SPACEWELL
A NEMETSCHEK COMPANY

WHITE PAPER

Digital Twins & Building Lifecycle Intelligence

Getting to Real Estate 4.0

Contents

01 What is a Digital Twin?

Named as one of Gartner's top 10 strategic technology trends for 2019,[1] "Digital Twins" are among the most anticipated technologies for the construction market. Dating back to NASA's "pairing technology" and sometimes referred to as "Industry 4.0," digital twins are extensively used in manufacturing and industrial applications. Their value in achieving cost savings and productivity enhancements in those sectors has generated growing interest in the slower-moving real estate and construction industry. Yet even as expectations are high, there remains a notable lack of consensus around what people actually mean when they talk about digital twins.

In its most basic form, a digital twin is a digital copy, model, or simulation of a physical object. This twin is used to capture information about systems, assets, or processes, which can then be leveraged to optimize the use of the physical object. Applied to the building sector, this basic definition of a digital twin includes well-established technologies like Building Information Modeling (BIM)[2] or even more straightforward 3D models. Notably, however, by many newer standards, this basic definition does not qualify as a true "digital twin."[3]

Over the past few years, those more sophisticated definitions of digital twins have gained ground. In a more demanding definition, the digital twin must be more than a static copy. Instead, to count as a true digital twin, a real-time connection to the physical twin must exist. This means that changes in the physical twin must be reflected in the digital model, typically through extensive use of Internet-of-Things (IoT) devices and sensors. Ideally, the digital-physical link should be bidirectional, meaning that the digital twin can actually produce changes in the physical object, with those changes registering back in the virtual copy.

How is such a bidirectional link achieved? Digital twins can produce changes in the physical world when they are tied to control systems – for example, a building management system (BMS). In that case, sensor data are fed into control systems programmed with automated triggers. Whenever defined thresholds are reached, instructions are sent to the BMS, whose actions produce changes in the physical twin, which in turn are registered by the sensors. In this way, a feedback loop between the physical and the digital is built and enabled by sensors and software. In a fully autonomous, artificial-intelligence enabled system, there may not even be a need for pre-defined thresholds; learning algorithms would determine optimal conditions and act accordingly.

To illustrate this process more concretely, imagine an office tower that is equipped with temperature sensors throughout the building. Thermostats collect temperature readings and carry them to the digital twin, which shows room-by-room heat patterns on a 3D model of the building. When the temperature in one space rises above a fixed threshold, an alert is triggered, directing the HVAC system to activate the air conditioning system. The space cools down, the 3D model shows cooler temperatures, and the air conditioning fans slow down to maintain the temperature. The digital twin and the physical twin of the building operate in a seamless way to keep the building comfortable for occupants.

Perspectives: The Future of Digital Twins

Digital Twins bring Smart Buildings to Life

Interview with Wouter Hartemink, Chief Revenue Officer Spacewell

Q: We've heard about Manufacturing 4.0 for some time now. Why has it taken so long for digital twins to arrive in the real estate sector?

A: The digital twins in manufacturing that are held up as a model for other applications have several features that have made them an easier case for adoption than buildings.

First, they have tended to focus on mechanical parts whose physical properties are well understood. This means that it is clear what needs to be monitored – for example, temperature or rotational speeds – and what needs to be done in terms of preventive maintenance. While buildings certainly have systems that share these features, some of the most significant use cases in real estate involve people, who are much less predictable than machinery.

Second, digital twins in manufacturing have been typically focused on critical components. The ROI for keeping your production line running is obvious,. For many buildings, the business case isn't always as clear-cut: you are unlikely to lose millions in rent if one of your elevators is down for repair for a day, so how much are you willing to invest in sensors to keep it running?

Digital twins in buildings are starting to capture attention because the industry is getting better at explaining the ROI and, crucially, because sensor costs have dropped to an extent that monitoring an entire building is becoming feasible.

Q: What do you see as the most likely use cases for digital twins?

A: The low-hanging fruit for digital twins for the moment is largely in predictive maintenance and energy efficiency. Again, it is much easier to make a compelling case for investing in monitoring mechanical systems that are well-understood, and whose results are easy to capture.

Over time, though, I believe the real value of digital twins is twofold. First, in the operations phase of buildings – which is Spacewell's core segment – digital twins have the potential to vastly elevate the user experience. Personalized environments and recommendations are ways to increase office attractiveness (and enhance employee retention) and to boost productivity, both of which are major benefits, especially in knowledge industries.

Second, digital twins are likely to become valuable assets in their own right. We all have heard that knowledge is power and we've seen how much value tech companies can generate with detailed information about people. Similarly, granular, practical data about buildings and human behavior within those buildings is going to be incredibly useful to building owners and operators, as well as to architects, planners, and construction companies in other stages of the building lifecycle.

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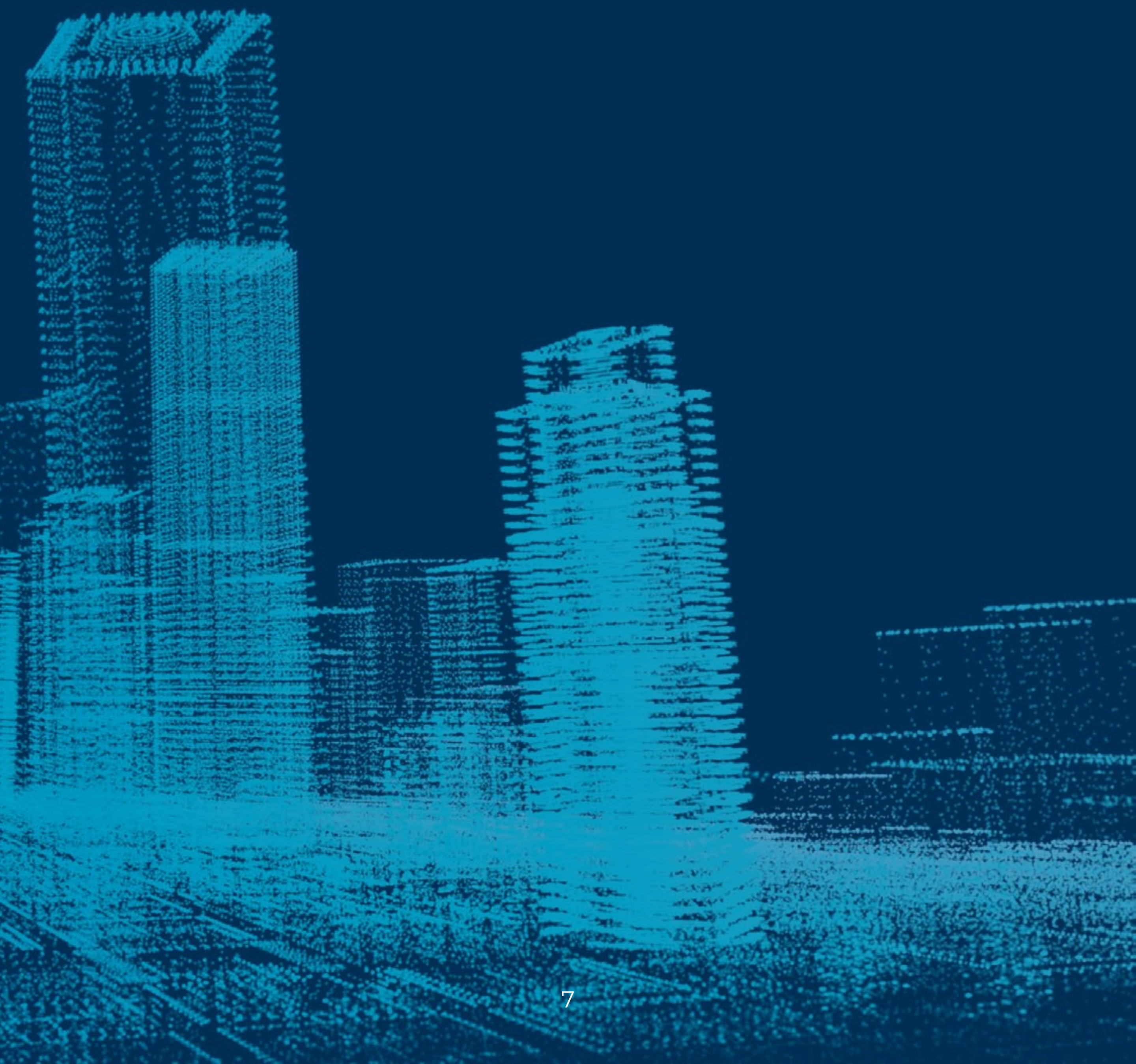
02 How do Digital Twins generate value?



The scenario described above hints at a number of ways in which digital twins – particularly in their most sophisticated forms – can add value, from reaction speed to user experience. This section walks through some of the benefits of digital twins across three levels of sophistication. Notably, the maturity of digital twins does not need progress in a linear way and digital twins do not have to be comprehensive – they might extend to all assets within a building, or they might just be copies of a single component in an engine.

Potential adopters need to keep their individual needs in mind when thinking about the level of maturity and pace of adoption that they want to pursue. As one study focusing on digital twins in manufacturing noted, digital strategies often disappoint due to an excessive focus on technology over cost.[4] Digital twins should be designed to meet a specific need, not simply to exist as technological marvels.

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Basic Twin

Detailed digital copy (e.g. BMS)

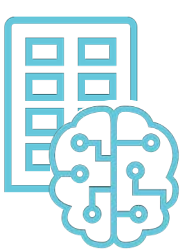
Centralized repository of data about building systems, processes, and assets

Enhances productivity, reduces errors

Smart Twin

Digital copy enhanced with real-time data, though largely still unidirectional

Creates more responsive building management, enhances data analytics for optimization, and generates a better user experience



Autonomous Twin

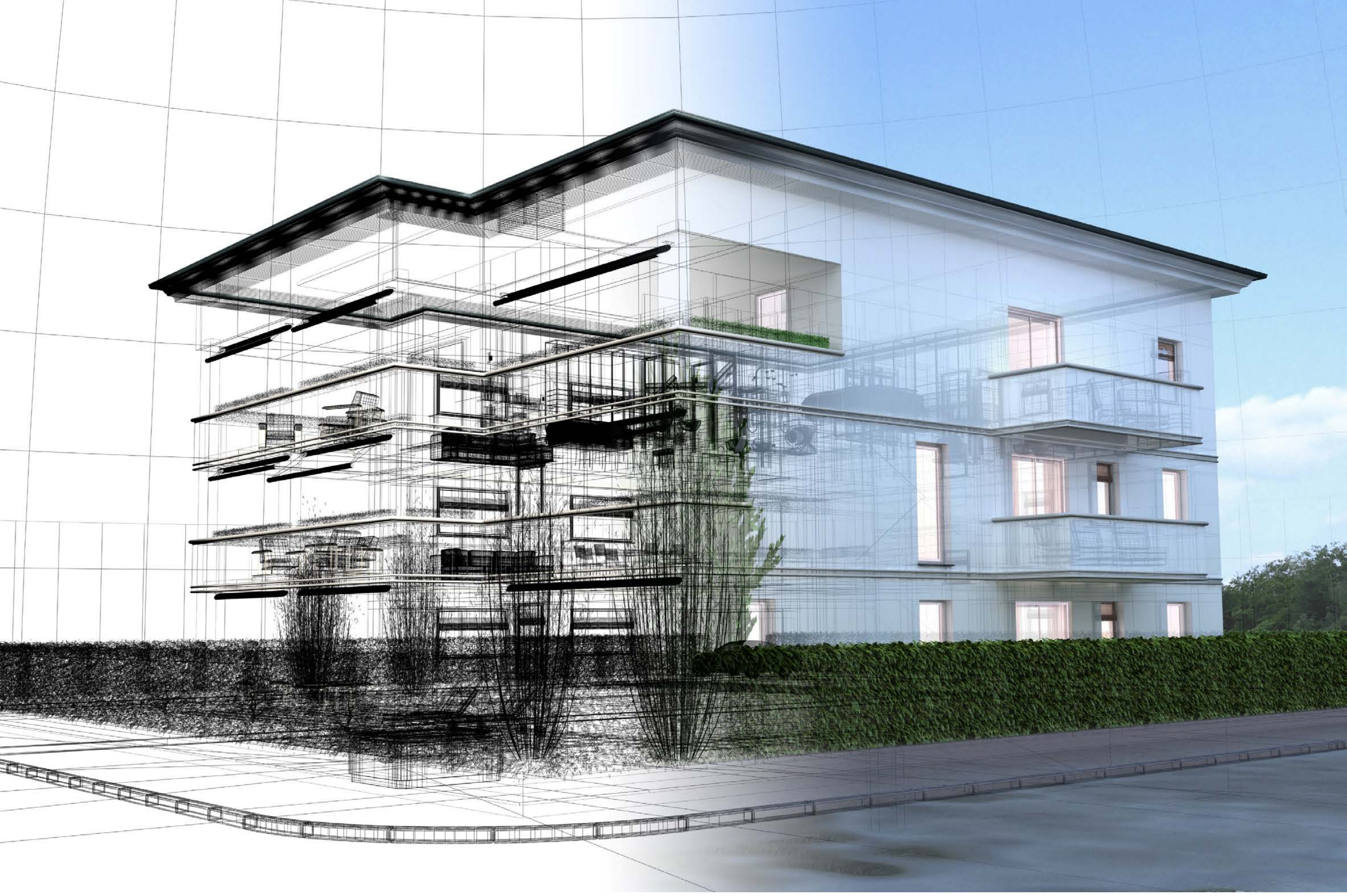
Fully bi-directional link between digital copy and physical world

Enhanced with AI, can generate fully autonomous buildings that optimize building functions and user experience

The Basic Twin: A Detailed Digital Copy[5]

As growing demand for digital transformation reveals, detailed digital records are becoming essential. Not only do digital copies provide a valuable overview of assets when working remotely, but digital information can be easily shared across stakeholders, enabling streamlining of business operations and knowledge transfer across business silos – or across different phases of a building's lifecycle.

When a facilities manager is planning an office move, for example, having a clear inventory of all of the assets and a visualization of the floorplans will make communication with movers and post-move inspections much easier than relying solely on physical records. Moreover, even in a static information model, the manager can keep a record of the chain of custody for each item, maintaining accountability throughout the move process.



Significantly, digital copies of assets can also be easily linked to other relevant information, providing a much richer, contextually detailed overview of assets than physical records or objects. The digital twin can draw on multiple datasets within the company and also integrate external sources to bring all relevant information together in one place.

For example, a digital twin of an elevator system will not only be able to show you where the elevators are located, but can link to a detailed description of their manufacturer, warranty documentation, maintenance record, replacement part inventory, and potentially even its call schedule. Having all of this information in one place ensures that, if the elevator malfunctions, technicians know exactly what equipment they need to make repairs and where to go for help if additional support is needed. This means that elevators will have shorter downtimes and building users will be much happier with the elevator service.

Overall, basic digital twins can enhance productivity by saving time spent looking up key information. This produces better-informed decisions, reduces the risk of errors, facilitates long-term planning, improves governance of assets, and promotes information sharing.

The Smart Twin: Digital Twins with Real-Time Inputs

While static digital twins can help make decisions in the moment, those decisions are not based on real-time data. For that, connected devices and systems, sensors, and other dynamic data collection are necessary. A Smart Digital Twin establishes a one-way connection in which data flow from the physical twin to the digital twin in (near-) real time. This constant flow of information means that the digital twin is enriched not only by greater accuracy, but by vastly larger quantities of information. Real-time data therefore give this more sophisticated digital twin added capabilities.

To begin with, real-time data greatly enhance responsiveness, particularly in building operations. Up-to-date knowledge about whether an elevator has stopped running, whether a reserved room is unoccupied, or the temperature has reached uncomfortable levels can all be used to prompt specific interventions. Those interventions can be manual, as when a technician is notified to examine a malfunctioning elevator, or they can be automatic, such as when an unoccupied space is automatically released for reservation or the HVAC system is automatically triggered.

In all of these cases, higher responsiveness can drive substantial improvements in productivity. In the elevator case, faster interventions translate into greater uptime, which in turn means that users spend more time working rather than getting to their destinations. For reservations systems, auto-release of empty-but-reserved rooms can save other users time finding rooms as more spaces are made available for reservation. In some cases, more efficient reservation management might even allow offices to free space for other uses altogether, leading to real estate savings. Temperature management likewise has been tied to performance: improved ventilation has been linked to employee productivity gains of up to 11% over multiple studies.[6]

Another added capability concerns data analytics. The exponential increase in relevant data produced by sensors means that smart digital twins can be leveraged more effectively than static twins to run simulations. Because the digital twin so closely mirrors the physical reality, it can be possible to forecast the likely outcome of a wide range of potential interventions before implementing those changes in reality. This can result in huge cost savings compared to physical experimentation. Beyond simulations, data can also be used for training machine learning algorithms for applications like predictive maintenance to further improve asset uptime.

Data analytics are not simply improved due to volume of data but also quality of data. By continuously collecting data on such measures as utilization, sensors can produce a more comprehensive view of user behavior than static models. This complete view can be used to optimize building management, including workplace transformations. Understanding what types of spaces are used by how many people and when can allow building managers to streamline the mix of spaces and the overall footprint of the building in such a way as to better meet user needs while also reducing space requirements. Depending on the building location, this can represent enormous cost savings for tenants.

Real-time data fed into a digital twin can also improve a building's user experience, particularly when the data involves information about utilization.

Building designs and features, ranging from the number of conference rooms or workstations, availability and placement of windows or other visual features, proximity to key rooms, are frequently implemented based on "best practices" or research drawn from third-party experiences. But many factors internal to a company, including its culture and workflows, will lead to deviations from the assumptions that drive those design choices. Real-time usage data can help determine which features actually work best in the sense of attracting users and can be used to adapt designs, reservations features, and services to make the built environment work better for a particular user base.

Thus, the “true” digital twin that incorporates real-time data is valuable because it gives decision-makers more powerful tools to truly optimize the building at multiple levels. Productivity, service, experience, and operations can all be improved with a range of interventions, and real-time data enable managers to track and verify that their efforts are working.

The Autonomous Twin: Digital Twins with Bidirectional Effects

Ultimately, the goal of many proponents of digital twins in the building space is to track a wider range of building features and characteristics, tie them to a digital twin, and link the twin to a comprehensive set of building services with the goal of creating autonomous buildings. Fully autonomous buildings would automatically adjust environmental controls, elevator movements, building access, etc. to the needs of the building's occupants in real time, without the need for human intervention.

In the building sector, this fully-developed digital twin is still largely an idea rather than a reality.[7] While human decision-makers might not be required to actively manage portions of the HVAC system beyond establishing relatively straightforward decision rules, many other functions of building management still require external decision-making. In part, this is because office buildings serve a number of social purposes and human behavioral patterns have proven more difficult to predict than physical laws.

That said, with enough data collection over time, machine learning and artificial intelligence may be able to detect patterns in usage that can be used to inform a building's service delivery, build profiles of different users that create a more tailored user experience through workplace apps.

The ultimate promise of this fully-realized version of a digital twin is to dramatically improve the speed and efficiency of responses for any building operations managed by the digital twin. Energy utilization, service delivery, and user experience would all be fully streamlined and, to the extent that any human intervention is necessary to manage operations, it could take place remotely. In the words of one recent MIT report, "Digital Twins, when paired with a Smart Building, could be supercharged for operational, process, and simulative performance outcomes." [8]

The Estimated ROI of Digital Twins

Increase occupancy by up to

3.5%

with BIM

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

Shorten project timelines by up to

7%

with a digital twin

Center for Integrated Facility Engineering (CIFE), Stanford University

Up to

9%

reduction in operational costs

Center for Integrated Facility Engineering (CIFE), Stanford University

Up to

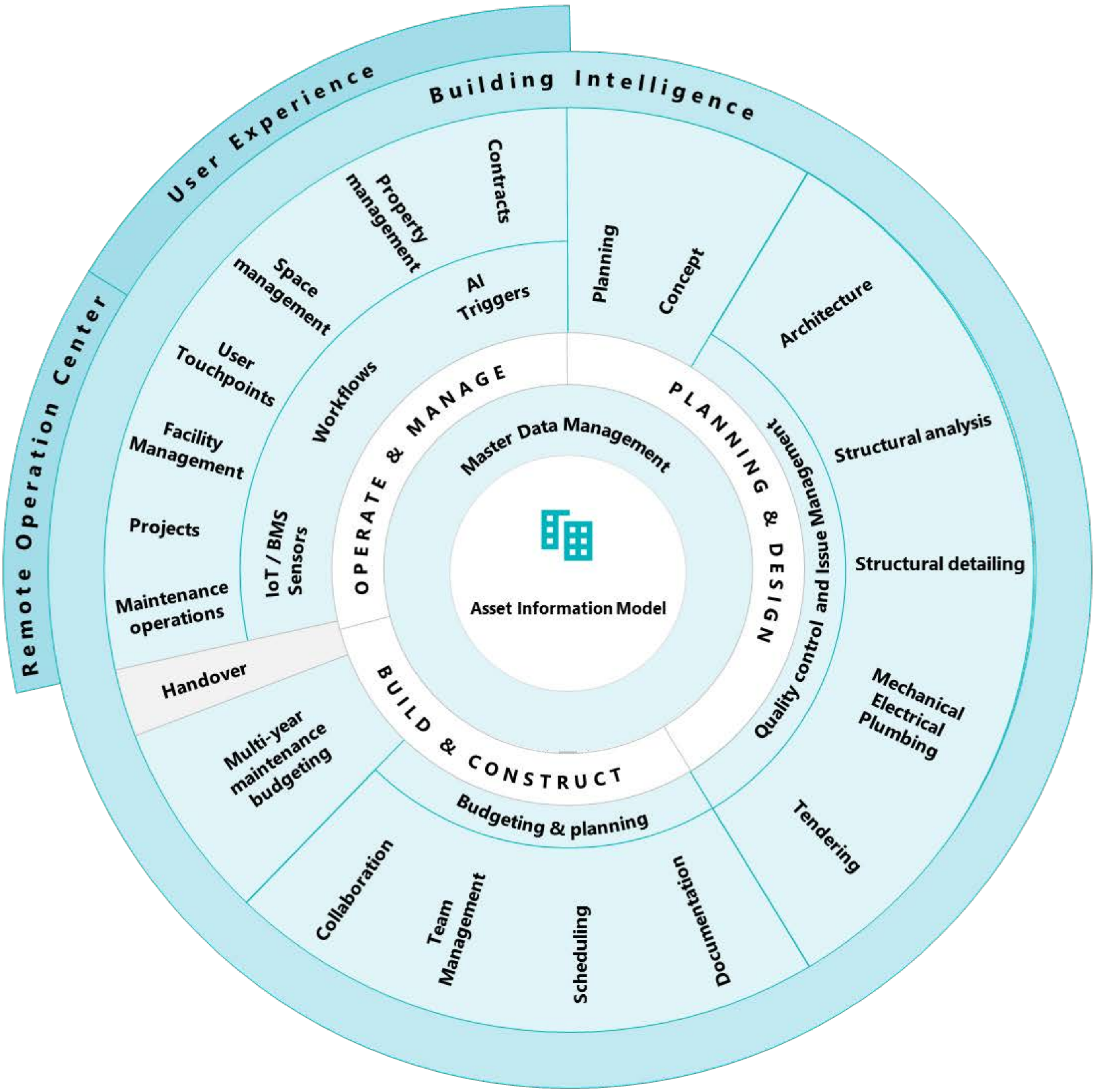
10-15%

improvement in tenant retention for office and industrial assets

Arup

03 Building Lifecycle Intelligence: Leveraging Digital Twins over Time

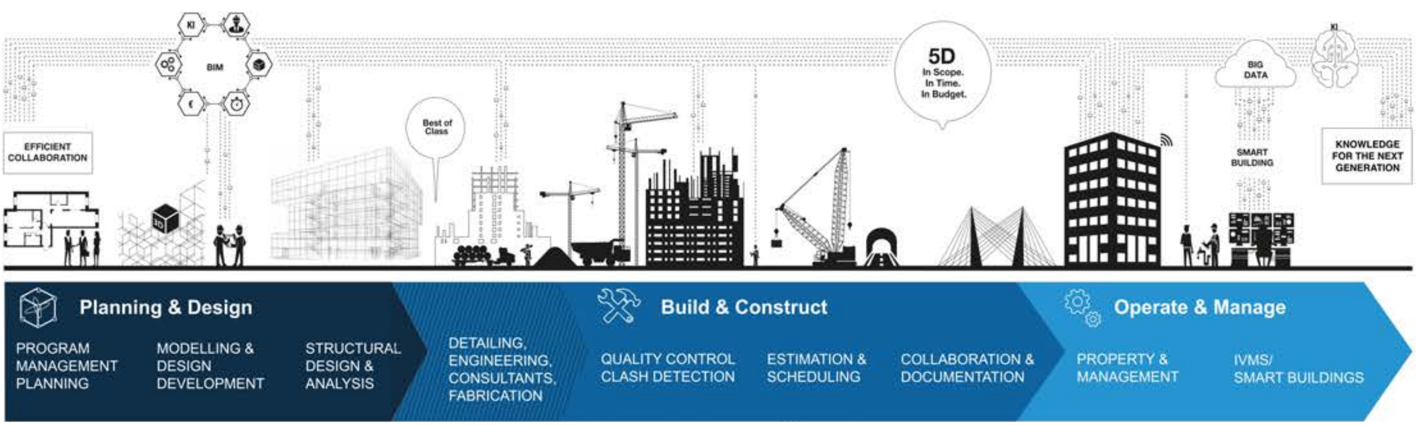
Digital Twins over the Building Lifecycle



Building Lifecycle Intelligence

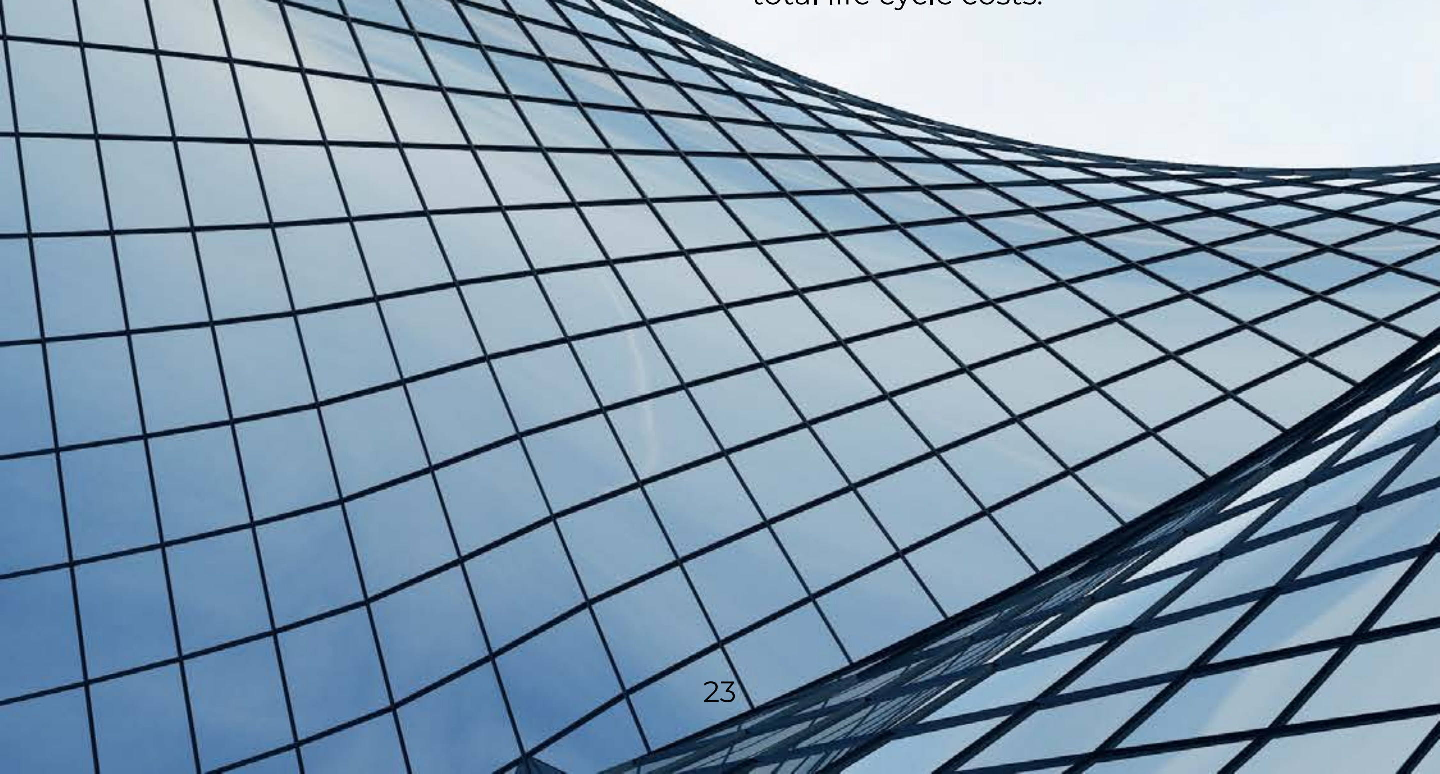
Most discussions of digital twins in the construction sector focus on the way digital twins can provide advantages within distinct phases of the building lifecycle: Planning & Design, Building & Construction, and Operation & Management. The preceding section is no exception, focusing heavily on the operations phase.

However, there is enormous potential for digital twins to leverage information from across different phases – and even across buildings – in a transformative way. Information from each stage of a building lifecycle has important implications for other stages, whether in terms of cost, durability, or user experience. Aggregating information from each stage, across different building owners, and over multiple building lifecycles can help us learn about what the downstream effects of every design or construction choice are likely to be. Ultimately, those lessons can help architects, engineers, and building managers develop and operate better-performing buildings. This knowledge accumulation is known as Building Lifecycle Intelligence (BLI).



To elaborate on this concept, practitioners in each stage of the building lifecycle have made enormous progress in collecting and streamlining the use of critical information for their business. However, each time a handover of a model occurs, some amount of information is wasted or corrupted. Perhaps the engineers on the ground cannot secure the exact materials that had been planned in the design stage and make a substitution that isn't entered into the model. Maybe a building in the operational stage is sold and only “critical” information is passed on to the new owner.

If, instead, all data were centralized in a “single source of truth” that tracked all of the changes over all of the phases of the building's lifecycle, protected and anonymized that data to account for proprietary uses, then the value of the information would be maximized and future planners would benefit from all of the potential insights gained between planning and decommissioning.



This model becomes even more exciting when building information also includes sensor data that monitors actual usage. If a planner has empirical evidence to support the idea that certain types of window configurations lead to more extensive use of a space across decades of building use, then that could inspire future design alterations – and could even justify investment in more expensive design choices. Likewise, if utilization data point to changes in the way common spaces are used, newer buildings could adapt to those patterns, creating a more tailored environment.

Significantly, BLI also addresses one of the inherent challenges in the buildings market: while the costs of construction are borne up front and tend to drive budget calculations, in fact as much as 80% of a building's lifecycle cost occurs during the operational phase.[9] By driving insights about the long-term operational costs of design choices, we can develop more efficient buildings with lower total life cycle costs.

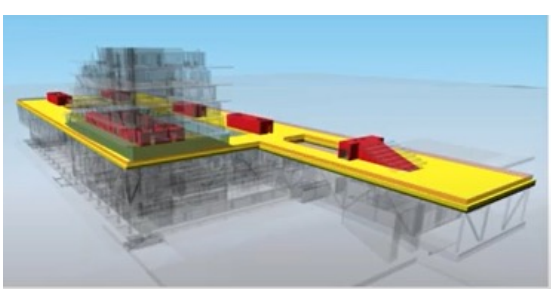
Leveraging a Digital Twin Across All Stages of the Building Life Cycle

Case in point: Maritime Campus Antwerp

Interview with Bart Huybrechts

Q: What is the MCA project about?

A: The idea of the Maritime Campus Antwerp arose from the observation that the maritime sector in Europe is fragmented and lacks the scale for strong innovation. With the MCA project we are on a mission to change that; it aims to drive innovation, develop new business models, pool knowledge from around the globe, and build an activity community. MCA is also a physical site with a mix of functions, as well as a public hotspot that will bring together very different people. It will provide space for activities such as R&D, labs, auditoria and training facilities, offices and coworking spaces for start-ups, catering, concerts, exhibitions, and events.



Q: How will a digital twin bring value to the MCA project?

A: MCA is an investment project for the long term – we will have the site under management for at least 30 years and therefore design for total life-cycle cost. The site needs to be highly flexible and adaptable. We require the flexibility to shift functions and convert, for example, an R&D lab into, say, a virtual reality room or a collaboration space. We are creating the digital twin with that end in mind. This is why we are setting up the digital twin from the very early stages of the planning and design phase, not just for the purpose of collaboration during design and construction, but already now with the management phase in mind, answering questions such as:

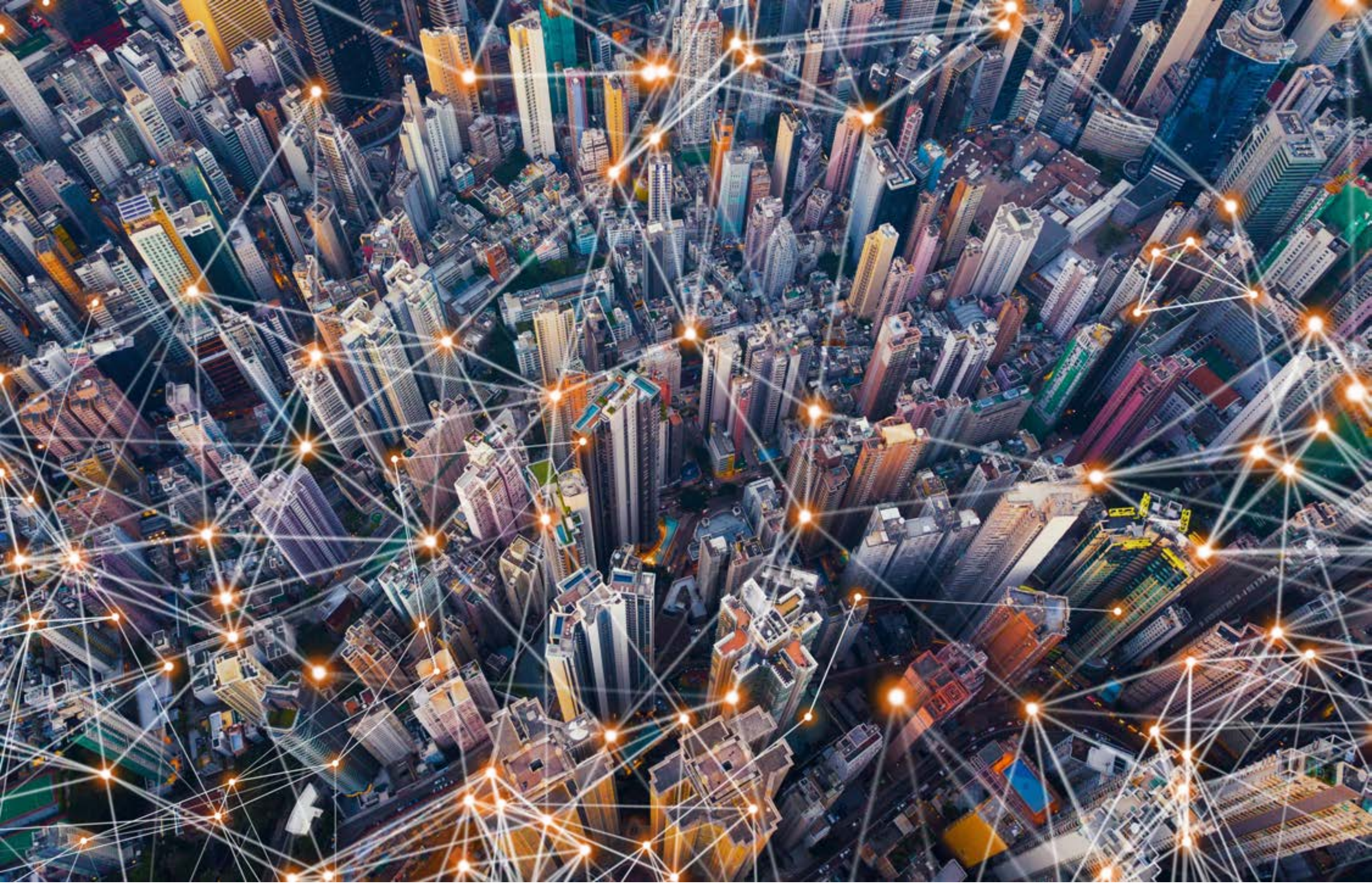
- How will design choices impact long-term maintenance costs?
- How will the users experience the building, in terms of wellbeing and productivity?
- How will it help us attract and retain the right talent?
- How will the site facilitate the 'matchmaking' between different parties?

We will also open the site virtually and invite people to experience it before it is actually built.

04 Choosing the Right Digital Twin Solution

As this paper has demonstrated, digital twins exist on a maturity curve, from the simple to the smart, to the autonomous, and even to twins that inform the full lifecycle. Within each of these stages, decisions must be made about what is included or excluded and how detailed the information should be. As one study noted, digital twins do not need to be realistic to be effective; they need to be relevant and fit-for-purpose.[10]

While it might make sense for an oil company to develop a detailed digital twin of a drilling rig down to tracking every last detail around rotational speeds, temperature, material of the drill bit, and soil composition, the same level of detail is not necessary in other applications. The cost involved in real-time monitoring of the turns of a doorknob are unlikely to generate sufficient returns to justify the investment for a building owner.



In choosing the right digital twin solution, adopters need to develop a clear use case and build their model around that particular need. Capturing all measurable information from across an entire building – let alone an entire portfolio or even city – is simply cost prohibitive. As a result, adopters need to proceed by prioritizing the information that would generate the highest returns within a given time frame and proceed in that order until a clear business model can be presented.

Another question that potential adopters should ask themselves is whether and to what extent they wish to join a broader ecosystem of digital twins. Singapore, the UK, and other countries are developing city- or nation-wide digital twin networks to share information, empower civil servants and generate public benefits. Adopters of digital twins should inform themselves of domestic initiatives, laws, and potential funding sources in determining what to monitor and how the business case might change in response to this local context.

Digital twins are rapidly emerging as an exciting development in real estate and promise to create entirely new opportunities for productivity enhancement, cost savings, improvements in the building lifecycle, and an overall better user experience. With the cost of sensors falling and continued improvement in computer processing power, there is a strong business case for digital twins at all levels of maturity. Nevertheless, potential investors need to establish a strong vision for how digital twins will support their business case, build a strong network of internal stakeholders, and find a reliable technology partner to ensure successful adoption.

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[2] Siemens (September 2018) "Digital Twin: Driving business value throughout the building life cycle."

[3] Khajavi et al. (2019). "Digital Twin: Vision, Benefits, Boundaries, and Creation for Buildings" IEEE Access. doi: 10.1109/ACCESS.2019.2946515.

See also Arup (2019). "Digital Twin: Towards a Meaningful Framework"

[4] Microsoft (2017). "The promise of a digital twin strategy"

[5] As noted above, by many definitions, this "Basic Twin" does not qualify as a full digital twin. Because this basic iteration is a core building block of the digital twin, we follow the approach taken elsewhere and include it in our discussion.

See The Institution of Engineering and Technology and Atkins (2019). "Digital twins for the built environment" which covers the "Basic Twin" in Elements 0-2.

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Paper prepared by Spacewell
October 2020

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