Bentley
Advancing Infrastructure

ARTICLE

Harnessing IoT to Transform Heavy Civil Construction

Matt Gijselman, John Da Mina, and Raylan Zhang Bentley Systems

Heavy civil construction projects—such as highways, bridges, dams, and tunnels—form the backbone of the world's infrastructure. As technology continues to evolve, the Internet of Things (IoT) has become a powerful catalyst for change within the construction industry. In this paper, we explore how IoT technology is enhancing productivity, safety, and overall project management in heavy civil construction.

IoT has profoundly altered the landscape of various industries, heralding a new era of interconnectedness and automation. Within this digital revolution, the civil construction sector stands out as a notable beneficiary. With a myriad of sensors, devices, and platforms, IoT offers unparalleled opportunities to gather real-time data, monitor equipment, and ensure the safety and efficiency of construction processes. This technology not only revolutionises the way we perceive and manage construction projects, but also paves the way for innovative solutions that address longstanding challenges in the sector.

Civil construction grapples with complexities ranging from project management to on-site safety. As projects grow in scale and intricacy, the need for intelligent and adaptive systems becomes imperative. This is where IoT steps in, transforming traditional construction methodologies into smart, data-driven approaches. From remote monitoring of machinery to sophisticated digital twins that mirror real-time project progress, IoT capabilities have expanded to encompass a vast array of functionalities.

The following list delves into the multifaceted ways in which IoT is reshaping heavy civil construction, offering a glimpse into the future of the industry:

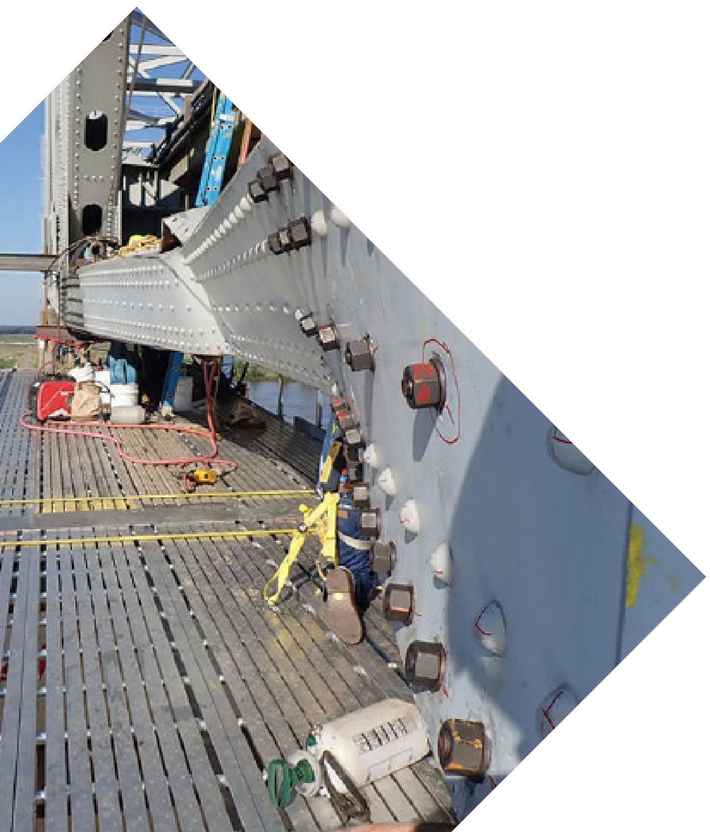
Project Monitoring, Management, and BIM Integration	• **Real-time Tracking:** Monitoring equipment and processes, location, fuel consumption, and maintenance needs. • **Data-driven Decision-making:** Utilising real-time data for monitoring equipment performance, worker productivity, and environmental conditions. • **BIM Integration:** Combining BIM with real-time IoT data for accurate project progress, enhancing planning and decision-making.
Site Safety, Health, and Environmental Monitoring	• **Worker Safety and Health:** Using wearable devices like smart helmets and vests for monitoring. Sensors for detecting hazardous conditions like gas leaks. • **Environmental Adherence:** Monitoring air quality, water quality, noise levels, soil conditions. Ensuring adherence to environmental regulations and sustainability, optimising energy and water use.
Asset Management and Data Acquisition	• Equipment Management: Automated tracking and maintenance, providing data on equipment usage, wear, and predictive maintenance. • Data Handling: Flexible API integration, real-time data monitoring, FTP automation for file data ingestion, storing raw data, adjusting data based on sensor configurations, and managing sensor configurations over time.
Site Safety, Health, and Environmental Monitoring	• Data Analysis: Time series charts, custom dashboarding, X/Y scatter plots, overlaying sensor markers on images and maps. • Visualisation: Capturing data from engineering design applications, visualising 3D models, reality meshes, point clouds, and displaying IoT sensors in 3D locations with heatmaps.
Alerting Systems and Reporting	• Alerts: Configuring data and status alerts, dynamic threshold setting, and notifications via various platforms. • Reporting: Comprehensive report generation for stakeholders, scheduling, and notifying users through various channels.
Issue Resolution and Mobile Application	• Issue Management: Creating, assigning, and tracking issues with the addition of comments, attachments, and mark-ups. Collaborative tracking and updates. • Mobile Features: Sensor network commissioning using mobile devices, remote and manual data collection on site. Compatibility with both iPhone and Android.
Administration and Delegation	• Administration: Role-based project management, user access controls to configurations, and issue management for delegation and tracking. • Delegation: Clear assignments of tasks and issues with collaborative tools to ensure progress tracking and completion
Extended Features	• Visual Enhancements: Displaying sensor data as 3D heatmaps, overlaying sensors on 2D maps for spatial context. • Integration and Compatibility: Ensuring sensor-agnostic design, supporting remote sensing data, and seamless integration with various platforms.

To understand current and future condition monitoring trends and practices among both service providers and asset owners, Bentley Systems and ThoughtLab conducted a global survey of 500 companies in March 2023. According to this research, time delays were cited as the largest challenge for over 50% of organizations surveyed. These delays often result from complex data processing and analysis, equipment downtime, and lack of automation.

Bentley®
Advancing Infrastructure

CASE STUDY: Sunshine Bridge

In 2018, the Sunshine Bridge, a cantilevered structure situated in Louisiana traversing the Mississippi River, encountered significant infrastructural compromise due to an inadvertent collision by a barge equipped with a crane.



To bolster this remediation initiative, the repair team leveraged the advanced functionalities of Vista Data Vision®, a premier IoT data management platform. This integration was pivotal, facilitating key objectives in the bridge's rehabilitation.

- Structural Monitoring: The platform aggregated and synthesized data procured from an array of sensors positioned across the bridge's expanse. Real-time metrics pertaining to load dynamics, material strain, and spatial displacement were gathered on the bridge's structural fidelity.
- Environmental Oversight: Owing to the bridge's position over the Mississippi River, it was vital to scrutinise variable environmental characteristics. IoT instrumentation played a key role in determining aquatic altitudes, hydrodynamic currents, and atmospheric metrics, allowing the crew to dynamically recalibrate their construction schema.
- Progress Tracking: A salient feature of the Vista Data Vision capability was its capacity for real-time project surveillance. By tapping into the granularity of IoT-derived data, the platform facilitated analytical perspectives on workforce efficiency, and the overarching repair progression.

Utilising Vista Data Vision profoundly transformed operational procedures for the project. This system not only bolstered safety measures, ensuring enhanced security for on-site personnel, but also provided the capability to swiftly adapt to changes based on real-time environmental data. The continuous monitoring and adaptability introduced a proactive approach, instrumental in the early identification and subsequent rectification of potential obstacles. Such proactive measures not only ensured heightened safety, but also led to significant time and financial savings.

The accessibility of accurate, up-to-the-minute data significantly enhanced decision-making capabilities, especially during the rehabilitation phase. This availability resulted in a more streamlined repair timeline, reducing disruptions to the local community and ensuring more efficient operations.

The refurbishment efforts on the 2018 Sunshine Bridge exemplify the groundbreaking potential of IoT frameworks in the domain of heavy civil construction. Platforms similar to Vista Data Vision point to an emerging era where the construction sector is anticipated to adopt a more secure, and organised set of operational standards.

The adoption of IoT in infrastructure management, especially when combined with digital twin technology, has marked a significant change. Together, these tools provide a solid foundation for real-time observation of both human-made and natural environments. Using secure, cloud-based setups, they can process sensor data to produce large datasets and then display these datasets in a rich visual manner. This approach enhances data-driven strategies, making sure that infrastructure assets work at their best while also reducing risks.

A key benefit of these modern platforms is their ability to offer cost-effective monitoring across various areas, such as dams, bridges, tunnels, railways, roads, and mining. In the past, these sectors faced difficulties in using automated and continuous sensors, mostly due to technical issues or high costs. But today's solutions overcome these problems, leading the way for new uses that allow organisations to go beyond old operational limits.

The successful use of these tools in infrastructure projects greatly depends on their compatibility with building information modelling (BIM). Combining real-time IoT data with detailed digital asset images gives project teams a detailed, current view of project details. This combination speeds up planning, aids in precise coordination, and strengthens decision-making. A core principle of this method is its open design, which allows easy combination of different IoT devices without the restrictions of specific vendors. Focusing on real-time data analysis, these platforms support fast and evidence-based decisions. One standout feature is the detailed digital twin visualisation, which blends current data with detailed 3D models to give a full asset view. Advanced warning systems, based on machine learning, support proactive asset management by sending automatic alerts for set safety standards and overseeing network health. Built-in reporting sections offer data gathering and sharing, vital for keeping stakeholders informed, while a special problem-solving section promotes shared tracking and management. The widespread use of dedicated mobile apps guarantees constant data access, paired with features that allow sensor setup via mobile.

With detailed control settings, these platforms offer detailed access and role setup, showcasing the best of today's project management capabilities. Combining all these aspects, backed by quality security measures, highlights the growing importance of these platforms in promoting IoT uses in infrastructure management.

CASE STUDY:
Perris Dam

The California Department of Water Resources (DWR), responsible for the Perris Dam in California, identified the dam as a high-priority structure during an assessment that evaluated the condition of several dams across the state.

This review particularly assessed dams near fault lines, and the Perris Dam was found to have a failure zone potentially at risk during seismic events. Given these findings, Terracon partnered with the California DWR in 2017 to carry out the necessary seismic retrofitting over the next year.

Given the significance of the retrofit project, there was a clear need for detailed condition monitoring of the dam and its foundation. Terracon and California DWR decided to use the sensemetrics' monitoring platform for their data management needs. They employed sensemetrics' wireless edge devices, known as 'Threads,' to monitor changes in groundwater pore pressures during the Cement Deep Soil Mixing (CDSM) reinforcement work. The system's compatibility with existing and new geotechnical sensors, coupled with its efficient installation process, made it a suitable choice. This platform integrated with the on-site tools, such as inclinometers, piezometers, and weather stations, and introduced enhanced monitoring capabilities. Automated readings were taken from multiple observation wells using Geokon GeoNet devices with vibrating wire interfaces, and the system was paired with Geokon vibrating wire piezometers. Additionally, a Vaisala weather station was added to provide real-time barometric pressure data and other atmospheric information.

A significant advantage of the sensemetrics platform was its cloud-based nature, allowing users from Terracon and California DWR to access data remotely from any web browser. This feature enabled real-time monitoring and access to historical sensor data. The project's completion saw notable cost savings for the California DWR, with significant reductions reported for each of the sixty sensor stations around the dam. In summary, the retrofitting of the Perris Dam highlights the potential of IoT in civil construction, offering both technical and financial benefits.

Bentley
Advancing Infrastructure

CONCLUSION

IoT is transforming the heavy civil construction industry by boosting productivity, improving safety, and streamlining project management. As illustrated by the case studies above, IoT technology enables real-time monitoring and control, enhances site safety, optimises asset management, supports data-driven decision-making, and contributes to environmental monitoring and sustainability.

Looking forward, the potential advances in industrial IoT promise to further revolutionize heavy civil construction. The developments of edge computing, 5G connectivity, and advanced analytics will enable even faster and more accurate data processing and decision-making. Moreover, the integration of artificial intelligence (AI) and machine learning with IoT systems will lead to more sophisticated predictive maintenance, resource optimisation, and autonomous construction equipment. Additionally, advancements in IoT security will help protect critical infrastructure projects from cyber threats, ensuring data integrity and system reliability.

With the construction industry increasingly adopting IoT technology, we can anticipate continued innovation and improvements in the efficiency and quality of heavy civil construction projects.