**Exhibit D**

**Research Project Requirement Template**

## Deep Learning with LiDAR Point Cloud Data for Automatic Roadway Health Monitoring

**Recipient/Grant (Contract) Number:** The University of Texas at Austin; California State Polytechnic University, Pomona / 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):** Yongping Zhang

**Project Partners:** N/A

**Research Project Funding:** $250,000 (Federal + non-Federal funding)

**Project Start and End Date:** 11/1/2023 - 5/31/2024

**Project Description:** Traditional methods for monitoring road conditions are fraught with challenges. Field inspections are labor-intensive and costly, aerial photography is subjective, and mobile measurement systems (MMS) require substantial investment in geospatial technology. In response to these limitations, there is a growing interest in leveraging advanced 3D scanning technologies, such as LiDAR and RGB-D scanners, in conjunction with deep learning algorithms for infrastructure assessment. 3D point cloud data, analyzed through deep learning models, offers several advantages over traditional 2D-based computer vision techniques. These include enhanced spatial resolution, superior object recognition, and the ability to handle complex scenes more effectively. However, this approach also introduces challenges, such as greater computational demands and the need for specialized hardware. Therefore, albeit with the tremendous benefits associated with the 3D point cloud, there are very few studies dedicated to the application of 3D point cloud-based deep learning models to the infrastructure operation and assessment. To bridge this research gap, this study aims to investigate the efficacy of various point cloud-based deep learning models in automating roadway health assessments.

Given the vital nature of this topic, the research will evaluate promising deep learning architectures, such as PointNet, PointNet++, 3D-CNNs, and PointCNN, using point cloud data gathered from multiple roadways in Southern California. Additionally, some typical technical challenges such as the noise filtering, data alignment, and dimension reduction via resampling, etc., will be further explored. This investigation aims to offer valuable insights into the pros and cons of these models under diverse conditions, thereby contributing to future research in this emerging area. Most importantly, these applications combine to offer a more comprehensive, real-time understanding of roadway health, facilitating proactive maintenance, reducing costs, and improving public safety.

**US DOT Priorities:**

**DATA-DRIVEN INSIGHT (P. 58); Data Science:** Harness advanced data collection and data processing capabilities to create timely, accurate, credible, and accessible information to support transportation decision-making. (P.59)

- Conduct exploratory research on transformational mobility data analytics.
- Develop and make accessible data sources, data analysis, and visualization tools to support transportation stakeholders and researchers.

**NEW AND NOVEL TECHNOLOGIES (P.59)**; **Automation:** Support the development and responsible deployment of automated technologies that improve the safety, efficiency, equity, and accessibility of transportation. (P.60)

- Conduct research to develop an effective and efficient safety assessment framework for auto-mated systems across all modes of transportation.
- Establish the methodologies, environments, infrastructure, tools and expertise to review, assess and validate the safety of automated transportation systems across all modes of transportation.
- Develop the next generation of roadway infrastructure design and concept of operations to be optimized for digital and automated systems and operations. optimized for digital and automated systems and operations.

**Outputs:** The anticipated outputs for the proposed research include: (1) **Advanced Algorithms**: Novel deep learning algorithms specialized in integrating with existing roadway management systems to automatically monitor and assess the health of roadways, including the detection of various types of roadway damages like cracks, potholes, and surface deformations, (2) **Hardware Recommendations**: A comprehensive guide on the types of specialized hardware most effective for 3D data capture, with considerations for cost-efficiency, (3) **Policy Guidelines**: Recommendations for transportation authorities on how to incorporate automated 3D point cloud assessments into their maintenance protocols and procedures, (4) **Noise-Filtering Techniques**: Best practices for filtering out data noise during point cloud data collection, enhancing the reliability of the assessments, (5) **Performance Metrics**: Establish a set of key performance indicators (KPIs) to evaluate the effectiveness of point cloud-based monitoring, facilitating continuous improvement, (6) **Cost-Benefit Analysis Tools**: Financial models that allow municipalities to evaluate the economic viability and ROI of adopting 3D point cloud-based roadway health monitoring systems, and (7) **Open-Source Repository**: An open-source repository of code, algorithms, and data sets, encouraging community contributions and continuous improvement.

**Outcomes/Impacts:** The anticipated outcomes of this research are manifold and have the potential to instigate transformative changes in the transportation sector. They include: (1) **Improved Safety Protocols**: The real-time, comprehensive data could lead to dynamic updates in road safety measures, including timely road repairs and preventive actions against hazards, thereby reducing accidents, and improving public safety, (2) **Technological Adoption**: As a proof-of-concept, this research could accelerate the adoption of advanced 3D scanning and deep learning technologies across transportation agencies, setting a new industry standard, (3) **Resource Allocation**: With more precise data, city planners and officials can make informed decisions about where to allocate resources for maintenance, thereby optimizing the use of public funds, and (4) **Environmental Impact**: The adoption of efficient monitoring systems can contribute to sustainability goals, by prioritizing repairs that would mitigate against more resource-intensive damages in the long run.

Overall, the research aims to forge a paradigm shift in how roadway health is monitored and managed, encouraging a move from reactive to proactive maintenance, and fostering an environment conducive to technological innovation and policy reform.

Anticipated impacts include: (1) **Safety Enhancement**: The most immediate impact will be a notable reduction in road-related accidents and fatalities through timely detection and repair of cracks, potholes, and other hazards, leading to safer roadways, (2) **Cost-Efficiency**: Proactive maintenance facilitated by the research could substantially reduce long-term capital and operating costs involved in road management, thus freeing up public funds for other critical areas. (3) **Community Well-being**: Improved road conditions will positively impact community health by reducing travel time and vehicle wear-and-tear, enhancing overall quality of life, and (4) **Knowledge & Workforce Development**: The research outcomes will fill an existing gap in academic literature, providing new avenues for further research and educational curricula, thereby training a new generation of transportation professionals in state-of-the-art technologies.

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