# Exhibit D

**Research Project Requirement Template**

**Research project name: Environmentally-Informed, Data-Driven Precast Concrete Bridge Condition Modeling for Future-Proof Transportation Infrastructure**

**Recipient/Grant (Contract) Number:** University of Illinois at Urbana-Champaign / Grant Number 69A3552348333

**Center Name:** Transportation Infrastructure Precast Innovation Center (TRANS-IPIC)

**Research Priority:** Improving the Durability and Extending the Life of Transportation Infrastructure

**Principal Investigator:** Eun Jeong Cha

**Project Partners:** None

**Research Project Funding:** $103,851 ($64,991 Federal and $38,860 Non-Federal)

**Project Start and End Date:** 01/01/2025 – 12/31/2025

Executive Summary:

This research aims to develop a robust, climate-informed, data-driven model to predict and project bridge conditions, with a focus on precast concrete (PC) infrastructure, addressing the impact of climate change on bridge durability. Current models lack comprehensive integration of climate factors, which accelerate deterioration. Using data from the National Bridge Inventory (NBI), National Bridge Elements (NBE), and regional climate and traffic data, advanced statistical and machine learning techniques will assess bridge conditions under future climate scenarios. The case study will project future conditions for PC, reinforced concrete (RC), and steel bridges, identifying high-risk structures and informing maintenance strategies. The outcome will be a validated tool to enhance the durability and extend the life of PC bridges, aligning with TRANS-IPIC/USDOT’s priorities of infrastructure longevity, climate adaptability, and safety, while supporting workforce development and educational goals.

Need for Research:

Bridge condition is influenced by climate conditions, which have been identified as key variables in bridge deterioration research (Liu and El-Gohari 2022, Liu and Zhang 2020, Liu et al. 2018, Huang et al. 2010). With climate conditions expected to change in the future due to global warming and other environmental factors, the bridge performance may change in future. While the effects will likely vary by region and structure type, it presents new challenges for maintaining bridge infrastructure. Precast concrete (PC) bridges, in particular, are vulnerable to thermal expansion, cracking, and moisture-induced deterioration, which can accelerate degradation under extreme weather conditions. Bridges in coastal regions, areas with significant temperature fluctuations, and those prone to severe weather events are especially at risk. However, existing bridge condition estimation models do not comprehensively incorporate and assess the long-term impact of climate variability on bridge deterioration, resulting in a critical gap in our understanding of future bridge conditions.

To address this gap, it is essential to develop a robust and comprehensive bridge condition estimation model that integrates climate variables and can project future bridge conditions under a range of climate scenarios. Such a model would allow infrastructure planners to anticipate climate-induced risks and inform maintenance strategies to extend the service life of bridges. Additionally, applying this model to a specific case study region will offer detailed insights into how climate variability may impact future bridge conditions at the regional scale, providing practical guidance for future bridge infrastructure resilience planning. This research is vital for ensuring the long-term durability and safety of transportation infrastructure in the face of climate change.

The proposed research supports the USDOT Strategic Plan goals in the following manner. 1) The research directly addresses climate adaptation by projecting the impact of climate change on bridge infrastructure, which aligns with USDOT’s goal of enhancing sustainability and resilience. 2) By identifying vulnerable bridges and forecasting their future condition, the research supports safety goals by helping prevent structural failures that could result from unexpected deterioration patterns. The research pushes forward the transformation of traditional bridge condition assessment methods by incorporating advanced climate modeling and data analysis techniques. Furthermore, the research supports the Application of New Materials and Technologies theme of the TRANS-IPIC by developing and applying novel data-driven models utilizing the state-of-the-art climate projection data. Overall, the research has a clear potential to contribute to improving the durability and extending the life of PC bridge infrastructure, as it equips planners and engineers with predictive tools to address future climate risks.

Research Objectives:

The primary goal of this project is to project the impact of climate change on the condition of bridges, enabling improved planning, risk mitigation, and adaptation to future climate scenarios to improve the durability and lifespan of bridge infrastructure. To achieve this goal, we have identified two key objectives that will guide the research. Each objective focuses on a specific aspect of the project and addresses critical components needed to reach the desired outcomes. These objectives are as follows:

Objective 1: Data-Driven Bridge Condition Estimation Model Development Considering Climate Conditions. This research will develop a robust, data-driven model for predicting bridge conditions. This model will integrate various climate conditions, such as temperature fluctuations, precipitation, humidity, and extreme weather events, to assess how these factors influence the structural integrity and longevity of bridges. By leveraging historical data, the model will provide a comprehensive understanding of the effects of climate variability on bridge conditions. Key research questions and hypotheses are summarized below.

1. What are the key climate variables that significantly impact bridge condition? We hypothesize that climate factors influence bridge deterioration by exacerbating cracking, corrosion, and material fatigue. A comprehensive data analysis can identify and quantify the most influential variables.
2. How do key climate variables differently impact various types of bridges? We hypothesize that climate variables affect various types of bridges differently, with PC bridges particularly vulnerable to thermal expansion, cracking, and moisture-induced deterioration, leading to accelerated degradation under extreme weather conditions.

Objective 2: Bridge Condition Projection for Case Study Location The developed model will be applied to a specific case study location. By utilizing local climate projection data and other bridge records, the model will project future bridge conditions under different future climate scenarios. This will help identify potential changes in the risk profile for bridges and aid in formulating strategies to mitigate the impact of climate change on PC bridges in the selected region. Key research questions and hypotheses are summarized below.

1. How will future climate conditions accelerate bridge deterioration compared to current climate conditions? We hypothesize that, under future climate conditions, bridge infrastructure in regions with high climate variability faces increased deterioration at a significantly faster rate than under current conditions, exacerbating issues such as thermal cracking, corrosion, and material fatigue.
2. How do climate impacts vary by bridge type? We hypothesize that climate impacts, such as thermal expansion, freeze-thaw cycles, and corrosion, will affect PC, RC, and steel bridges differently, with PC bridges experiencing more pronounced thermal and stress-related deterioration.
3. How can uncertainties associated with climate projections be addressed? We hypothesize that uncertainties associated with climate projections, such as model variability and long-term forecasting limitations, can be managed through multi-scenario-based planning.

Expected Implementable Outcome:

The key implementable outcome of this research is a climate-informed bridge condition prediction and projection tool designed for infrastructure managers, engineers, and policymakers. This tool will integrate climate data, bridge condition records, and predictive modeling techniques to forecast the bridge conditions, for PC and other bridges, under various future climate scenarios. By providing an accessible platform for projecting future bridge conditions, this tool will enhance infrastructure maintenance planning and climate resilience strategies, allowing for data-informed decision-making to extend the service life of bridges. This technology can be implemented by state DOTs, local agencies, and other infrastructure stakeholders to: 1) identify high-risk bridges vulnerable to climate change impacts, 2) prioritize maintenance and repair based on predictive insights into future conditions, 3) plan retrofitting and upgrades for PC and other bridges to improve durability under future climate conditions.

To facilitate adoption, several technology transfer activities will be undertaken, including: 1) training modules and 2) user manuals and technical documentation, providing clear, step-by-step guidance on model application with the case study example. If successfully adopted, this tool will offer a practical solution for improving the durability and extending the life of PC infrastructure, directly supporting TRANS-IPIC’s mission and goals.

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