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The Evolution of Digital Twin Technology

On the Path to Real Estate 4.0

In recent years, digital twins have gradually evolved from a mere concept into a wide range of increasingly sophisticated and transformative systems. From manufacturing and aerospace to healthcare and energy, digital twins boast a variety of industry-specific applications, all of which aim to generate new value through the harmonization of physical and digital processes.

Given their impact on the industry, it is important to understand the ins and outs of digital twins, as well as the effect they have on construction and building management. In this white paper, we will provide a brief introduction to the concept of Building Lifecycle Intelligence and the role of digital twins, followed by exploring existing applications across a variety of industries. The paper aims to highlight how these industries generate a unique value and how this could be reflected on business leaders and developers in the construction industry to accelerate its adoption, despite being admittedly behind the curve.

Digital Twins: An Introduction

What is a Digital Twin?

The term "digital twin" is thought to have made its first official appearance in a draft version of a technical roadmap published by NASA in 2010, but utilization of the underlying concept dates back to the institution's use of "pairing technology" in the 1960s. However, due to both the novelty of modern iterations and diversity of expanding use cases, there remains a lack of official consensus around what specifically constitutes a digital twin.

In the most basic sense, a digital twin can be loosely defined as a digital replica of a physical object. The object might be anything from a building to an aircraft or even a human being, while the "replica" typically takes the form of a virtual model that could be leveraged for performing different simulations and evaluations. Importantly, digital twins currently exist on a spectrum of sophistication and functionality.

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For example, geometric 3D models used in architecture and real estate, in addition to semantically rich Building Information Modeling (BIM) models, might be considered less sophisticated, producing the necessary digital representations that can be leveraged as basis for delivering insightful values through a digital twin.

True Digital Twin = Real-Time Connectivity

So what level of sophistication or functionality is required for a technology to be considered a "true" digital twin? At the very least, there must be a real-time connection established between the digital replica of the asset and the physical object. Through this connection, typically achieved by leveraging various sensors and Internet-of-Things (IoT) technologies, changes in the physical twin should be reflected in the digital replica (which could be a simplistic dashboard, 2D view, or a complex 3D representation). For example, if a piece of equipment such as a conveyer belt stops functioning, the halt in activity would be reflected in the digital replica in real-time, prompting automatic or manual intervention.

In the most comprehensive example, the connection between the digital twin and physical object would be bidirectional, meaning changes in the digital twin could also prompt changes to the physical object. Building management systems (BMS) often feature a bidirectional link, with changes in the digital twin prompting adjustments to the environment of the room, such as temperature; if the temperature rises beyond an established threshold, this is reflected in the digital model through visual heat patterns, triggering HVAC systems to filter cool air into the room.

How Digital Twins Generate Value: An Industry Overview

digital twins are already deployed in many industries, with different levels of integration generating a unique and sustainable value.

Manufacturing

Virtual prototyping. Whether you are designing a large vehicle or a small tech gadget, prototypes take time and cost money to develop. Utilizing a digital twin allows manufacturers to run simulations and experiment with different variants before making an investment. In addition to time and cost savings, the added flexibility of designing in a virtual context can allow for the development of a well-evaluated product.

Production process optimization. Manufacturing facilities are dynamic environments, and the productivity of a given facility will depend on the performance of all individual components and equipment. This is where digital twins come in: By consulting a virtual model that not only monitors performance but collects and updates data related to each process in real-time, it becomes much easier to identify and mitigate pain points, as well as make higher-level improvements that prevent negative outcomes from reoccurring.

Product servitization. Similarly, the need to run diagnostics and perform maintenance on equipment is an unavoidable reality of running a manufacturing facility. But when digital twins are introduced into the monitoring process, these efforts can be significantly improved through the real-time visibility of equipment's performance and the elimination of manual intervention wherever possible. This can be achieved through the remote diagnosis and repair of software components, and in more advanced cases, through artificial intelligence (AI) based predictive maintenance processes.

Healthcare

Digital twins for complex operation rehearsals. The use of digital twins to run simulations is a popular application across industries and is a particularly critical area of focus for the healthcare sector. More specifically, an accurate digital twin of a patient's body can allow a practitioner to rehearse complex operations, ensuring the operation is performed as intended and potentially predicting unforeseen negative outcomes in advance of the procedure.

“As can be seen from those diverse examples, digital twins have already evolved far beyond the basic definition of a static replica, and are only expected to become more and more advanced as the technology matures.”

Predictive diagnostics. Despite everything medical professionals understand about the human body today after centuries of research, monitoring internal functions is still a significant challenge. Moreover, it can be difficult to predict exactly how a human body will respond to medication or how an illness might impact the body over time. To address this issue, leading developers in the healthcare space are developing digital twins of internal organs. This includes a digital twin of the human heart developed by Siemens to predict the outcomes of patients recovering from heart failure. Additionally, the use of digital twins is being researched extensively in the field of dentistry and orthodontics as a way to simulate an individual's dental health and to predict the amount of pressure to apply during a procedure without causing further damage.

Aerospace

Predictive Analytics. Needless to say, safety is the top priority for any aircraft developer, and the complexity of both the individual parts and how they function together make risk mitigation a demanding task. This is why top engine manufacturers, including the likes of GE and Rolls Royce, have remained ahead of the curve in adopting digital twin technology; through the use of real-time monitoring and AI-based predictive analytics, safety issues related to the engine, or any individual component can be more accurately anticipated, adding an additional layer of protection against negative outcomes.

Design and Engineering Optimization. In addition to monitoring and safeguarding existing aircraft, the data-rich feedback produced by digital twins are used extensively in the development and manufacturing of newer aircraft models. For example, if a new engine is being designed, simulations can be performed to determine the engine's performance in a variety of environmental conditions, or to evaluate how the engine will hold up after extended use.

Energy

Replicating Power Grids. The failure of any component in a power grid can have devastating consequences, and the process of maintaining these systems on a daily basis is extremely time-consuming and often requires manual intervention from onsite technicians. Understanding the need to optimize this process has led to a growing interest in utilizing digital twins, as evidenced by Singapore's recent investment in a digital power grid replica. By working from a digital model, Singapore hopes to gradually optimize all aspects of the management process, from overall performance to asset health analysis and real-time condition monitoring.

Enabling (partly) remote operation of offshore facilities. Effectively managing offshore oil and gas production facilities has a number of inherent challenges, from reigning in high operating costs to keeping up with scheduled maintenance. But thanks to new digital twin technology developed by the likes of Siemens and others, the process is gradually being simplified through an enhanced capacity for automation and easier access to performance analytics. More specifically, Siemens recently used the technology in the optimization of an Aker BP operation off the Norwegian coast, which effectively reduced manpower requirements on their production platform and led to significant improvements to the facility's equipment maintenance schedules.

As can be seen from those diverse examples, digital twins have already evolved far beyond the basic definition of a static replica, and are only expected to become more and more advanced as the technology matures. And there are many more notable developments across the different industries. These include the use of digital twins in logistics and supply chain management, automated monitoring of crop health and soil health in the agriculture sector, and even physical store design optimization in the retail industry.

Digital Twins in Construction and Building Management: Achieving “Real Estate 4.0”

First of All: Why the Delay?

Many industries are successfully deploying digital twins. What is hindering the construction industry? Three possible explanations:

Maturity and connectivity of AEC data sources. The AEC industry comprises plethora of data sources, where each can be represented in various formats. During the recent years, the data generated during design, construction, and operation of assets was kept decoupled in data silos, hindering its integration together and also with external data sources. Hence, practitioners had to maintain multiple data silos and invest high effort in manually creating value from its combination.

People are less predictable than machines. One of the core functions of digital twin technology is to facilitate the creation of predictive models, with the goal of achieving operational improvements, increased productivity, and cost reduction. But whereas an industry like manufacturing is primarily focused on optimizing processes and machinery that are relatively familiar, construction and building management companies must also factor in an equally critical, yet far less predictable variable: the habits, preferences, and attitudes of the people who occupy the building.

Understanding Return on Investment (ROI). Because adopting a new technology can be costly and time-consuming, most businesses will first need to understand in considerable detail exactly how a solution creates value before even thinking about making an investment. In industries such as manufacturing and aerospace, the value propositions associated with digital twins are fairly obvious (i.e., less downtime, more reliable safety features), and until recently, the benefits of digital twins to the construction industry have been less straightforward, making it difficult for business leaders to invest in costly sensor technology.

Fortunately, as time has passed and research has compounded, the adoption of open standards has witnessed a tremendous adoption among domain experts, increasing the trust in using them among the different disciplines and also to owners as a handover deliverable. Additionally, we are now in a more reliable position to estimate the ROI of digital twin utilization in the real estate sector:

Building information modeling (BIM) can increase occupancy by up to

3.5%

(Handbook for the Introduction of Building Information Modeling by the European Public Sector)

Digital twins may shorten project timelines by up to

7%,

&

reduce operational costs by up to

9%

(Center for Integrated Facility Engineering (CIFE), Stanford University)

Digital twins can improve tenant retention for office and industrial assets by up anywhere from

10-15%

(Arup)

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From “Static” to “Smart”

As mentioned previously, digital twin technology exists on a spectrum of functionality and sophistication, and so far, we have seen the construction industry move gradually from the utilization of

more basic technologies to those that feature real-time connectivity and leverage automation tools, or what we’ll refer to as “smart” twins.

The following two existing applications of both models illustrate how they create value in the context of construction and building management.

Centralized Data Repository. A “basic twin” exists as a detailed digital replica of a building, including an easily accessible, centralized repository of data related to various assets within the structure. This enhances productivity by eliminating the need to retrieve information from siloed entities throughout the facility when an issue arises and makes it easier for information to be shared with third parties and across the organization. If an office move is being planned, for example, the digital twin helps streamline communication with movers by providing a detailed inventory alongside an intuitive visualization of the floor plan.

Building Management System (BMS) with Real-Time Input. A “smart twin” improves on the basic digital copy by enhancing it with real-time connectivity, typically through the use of sensor technology. This model provides two primary benefits: Increased responsiveness and enhanced data analytics capabilities. Because sensors are constantly feeding information to the digital replica in (near-) real time, an issue such as an elevator shutdown may immediately trigger communications with a maintenance team, expediting the repair process. And because smart twins are constantly collecting and storing information, the detailed data being fed to the digital copy is always accessible and gradually leads to an improved capacity to forecast outcomes, make adjustments, and optimize user experiences.

> “... the digital twin helps streamline communication with occupants by providing a detailed inventory alongside an intuitive visualization of the environment.”

Building Lifecycle Intelligence (BLI): A Full-Circle Approach

Now, while we have seen what the construction and broader real estate industries have been able to accomplish so far through the utilization of basic and smart digital twin technologies, the question remains: Where do we go from here?

Ideally, technological advancements will lead to the proven conception of an “autonomous twin.” This would, in theory, result in the creation of autonomous buildings, which would be fully bi-directional, and automatically control and adjust everything from environmental controls and elevator movements to access to specific areas or even the building itself. This is a genuinely possible, albeit longer-term outcome, but in the meantime business leaders have an opportunity to maximize the value generated by individual digital twin solutions by integrating each into a single, comprehensive process known as Building Lifecycle Intelligence (BLI).

What is BLI exactly? Put simply, it is* the accumulation of data from all phases of the building development process, converted into a single “source of truth.” Generally, the use of digital twin technology in the construction space has targeted the individual phases of Planning & Design, Building & Construction, and Operation & Management. And while these solutions have proven effective in their own domain, the value tends to be diluted as a project inevitably progresses or a building change hands.

For example, a design team might feel empowered by the use of a digital twin to enhance collaboration throughout the planning process; but what happens when an engineer on the ground needs to substitute materials, and has no way of recording this change within the design team’s model? Or perhaps a building is being sold after reaching the operational phase, but the sale is held up by the purchaser’s lack of access to information regarding all phases of the building’s development. The fix? Utilizing a BLI model that provides all parties with immediate access to the information they need, regardless of where the project sits in the overall lifecycle.

In addition to optimizing processes in the short term, the BLI model provides a number of long-term benefits. For one thing, conclusions drawn from the accumulation of data can be used to inform future design choices. Maybe a correlation is established between employee productivity and exposure to sunlight; this could help inspire renovations or the design of a new workspace. And what about comparing the unique cost of specific design choices? By evaluating costs against outcomes through the use of BLI, developers can learn new strategies for improving building efficiency while lowering costs related to specific phases of the lifecycle.

Overall, digital twin technology is on a rapid course of advancement and adoption, with a unique and transformative value proposition to offer virtually all industries. From the remote operation of complex offshore energy facilities to an enhanced capacity to predict the recovery timeline of a damaged human heart, the possibilities of what can be achieved through the use of digital twins appear increasingly limitless. And while construction and building management companies might be on a slower path to achieving “Real Estate 4.0” status, their patience may ultimately be rewarded through the careful, intentional utilization of all developments to date. ■

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