A Time for Transformational Change in Civil Engineering Education

by Dr. John Schemmel, Texas State University

In the context of civil engineering, the term "infrastructure" refers to the structures and systems that are vital to the economy, health, and prosperity of a population center. Whether publicly or privately owned, infrastructure assets tend to be physically large and have a high initial cost, with variable long-term maintenance costs. Bridges, energy grids, water and wastewater treatment plants, hospitals, and educational institutions are just a few examples of infrastructure assets. Traditionally, civil infrastructure assets have been designed to meet the functional needs of the owner and provide safe operation by the general public. Facility maintenance often occurs only after a repair need is identified and implemented. For example, most bridges are inspected on a two-year cycle. Unless there is prominent, easily identified damage to a bridge, maintenance will only take place following the routine inspection of the bridge.

Recently, terms such as "sustainability" and "resilience" have been used to describe the longer-term performance of an asset. As populations grow and natural resources are depleted, engineers must now think beyond initial design and construction and imagine how an asset will be monitored, managed, and maintained during its life span. In addition, engineers must attend to the continued safe use of existing infrastructure assets. Advances across a broad range of interdisciplinary technologies are now enabling engineers to monitor the condition and performance of assets in real time, making maintenance proactive instead of merely reactive.

Advances in Asset Monitoring

Although the use of technology to monitor and maintain infrastructure assets is rapidly advancing, it is still in its infancy. However, each time a new monitoring device, power supply, data storage system, analytic method, or asset management tool is released, we inch closer toward widespread technology implementation.

The ability to remotely monitor a structure, component, or process over time and then use the observational data to manage the asset will profoundly impact scientific and engineering professions. It is envisioned that technology will ultimately advance to the point of autonomous life-cycle management, such that every infrastructure asset will become a living structure with self-monitoring and repair capabilities. The feedback loop from the use of these technologies will contribute to fundamental changes in the way assets are designed, constructed, repaired, maintained, and managed. These advancements will produce opportunities for transformative change and innovation in the ways that scientists and engineers are educated, the research that is conducted, and the commercialization of new technologies. Eventually, a tipping point will be reached, and asset monitoring and maintenance will become standard operating procedure.

Technology-Enhanced Infrastructure

Today, terms such as "smart cities," "smart infrastructure," and "structural health monitoring" are commonly used to refer to the use of technology to monitor and maintain infrastructure. However, these terms do not encompass the full array of technologies that can contribute to the improved life-cycle performance of an asset. Moreover, the term "smart" implies the technology has an autonomous reaction to an event, which is not always the case with all infrastructure monitoring systems. The term "technology-enhanced infrastructure" (TEI) may be a more appropriate descriptor because TEI encompasses all technology—smart or otherwise—that contributes to the management and maintenance of infrastructure. With TEI (**Fig. 1**), event-detection devices, data-harvesting and transmission systems, cybersecurity, big data analytics, and predictive models are used to improve the tools employed in the maintenance of assets such as highway bridges. It is envisioned that this paradigm shift will stretch current thinking about infrastructure and the role that technology can play to enhance the safety, longevity, and economic value of any asset.

As consulting firms, construction companies, departments of transportation, owners, and others begin to understand and appreciate the benefits of implementing TEI concepts, each stakeholder will do so with increasing regularity. One challenge these groups will face, particularly in the next decade or so, is where to find college graduates with the necessary skills to evaluate and implement TEI products and services. A classic civil engineering program does not have the flexibility to add TEI-related courses to its mainstream curriculum. Programs may initially have to add such courses as electives, if electives are an option in their curricula. Consequently, civil engineering education is on the cusp of a truly transformational change. New academic programs will need to include TEI concepts throughout their proposed curricula. The Accreditation Board for Engineering and Technology (ABET) and the American Society of Civil Engineers will need to recognize the importance of TEI principles and therefore modify their accreditation requirements and program criteria, respectively. Existing academic programs will need to examine their curricula to determine how they can include TEI concepts within their current framework.

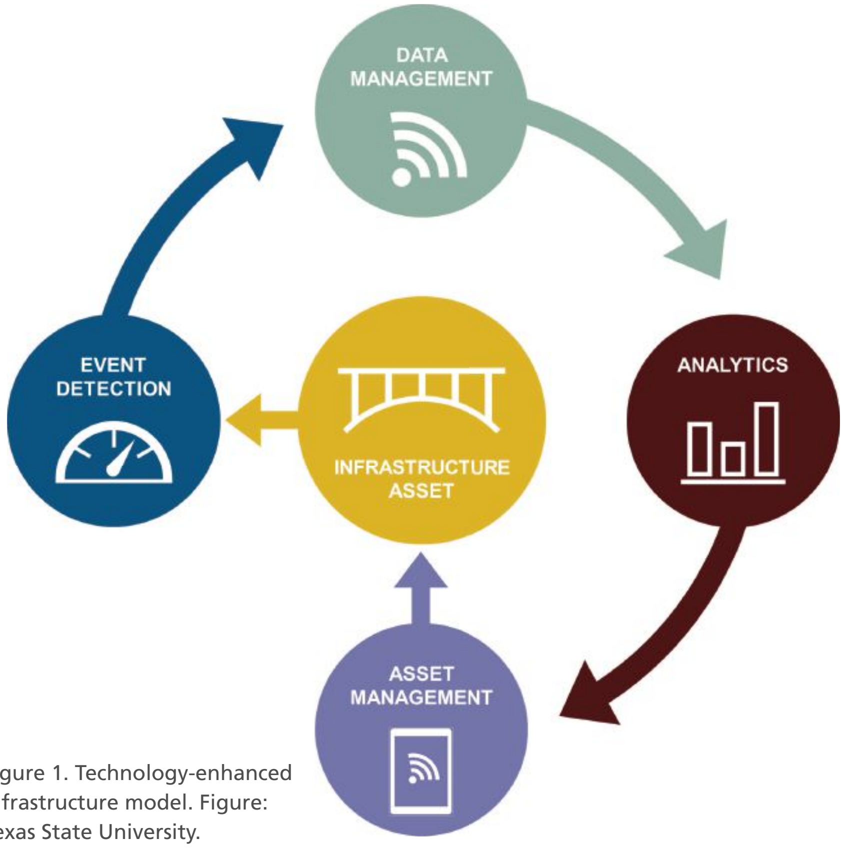

Figure 1. Technology-enhanced infrastructure model. Figure: Texas State University.

It will take considerable effort for the more than 250 ABET-accredited civil engineering degree programs to include TEI courses or concentrations or shift the programs' collective focus to TEI. Regardless of the difficulties and challenges associated with moving the civil engineering undergraduate education in the direction of TEI concepts, this effort must begin today. Otherwise, the civil engineering profession will be behind the curve with respect to reaping the benefits modern technology can provide in terms of monitoring and managing the nation's infrastructure.

Integrating TEI in Civil Engineering Education

One example of a novel approach to engineering education is the new civil engineering program in the Ingram School of Engineering at Texas State University. A required five-course sequence developed in collaboration with the computer science and geography departments introduces students to technology and planning concepts from a civil engineering perspective. All traditional classes include at least one aspect of event detection (sensors), data management, analytics, or asset management related to the core content of the course. For example, embedded strength sensors are covered in the reinforced concrete design course, and water quality data analysis is included in the environmental engineering class. Senior design projects will include monitoring plans along with drawings and specifications. Current ABET requirements are met, and students learn the benefits of TEI through hands-on monitoring exercises and coursework.

Acknowledgment

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EDITOR'S NOTE

Electrically isolated tendon (EIT) systems are examples of the TEI concept discussed in this article. EIT technology was installed in the Coplay-Northampton Bridge, which is discussed in the Project article on page 20 of this issue of ASPIRE®*. The system, which was installed at the request of the Federal Highway Administration to demonstrate EIT technology, will allow long-term monitoring of the condition of several post-tensioning tendons, as discussed in a Concrete Bridge Technology article in the Spring 2019 issue of* ASPIRE*.*

The Coplay-Northampton Bridge, which has sensors installed on several post-tensioning tendons to monitor the condition of those tendons, is an example of a technology-enhanced infrastructure asset. Photos: Dr. Clay Naito.