Construction

Top-Value Twin

Three steps to an intelligent digital building model

Porsche Consulting

Strategic Vision. Smart Implementation.

Introduction

The construction industry has been booming for years. Currently, it accounts for 9 percent of the European Union's GDP. However, the industry has a lot of room for improvement, because compared to other sectors such as the manufacturing industry, it is inefficient and not very productive. Although the construction industry currently has excellent prospects, a shortage of resources and partners means it can no longer adequately handle or complete many projects. Changes are required. Existing organizational structures, processes, and business models should be critically examined and modified where necessary. Above all, the industry needs a digital transformation. According to the annual digitalization index[1] , the construction industry lags substantially behind other sectors in putting digital solutions into practice.

BIM—short for Building Information Modeling—is the magic formula. What does it mean? The abbreviation stands for a collaborative method of planning, implementing, and managing construction projects with the help of software solutions. Relevant project data are digitally modeled, registered, and compiled. The aim is an object-based planning with a 3-D data model that is uploaded to a central platform. This has the advantage of eliminating time-consuming traditional means of comparing different planning stages, compiling these plans manually, and engaging in error-prone communication processes. Another advantage consists of improving processes thanks to clash analyses, which automatically and immediately identify discrepancies among different project drafts. BIM is especially beneficial to decentralized project teams.

BIM generates a data model on the component level—a digital twin of the building that will later be constructed of bricks, steel, and glass. The model is successively enriched with relevant data, and grows piece by piece. This method yields an enormous increase in efficiency. Other sectors also use digital twins as copies of physical assets for purposes of simulation, control, and optimization. In the automotive industry, for example, the method opens entirely new horizons for vehicle developers. A car model's body, drivetrain, suspension system, and electronics are designed digitally and the functions are simulated. This acts as a virtual safeguard for the properties of the finished vehicle. One example is the development of the first all-electric Porsche, which uses a method that enables transdisciplinary coordination of the energy management system. Virtual components act and react like real ones—and deliver precise results to the developers. One outcome: there is no longer any need for construction-stage vehicles in developing the Sport Turismo variant of the Panamera.

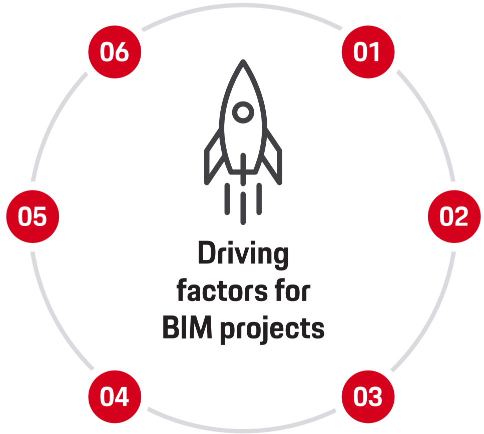
The use of BIM in the construction industry can cut costs by 10 percent. But that is not all. Project times can be cut by up to 7 percent[2], because planning can be shifted to a stage of the project in which cost and time drivers can still be influenced. This shift also eliminates the strict distinction between planning and construction. Moreover, this new type of collaboration creates a stronger project culture, which is reflected in the requirements for planning tools and collaboration processes. BIM is therefore a good method for generating production-oriented plans as well as actually completing construction products. Best of all, the information and data can be used after the design phase as well. Figure 1 shows the driving factors for introducing BIM.

[1] https://www.digitalisierungsindex.de/wp-content/uploads/2018/11/Telekom_Digitalisierungsindex_2018_BAUGEWERBE.pdf (only available in German)
[2] Azhar, S.]. (2011) Building Information Modeling (BIM): Trends, Benefits, Risks, and Challenges for the AEC Industry, Leadership and Management in Engineering, 11(3), 241-252

Cost savings and monitoring
Risk reduction due to result monitoring and cost-overrun calculations

Time savings
Simulations positively influence processes/materials

Life-cycle value for clients
Provision of environmental, energy, cost, scheduling, and spatial analyses



Pressure from public sector, clients and competitors
Required for all public-sector projects in Germany. Also becoming more important for the private sector.

Project team communications
Precise planning and collision detection for construction processes

Prefabrication
Detailed and informative models enable flawless prefabrication

Figure 1. Driving factors for BIM projects

01 Pressure from the public sector, clients, and competitors

With BIM required for public-sector contracts, companies in that field will need to familiarize themselves with it. Some private-sector clients now also include it in their calls for tenders. Whether the contract is public or private, if this data model is stipulated it will ensure availability of the correct data at early stages of the project. Advantages for clients include early and solid decisional foundations and the opportunity to provide subcontractors with detailed and accurate job specifications.

02 Project team communications

Communications are considerably simplified when everyone involved works together with a single database that can communicate with other systems. Automatic collision checks in the planning process ensure that time-consuming modifications will be avoided early on. The other project stages are also linked with each other—and the digital construction model becomes the source of information for both constructing and operating the building.

03 Prefabrication

The digital twin can serve as the basis for data needed to prefabricate certain modules or sub-modules. The depth of available detail gives both external and internal suppliers access to all the information they require for prefabrication purposes. A corresponding level of intelligence should be established that describes how components can be combined into systems or modules. CAD systems are currently unable to achieve this because they are not able to extensively model intelligence properties for specific components.

04 Life-cycle value for clients

BIM provides detailed information on how a building is operated. Around 20 percent of the data generated in the planning stage are later relevant for operations[3]. CAFM[4] systems can take over the BIM data they need. In addition, data analyses can be improved such that any calculation or planning errors can be documented and the results used productively for subsequent projects.

05 Time savings

BIM saves considerable time in the planning stage. It can also benefit later project stages. For example, different scheduling scenarios can be digitally generated and the use of materials, processes, and/or modules simulated. The aim here is to shorten and stabilize the time needed for projects.

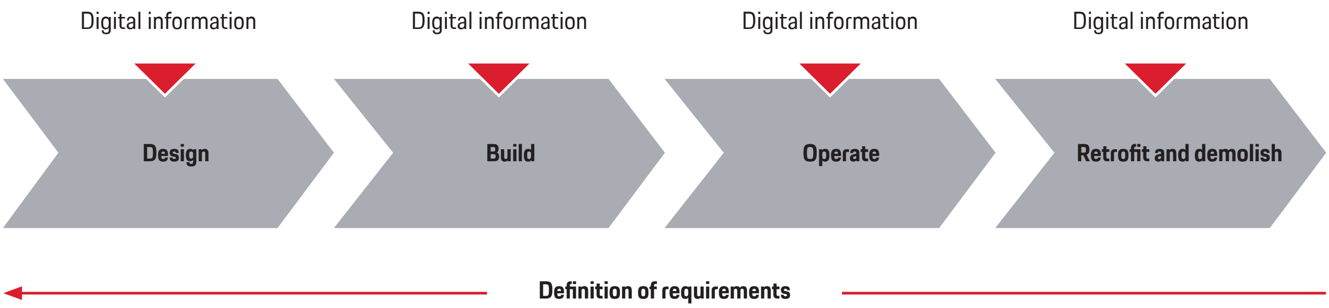
06 Cost savings and monitoring

BIM can be used to detect conflicts, problems, or collisions. This lowers costs. And costs can be simulated before the construction stage begins. By comparing these data with the actual situation, deviations can be identified earlier. And when putting the project back on course, countermeasures can be simulated before putting them into practice.

[3] University professor Christoph M. Achammer, ATP architects engineers
[4] Computer-Aided Facility Management

The construction industry has not yet recognized the full potential of BIM. A digital twin from the planning stage gives project participants a precise model of the building, which lays the foundation for greater efficiency and new opportunities in the construction and operational stages. A dynamic level of detail for all components and objects is key here. Information from each individual stage needs to be added to the digital twin—the right information, at the right time, with the right degree of detail, in the right system, in the right amount.

Because many people do not yet recognize the added value of BIM—especially for the facility management stage—it is difficult to motivate clients to increase their investment and provide the digital twin with a high level of detail. Available components are not yet enriched with the information needed to utilize the full potential of a digital twin. Other sectors are further ahead. According to a study by Gartner[5], 75 percent of companies that produce components for the Internet of Things (IoT) already use digital twins for simulation purposes.



Share of life-cycle costs			
2 %	20 %	70 %	8 %

Use today			
70 %	20 %	5 %	5 %

Benefits per phase

- Less need for coordination
- Higher level of teamwork
- More efficient collision detection
- Fewer new design & engineering
- Atomized component and material specification
- Better basis for discussion
- Simulation of different variants in different dimensions

- Streamlined resource and capacity planning
- Simpler application of lean construction principles
- Virtual monitoring of progress plus simulations
- Lean logistics via pull systems with prompts from process simulations

- Predictive maintenance
- Material and component tracing
- The digital twin can be updated if an expansion and/or restructuring is required

- Catalog and detailed information for all materials and components used
- Overview of materials with special disposal needs
- The digital twin can simulate demolition processes
- Detailed information on materials used for revitalization or renovation

Source: University professor Christoph M. Achammer, ATP architects engineers

Figure 2. Digital twins add value to the entire building life cycle

[5] https://www.gartner.com/en/newsroom/press-releases/2019-02-20-gartner-survey-reveals-digital-twins-are-entering-mai

If later life-cycle stages are to benefit from the digital twin, the future facility manager needs to specify the data model's level of detail. There are four main stages, with varying amounts of added value. Added value in the final life-cycle stage—that of retrofit and demolition—is generated from data added to the digital twin at an earlier stage (Figure 2). What share does each project stage represent in the overall life cycle? Of note here is that comparisons with the current main area of application for BIM yield a skewed picture. The digital twin plays a subordinate role in the stage with the highest share of life-cycle costs.
It is therefore essential to formulate use cases so as to define requirements not only for the operations stage but also for the retrofit and demolition stage. Thus information profiles can be defined early on, which would then benefit the later stages of the life cycle.

One thing is clear: governments will soon be issuing stricter regulations on construction materials that harm the environment or strain resources. A digital twin that stores all component properties, including sources and manufacturing processes, could be linked to a database of hazardous substances in order to monitor adherence to regulatory limits throughout the entire building life cycle. In other words, this is an ongoing sustainability analysis. This would take into account, for example, the demolition stage already at the start of the project.

Provider	Content		Revenue model		
Selection	3D generation	Provision of 4D, 5D, and 6D information	Free of charge	Fee-based*	Additional offers
bimobject	✓	✗	✓	✗	• Marketing campaigns and analysis solutions
bimstore	✓	✗	✓	✗	• Sale and tracing of BIM components across ecosystem
BIM [systems]	✓	✓	✓	✗	• Central database for analyzing, managing, and linking data models
MagiCAD Cloud	✓	✗	✓	✗	• Focus on MEP** planning
NBS	✓	✗	✓	✗	• NBS Standard authorized objects
polantis	✓	✗	✓	✓	• Also offers generic or specific objects

* Download of special 3-D objects ** Mechanical, Electrical, Plumbing | Source: Porsche Consulting

Figure 3. Focus on 3D and 4D - 5D or 6D information still not sufficiently available
(* Download of special 3-D objects | ** Building Services Equipment)

The construction industry is making ever greater use of externally prefabricated components such as modules or partition walls. That means digital twins need to have a high level of detail. The information is exported to production planning and control programs, which means the data have to be provided in readily exportable form. Future construction projects could well incorporate a large number of digital twins. Technical systems and other installations would be integrated into the building model separately. The problem here is that only some of the relevant information is stored during the early planning stage (e.g. size, weight, material). As time goes on, more information is needed, and BIM objects need to include this information. Quite a gap is evident in this area: providers of 3-D objects currently do not offer this level of detail. Information therefore has to be collected and integrated by whoever creates the model. This is time-consuming and inefficient. Moreover, some of the available 3-D objects are not updated because the producers are not able to move quickly enough. Gregor Müller, CEO of BIMsystems, is familiar with the problem: "Manufacturers are the lords of their data. Digitalizing data for BIM is an enormous task. The only way to enter the BIM cosmos is to have lean processes that generate BIM content and use existing sources. So it's crucial to have automated processes that digitalize product data up to intelligent BIM content, including the relevant structured and automated quality assurance."

Figure 3 shows a selection of current 3-D object providers and the associated depth of information. Suppliers in the construction industry need to provide 3-D objects with a suitable level of information that also meet future requirements for subsequent stages of the life cycle. Many construction companies are creating their own databases in which the objects all have the requisite levels of detail and information.

At a glance: Benefits of digital twin

ACCESSIBLE	Information from the digital twin is available everywhere and at all times. This considerably reduces dependency on plans, function descriptions, detailed sketches, etc.
RELIABLE	The information in the digital building model always reflects the current state of the project. If the information is in the digital twin, it can be relied upon and used as the basis for planning.
EXPANDABLE	A digital building model can contain an unlimited amount of information. Often just a link to an external database is sufficient.
SHARABLE	The digital building model can be made available to all project partners, including those involved in the later stages of the building life cycle. Plans no longer have to be distributed manually.

How a digital Twin can benefit the entire builing life cycle

A digital twin is a multidimensional data model. It can have spatial dimensions (3-D), as well as further dimensions such as time, costs, and building management information. The result is a six-dimensional model. Figure 4 shows how use cases and their respective participants and drivers change in accordance with the dimension or target category.

The target categories are divided into a series of attributes that are entered into the digital twin. The more attributes there are, the more information there is about the building and the components and materials used. These details can be accessed from the digital twin throughout the stages of the life cycle (see Figure 2).

Dimension	Use case	Participants	Target category
BIM 3D	01 New design or surveying	Architect/engineers/contractor, owner	Costs
	02 Variant analysis	Engineers/client/contractor, owner	Time, costs
	03 Visualization	Architect/contractor, owner/authorities	Time, costs, customer experience
	04 Work preparation, quantity specification, and calculation	Engineers/client	Costs
BIM 4D (time)	05 Coordinating plans and monitoring progress	Architect/engineers/contractor, owner	Costs, quality
	06 Process simulation and scheduling	Engineers/client/contractor, owner	Time, costs
	07 Logistics planning	Client/site logistics	Time, costs
BIM 5D (costs)	08 Contract specification, call for tenders, contract awards	Engineers/client/contractor, owner	Costs
	09 Time and cost planning for the construction stage	Engineers/client/contractor, owner/bank	Time, costs
	10 Progress calculation, recalculation, and accounting	Engineers/client/contractor, owner/bank	Time, costs
	11 Defect management	Client/contractor, owner	Time, costs, quality
	12 As-built documentation	Client/engineers/facility management/ contractor, owner	Time, costs
BIM 6D (operational information)	13 Operations and facility management	Facility management/contractor, owner	Quality, profit

Source: Porsche Consulting | Use cases of prioritized stakeholder groups for FME Technical Operations (based on outside-in view prior to project) | * Facility management

Figure 4. Use cases for different dimensions

Especially relevant use cases for a 3-D model include visualization, variant analysis, and work preparation. The benefits here lie in lowering both time and costs, but also in the key area of customer experience. Clients develop a better idea and understanding of their building, which means they can also formulate any changes they desire early on. Adding the temporal dimension is of interest to use cases with coordination, sequencing, and logistics strategies. The focus here is on time, cost, and efficiency drivers. For example, the current state of a construction project can be discussed using a 4-D model that has been enriched with the latest progress-related information from the site. If the cost dimension is incorporated into the model's data set, costs can be monitored in streamlined and automated ways. If the data sets are made available for the operations stage, further managed, and incorporated into an "as-built" model, this yields a 6-D model that can also be used by facility management personnel. It offers important added value to the building operator and/or owner. This stage can access information from the construction phase, which is important for addressing any defects and clarifying who the responsible parties are.

According to Siemens, a digital twin can be the basis for a completely new ecosystem. Its data enable building operational services to be organized in a completely new way[6]. Moreover, it is only a matter of time before new business models are developed on the basis of these data.

The Integrated Planning and Industrial Building research area at the Institute for Interdisciplinary Construction Process Management at TU Wien (Vienna Technical University) has experience with several pilot projects for which a digital facility manager was integrated from the outset, which ensured that the BIM data would later be compatible with the respective CAFM systems.

The road to an intelligent digital twin

The more a digital twin "knows," the better it will become. In other words, each informational dimension added to a digital building twin will increase the model's complexity and thereby also the demands on putting BIM into practice. Good interface management or a seamless system model will therefore become success factor (Figure 5).

BIM applications used to be limited to the planning stage. To avoid adding another dimension to the six that already exist, we have termed the final developmental step in the digital building model the "intelligent digital twin." This building model contains all the information generated across the building's life cycle. It can be integrated into an intelligent urban planning system, because it contains all the interfaces and requisite infrastructure. The data have a very high level of detail, so it is necessary to clarify who is responsible for managing them. Each party involved can benefit from the data throughout the building's life cycle. But that does not come free of charge. Who will pay for it—those that provide the service or those that benefit from it? In parallel to focusing on the technical aspects of implementation, this question too requires serious consideration.

The intelligent digital twin is an important innovation for the construction industry. More such steps must follow. The key here is artificial intelligence (AI). This technology can be used to improve the planning not only for a project's processes but also for its operations, to ensure early detection of problems in building services equipment on the basis of anomalous systems data. AI can also be used to analyze the effects of different seasons and/or times of day on a building. This information can help prepare the building for future climate conditions. For example, winter sunshine can be used to heat the building. This would considerably reduce its carbon footprint and greatly increase energy efficiency. AI can also interpret and analyze the data gathered across the building's life cycle and thereby improve the demolition process. The conclusions drawn from AI can help answer questions such as which materials are best suited for a given building. This opens up new possibilities for process optimization and automation, and for generating new business models. Another application for AI consists of analyzing the plans for construction processes. This can optimize the processes for subsequent projects and identify the best versions—including consideration of possible alternatives. AI can also optimize occupational safety and progress assessment.

The "future of construction" will be shaped by AI. To use this technology, the right data need to be available in the right quality at the right time. That in turn requires digitalized processes and complete, structured data sets.

[6] https://new.siemens.com/global/en/company/stories/infrastructure/three-perspectives-on-digital-twins.html

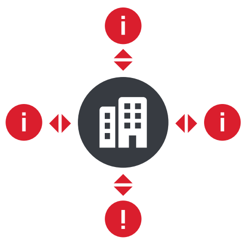
Dimension	Description	Responsibility		Stage	Level of detail
3D	**Planning** Construction stage input from various planners	Architect and planners		Design	Low
4D	**Scheduling** Based on input from planners, the processes are given a temporal dimension	Contractor		Build	
5D	**Calculating** Calculations are made based on current level of input	Contractor		Build	
6D	**Managing** The information available is used for operations; the digital twin is enriched with further information	Facility manager		Operate	
Intelligent digital twin	**Connecting** Various interfaces to databases and other IT systems	Every-one		Retrofit & demolish	High

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Figure 5. The road to an intelligent digital twin

Outlook: Where do we go from here?

An introduction to BIM and the use of digital twins enriched with additional information offers new opportunities for the entire construction industry. Consideration of a building's entire life cycle provides data for the facility management stage as well as the retrofit and demolition stage.

Buildings that have a digital twin with structured and coherent data sets will become increasingly important in the future and witness a substantial increase in value. According to the Integrated Planning and Industrial Building section of the Institute for Interdisciplinary Construction Process Management at the TU Wien (Vienna University of Technology), BIM systems will also be able to initiate procurement processes and possibly thereby avoid wholesale purchasing. Procurement processes, some of which take up to four steps, can be greatly simplified. Even simple materials like cement are currently purchased via wholesalers. That type of service only exists because of the need for rapid supply—without proper preliminary planning, although the requisite data were already available for weeks. In the future, suitable platforms could also integrate and automate bidding processes.

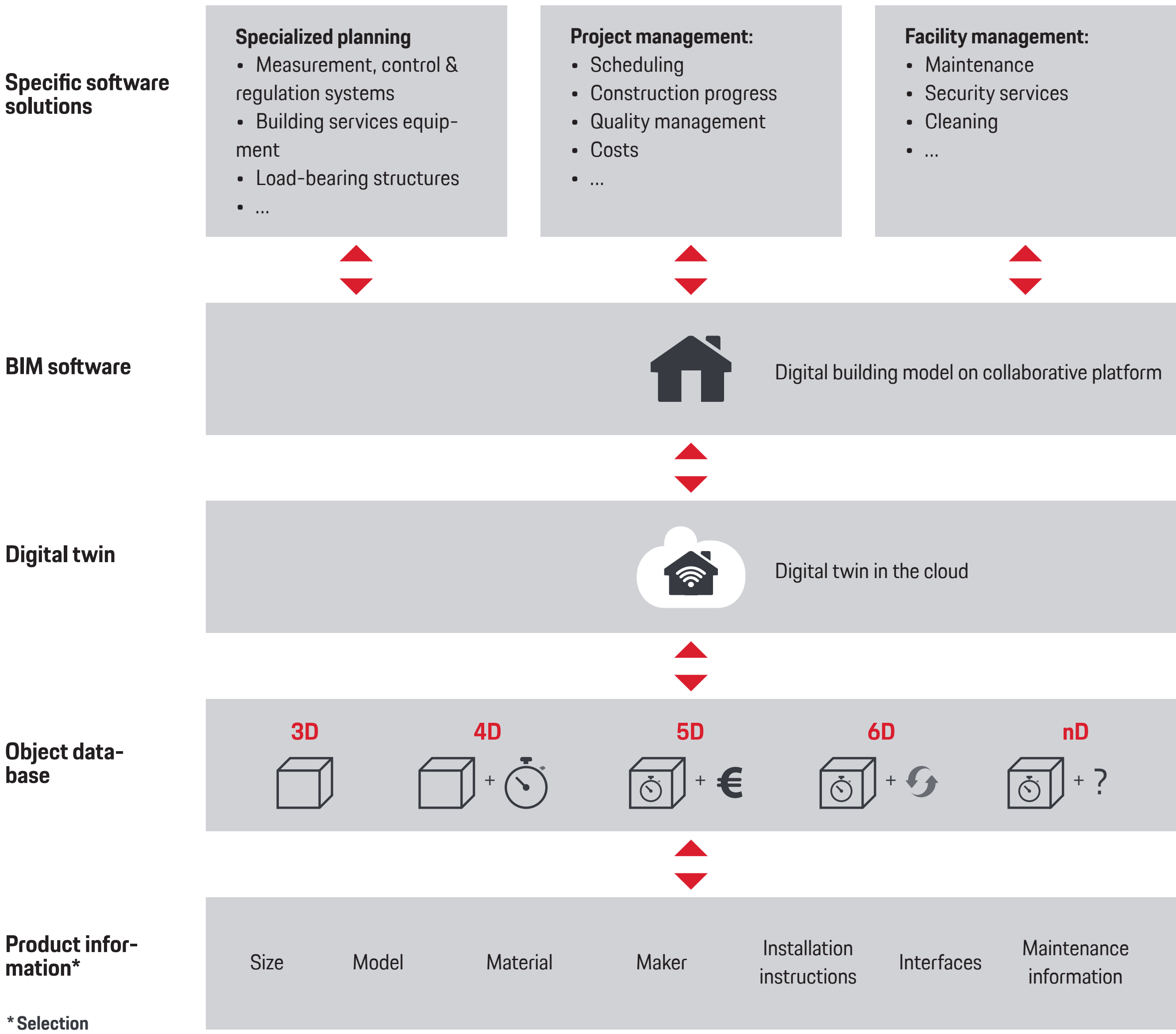


Figure 6. Technology stack for an intelligent digital twin

Figure 6 shows the technology stack needed to put the vision outlined above into practice. Manufacturers need to continue making product details available in digital form. Are the manufacturers the ones who also have to provide and prepare all the relevant information? Or do service providers assume the job of preparing all relevant information adduced to a given object? There are several providers of 3-D objects, but not of objects with a depth of information derived from the later project stages of construction and operation[7]. This could become a "battleground" in the future. After all, all the data are gathered and compiled in an intelligent digital twin, which is then a valuable pool of data with the potential for many value-adding analyses across all stages of a building's life cycle. Connections to infrastructure systems that require specific building data are possible at all times.

Conclusion: New opportunities and business models are arising. All players in the construction industry need to advance and use BIM applications and digitalization to create digital twins in order to utilize the enormous associated potential for optimization.

Three steps to a successful strat with an intellegent building twin

01 Formulate concrete use cases

Define a step-by-step plan to comprehensively digitalize company processes and define them to ensure the requisite level of detail for the projects. Use this foundation to develop use cases in order to specify different uses and scenarios for the digital twin. These provide orientation and clarity for the requirements associated with the scenarios. Prioritization can follow, then derivation of concrete measures to put the use cases selected into practice. Based on knowledge gained, consider whether there is further potential in developing new products and/or services. This can lead to new business models and ideas.

02 Define requirements promptly

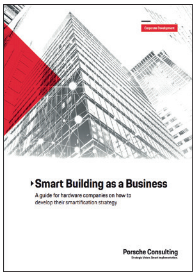
Based on the measures planned, define the systemic, process-related, and organizational requirements. Standards are relevant here, e.g., data formats, interfaces, process flows, documents, IT tools, and training. Carefully define the process steps that lead from creating a digital building model to a digital twin. All other needs can be derived from here. Information should not be lost at project interfaces, and project partners need to be informed early on of the benefits of a digital twin. This will prevent "losses to friction." In addition, at an early stage identify partners who are able to provide the requisite data for generating a fully digital twin. If relevant, training measures also need to be identified early on and a training strategy formulated that ensures the company has the necessary skills and expertise.

03 Dare to make an early start

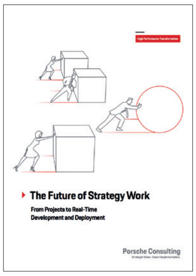
Speed secures a head start over the competition. This is why experience with digital twins should be gathered rapidly and channeled as "lessons learned" into continuous improvement and further development of processes. The potential that BIM also offers for a building's operational stages should be emphasized, and the resulting benefits discussed early on with clients and partners. Construction projects urgently need to include well-thought-out generation of digital twins. This is a matter of generic representation of the relevant processes for an ideal product creation process. The goal is to safeguard the scheduling, quality, and costs of construction projects. The product creation process should ideally be shown on a process map that defines all activities for the respective steps and the associated roles and tasks. This representation of the overall life cycle can simply and effectively show the steps required to create a digital building model and continuously enrich it with relevant information.

[7] Hausknecht, K., Liebich, T. (2016) BIM-Kompendium – Building Information Modeling als neue Planungsmethode, Fraunhofer IRB Verlag (only available in German)

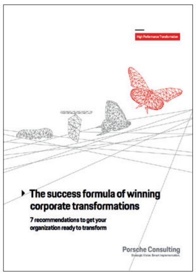
More information



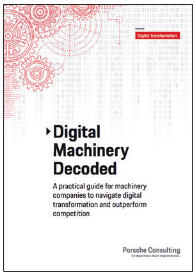
Smart Building as a Business



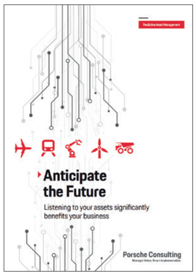
The Future of Strategy Work



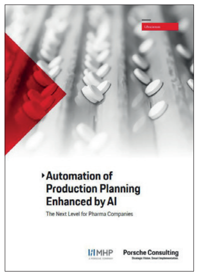
High Performance Transformation



Digital Machinery Decoded



Anticipate the Future (Predictive Asset Manage-ment)



Automation of Production Plan-ning Enhanced by AI

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