

**Transportation Infrastructure Precast Innovation Center**

**(TRANS-IPIC)**

**University Transportation Center (UTC)**

**IoT-Driven Digital Twin Framework for the Design and Fabrication of Precast Elements**

**UT-24-EP-01**

Quarterly Progress Report

For the performance period ending March 31, 2025

**Submitted by:**

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**Collaborators / Partners:**

N/A

**Submitted to:**

TRANS-IPIC UTC

University of Illinois Urbana-Champaign

Urbana, IL

**TRANS-IPIC Quarterly Progress Report (Section 1 – 7, 5 pages max.):**

**Project Description:**

1. Research Plan - Statement of Problem

Precast concrete components are used extensively in construction due to their effectiveness and quality, and the incorporation of the Internet of Things (IoT) and digital twin (DT) technologies promises to improve their design, manufacture, and lifecycle management. Real-time monitoring lowers defects and ensures improved quality by enabling precast concrete companies to swiftly modify operations to match design criteria. IoT and DT technologies can drastically reduce labor, material, and energy costs by detecting inefficiencies and streamlining production schedules. This project explores the integration of IoT and Digital Twin technologies into the design and fabrication of precast elements through the development of an IoT-Driven DT framework. The findings of this study are expected to provide insights into how IoT and DT technologies can be effectively integrated to enhance quality control, optimize production processes, reduce costs, and improve the lifecycle management of precast components*.*

1. Research Plan - Summary of Project Activities (Tasks)

*Task 1 - Characterize the potential applications of Digital Twin and IoT in the design and fabrication of precast elements:* A structured review of existing studies will be conducted to identify the different applications of DT and IoT in the design and fabrication of precast elements. This would be accompanied by a visit to precast facilities to observe the fabrication processes, gather onsite information on the different applications, and identify real-world issues and bottlenecks.

*Task 2 - Evaluate stakeholders' perception of the impact of IoT-enabled Digital Twins on the efficiency of precast element design and fabrication:* A focus group or interviews will be conducted with industry experts, engineers, and managers who have experience with IoT and DT implementations, as well as precast manufacturers and technology providers to gain insights into the processes, benefits, challenges, and future opportunities. The data generated will be analyzed and documented as scientific information for developing the IoT-enabled DT framework.

*Task 3 - Develop an IoT-enabled Digital Twin framework to enhance the efficiency of the design and fabrication of precast elements:* Based on the findings of tasks 1 & 2, a framework that models the critical component of an IoT-enabled DT system for the design and fabrication of precast elements including the design phase, IoT sensor integration, fabrication, transportation, installation, and post-installation monitoring will be developed.

*Task 4 - Prepare final report:* A final report containing the results of the research study will be prepared and submitted to the Transportation Infrastructure Precast Innovation Center (TRANS-IPIC). The report will describe the research activities, and findings, along with recommendations for future investigations and implementation in practice.

**Project Progress:**

1. Progress for each research task

*[Describe the progress made this quarter for each research task and the % completed]*

*Task 1 progress [70% completed to date]*

The research team has begun a systematic review of literature by probing databases such as (Web of Science, Scopus, Google Scholar, ASCE Library, etc.) to identify the different applications of DT and IoT in the design and fabrication of precast elements, as well as existing case studies of IoT- and DT-enabled precast production. In our efforts to obtain practical information, the team developed and implemented a selection procedure to identify precast concrete companies near San Antonio, Texas. The selection criteria were based on product range (availability of various precast products such as beams, slabs, columns, bridge elements, others); technical capabilities (production capacity and ability to scale for specific project requests, compliance with industry standards such as ASTM, EN, ACI, others, and quality control and certifications); manufacturing facilities (location and proximity to San Antonio); technology (modernization and automation level in production); experience and reputation (years in business and track record of success, and industry reputation and customer satisfaction ratings. Sevent (7) precast concrete manufacturing companies were identified and contacted. The team has secured the agreement of a precast concrete company, Capital Precast, LLC for a tour of their facility which is scheduled for Monday, April 7, 2025. The team met with the sales manager of Capital Precast on Monday, March 17, to discuss and plan the tour and how they can collaborate with the team on the project.

*Task 2 progress [50% completed to date]*

Based on literature review and investigations conducted so far, survey and interview instruments are being developed. The data collection instruments contain questions and prompts to assess familiarity with IoT and DT technologies, current IoT and DT implementation levels, challenges in precast production, expected benefits of IoT & DT integration, perceptions of IoT and DT impact, barriers to IoT and DT adoption, desired features in an IoT/DT system, future trends, and training needs.

*Task 3 progress completed [10% completed to date]*

Limited information related to relevant models or framework obtained from literature review (task 1) has been done so far on this task, as the initiation and progress of this task will be dependent on the findings of tasks 1 and 2.

*Task 4 progress completed [0% completed to date]*

This will begin after task 1 is completed.

1. Percent of research project completed

About 40% of the research project is estimated to have been completed by the end of this quarter.

1. Expected progress for next quarter
* Complete the systematic literature review and precast facility tour (task 1)
* Administer survey or conduct interview or focus group to evaluate stakeholders' perception of the impact of IoT-enabled DT on the efficiency of precast element design and fabrication (task 2)
* Develop an IoT-enabled DT framework to enhance the efficiency of the design and fabrication of precast elements (task 3)
* Prepare final report (task 4)
1. Educational outreach and workforce development

Supported and trained two Ph.D. students, Tolulope Oyeyipo and Mehdi Torbat Esfahani.

1. Technology Transfer

N/A

**Research Contribution:**

1. Papers that include TRANS-IPIC UTC in the acknowledgments section:

In progress

1. Presentations and Posters of TRANS-IPIC funded research:

N/A

1. Please list any other events or activities that highlights the work of TRANS-IPIC occurring at your university (please include any pictures or figures you may have). Similarly, please list any references to TRANS-IPIC in the news or interviews from your research.

N/A

**Appendix 1**: Research Activities, leadership, and awards (cumulative, since the start of the project)

1. Number of presentations at academic and industry conferences and workshops of UTC findings
* No. =
1. Number of peer-reviewed publications submitted based on outcomes of UTC funded projects
* No. =
1. Number of peer-reviewed journal articles published by faculty.
* No. =
1. Number of peer-reviewed conference papers published by faculty.
* No. =
1. Number of TRANS-IPIC sponsored thesis or dissertations at the MS and PhD levels.
* No. MS thesis =
* No. PhD dissertations =
* No. citations of each of the above =
1. Number of research tools (lab equipment, models, software, test processes, etc.) developed as part of TRANS-IPIC sponsored research
* Research Tool #1 (Name, description, and link to tool) =
* Research Tool #2 (Name, description, and link to tool) =
* Research Tool #3 (Name, description, and link to tool) =
1. Number of transportation-related professional and service organization committees that TRANS-IPIC faculty researchers participate in or lead.
* Professional societies
	+ No. participated in =
	+ No. lead =
* Advisory committees (No. participated in & No. led)
	+ No. participated in =
	+ No. lead =
* Conference Organizing Committees (No. participated in & No. led)
	+ No. participated in =
	+ No. lead =
* Editorial board of journals (No. participated in & No. led)
	+ No. participated in =
	+ No. lead =
* TRB committees (No. participated in & No. led)
	+ No. participated in =
	+ No. lead =
1. Number of relevant awards received during the grant year
* No. awards received =
1. Number of transportation related classes developed or modified as a result of TRANS-IPIC funding.
* No. Undergraduate =
* No. Graduate =
1. Number of internships and full-time positions secured in the industry and government during the grant year.
* No. of internships =
* No. of full-time positions =

**References:**

 N/A