Smart Infrastructure Requires Infrastructure Digital Twins Enabled by an Open Cloud Platform

By Antonio Montoya, industry marketing director for iTwin platform, Bentley Systems

The built world is becoming increasingly smart, connected, and dynamic. Infrastructure assets – from roads to bridges and tunnels, from dams to power grids and water pipelines, from cities to airports – are becoming digitally enabled either from the moment they are built or as a retrofit to bring them up to newly established standards and expectations. This process is happening in response to critical and diverse societal demands, such as increased resilience, reliability, and sustainability, along with enhanced safety and wellbeing for its users. New technologies such as Internet of Things (IoT), reality capture, artificial intelligence (AI) and machine learning (ML), and augmented or virtual reality (AR/VR) are enabling and accelerating this change and impacting the way that we plan, design, build, operate, and care for the built world. As new smart infrastructure assets are built and existing ones are retrofitted, the need for a digital "central nervous system" is shifting from innovation to necessity. This central nervous system for infrastructure assets is the infrastructure digital twin.

Image Link:

Image Caption: The need of a digital "central nervous system" is shifting from innovation to necessity, and that system for infrastructure assets is the infrastructure digital twin. *Image courtesy of Bentley Systems.*

“Smart” Is Becoming the New Normal

As seen in many of the finalists in the 2022 *Going Digital Awards*, digital technology is becoming a foundational component that is embedded in the infrastructure assets that Bentley clients are designing and building today. From smart water conservancy, to intelligent cities and airports, to smart dams, most – if not all – of the infrastructure projects celebrated at *The Year in Infrastructure* and *Going Digital Awards* in the past several years will result in infrastructure that includes sophisticated digital sensors and actuators to facilitate their construction, maintenance and operation. They are digital from the start. Digital enablement is not limited to new infrastructure, but it is also becoming an option as an add-on technology solution provided by third-party technology vendors and integrators.

New infrastructure, especially critical infrastructure, is designed and built to include a broad variety of digitally enabled components and materials. Digitally enabled infrastructure assets are meant to provide and even consume a rich stream of data from day one. This data includes not only asset status, but also operational data such as automatic incident detection, air quality and temperature, and energy consumption. The ITER project is building the largest tokamak fusion reactor in the world, with the goal to assess the feasibility of this energy source for large-scale, carbon-free energy generation. This project is a remarkable example of an infrastructure asset that needs be digitally enabled by design, as it cannot operate without an AI system that is fed by an extensive array of sensors to safely control the plasma inside the nuclear fusion reactor.

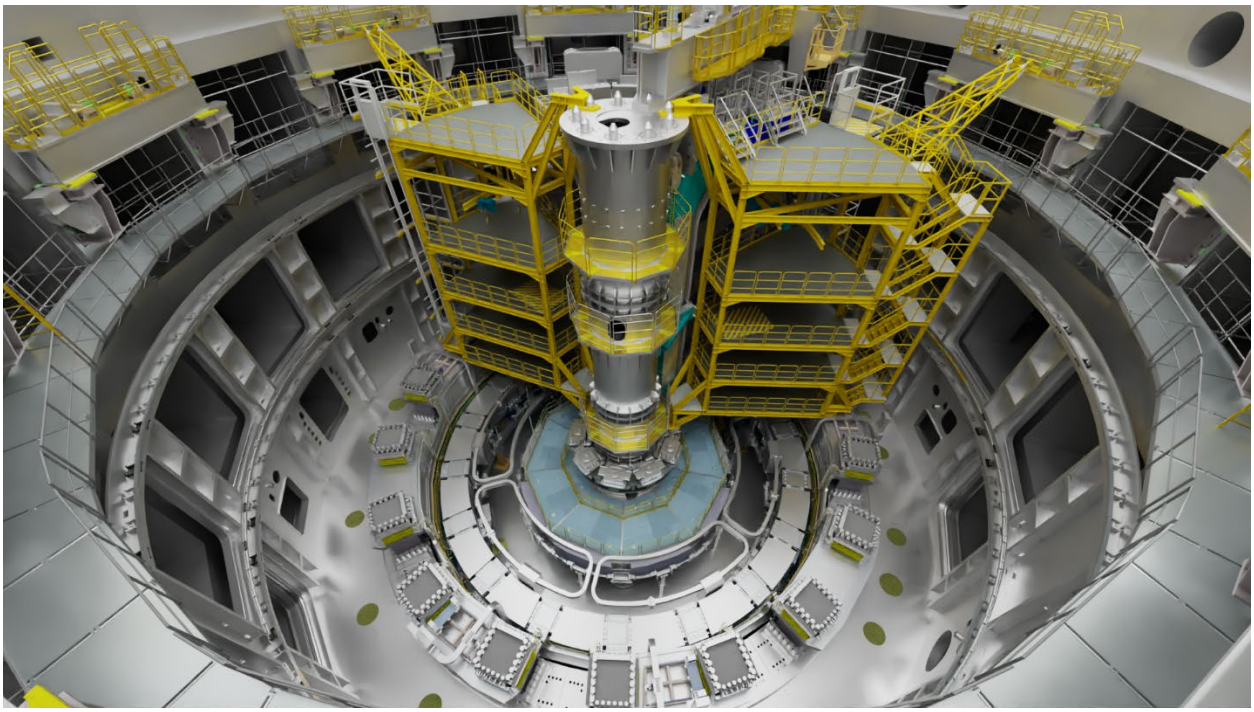

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Image Caption: Engineering-grade, millimeter-accurate visualization of the Tokamak device that will contain the nuclear fusion reaction at the ITER facility being built by a consortium of 35 nations in the south of France. *Image courtesy of ITER*.

In addition, infrastructure technology companies and systems integrators are building new and exciting applications to digitally enable existing infrastructure for a multitude of applications. A great example is SmartViz, a property technology company that built a digital twin analytics solution for building performance and optimization on the Bentley iTwin platform. Their solution integrates IoT data, energy consumption, and occupancy analytics, allowing their AI engine to analyze building performance and generate predictive models that help boost building energy efficiency and performance while enhancing occupant experience and wellbeing.

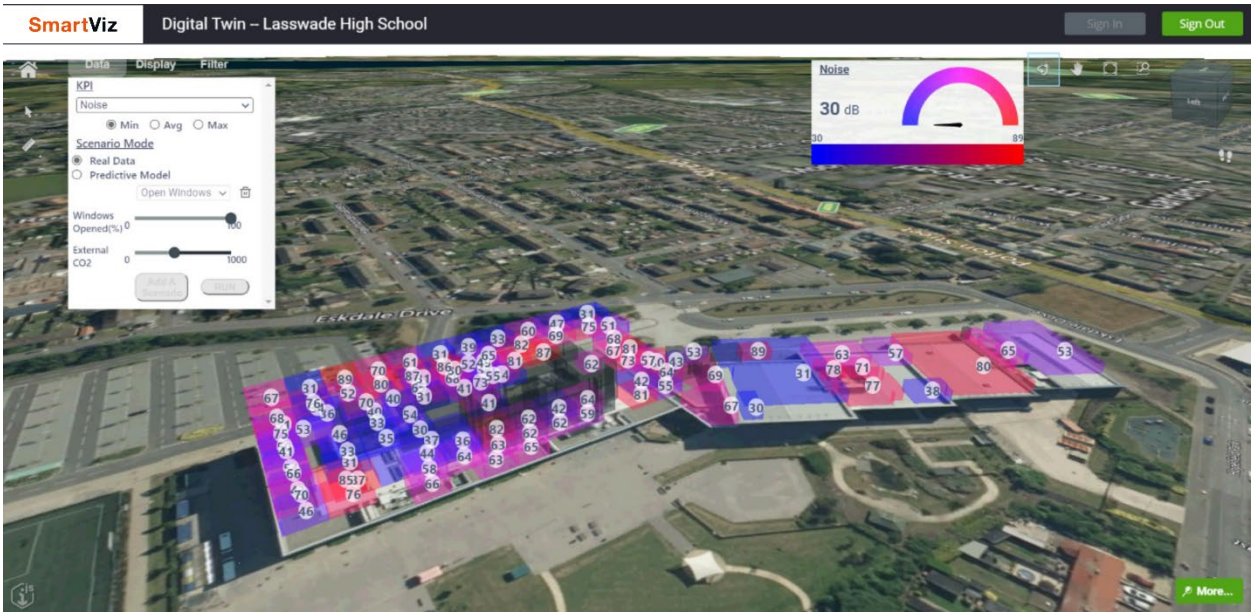

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Image Caption: Visualization of noise levels on a school building in Scotland produced by SmartViz's building performance solution, powered by the Bentley iTwin platform. *Image courtesy of SmartViz*.

Reality Capture Is within Our Grasp

Once the domain of highly specialized firms leveraging expensive and temperamental equipment, reality capture is now becoming more accessible, affordable, and versatile. Sensor form factors continue to get smaller, processing software smarter and more automated, and capture platforms more diverse and versatile. These facts are enabling an explosion of usage and broadening of applications for reality data past the design and construction phase and into the operations.

The impact of the rapid technological advancement of reality capture has been augmented by the recent pandemic. Many engineering firms and owner-operators have realized the significant advantage that can be derived from being able to rely on reality capture data to enhance critical tasks and make them more efficient and secure. It has revolutionized how project teams conduct inspections, walkthroughs, and owner/stakeholder briefings, not to mention design, construction, and handover activities.

What this means for the digital enablement of the infrastructure asset is an ever-increasing amount of data that will enrich and inform maintenance and operations, as well as interventions in infrastructure assets, but that also demands a strong technology platform that can consume this rich and voluminous data and make it available for analysis and visualization. A good example of this trend is digital twin data provider Allvision.ai. They integrated their rapid digital twin audits generated from the field data and AI as a federated source in the Bentley iTwin platform, which allows decision makers in the mobility space to improve their workflows and monitor infrastructure changes.

Artificial Intelligence and Machine Learning are Key

Infrastructure digital twins bring together a broad spectrum of data. Much of the existing infrastructure data is locked up in opaque documents, such as PDFs and drawings that computers cannot read. In other cases, new data – especially reality capture data – can be overwhelming in its volume and detail. Machine learning can help unlock this data and tie it together from multiple sources.

Furthermore, AI is becoming an indispensable tool to detect patterns and trends on the growing volumes of data generated by digitally enabled infrastructure. AI provides insight to augment and enhance the decision-making process of engineering practitioners, owner-operators, and infrastructure users. Engineering application developer Phocaz leveraged the Bentley iTwin platform and AI to build a solution to aggregate traffic design data and graphic workflows for transportation agencies. Phocaz used AI to synchronize report records with feature location, allowing transportation engineers to track design issues such as missing lengths, pay items, or alignment names in road designs.

Enter the Metaverse

AR and VR, along with gaming engine and advanced graphic processing technologies, are starting to enable a metaverse for infrastructure. The metaverse gained quite a bit of visibility in 2022, mainly after the announcements of several mainstream technology companies as the next evolution of the web as an experiential technology. The metaverse was a term coined and vividly described by Neal Stephenson in his novel *Snow Crash* in 1992 and has been credited with inspiring other seminal technologies, such as Google Earth. The metaverse has become an

umbrella term that spans the technologies that allow us to virtually experience worlds, real or imagined, in a collective and collaborative way with other people located anywhere in the world.

VR allows infrastructure to be experienced virtually. This means that project teams and stakeholders can step into the "infrastructure metaverse" to visit a project design or an as-built version, including reality capture data for a virtual walkthrough to troubleshoot issues and inform key decisions. This technology proved invaluable during the pandemic, but it has also proven to be a much safer and convenient approach to once risky and disruptive activities, such as bridge inspections.

AR gives onsite users the ability to overlay design data, simulations, and analysis over the physical infrastructure to experience rather than read about the expected impact of planned decisions or interventions, as well as to virtually bring contextualized data from the infrastructure digital twin to the field. One quite useful feature of AR is the capability to see what is inside walls and underground at a particular location.

Briefly stated, VR allows us to virtually teleport inside an infrastructure digital twin while AR allows us to bring the infrastructure digital twin to the field and overlay it over the real world. Innovators like NeARabl and REscan are leveraging the Bentley iTwin platform to provide AR and VR experiences on mobile devices to visualize, experience, and navigate building and construction sites, bringing infrastructure digital twins to the field and construction sites to the office.

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Image Caption: Mobile augmented reality experience for construction site navigation developed by NeARabl on the Bentley iTwin platform. *Image courtesy of NeARabl*.

Open Platforms and Ecosystems

From a technical perspective, the infrastructure digital twins needed to support digitally enabled infrastructure require a purpose-made platform that is open, vendor-neutral, and scalable to meet the demands of infrastructure design, engineering, operations, and maintenance, as well as to support a dynamic information connection from and to the asset. From a human enablement perspective, such a platform must support and encourage a thriving ecosystem made up of two critically important communities: a community of practice and a community of innovation.

The community of practice brings together practitioners from the engineering, architecture, construction, and owner-operators (AECO) specialties and IT to build the processes and standards necessary to empower practitioners with the knowledge that they need to build, maintain, and make the most out of infrastructure digital twins and their digitally enabled counterparts in the built world. Organizations like the Digital Twin Consortium, the Construction Innovation Hub, and the pioneering Centre for Digital Built Britain (that led the development the seminal Gemini Papers) are but a few notable examples of these emerging communities of practice.

The community of innovation is made up of the digital transformation and research and development practitioners at AECO firms, along with technology companies, consultants, and system integrators that are working together to advance the state of the art of infrastructure technologies and practices.

Why You Can't Ignore Digitally Enabled Infrastructure

"The change from atoms to bits is irrevocable and unstoppable. Why now? Because the change is also exponential – small differences of yesterday can have suddenly shocking consequences tomorrow." – Nicholas Negroponte, Founder, MIT Media Lab

As with other aspects of our real world like phones, cars, and newspapers, digital enablement has been set in motion in our built world. Cars might be a good proxy of what the future could bring for infrastructure; after all, pushed by innovators like Daimler-Benz, BMW, and Tesla, cars are now well ahead in the path to digital enablement. They have an impressive and growing array of sensor technologies that allow them to perceive their external and internal environments and make decisions to assist the driver and increase safety, optimize energy consumption, and reduce their carbon footprint.

The nature of the digital enablement for infrastructure will not be as absolute as it was for newspapers (which was the focus of the quote by Negroponte back in 1992), but it will be equally significant and potentially even critical for our progress as humanity. After all, infrastructure is credited with approximately 79% of all global greenhouse gas emissions, as noted by my colleague Rodrigo Fernandes, director of ES(D)G – empowering sustainable

development goals, earlier this year. Any impact that we can have collectively as a community of practice and innovation for infrastructure will certainly pay dividends to our children and their children for generations to come.

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