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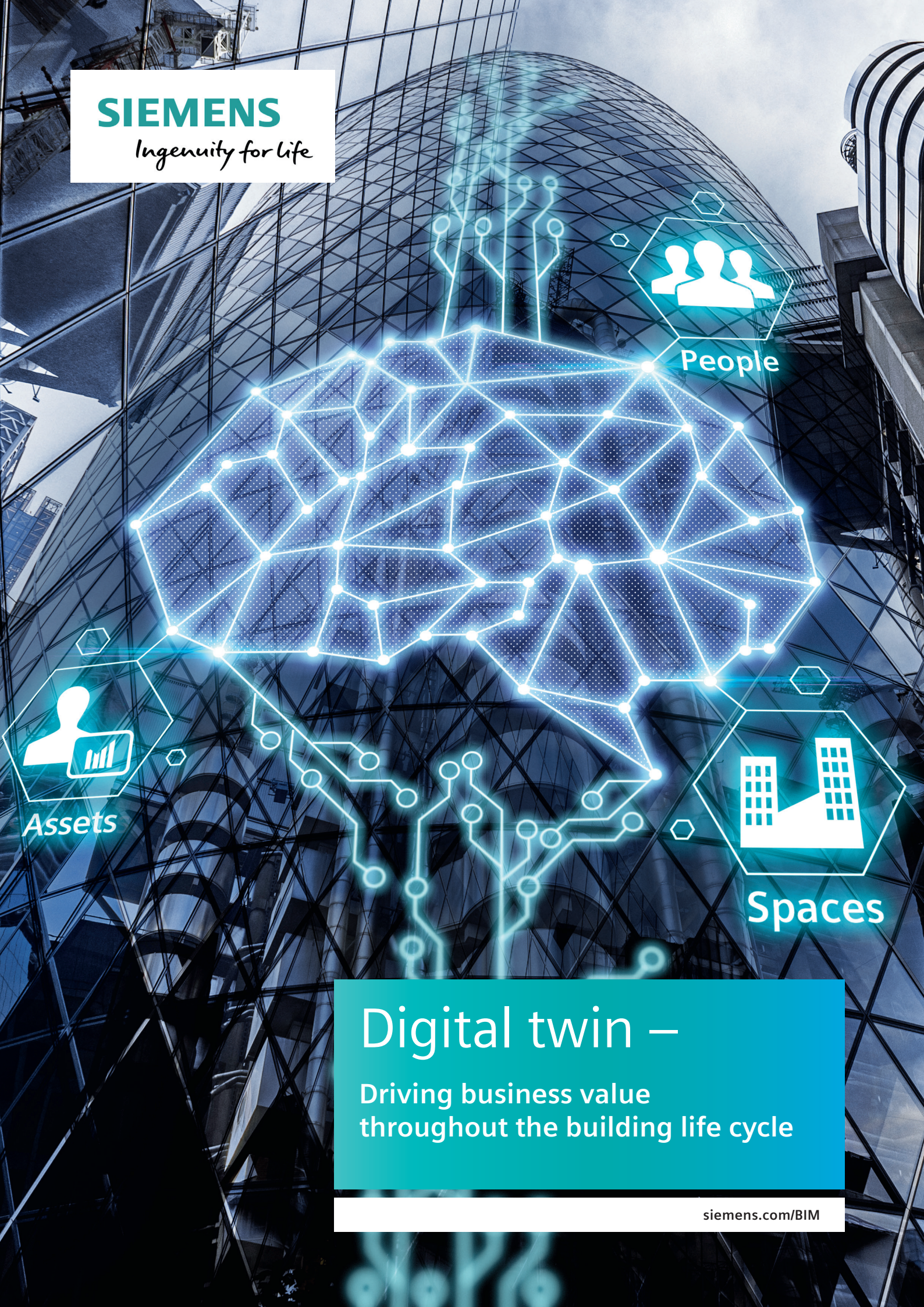

Digital twin –

Driving business value throughout the building life cycle

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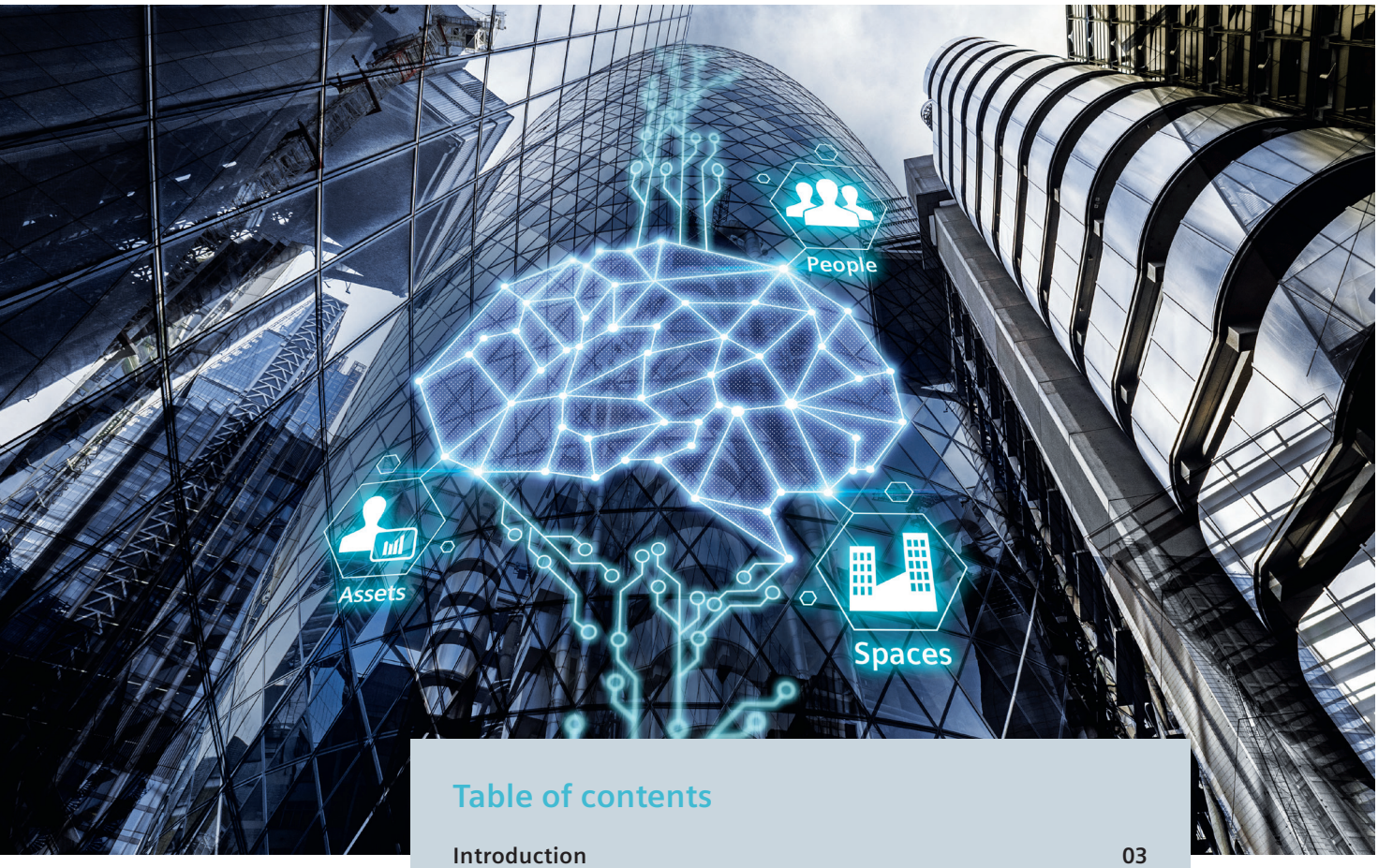

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Introduction

Digitalization is fundamentally changing the way buildings will be planned, constructed, used and, ultimately, managed. This transformation is taking buildings to whole new levels of efficiency, security and comfort. With sensors installed throughout coupled with comprehensive analysis of the collected data, buildings can respond intelligently to their environments and leverage their benefits over the long term in conjunction with other buildings and infrastructures.

Written by Siemens Building Technologies with contributions from Dodge Data & Analytics, BSRIA and M+P GmbH, this white paper provides future perspectives on digital engineering in buildings with respect to the services delivered using digital twin, which will drive the level of user-centricity in buildings. This paper is aimed at raising awareness among building owners, facility managers and building operators to enhance the capabilities of the services in their building with respect to the Building Information Modeling process and the associated digitalization of their building. It will also benefit clients, investors, consultants and contractors, who commission, design or deliver new buildings that will require increasingly advanced features and at the same time be more energy efficient, environmentally and human-friendly.

Digital twin addresses building industry challenges

Traditionally, building planning has been carried out separately by various planning consultants for mechanical and electrical systems to plumbing, etc. This lack of coordination often results in severe problems during the construction phase. Building Information Modeling (BIM) centers around developing the entire building with all its disciplines first on a computer and then simulating, testing and, if needed, correcting it in a virtual model. BIM is used to virtually simulate a physical building using what is called its "digital twin".

This makes it easy to eliminate any errors or inconsistencies. A digital twin can also be used to analyze the building's dynamic response to changes in occupation or energy supply and can even indicate the need for building maintenance or upgrades. Among other things, this planning leads to optimal energy efficiency, cost savings and increased sustainability. It also accommodates the understandable desire of owners and operators to use once-generated data during the utilization phases of the building.

Planning across various disciplines at the same time allows for creation of a coordinated multi-discipline solution with early verification of detailed design choices to optimize building performance. This joined-up approach can show whether an additional door or window, for example, will affect future evacuation scenarios, comfort or heating costs. The result is a more cost-effective, straightforward and sustainable building design and construction process that result in a safer, more efficient building.

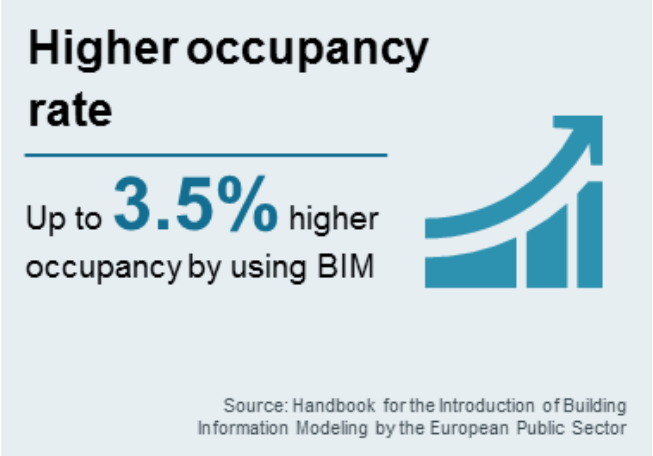
Visual 1: Changing customer needs

"I want to minimize risk while maximizing business growth and employee productivity." – Owner

Building owners are increasingly focusing on digitalizing the construction and the operation of the building to meet the demands of the market that is shifting from being facility-centric to being tenant-centric. More emphasis is being placed on the changing needs of the building occupants. Millennials will constitute 75% of the workforce in office buildings by 2025[1] . A similar trend is expected in other building types including hospitals, airports, hotels, etc. Millennials are tech savvy, and approximately 87% of them have their smart phones ready for use at all times[2]. The market and demands are also changing, as customers seek a new level of building functionality:

- More flexibility in the design and utilization of assets and space (more versatility)
- Building functionalities designed to enhance user productivity
- Faster response time to identify and resolve problems
- mitigation of construction risk without compromising quality, while maintaining delivery time and budget

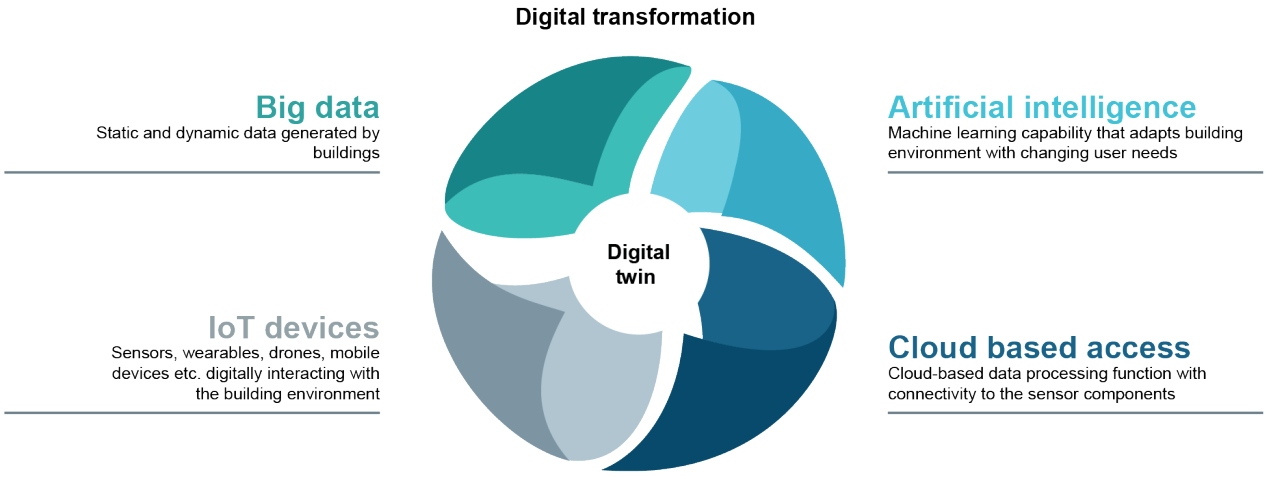
The challenge remains, however, to put in place the appropriate process steps to bring together the numerous fragmented stakeholders with their different interests – including the companies and people who work on the individual processes or disciplines within a building. Other barriers to fully optimizing building design with BIM include the comparatively high purchase costs of suitable software tools and the capabilities of using those tools, a lack of standards and interfaces, and the limited number of manufacturers that, to date, have been able to provide BIM-compatible data for their components. Furthermore, "digital" planning and simulation are typically neither budgeted nor reflected in the project fee schedules.



1 Source: BSRIA, Workplaces of the future, 2016
2 Source: Mitek/Zogby Analytics

Digital transformation driven by a connected world

Important technological and market developments are jointly driving the trends towards digitalization. The underlying technologies enabling the trends towards digitalization are relatively similar across industries. Embedded sensors, mobile solutions, cloud computing, machine learning and advanced data analytics are influential fields of technology that enable major transformational potential for digitalization. While the application of these technologies differs, many of the underlying technological enablers are related.



Visual 2: Four key elements driving digital transformation in buildings.

Big data

Smart buildings generate a lot of information. This big data, however, requires intelligent evaluation and analysis to produce meaningful operational and economic insights and to understand trends and patterns in user behavior or consumption. Data from all disciplines in the building (power management, heating, ventilation and air conditioning equipment and controls, access and security systems), different types of energy (renewable, oil, gas, electricity), the various stakeholders (planners, general contractors, facility managers, owners, users) as well as hardware and software components (energy, infrastructure and ERP systems) are still a hidden resource that offers great potential for enhancing existing business or even creating new opportunities.

Artificial intelligence

With the right analytics tools, the input of human expertise and, in the future, machine learning strategies, continuous optimization of buildings can be achieved with artificial intelligence.

Internet of things

Connecting machines, devices, components, sensors, actuators and other objects – is another important building block for digitalization. Converging real and digital worlds is the foundation for offering new user centric applications and for creating new digital services.

Cloud based access

The digital transformation is providing increased availability of applications as a service (SaaS), which create an easy way to provision users and oversee the assigned rights. Cloud based access allows customers to access the system remotely via a browser or app. In a building, remote service solutions make it possible to detect and correct component problems quickly and efficiently from virtually anywhere. With devices communicating their status and health, new concepts for preventive maintenance can be implemented to minimize downtimes and maintain business continuity.

Digital twin

These four key elements driving digital transformation are the key building blocks of the digital twin. This prepares the ground for digitally enhanced automation resulting in autonomous buildings, which control and optimize themselves based on artificial intelligence. These smart buildings will communicate with occupants and are also expected to work with external data generated from electrical grids, environmental conditions, hence supporting the mission of their organizations – beyond the building itself.

Digital twin for the building life cycle from planning and construction to operation

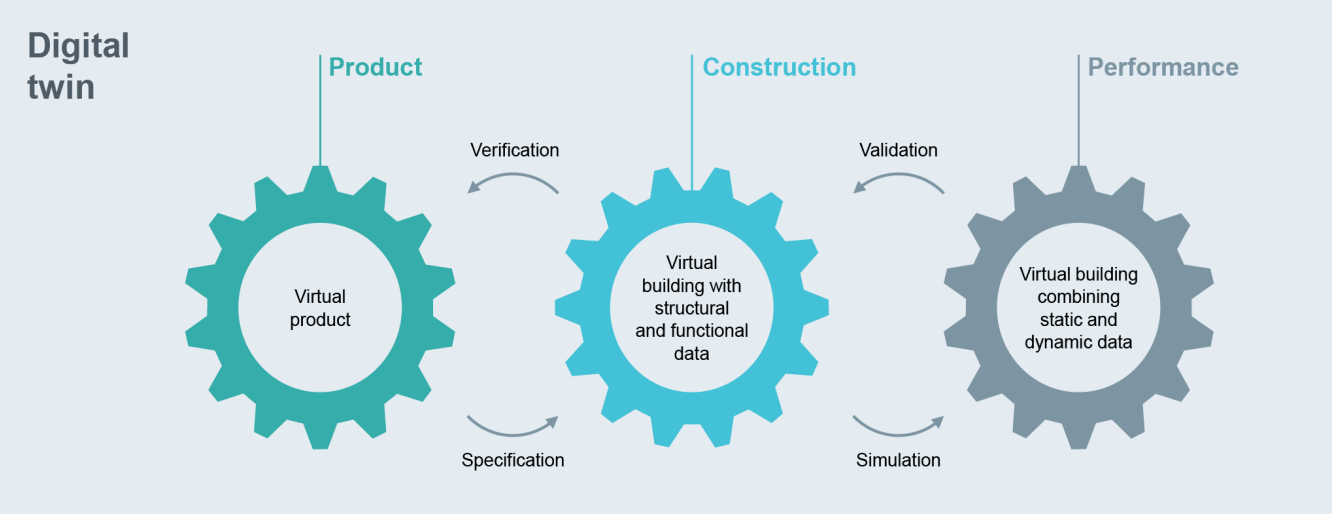
The BIM value chain ranges from basic analysis, preliminary and design planning to construction and operations. In addition, it covers the manufacturing process including quantity determination and scheduling, as well as everything from site, operation and facility management to post-processing including property demolition or renovation. Ideally, the digital twin follows all modifications of the real building and dynamically readjusts itself in case of recorded performance differences.

A digital twin is a digital copy of a physical building, which includes a 3D model of a facility combined with dynamic data to allow easy-to-understand visualization and analysis.

A digital twin consists of

- Digital twin of the devices in a building
- Digital twin of the structural components (static data) of a building (floor plans, asset locations, etc.)
- Digital twin of the dynamic data (performance data, time series data)

However, in order to achieve the full functionality of the digital twin, three twins are needed, which together form what is called the digital life cycle ecosystem.



Visual 3: Digital twin defined

1. Product twin

The digital product twin is used primarily to describe size, levels, walls and wiring used for the simulation of BIM-compliant products. The BIM objects are the building blocks that complete the static data foundation of the digital twin. Every asset within the physical building has a corresponding object, from the windows and doors to the system components and furniture. These BIM objects not only provide a geometrical representation of the asset, but also hold all the associated product information required – including technical data, manufacturing materials, operational & functional information, for example.

2. Construction twin

This twin is a static representation of all assets installed in the building such as the boiler, HVAC units, etc. and static construction data – the as-built layout and installation of these components. The digital construction twin improves engineering efficiency and is used for visualization, engineering, commissioning, simulation of system behavior, and artificial intelligence learning.

3. Performance twin

The digital performance twin is used to improve operational efficiency, predictive maintenance, and dynamic simulation. This twin acts as a **digital cortex** of the building, as it has the capability to combine the static data with the dynamic data produced throughout the operational life of the building. This digital cortex is able to constantly learn from changing user needs and the environment using artificial intelligence. The dynamic data is essentially produced by the various systems installed in a building and the user interfaces. These systems would typically include fire detectors, lighting, HVAC (heating, ventilation, and air conditioning) equipment, security equipment, energy meters, indoor positioning systems, indoor environment quality sensors and external data including weather, daylight, etc.

Business value of the digital twin

A pressing concern for possibly any company that starts on the journey to digitization could be the clear ability to show benefits and realize value from its investment in creating a digital twin. How could this new approach help a company change the way it operates and conducts business to achieve measurable business value? With the emergence of increasingly favorable storage and computing costs, the number of use cases and possibilities to enable a digital twin has greatly expanded, in turn driving business value. Another important element driving business value with a digital twin is the scalability it provides. The data from the digital twin can be used to create new applications with limited effort/cost. For example, the dynamic data from the HVAC sensors can also be used to detect the occupancy in the room and hence allow the digital twin to analyze space utilization. This data can also help achieve energy efficiency in the room by turning off the HVAC or switching to economy mode when the room is unoccupied.

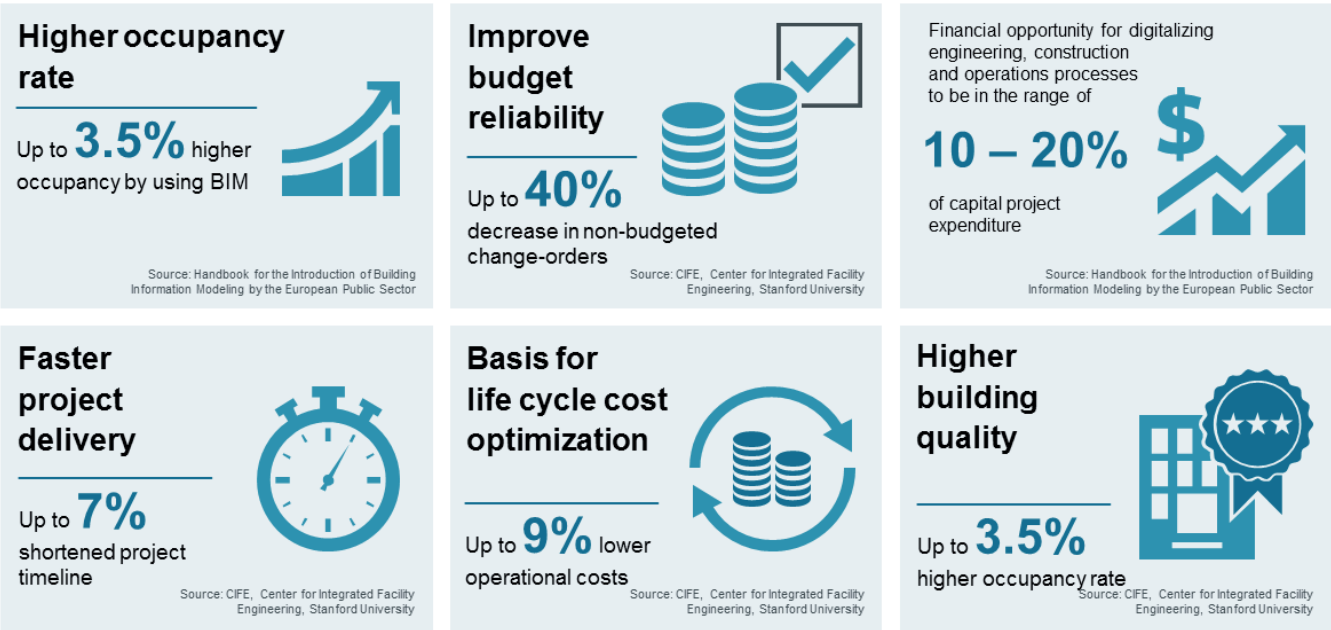
The building can thus be made more comfortable for its users and processes in the building can be made more efficient with a quick return on investment.

Some of the use cases facilitated by the digital twin

- Analyze incoming data from building systems in real time, allowing for monitoring and optimization of their performance and heading off problems before they occur
- Track how spaces are being used throughout the facility
- Track dynamic locations of people and equipment throughout the facility
- More quickly identify security threats or liability issues
- Actively manage the technical systems with timely predictive and preventive maintenance
- Correlate data from different sources to create new insights including the impact of room conditions on patient satisfaction, for example

Digital twin can also be used to simulate what-if scenarios, which allow the building operators to test scenarios in advance and make business decisions about their facilities, such as

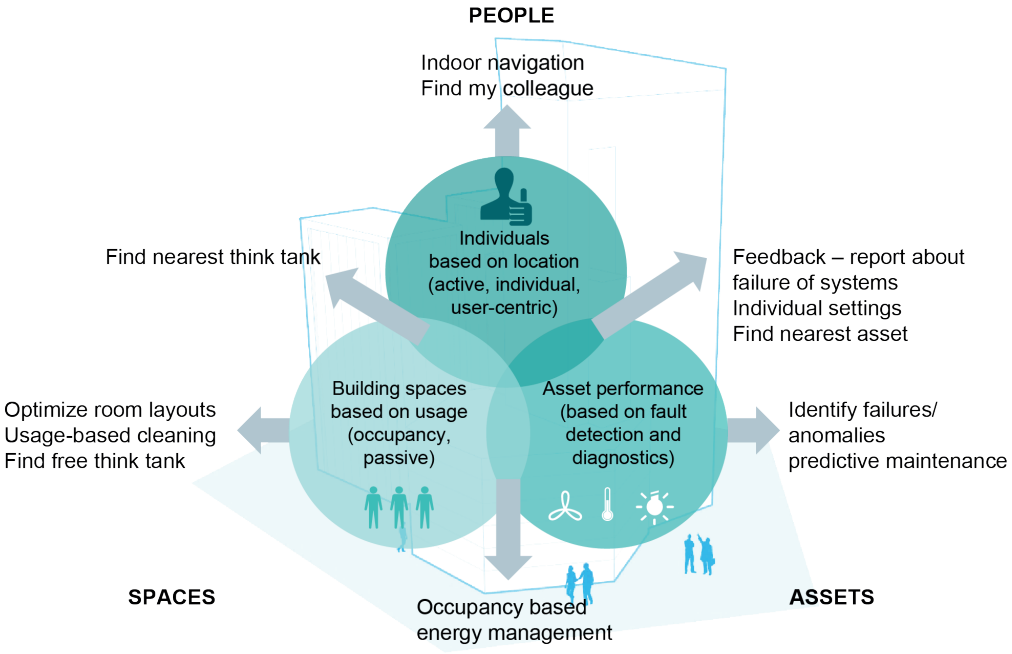
- Simulate evacuation possibilities with large crowds to determine in advance the ability of the facility to adequately respond and then potentially improve the design
- Test ideas for extensions or renovations to determine the degree to which they would improve operations and functionality
- Leverage data about existing facilities to improve the design of new projects



Visual 4: Business value of implementing the digital twin

Digital engineering in buildings focusing on the elements of people, spaces and assets

The building is not only an entity that hosts the business, but also becomes an integral part of the business identity. The digitalization of the building industry could provide the tools to not only make the building live, but enable users to interact with it in more productive and efficient ways not previously considered. In the future, buildings will increasingly be centered on people, spaces and services.



Buildings of the future are composed of a network of people, services and spaces that can be combined to deliver higher customer value with advanced digital engineering.

Visual 5: Buildings of the future will focus on three key elements

People

The growing number of millennials in office buildings is expected to impact the way people work together. This generation focuses more intensively on work-life balance, health and wellbeing, achievement and recognition, etc. An exclusive survey conducted by Dodge Data & Analytics on behalf of Siemens Building Technologies to understand the key use cases with a digital twin in a hospital and airport facility concluded that improving patient experience in a hospital and improving passenger experience in an airport were one of the key outcomes that the respondents (senior executives and decision makers) are looking for. The study also showed that, in hospitals, the ability to provide real-time information on the location of patients and staff according to schedules, restrictions, etc. greatly contributes to hospital staff productivity.

Spaces

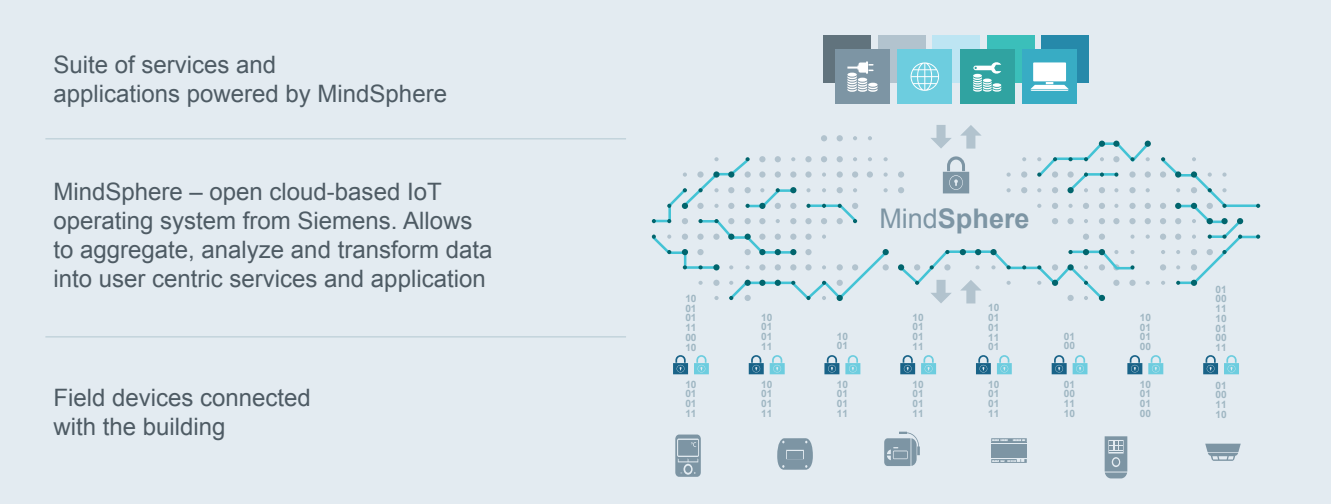
The interest in increased spatial and temporal independence is extremely influential. Many employees can do their jobs from virtually anywhere and at increasingly flexible times via laptops and other mobile devices. According to an independent study conducted by CBRE, the global average utilization of assigned seats (excluding vacant seats) is up to 60% and the global average meeting room utilization is up to 30%. Hence, the increasing adoption of digital engineering in the future buildings will be greatly aimed at measuring and optimizing the building space.

Assets

Buildings will increasingly focus on the performance of individual assets within the building. Intelligent methods such as fault detection and diagnostics and machine learning will greatly support the delivery of real-time insights into a building's infrastructure including individual pieces of equipment and systems. Such insights enable intelligent maintenance of assets allowing the operator to detect and prevent failures before they happen. Digital twin will allow building operators to improve maintenance efficiency and simulate how response will impact overall performance. Together, this will result in assets that perform as expected for longer, maintenance programs that prioritize the issues that matter most, and a greatly improved OPEX structure for building operators.

Suite of services enabled by an open cloud based IoT operating system

A holistic digital twin with the full capability of data analytics and artificial intelligence finally results in a valuable suite of services targeted at the building users. Valuable data collected from field devices and building performance are aggregated, for example, with the help of an open cloud based IoT operating system. Siemens is successfully driving the digitalization of buildings forward based on its comprehensive portfolio, state-of-the-art technologies and in-depth expertise. The unique capability of Siemens to analyze a combination of static and dynamic data takes data analytics and data-driven services to the next level. MindSphere is an open cloud based IoT operating system from Siemens that serves as an enabler of these user centric services.



Visual 6: MindSphere – the cloud-based, open operating system for the Internet of Things from Siemens

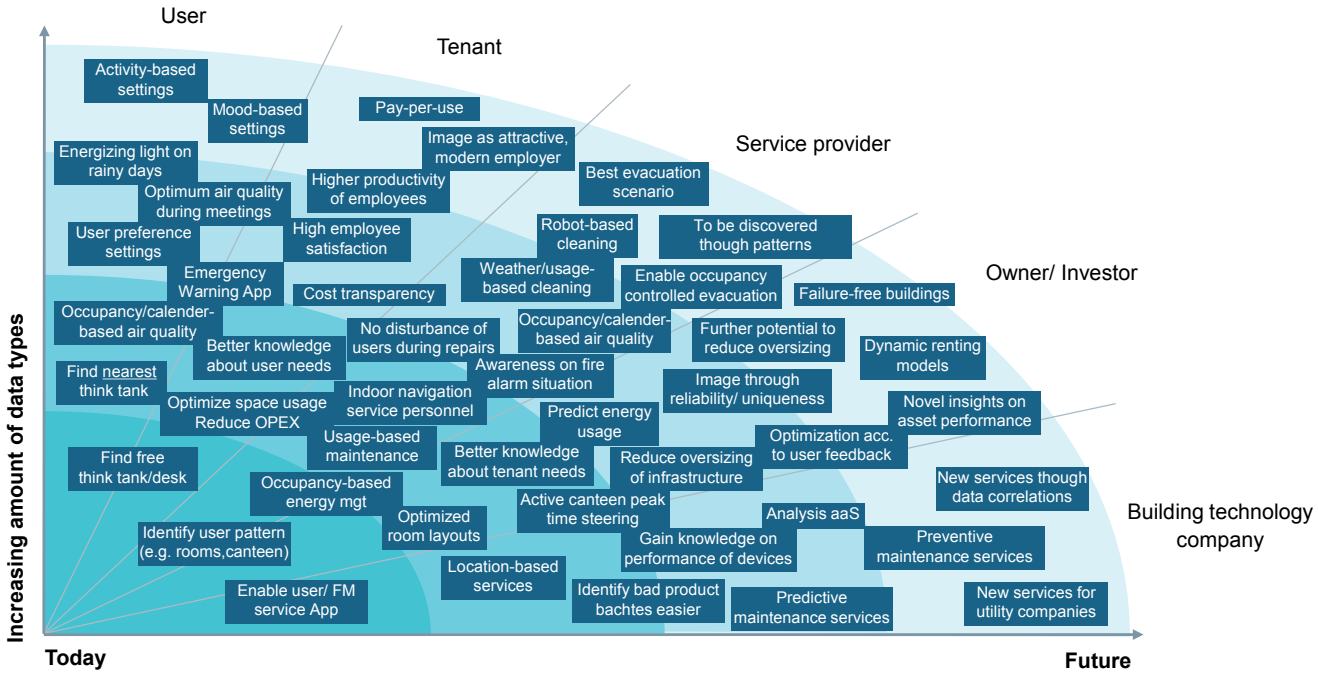
The data generated from various field devices in a building is analyzed and transformed into user centric applications, which can include the building constantly learning and implementing the ideal comfort conditions for the building users. At the same time, users are also in control of the building environment through applications on their mobile devices, giving them the flexibility to digitally navigate through the building and book available spaces. In a hospital environment, the staff is able to digitally navigate through a building and track emergency equipment and assets. Such services will positively impact the process flows in a building.

Implementing a digital twin

The survey conducted by Dodge Data & Analytics on behalf of Siemens Building Technologies for hospitals showed that reducing **operating costs** is the top factor most frequently listed by respondents when asked for the most important way a digital twin would provide value. Other factors frequently mentioned as valuable in the analysis of specific use cases are **improving efficiency, reducing liability and improving the patient experience**.

The survey reports that the top category for value is the **ability of the digital twin to connect with the internet of things for operating equipment**.

The following illustration summarizes the increasing benefits of the digital twin as the number of connected data sources increases.



Visual 7: Increasing and improved data provides more opportunities

Potential benefits: emergency response scenario simulation

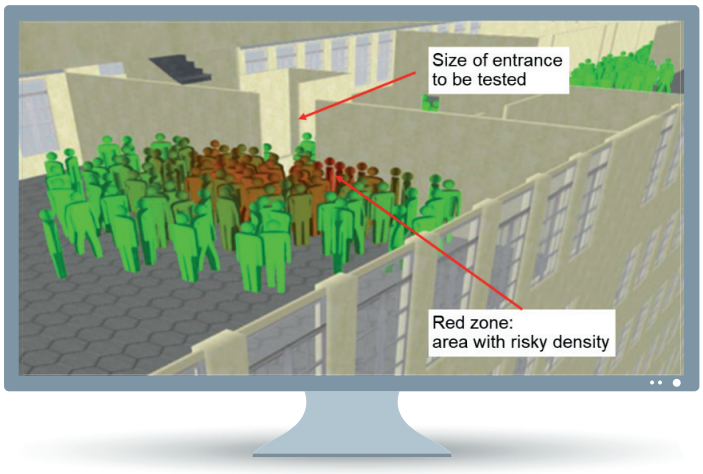
- Improve safety (reduce liability) by matching the count of people in evacuation area with that of people in assembly area
- Compare simulation to actual data from an emergency to capture real behavior. Help police and fire personnel assess situations and determine response plan
- Communication efficiency: use data to determine safe routes and then communicate those routes to passengers/staff
- Save time on escape routes

Source: Dodge Data & Analytics survey on behalf of Siemens Building Technologies, 2018.

Use case 1 – emergency response scenario simulation

The design of the emergency evacuation routes is typically based on rules and regulations defined in the relevant building laws. However, with the lack of being able to test a design by simulating an actual emergency condition, it is hard to confirm if this design will provide for truly efficient evacuation.

A digital twin allows for emergency response scenario simulation which leverages the people flow data collected to simulate emergency response scenarios at various times of the day/year. This enables the best routing scenarios to be implemented during an emergency. Both the static (structural and functional) data and the dynamic data of a building are analyzed. Different scenarios are possible, e.g. for standard usage of the building or for peak usages. Scenarios can also evaluate different disaster types, e.g. a fire in a specific room or other locations, and simulate the real evacuation process. The digital twin is able to simulate complete or partial (floor by floor) evacuations of the building at the time of an emergency without disrupting ongoing business.



Visual 8: Digital twin showing evacuation simulation

Based on the simulation, an efficient evacuation design and plan can be implemented. In the above illustration, the simulation concludes that the door along the evacuation route should be wider in order to avoid a bottleneck at that point.

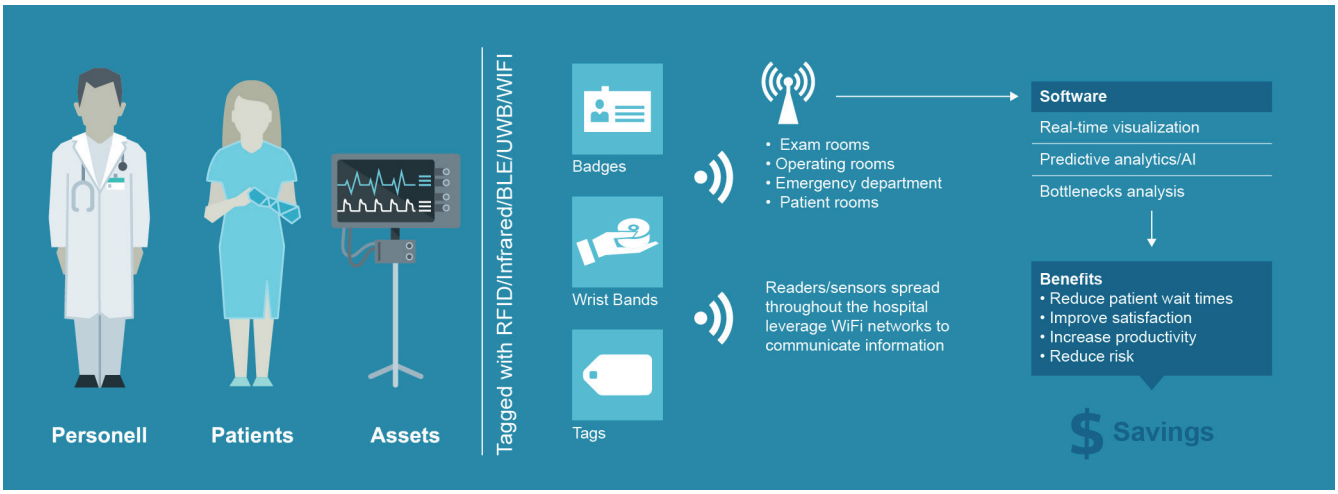
A digital twin allows for such simulations already during the design phase of a project, which greatly helps planners be able to deliver a design with the most efficient and tested evacuation route.

Most important ways that having a digital twin provides value in hospital buildings

- Reduced operating costs
- Ability to manipulate space and data to create scenarios and help in financial decision-making
- Combining disparate data in a simple way
- Reduce liability
- Improve communication
- Improve patient experience
- Regulatory compliance

Source: Dodge Data & Analytics survey on behalf of Siemens Building Technologies, 2018.

Use case 2 – location information on patients and assets in hospitals

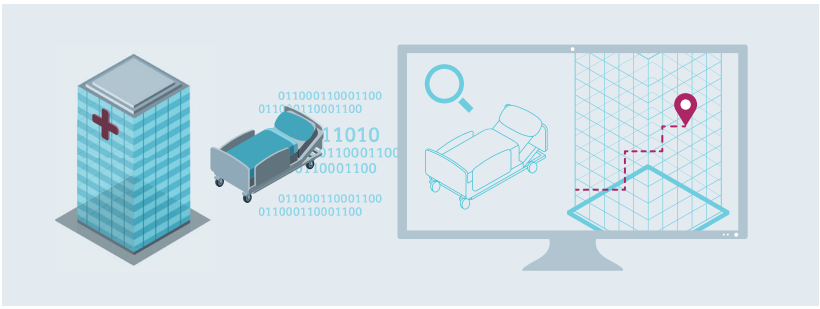


Visual 9: Optimizing patient flow and staff efficiency

In everyday hospital life, it is easy to lose an overview of all the equipment and assets. This leads to inefficient processes and unnecessary search times. This can result in a surplus stock of equipment. In addition, employees are less productive when having to search for materials. On average, hospital staff needs 1 hour out of an 8-hour shift to search for equipment[3]. Asset tracking considerably increases the transparency and utilization of the assets.

In addition to misplaced assets, wandering patients also disrupt the hospital processes.

Location tags are being successfully used by many healthcare organizations to label a variety of mobile devices, including infusion pumps, syringe drivers, feeding equipment, scanners, monitors, wheelchairs, mattresses and beds.



Visual 10: Patient and asset tracking enabled by digital twin

The digital twin analyses the static (structural and functional) data of a hospital building with respect to the dynamic data being the flow of tagged assets and patients. The hospital staff is able to digitally navigate and locate the missing equipment and the wandering patient.

Potential benefits: location information on patients and assets in hospitals

- Reduce liability and improve security: keep people/visitors/contractors out of restricted areas; alarms indicate when people leave rooms; provides data on whether staff have responded to alarms
- Reduce operating costs: monitors flow of people to see how it could be more efficient, such as allocation of supporting services based on the utilization rate of the spaces
- Save time: find people quickly
- Added patient value through better room utilization: data and better communications with patients could help reduce/eliminate spaces like waiting rooms
- Improve patient experience
- Analysis and planning: understand workflow planning for future facilities

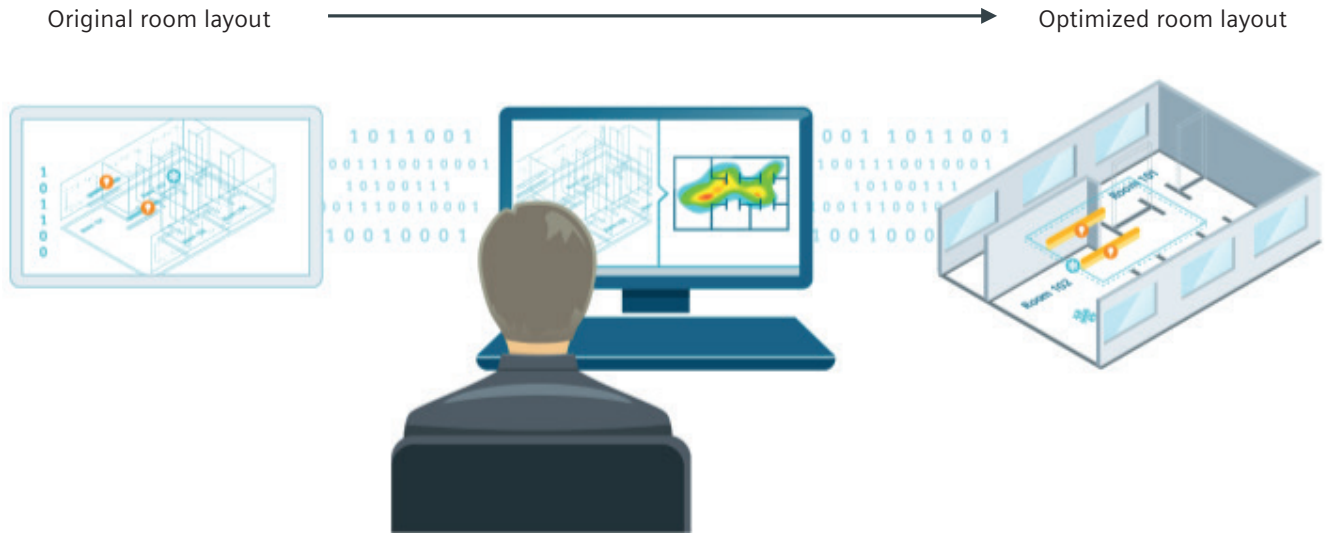
Source: Dodge Data & Analytics survey on behalf of Siemens Building Technologies, 2018.

3 Source: ROI of Locatible RTLS for Healthcare, Frost & Sullivan

Use case 3 – optimized space usage

Organizations currently optimize their space by drawing design options manually, which can be time consuming and suboptimal. The digital twin is able to measure usage of space in real time and, based on that, the layout can be optimized to reflect people's needs. Indoor positioning systems track the usage of all areas of a building.

Such information is used not only for managing lighting in a room or for optimizing heating or air conditioning, but also to identify the areas that are used heavily or the areas that are underutilized. This can be visualized in so-called heat maps, which show space usage.



Visual 11: Floor layout changes enabled by data analytics

Such data analytics delivered through a digital twin can help redesign the internal building layout during the operational phase of the building, thus allowing optimal usage of available space. The direct benefit is not only to tenants, but also to the building owners, who can maximize rental space and thus directly impact revenues.

Potential benefits: optimized space usage

- Reduce operational costs: not wasting money on unused space
- Improve analysis and usage of existing space: reallocation of spaces like underutilized waiting rooms in hospitals
- Save time: improves traffic flow
- Communication: flow patterns can be analyzed to design spaces for colocation

Source: Dodge Data & Analytics survey on behalf of Siemens Building Technologies, 2018.

Conclusion – framework for future success

Building tenants and occupant no longer just want an attractive, climate-controlled building. Instead, they demand infrastructures that ensure their safety; provide real-time information, guidance and productivity; and not only manage emissions, but generate sustainable energy. The list goes on and on. A digital infrastructure is necessary to make any or all of these services a reality. And to provide a digital infrastructure, the complete building construction and operations value chain need to adopt digitalization.

In its survey, Dodge Data & Analytics also reports the top challenges that hospital organizations face when implementing the digital twin

- Dealing with data security issues, which are of particularly high priority in healthcare
- Justifying the investment to obtain funding, not just for finance, but for some relatively skeptical participants in the study

Siemens Building technologies recommends building owners, planners and operators to use digital technologies to fuel growth, increase productivity and kick-start innovation. In order to meet growing customer demand for digital buildings, here are a few first steps

Adapt and simplify business model

A business model logic is essential to digital transformation in building automation, construction and real estate. A business model includes a company's value proposition, value creation and value capture. Digitalization and artificial intelligence will substantially affect the core business of most companies by shifting their value propositions – at least on the medium term. Executives need to conduct game-change analyses and put the challenges at the top of their agendas. New services and digital solutions will typically come along with new revenue models. Service-based payments, licensing models or micro-financial transactions as a compensation for sensor-based data transfers will lead to substantial shifts in the revenue streams of many companies.

Invest in technologies that ensure business value from a digital twin

In a tenant centric market, it is important to make investments in technologies that are driving the digital transformation in these markets. Wearables, drones, augmented reality, sensors and automation are not only essential to connected buildings, but in turn multiply the value in terms of services that can be unlocked with BIM and 3D technologies. The importance of advanced analytics based on artificial intelligence will create great opportunities for building automation in the future. Companies need to develop sufficient internal expertise to proficiently collaborate with external service providers.

Develop digital communities through right partnerships

Digital transformation requires new capabilities and often includes active collaboration with multiple partners. These collaborations usually extend traditional industry boundaries and include diverse partners in ecosystems to enable completely new digital solutions. It is not about building digital know-how from scratch, but rather performing the required due diligence to find the right partners with the appropriate digital knowledge to grow the business, increase productivity and foster innovation.

Acknowledgements

About Dodge Data & Analytics

Dodge Data & Analytics (DD&A) is North America's leading provider of analytics and software-based workflow integration solutions for the construction industry. Building product manufacturers, architects, engineers, contractors and service provides leverage Dodge to identify and pursue growth opportunities and execute on those opportunities for enhanced business performance. The company's construction project information is the most comprehensive and verified in the industry.

The Research & Analytics division of DD&A provides expert research, analysis and forecasting for the construction industry. DD&A's team of expert researchers and economists analyze and interpret construction industry data and provide an annual outlook report and conference, which provides the forecast for U.S. construction starts, including details about the industry's economic environment and market trends. In addition, the custom market research group provides information on product awareness/brand equity, customer satisfaction, new product development and customer segmentation to a broad array of clients, including manufacturers, contractors, distributors, owners, architects, engineers, industry associations and adjacent markets. DD&A also conducts industry research on transformative trends in the construction industry, funded by industry partners, which is published in the SmartMarket series of reports and briefs. Publications have included over a dozen reports since 2006 on sustainability, over a dozen reports since 2007 on BIM, and reports featuring other trends like safety management, lean organizations, information mobility and workforce shortages.

DD&A's unique research capabilities include online panels of design and construction professionals, which enable quick affordable primary market research, the proprietary Dodge database of construction projects, far-reaching industry relationships that enable high-impact qualitative interviews, and an experienced team with deep knowledge of the construction industry, market trends and economic conditions.

Contribution from Prof. Dr.-Ing. Alexander Malkwitz, Managing Partner of M+P

M+P is a team of experienced, forward-thinking, collaborative partners that provides our clients with immediate meaningful results and long-term project success. Our consultants' many years of project experience have included serving as trusted advisors for CEO agenda and project business related issues to the world's leading organizations across all major engineering industries and sectors.

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About BSRIA

Founded in 1955, BSRIA has the mission to make buildings better, supporting industry in designing and operating buildings that perform well economically, socially and environmentally. We do this through providing independent testing of products and buildings throughout the construction industry; the sale, calibration and rental of instruments; market intelligence; information; and consultancy services for design, construction, facilities management and manufacturing.

By working together with the whole built environment chain from client to consultant, contractor and facilities manager, BSRIA generates and disseminates knowledge and the latest best practices to provide a sustainable and improved built environment.

BSRIA's services are fully independent.
This independence means that we provide

- An objective approach and the most appropriate solution in each individual case
- Authoritative reports that are widely recognized and accepted
- Innovative solutions to help provide a competitive edge

With an annual turnover in excess of £15m and over 220 staff, BSRIA with its offices in the UK, France, the United States and China combines Global oversight with local knowledge and blends technical with market expertise to provide the best solution to ensure that buildings create an economic, environmentally safe arena to allow their occupants to thrive. **www.bsria.co.uk**

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