Technology Enhanced Infrastructure:
A New Paradigm

A CMG & Digital 360 Summit
White Paper

By

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TEI Summit launches new Civil Engineering Program at Texas State University

On Thursday, September 5, 2019, Texas State University's College of Science and Engineering, the Ingram School of Engineering, and new Civil Engineering Program hosted the inaugural TEI Summit. This day-long conference was held at the university's Science, Technology, and Advanced Research (STAR) park in San Marcos, Texas. The purpose of this first summit was to introduce the Technology Enhanced Infrastructure (TEI) based Bachelor of Science degree program in Civil Engineering. The 126-credit, multi-disciplinary academic program commenced with the 2019 fall semester.

Civil Engineering Program founded on Technology Enhanced Infrastructure

The concept of TEI focuses on the dynamics and interrelationship between Event Detection, Data Management, Analytics, and Asset Management as they relate to the lifecycle of any infrastructure asset. This interrelationship is depicted in Figure 1. In this context, "technology enhanced" refers, in part, to the deployment of digital devices into virtually every component and processes of an infrastructure asset, that in the past operated either without monitoring or depended on analog-based monitoring and maintenance.

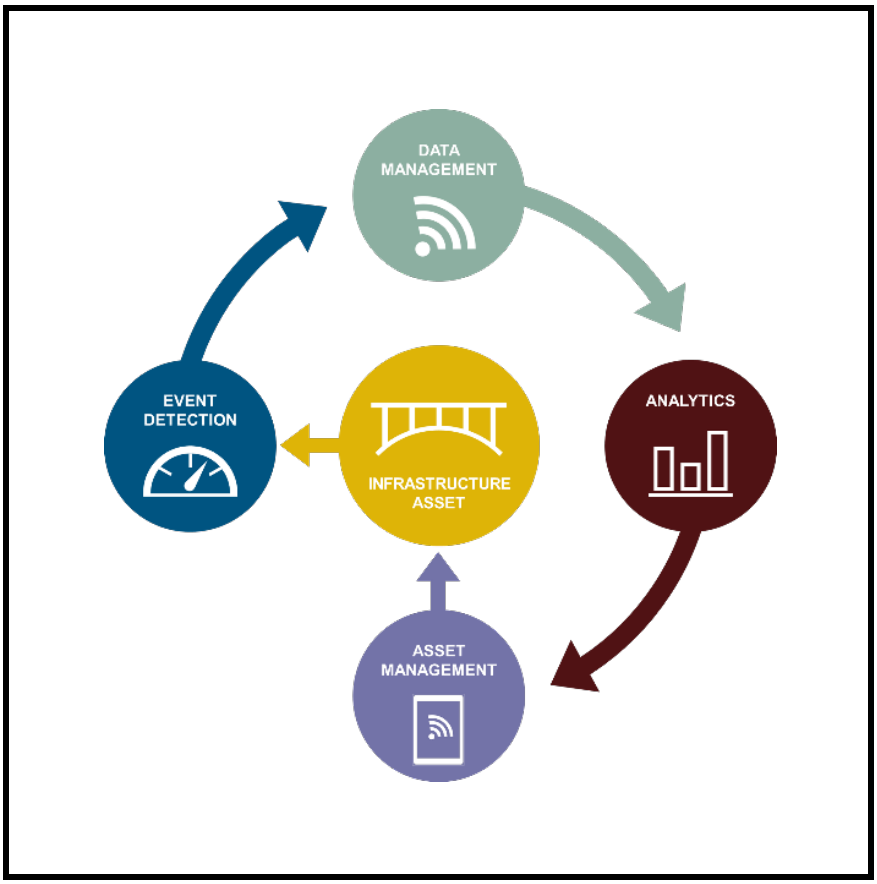

Figure 1. Texas State's Technology Enhanced Infrastructure Concept.

Digital sensors can be embedded, attached, or positioned remote to an asset. Sensors not only monitor but, allow humans to control and manage the temperature, pressure, vibration, humidity, air quality and movement on an increasingly diverse array of physical objects and the processes to install, repair and replace them. In the event of a data or protocol anomaly, digital sensors will signal out electronically to alert occupants, owners, and operators of possible system intrusion or impending component failure. The potential value proposition to industry and society is incalculable at this time.

Sensors are becoming smaller, cheaper, with significantly lower energy requirements, while providing higher capabilities (e.g. local, instantaneous, automated decision-making) at the infrastructure edge. As a foundation to this new world of distributed intelligence, IoT-enabled microchip sensors are being embedded into factory robots, electric substation transformers, shipping port container movers, street lighting systems, commuter train speedometers, home appliances, HVAC systems, slabs of freshly poured concrete, radiant floors, thermal walls, pollutant free ceilings, and safety windows, each providing sensory data and visibility into virtually any *distributed endpoint and infrastructure component* imaginable. A panelist at the summit described IoT chips as "placing a whole PC motherboard onto intelligent, sensing devices."

The TEI based academic program at Texas State is designed so that students will be positioned to help shape this emerging world of distributed, high-speed, interconnected intelligence. Thus, setting up the first class of graduates to enter the job market in spring 2023 as the global transformation to digital infrastructure accelerates.

In support of the academic program, Texas State University has embarked on a mission to recruit industry collaborators and sponsors to work in partnership with, and benefit from, the university's high-priority academic and research programs. Students and faculty will study several converging technologies, such as:

- Digital sensors
- 5G/LTE/IoT communication networks
- Cloud databases
- Artificial Intelligence/Machine Learning (AI/ML)
- Blockchain distributed ledger

The School of Engineering faculty and students are committed to identifying all of the benefits and formulas necessary to calculate improvements and costs from these and other technologies. Thus far, some 20 companies have expressed interest in participating in a joint venture with Texas State University in this endeavor.

CIEDAR Smart Neighborhood to Support TEI at Texas State

In a related announcement, Andres Carvallo, Adjunct Professor and MARC (M A R C) Innovator in Residence at Texas State and CEO of TEI partner CMG Consulting, introduced the industrial research institute **CIEDAR – Connected Infrastructure for Education, Demonstration, and Applied Research**. CIEDAR is an umbrella for a living teaching and research laboratory and "smart neighborhood" to be located at STAR Park. Using current and future STAR Park facilities, students, faculty, and industry collaborators will evaluate, validate, create, and demonstrate innovations in smart, sensor-based infrastructure components, processes, analytics, and management. The primary object of the activities under CIEDAR is to bring innovation to the market in a rapid and responsible fashion.

Andres Carvallo, CEO of CMG Consulting, Adjunct Professor of Electrical and Computer Engineering and "Innovator in Residence" of Materials Applications Research Center at Texas State, described TEI's and CIEDAR's role as "a total playground of applied research designed to accelerate digitization and digitalization of industry. We want to reimagine all physical reality into a digital vision, to turn everything into ones and zeros and see what we can create."

IoT sensors are a cornerstone of TEI research and development. Carvallo discussed sensors that have evolved from simple monitors but now capable of being "ingestible, printable, gesture-based, thermal-based, color-based, self-powering sensors, and sensors with 'heartbeats' that sense and adjust to changing environmental, stress, motion, altitude, and location conditions such as vibrations; ceramics used for measurements, actively monitoring a concrete pour or battery restrictions on sending a signal every two seconds." Carvallo states that sensor technology is still at an early stage, and in some respects are 'chips in search of a problem.'

Carvallo stated that CIEDAR Institute will contain nine centers of excellence used as testbeds for innovation in the following increasingly digitally-interconnected domains: Smart cities, smart utilities, smart buildings, smart energy, smart water/wastewater, smart mobility, smart networks, sensors, data and software.

"You have to solve all the problems of the Smart Building on the way to solving the Smart City and Smart Utility ones," Carvallo observed, describing the TEI powered CIEDAR Institute research process as "peeling the onion" to understand the interrelationship between infrastructure assets and domains.

Carvallo pointed out that multidisciplinary technology development already exists at Texas State in the form of 268 CIEDAR-related research projects already being undertaken by 78 tenured faculty researchers. TEI will integrate these efforts into one cohesive effort.

The TEI program might be regarded as a natural progression of evolution to externalize biological processes onto the physical dimension. Just as our brain monitors and controls the organs and processes within the body, the unfolding IoT-based sensory apparatus will monitor and control millions of infrastructure elements, devices and processes in the physical world. Indeed, brain-computer interface (BCI) research at Carnegie-Mellon University has already demonstrated that human thought can control devices. The applications of the TEI program appear limitless.

Dr. Gene Bourgeois, Provost and VP of Academic Affairs at Texas State formally opened the TEI Summit by stating that when compared with the curriculum at Texas State, there are only two other likeminded civil engineering programs in country. Bourgeois went on to emphasize that within CIEDAR students and faculty will engage in TEI "*research with relevance*," conducting "translational research that will seek solutions to real world problems and challenges." He also noted that industrial partnerships will help propel the CIEDAR Institute, STAR Park Smart Neighbor, and innovative TEI research.

Dr. John Schemmel, the Bruce and Gloria Ingram Endowed Chair in Engineering at Texas State, stated that "the curriculum at Texas State represents a fundamental, transformative shift in civil engineering education." He described how classic civil engineering has remained static for

decades but is now evolving in a substantive and forward-thinking manner. He noted that the TEI based academic program and CIEDAR Institute "combine classic civil engineering with IoT sensors, data management, analytics, and data management in a manner that will advance the profession."

Dr. Chris Halley, Dean of Texas State's College of Science & Engineering, emphasized the university's commitment to the Civil Engineering program and stated that the college is in the process of hiring faculty to do educate the next generation of civil engineering while conducting TEI related research.

Following these opening remarks, the TEI Summit continued by examining each element of the TEI concept in succession, beginning with Event Detection. See Figure 1. Keynote speakers provided the backdrop for a panel discussion amongst Texas State officials, industry experts in each domain, and government or utility officials.

Defining and Solving Enhanced Infrastructure-related Construction Challenges by Asking the Right Questions

In a keynote address to Summit attendees, Brendon Dowdall, CEO of Boston based Concrete Sensors, advised attendees to "think deeper and more creatively about the role of sensors in infrastructure." Speaking to the Civil Engineering faculty and students in attendance, Dowdall recommends the following series of questions be asked when considering the use of sensors to monitor an infrastructure asset

- How do you measure things?
- What problems are sensors solving?
- Are you solving the right problem?
- What attributes do sensors measure?
- How are sensors gathering data?
- What can you do with the data?
- Is this a sensor in search of a problem?
- Are you asking the right questions?
- Are you solving the right problem on the job site?

Asking these questions, Dowdall urges the audience to note the focus *is not on the technology* per se*,* but on a deeper understanding of the use case; what is the context and specific construction or logistical problem to be solved? IoT sensors offer industry *real time construction data.* Among many possible uses, real time data enables improvements in safety, production, general working conditions, production quality, and regulatory compliance.

For example, discussing IoT benefits to compliance, Dowdall suggests imagining a construction project in which the EPA requires measurements of dust levels in various industrial settings. He asks, how do you monitor dust? What types of dust and at what levels? Is it silica dust? Sawdust? What were the conditions in which the measurements were taken? Were they too windy? Were sensors measuring concrete strength, material delivery status?

Dowdall refers to these questions as "immensely difficult problems that sensors can help solve." Using sensors to monitor material delivery at a large construction sites, for instance, points toward

the high potential value of blockchain distributed ledger technology, particularly its *smart contract asset tracking and automated decision-making* capabilities.

TEI powered CIEDAR Institute - A Playground for Applied Research

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Data Management and the Five Vs Framework

Caleb Phillips, who handles Data Management, Analysis and Visualization with NREL in Golden CO, stated in his Data Management keynote address that he was "initially skeptical about data analytics, but having worked with the computational power, deep neural networks, cheap storage, and increasing adoption-investment in analytics," was sold on the huge potential of benefits to industry and smart cities. Phillips urged students, as they research the flood of data coming their way via the IoT data tsunami, to examine Big Data in the context of the "5 Vs":

- Volume
- Variety
- Velocity
- Variability
- Veracity

Understanding the full depth and context each of those components brings to data management and analytics provides a valuable framework on which to approach TEI.

Automated Factory-based Construction in TEI Context

Pat Meagher, VP of Technology at Katerra, speaking on the Analytics panel, addressed TEI students present at the summit of the need to "reinvent industry, to move construction processes out of on-site and into production facilities and the material supply chain." His company is building a 600,000 square foot automated construction component factory near Texas State in San Marcos, Texas.

Meagher painted a dramatic portrait for students of a new, factory-based construction paradigm in which the design and manufacture of building components are embedded with IoT sensors before hitting the construction site.

Phong Nguyen, System Engineer with Honeywell, discussed the value of sensor placement algorithms to infrastructure construction, stating that "the more data we have, the more we can train AI models" to guide sensor-based design and projects. Nguyen urged students to appreciate "the importance for sensors to be multi-purpose, adaptive, to be able to commission them for life, to be able to change a sensor on the fly, which will drive cost benefits to the customer."

Other TEI Summit Panel Topics

Other panels and topics addressed the following that will be examined by the TEI-CIEDAR program:

- 5G/LTE-enabled Private networks
- Automated decision-making in edge computing
- Mini-service providers
- Real time analytics
- Security protocols
- Distributed data
- Drones
- 3D Printing
- Augmented Reality
- Building Information Modeling
- Microgrids
- Blockchain distributed ledger and smart contract technology
- Quantum computing

For further information on the TEI program, go to:
https://www.engineering.txstate.edu/civil-engineering/academics.html

Link to the TEI Summit on the CMG website:
https://512cmg.com/events/tei-summit/

Summary

The American Society of Civil Engineers (ASCE) gave the U.S. a D-plus score on its 2017 infrastructure report card – the same dismal grade it received in 2013. The ASCE has estimated that by 2025, $4.5 trillion in additional spending will be required to repair or replace the country's crumbling or very old infrastructure.

Our infrastructure is already old and inadequate in most places. Add to that the threat of natural disasters, terrorist threats, and cyber-attacks, and we are in for a very bleak future. The crisis is real. What can we do soon? Is there a way to upgrade or repair some of it as we go? Of course. The answer is technology. Applied technology to some and all of the most pressing problem would reduce the cost of replacement and enhanced the life of many assets. And we must change how we design, build, repair and manage civil infrastructure.

Hence why Texas State University has created a brand-new Civil Engineering program built on Technology Enhance Infrastructure and why STAR Park and the CEIDAR Institute will drive the right now imperatives to finding the solutions to extend the life of the assets, increase safety, and reduce risks. Texas State Civil Engineers will master and thrive in using sensors, networks, data collection tools, analytics plus machine learning and AI, and asset management frameworks and solutions to improve dramatically the life span and reduce the total cost of ownership of infrastructure.

Our labs already today, or by the end of 2020, have the answers using 5G/LTE/RF-Mesh/Lora, embedded sensors, automated decision-making in edge computing, real-time analytics, enhanced cybersecurity, drones, 3D printing, augmented Reality, and building Information Modeling.

Furthermore, the Civil program will also introduce Graduate Certificates in multiple disciplines to help working professionals and professional engineers learn the latest and greatest tools, techniques and best practices for the digitization and digitalization of infrastructure. From autonomous roads to bridges to tunnels, buildings to homes and new materials. Texas State's Civil Engineering program will change the industry in a short time frame.

For more information on our smart solutions to the challenges outlined in these pages or to ask any questions to our experts, please contact us via the following:

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