Digital Twins
in AEC

By Lachmi Khemlani, Founder and Editor, AECbytes

For those of us in the AEC industry, the concept of a digital representation of a building that can be analyzed prior to actually building it, as embodied by building information modeling, is hardly new. The concept is now being extended to infrastructure as well as entire cities. However, digital representations of physical objects are hardly unique to AEC—in fact, it came to us directly from the manufacturing industry and is now common in fields such as medicine.

One undisputed fact about technology is that it is always being improved, and this remains true for BIM methodologies. Taking its cue from the technology world at large, digital models can now be dynamic rather than static, thereby staying in sync with the physical objects they are representing. Now called digital twins, the name is taken from the twinning of the physical model with the digital model. The next step is to understand the potential of digital twins to go beyond BIM in terms of its impact and benefits for the AEC industry.

Digital Twins

In addition to being digital replicas of physical objects, digital twins also differ from simply being 3D models — even if they are modeled to an extremely granular level of detail — through the element of synchronicity. The digital prototypes are not static but are fed by sensors to stay in sync with the digital object. While the sensors are attached to the physical object, the data captured by them can be continuously fed to the digital model, so that it captures the representation of the physical object at any time and becomes a true digital twin. Any testing, analysis, or simulation that is needed can now be carried out on the digital twin rather than on the physical model, using accurate, real-time data rather than assumptions about its current properties.

Digital twins are directly applicable to all industries that work with physical objects such as manufacturing and AEC. However, a digital twin can also be used to replicate a process or a service, which allows it to be used in other industries. In short, a digital twin is used to fully test a scenario in the virtual world before applying it to the real world. A digital twin also helps an organization monitor the physical world through its virtual replica, while always reflecting the state of the physical world.

The advent of the Internet of Things has made digital twins possible. IoT technology attaches sensors and controls to physical objects that can connect to the internet and be part of a communication network. The number of aspects that IoT devices can sense continues to grow with devices that can measure temperature, pressure, light, humidity, proximity, motion, water level, smoke, chemicals, and so on. Obviously, the type of sensors deployed in a project depends on its nature.

Along with the availability of IoT devices, the development of IoT hubs has also been accelerated. These hubs take all the data collected by the IoT sensors deployed in a project and parse it into meaningful information and analytics, based on the deployment objective. For example, an IoT deployment in a retail project can track sales, inventory, and order status to provide an accurate picture of the business at any point. Machine learning is another technology that significantly contributes to IoT and digital twins. Machine learning parses the large amount of data coming from sensors into meaningful and actionable information.

Technology companies responsible for leading the development of IoT solutions are now at the forefront of digital twin exploration. IBM has launched digital twin capabilities on its Watson IoT platform, while GE Digital is building digital twins for its industrial assets and manufacturing processes on its Predix platform. Siemens is doing something similar with digital twins on its MindSphere IoT platform, and Microsoft has launched an Azure Digital Twins platform built on its Azure IoT Hub.

Going Beyond BIM to Digital Twins in AEC

A digital twin is a digital representation of a physical asset, process, or system, as well as the engineering information that allows us to understand and model its performance. Typically, a digital twin can be continuously updated from multiple sources, including sensors and continuous surveying, to represent its near real-time status, working condition, or position. A digital twin enables users to visualize the asset, check status, perform analysis, and generate insights to predict and optimize asset performance.

While static BIM models are very helpful in the design phase, their usefulness diminishes during construction. By the time the real-world asset is complete and handed over for operation and maintenance, the BIM model is usually so outdated it is kept as an archival record of the design rather than for day-to-day operations.

However, if the BIM model is continuously updated to stay in sync with the physical asset, and is also augmented by data from IoT sensors in the physical asset so that it reflects the current state of the asset at all times, then it becomes a true digital twin that can be used not only for day-to-day operation and maintenance of the asset, but also for many different types of advanced analytics. The analytics might include overall metrics for the facility such as cost, safety, and carbon footprint, as well as the simulation of what-if scenarios for specific aspects such as emergency evacuation, space efficiency, circulation, and energy analysis.

It is important to reiterate that BIM is the starting point for creating digital twins. You need to have a digital model of the building in which to add the data, and this would ideally be the as-built BIM model. The purpose of a digital twin is not to start over, as we did while transitioning from CAD to BIM, but to continue working with the BIM model and develop it further beyond the design or construction phase.

Implementation Examples

While BIM has, by now, become well established in AEC — it's difficult to find a new project today that is not implemented using BIM — implementing digital twins in AEC is still extremely nascent. This is understandable given the newness of the technology. Nevertheless, there are a few implementation examples in the field that illustrate the tremendous potential of digital twins.

In one of the most advanced examples of digital twin use in AEC, the elevator company thyssenkrupp commissioned a digital twin of its Innovation Test Tower in Rottweil, Germany. The building was constructed in 2017 to test and showcase cutting-edge innovations in elevator design such as an elevator without ropes. This design moves elevator cars both vertically and horizontally with multiple cars per shaft and brings several benefits including greater capacity, shorter waiting times, limitless building height or shape, and a significant amount of space savings. It was critical to test such concepts thoroughly, and the company that was commissioned to create a digital twin, used Microsoft's Azure Digital Twins platform to collect, integrate, and analyze hundreds of sources of data from sensors across the 246-meter tower (Figure 1), allowing the company to better understand the impact of the new elevator design on traffic, efficiency, safety, and other relevant criteria.

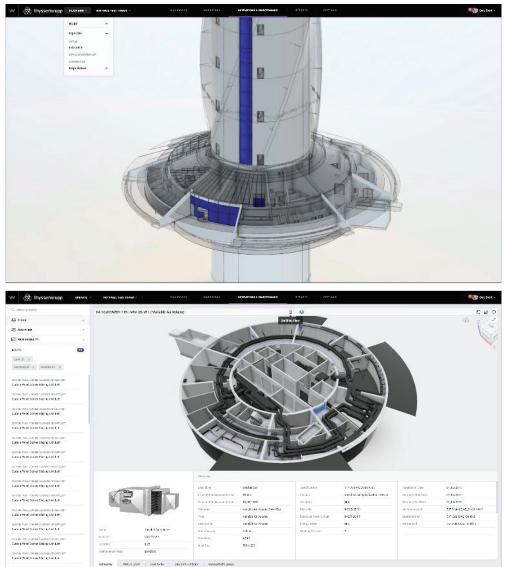

Figure 1. A digital twin of thyssenkrupp's Innovation Test Tower in Rottweil, Germany. (Image courtesy of: thyssenkrupp)

Another example of the implementation of a digital twin in AEC was created by the Institute for Manufacturing (ifM) at the University of Cambridge in the United Kingdom. This digital twin was intended to be a pilot demonstrator project for the Centre for Digital Built Britain (CDBB), which aims to guide the development of a National Digital Twin for the entire country. The aim of the ifM Cambridge pilot project is to demonstrate the impact of digital twins on facilities management, productivity, and wellbeing. The implementation consists of an as-built BIM model augmented by reality capture and photogrammetry to provide an accurate up-to-date geometric representation of the project (Figure 2), asset tags integrated with the BIM model to provide additional information about any piece of equipment, and an array of IoT sensors deployed at strategic locations in the building to monitor conditions and control operations of the IfM's critical assets and environment. Key applications used for this digital twins pilot project include Bentley's BIM and AssetWise® applications, reality capture solutions from GeoSLAM and Topcon, and asset tagging and integration from Redbite.

Bentley's iTwin® Services

As these examples of digital twins show, the technology is still quite new and evolving. While leading technology vendors such as Microsoft

Figure 2. The digital twin demonstration project of the Institute for Manufacturing at the University of Cambridge in the UK. (Image courtesy: Bentley Systems)

and Siemens are developing their IoT capabilities to process and analyze incoming data, create actionable insights, and communicate the required actions back to the IoT devices, these IoT hubs still need to be paired with BIM models for dynamic digital twins in AEC. This task naturally falls to the AEC technology vendors who develop BIM applications.

One of the vendors leading this charge is Bentley Systems, which develops a slew of building and infrastructure modeling applications as well as several reality capture solutions that, as we saw in the Cambridge example, are required to fill in the models with captured geometric data. In addition to partnering with both Microsoft and Siemens on their digital twin initiatives, Bentley has launched a suite of iTwin Cloud Services for creating and working with "iTwins," the term it uses for infrastructure digital twins. The suite includes tools for reviewing and validating designs and generating design insights. While the AEC industry already has a number of design review, coordination, and model checking tools, those tools were developed to work with static BIM models rather than dynamic digital twins. The idea behind a tool like iTwin Design Review, part of iTwin Cloud Services, is that you can upload a digital twin in Bentley's iModel® open file format to the cloud service and invite other reviewers to work on it. Since the service is web-based, it works within a web browser and is easily accessible to everyone 24/7.

Conclusion

The AEC industry has gone from manual drafting to CAD, then from CAD to BIM, and now from BIM to digital twins. As our homes get smarter with IoT devices, our buildings will also get smarter, not just with connected controls and smart sensors, but by connecting IoT devices to the BIM model of the building. This transforms the model into a digital twin, representing the real-world state of the building at any time. Extending this concept outwards, we can have digital twins for infrastructure projects and even for entire cities, which can be invaluable for performing citywide analytics of sustainability, services, zoning, congestion, disaster relief, and more. It might seem futuristic, but the future starts now.

About the Author

© Lachmi Khemlani is the founder and editor of AECbytes (www.aecbytes.com), a publication that has been researching, analyzing, and reviewing technology products and services for the building industry since 2003. She also consults on the development and implementation of AEC technology, author research reports, and white papers, and serves on juries for technology awards.

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