:
    - Transportation systems can detect and adapt to changing conditions, such as changes in traffic demand, advances in technology, or changes to the environment by reconfiguring capacity and adopting new technologies. Future risks are anticipated, and adaptation strategies are built into the planning, design and operations of infrastructure.

Outputs: First, this project will establish a traffic monitoring testbed with the installation of two emerging sensors: LiDARs and Pan-tilt-zoom network cameras at a selected signalized intersection in New York City. Second, the project will deliver a novel AI/ML-empowered data collection, fusion, and analysis framework utilizing cutting-edge spatial and temporal AI/ML/DL approaches to provide high-quality information on VRUs and other objects of interest. At least two research papers outlining the methodology and findings will be prepared and submitted to leading peer-reviewed academic journals for publications. A working system/prototype consisting of features proposed in this project will be delivered. Based on the preliminary data and results from this project, at least 3 proposals will be submitted by this team to national, state, and city agencies, such as NSF, DoD, DOE, NYS DOT and NYC DOT, for significant external funding. A technical report will be prepared for the final submission.

Outcomes/Impacts: The traditional method of obtaining VRU counts is labor-intensive. Additionally, identifying and analyzing VRUs is challenging due to their tendency/behaviors to deviate from well-defined routes. This project will leverage emerging multimodal sensing and AI/ML/DL technologies to provide an automated and effective method to improve the efficiency of VRU data acquisition and analysis. Furthermore, the VRU trajectories estimated from the proposed framework will significantly enhance the resolution of VRU data, providing valuable guidelines to improve intersection safety.

The method developed in this project potentially provides an automated and accurate way to analyze the VRU data at intersections, which could significantly reduce the workload and possible risk of manual VRU data collection and analysis, thus improving the effectiveness and safety of the transportation system.

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