

## Exhibit D

### Research Project Submission Template

**Recipient/Grant (Contract) Number:** University of Illinois Urbana-Champaign / University of Texas San Antonio / Grant No.: 69A 355 234 8333

#### AI-based Lift Path Planning for Robotic Installation of Precast Bridge Components

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

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

**Principal Investigator(s):** Jiannan Cai (PI), Ao Du (Co-PI)

**Project Partners:** N/A

**Research Project Funding:** \$105,000 (\$70,000 Federal and \$35,000 Non-Federal)

**Project Start and End Date:** 01/16/2026 – 01/15/2027

#### Project Description:

This project aims to develop and evaluate a practical-inspired and adaptive AI-based 3D crane lift path planning method for precast bridge installation. Specifically, 1) an industry workshop and site observations will be organized to understand the operation and site configuration of precast bridge component installation; 2) a generalized and adaptive AI-based lift path planning model will be developed by integrating deep reinforcement learning techniques and transfer learning, while considering the practical needs and constraints; and 3) the developed method will be tested in a real-world case study, and the performance will be compared with that acquired by human operators, evaluating the feasibility and efficiency for practical implementation. The successful testing and demonstration of developed methods with domain experts will largely increase the feasibility of practical implementation, thus improving the bridge construction efficiency and accuracy, saving costs, and benefiting long-term quality and durability of transportation infrastructure.

#### US DOT Priorities:

Accurate and rapid installation of precast components is crucial to ensuring the quality and productivity of precast bridge construction. Typically, large prefabricated structural components are transported by cranes to the installation location for initial positioning. Then, multiple workers are needed to collaboratively adjust the component pose so that it can precisely align with the target. The workers will need to cooperate with the crane to place the component to its final position. In current practice, the performance of crane operation is affected by multiple factors, such as the size and weight of the lifting components, experience of crane operator, complexity of jobsite, and status of outdoor environments. As a result, repetitive re-lifting and falling may be needed, which is time-consuming and reduces construction efficiency. Furthermore, it requires close coordination between skilled operators and ground workers, which is labor-intensive when the entire industry is facing a significant labor shortage crisis. Robotic technologies have great potential to improve the accuracy and efficiency of precast component installation by automating crane operation. It was found that a partially automated tower crane, or even a simple observation device, could decrease the lifting time by 10% to 50%. While existing research has developed methods for automated crane path planning, these approaches frequently overlook the inherent properties and kinematic constraints of the crane itself. To overcome this challenge, in our TRANS-IPIC Year 2 Exploratory project, we conducted a pilot study and developed a robotic AI agent using deep reinforcement learning (DRL) techniques and tested the feasibility of AI-based crane lift path planning for precast bridge component installation in a high-fidelity physics-based simulation environment. However, considering the heterogeneous site configurations and task specifications in bridge construction as well as the challenges and constraints on the jobsite, there is a critical need to generalize the method to various environmental and task configurations. Furthermore, the reliability and performance of AI-

generated lift path planning should be evaluated both quantitatively and qualitatively by practitioners. The successful testing and demonstration of developed methods with domain experts will largely increase the feasibility of practical implementation, thus improving the bridge construction efficiency and accuracy, saving costs, and benefiting long-term quality and durability of transportation infrastructure.

### **Outputs:**

The anticipated results include 1) findings on current practice and challenges in precast bridge installation, as well as needs and opportunities for robotic installation of bridge components; 2) A generalized and adaptive AI-based lift path planning model capable of generating safe, efficient, and practical paths for a variety of precast bridge installation scenarios; and 3) A comparative performance of the AI-based method against current practice, along with a summary of feedback from domain experts, which will inform the future direction of the research and its potential for practical implementation. If successful, the project will prove the feasibility and benefits of using robotic technologies for installation of precast components in transportation infrastructure. The developed framework will establish the technical foundation and could be potentially extended and implemented in real construction projects with complex design and site conditions, thus improving construction productivity and reducing human efforts, which will eventually benefit the quality and durability of transportation infrastructure.

### **Outcomes/Impacts:**

The primary outcome of this project is an AI-based 3D crane lift path planning method for automatic precast bridge component installation, along with a high-fidelity physics-based simulation that integrates real-world crane dynamics, site and task configurations to enable training and test of RL models. The developed method will be evaluated by domain experts for feasibility and usability in implementation. The outcome of this project could be potentially implemented in two ways: 1) it could be embedded in existing crane operations by providing intelligent solution for lift path planning based on realtime operation states and task configuration, thus improving installation efficiency and accuracy, and reducing operator's workload. 2) It could be used to develop future autonomous cranes as an essential module of automatic lifting. The resulting technologies can be used to construct various transportation infrastructure and improve construction productivity and quality.

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