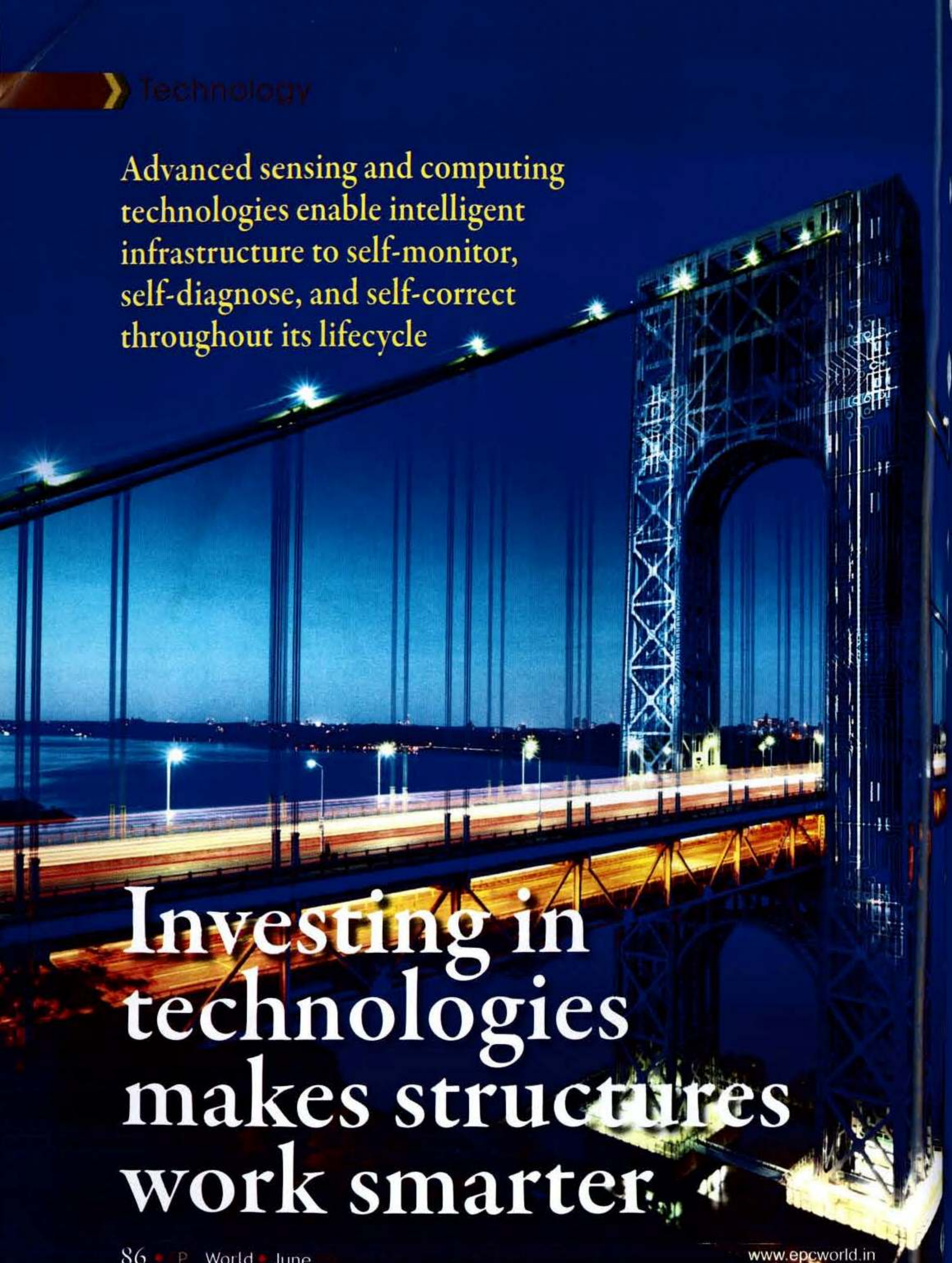

Advanced sensing and computing technologies enable intelligent infrastructure to self-monitor, self-diagnose, and self-correct throughout its lifecycle

Investing in technologies makes structures work smarter

In a world where all infrastructure is intelligent, rail networks predict equipment failures before trains are delayed, bridges signal for maintenance before unsafe conditions develop, and levees alert authorities about flood risks before waters rise. Smart highways charge motorists a fee to avoid traffic congestion, and intelligent drinking water distribution systems detect impurities and adjust dosing.

Electricity grids monitor wind and solar power and automatically ramp up or reduce other power sources to compensate. By using advanced sensing and computing technologies to monitor conditions, diagnose problems, and correct operations – often without human intervention – intelligent infrastructure offers improved safety and performance.

The United States has traditionally moved cautiously in regard to investments in tech-savvy infrastructure, but now that the US government is spending billions of dollars on various infrastructure projects to boost its sagging economy, the time is right to invest in technologies that make structures work smarter. That investment could jumpstart the estimated $2.2 trillion dollars in public and private funding required within the next five years for rehabilitation, replacement, and maintenance of existing infrastructure.

The 2009 Report Card issued by the American Society of Civil Engineers assigned a cumulative grade of D to the nation's infrastructure based on capacity, condition, safety, and other factors. The lack of significant improvement since the last assessment in 2005 indicates a need for wise investment of resources to raise the grade of roads, bridges, and other public works.

"As we launch a new investment cycle, we have the opportunity to symbiotically combine physical and digital investments into intelligent infrastructure," explained Bentley CEO Greg Bentley. "By using information modeling to leverage our extensive digital infrastructure to fuller advantage, I am confident that we can achieve higher return on investment at lower risks than ever, enabling our physical structures to work smarter. The resulting intelligent infrastructure will, in turn, sustain renewed growth in economic activity and productivity."

Physical + digital = intelligence

The physical structures built within the past 50 to 100 years are rapidly deteriorating and are in need of repair or replacement. These aging structures lack the digital infrastructure that has emerged in modern times – the information technology and communication networks that connect brains to the brawn. The 3D information model is, in effect, the central nervous system of contemporary infrastructure. It is the data repository that not only stores existing knowledge about the system, but also processes incoming data about emerging conditions.

The information model converts raw data from instrumentation deployed throughout the system into useful knowledge, allowing real-time adjustments to prevent malfunctions and maintain safe operating conditions. When real-time information from sensors in the physical infrastructure is combined with as-built information stored in the data model, the system becomes "self aware." It is truly

The Benefits of Intelligent Infrastructure

Faster time to market

- Shortened design/engineering cycle through data reuse and sharing
- Design and construction coordination streamlines safer construction
- Direct from design to industrial fabrication

Optimized delivery process

- Design and engineering resource utilization optimized
- Material resource utilization optimized in construction
- Reduced cost of delivery

Better performing infrastructure

- Leveraging technology in ways not possible before
- Infrastructure becomes productive faster
- Designed and built for lifecycle operations
- ROI is increased and more predictable

Adding Intelligence to the Bridge Lifecycle

Bentley's bridge information modeling (BrIM) is a new and innovative approach to bridge engineering and project delivery. It fosters the use of data beyond bridge design and engineering needs to inform downstream processes such as fabrication, construction, operation, maintenance, and inspection. A bridge information model can be an information definition of the bridge asset, co-created by many people using an array of technology to answer broad-ranging needs. BrIM can benefit the entire bridge lifecycle – project selection through rehabilitation – resulting in the development of new best practices. A 3D model of the bridge can serve as a window into the vast bridge information asset.

The cornerstone of BrIM is data reuse, with an emphasis on purpose-ready information delivery. With more flexible access to information about the bridge, organizations can begin to optimize business processes that cross the bridge lifecycle. Bridge model data is developed in earnest during planning, design, and construction. The close cooperation required of stakeholders during these phases depends not only on data reuse but also smooth interoperability between software/data systems. The information that is developed during these phases informs downstream processes and is, in fact, essential to bridge lifecycle sustainability.

intelligent infrastructure, interacting with the owner/operator to improve safety and sustainability.

According to Hojjat Adeli, Abba G Lichtenstein Professor in Infrastructure Engineering at The Ohio State University, intelligent infrastructure "will result in improved automation, better safety, and more effective use of natural resources, thus better sustainability." Adeli is co-author of the new book, Intelligent Infrastructure — Neural Networks, Wavelets, and Chaos Theory for Intelligent Transportation Systems and Smart Structures (CRC Press, 2009). He also wrote with co-author A Saleh the book Control, Optimization, and Smart Structures – High-Performance Bridges and Buildings of the Future (Wiley, 1999). He notes that the required technologies are not quite there yet, but are being rapidly developed.

In the United Kingdom, Network Rail is testing a network of sensors that will predict when rail equipment needs maintenance. The pilot project on the Edinburgh-to-Glasgow line includes 250 sensors that collect data about mechanical and thermal operations (for example, switches opening and closing, or equipment overheating). This point data is transmitted by wireless nodes on the track and trains, and processed in the data center. Software identifies patterns of behavior that precede equipment failure, then builds models that predict future failure. If successful, Network Rail reports that the program could cut operations and maintenance costs 20% by 2014.

Research raises IQ

Adeli attributes the trend toward intelligent infrastructure to the advances being made in sensor technology, sophisticated computational intelligence algorithms such as those developed by his research group and published in his recent book, and increasingly powerful computers, which allow researchers to correlate past and present data and predict future behavior of complex systems. Such advances in computing and sensing technologies will enable owner/operators to save long-term operations and maintenance costs as well as protect against natural and man-made threats.

Some emerging technologies that can raise the IQ of the world's infrastructure, which include:

- Actuators embedded in structures to apply forces that counteract the forces of nature
- Smart fibers and carbon nanotubes that create lighter, stronger, blast-resistant materials
- Biosensors that transmit data about biological, physiological, and chemical changes
- Laser scanners that measure deformations at the structural and member level
- Pervasive computing that connects transportation controls with in-vehicle systems

Researchers aim to improve the safety and service-life of infrastructure by automating routine detection and emergency response processes. Rather than rely on an inefficient visual inspection cycle for bridges, for example, smart bridges use embedded sensors to continuously monitor their health. Adeli cites the 2007 collapse of the I-35W bridge in Minneapolis, Minn., as an example of a disaster that could have been averted by smart bridge technology being developed by his research group. In fact, the replacement bridge designed by Figg Bridge Engineers (FIGG), uses smart sensors that detect the wear and tear of daily traffic and transmit real-time data to the Minnesota DOT for instant analysis. The new I-35W St. Anthony Falls Bridge sets an example for the achievements that are possible with innovation and advanced computer technology.

Models get smart

Smart structures start with intelligent design. FIGG's designers used MicroStation to build a 3D model of the structure and communicate with the builders, Flatiron-Manson Joint Venture. This integrated design process delivered an information model that was used throughout construction and into the operation and maintenance of the bridge. Coupled with advanced computing capabilities in the DOT control center, the information model became the brains behind the 1,223-foot long, 10-lane concrete bridge.

Building intelligent infrastructure requires the convergence of multiple disciplines, including control, computing, sensor, signal processing, and civil engineering. "These are very advanced technologies requiring cross-disciplinary approaches using computer science, electrical engineering, mechanical engineering, system engineering, and structural engineering," Adeli said. If the vision for intelligent infrastructure is to become reality, civil and environmental engineering programs need to take a leadership role by providing a multidiscipline education. Meanwhile, today's professionals can adopt available technologies to design and build smart structures and intelligent transportation systems. CDM, for instance, designed a $49 million facility in Okaloosa County, Fla., using intelligent 3D across all disciplines. As real-time operational data feeds into the computerized maintenance management system, a fourth dimension is added to the 3D facility models to provide a lasting platform for efficient operations and maintenance throughout the lifecycle. By using state-of-the-art technology in intelligent plant design, CDM delivered a sustainable and cost-effective project solution.

The CDM project is just one of many innovative applications of information modeling for intelligent infrastructure. "Certainly the investment wave in physical infrastructure, beginning with rail and then roads, paved the way for broad productivity increases. But the last several decades have instead been dominated by an economic investment in digital infrastructure for computing and communicating," concluded Greg Bentley. "The fortuitous opportunity our societies have now – as we determinedly launch a new investment cycle – is to continue coalescing physical and digital investments into intelligent infrastructure." EPC World

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Brain Waves and Controlled Chaos

In the new book, Intelligent Infrastructure – Neural Networks, Wavelets, and Chaos Theory for Intelligent Transportation Systems and Smart Structures (CRC Press, 2009), authors Hojjat Adeli and Xiaomo Jiang envision a better way to design and manage the world's infrastructure. The book presents a holistic approach to the intelligent infrastructure that includes both structures and transporation systems. The authors present novel technologies, methodologies, and algorithms for creating structures that continuously monitor their own health and actively control their behavior.

Smart structures such as these:

- Provide early warning of structural failure to reduce loss of life and property
- Improve understanding of structural systems under duress
- Facilitate proactive decision making for maintenance and repair