STUDY

Digital Twins

Leading the Way to Tomorrow’s Ecosystems

DETECON CONSULTING | DETECON DIGITAL ENGINEERING CENTER

In cooperation with

cross business architecture lab

Content

Executive Summary

A virtual mirror image of real plants and systems, a digital twin enables a variety of new application scenarios and business models. It is crucial for players in interconnected ecosystems to visualize clearly the advantages and prerequisites of the seamless exchange of information from the real world of operations as well as of digital simulation and control management.

What fields of action and challenges arise from the use of this groundbreaking digitalization concept? These and other questions are addressed in this pan-industry study "Digital Twins – Leading the Way to Tomorrow's Ecosystems" prepared by the management consultancy Detecon in cooperation with the Cross-Business-Architecture Lab e. V., the highly respected user association for best practices in digital transformation.

The results show that the vast majority (92 percent) of potential users expect the digital twin to have substantial impact and generate major opportunities relating to digitalization projects and are devoting serious attention to the topic, as is clearly indicated by the 36 percent of German companies and organizations that have already developed initial concepts for digital twins. Fifty percent of them plan to launch related pilot projects over the next twelve months, although more than 50 percent of the respondents do not plan to realize the transfer to ongoing operations for another three years. Moreover, the study offers the Detecon digital twin maturity model, a tool that enables users to determine their own maturity levels. Its major features concern the degree of standardization of the modeling data as well as the level of communication between real and virtual objects.

The aim of the digitalization concept of digital twins is to reproduce virtually real process flows and functions of products and systems in the greatest possible detail so that strictly virtual simulations can serve as a basis for business-relevant decisions at an early stage. Ideally, this should encompass the entire life cycle of a product. At least 60 percent of the study participants want to begin using the concept during all phases such as product design, development, production planning, production, use, and aftersales in the next five years.

Expectations for the potential in cross-company ecosystems are especially high. While today almost 80 percent of those surveyed still use the digital twin only within the company, the picture will most likely be reversed in five years' time; 77 percent want to be using the digital twin above all in a cross-company function by then.

When asked about specific advantages of a digital twin, over 90 percent of the participants cited efficiency benefits. Only a very small group of just under 7 percent does not expect any appreciable increase in efficiency. Nearly 90 percent also expect better coverage of customer needs, and 75 percent believe that the digital twin can facilitate the development of new products.

When asked about the greatest technological and organizational challenges in implementation, 78 percent of the companies acknowledged lacking the prerequisite know-how for the implementation of digital twins. Seventy-five percent criticize inadequate standardization, and 73 percent have not yet identified a suitable business model. Sixty-nine percent are aware that their IT infrastructure is inadequate, and 54 percent claim that external IT structures are poor.

Digital ecosystems a success factor

One important prerequisite that must be in place if digital twins are to provide decisive support for the success of holistic digitalization projects will be for previously closed, separate systems of processes and IT solutions to merge into ecosystems based on expedient platform architectures. Achieving such a goal, however, means introducing flexibility into previously rigid structures and breaking down strict borders. Silo-based approaches will have almost no chance of survival.

The hypothesis: Digital Twins are the key to a world of intelligent ecosystems

Opportunities and business models in the digitalized world change rapidly. Unless new forms of cooperation are developed – across corporate boundaries and even within organizations – it will be almost impossible to keep pace with the dynamics of these changes. Moreover, data silos must be broken open to make them universally accessible as information sources. All these new relationships in ambitious, complex digitalization projects involving increasing numbers of participants are always multilateral. A smart city, for example, in view of all its embedded IoT scenarios, must be planned comprehensively and holistically if its full benefits for society and economy are to flourish.

Processes become much more complex, confronting companies with demands never faced before – but which, if implemented correctly, can tap great potential. Interconnected collaboration will succeed, however, only if the once-closed separate systems of processes and IT solutions merge into ecosystems. Organizational structures must open up and overcome boundaries that have hitherto kept them apart. Only in an open ecosystem can all the advantages of data-based services and business models be exploited to the full. Yet, at the same time, copyrights must be protected to prevent the theft or misuse of data.

These goals cannot be achieved without combining technologies, data streams, and information flows. There is one digitalization concept that is predestined to act as the trailblazer for data-based ecosystems and goal-oriented orchestration of these digital models of the physical world: the digital twin.

According to Gartner, the market research institute, half of the larger industrial companies want to be using digital twins by 2021[1].Their hope is that the resulting standardized models for data exchange will massively advance the opportunities offered by the internet of things (IoT) and data analysis, making it possible to monitor assets and processes all the way down to the detail level and to optimize them continuously.

Complex industrial plants and machines as well as services and processes can be controlled and improved almost in real time and throughout the entire life cycle – from the idea to the conversion or dismantling. One example: by using the digital twin in conjunction with digitalization technologies such as virtual reality, possible errors can be detected early in the planning and design phase and processes can be optimized by initiating virtual operation of the plant prior to its actual construction. During live operation, machines and sensors constantly feed the digital image with data that are in turn incorporated into the model for the iterative refinement and improvement of processes.

The transparency needed to design, test, and optimize products, processes, and systems virtually is created. New applications and business models, even partnerships, can be tested digitally, rendering their expensive construction in reality superfluous.

At a high level of its evolution, the digital twin even sends direct feedback to its physical brother and joins it in a self-controlling and self-improving AI system. Information management is at all times the key to providing relevant information in good time and in reliable quality for decision-makers.

Our hypothesis: In the future, we expect ecosystems to mesh more and more and digital twins to act across systems. If alliances of this type are to be capable of collaboration at the technology level, innovative ecosystem architectures based on open standards, secure clouds, and the give-and-take principle will be indispensable. Approaches based rigidly on silos will have practically no chance of survival.

The objective of this study is to show how the concept of the digital twin can help companies to master the challenges of their own digital transformation and to stake out their position in the ecosystem of the future.

1 *Prepare for the Impact of Digital Twins, Gartner 2017*

Customer Journey – a day with Digital Twins

Even the personal life of every single individual is being digitalized and networked at an accelerating rate – wearables, connected home, connected car, and smart city are just a few of the developments that will impact the various areas of our lives to an ever greater breadth. The combination of new business models with technological developments integrates consumers more tightly into the added-value chain and even steadily raises their own expectations (World Economic Forum, Models for the Future of Consumption). The use of digital twins supports this consumer empowerment. A significant prerequisite for the consistent and friction-free integration of the digital twin into the everyday lives of consumers is the interconnection of companies and the coordination of their systems with one other.

The role of the digital twin in Paul's everyday life in 2025 could look something like this.

On a cold January morning, Paul's alarm clock goes off at 6:30. Paul gets up and, on looking out of his bedroom window, sees that it has snowed heavily overnight. On his way to the bathroom, his concerns about the weather prompt him to open the app of his building society on his tablet PC; he wants to make sure that all the sensors in the building are working correctly and that the room temperature and humidity have been set appropriately. A glance at the digital twin of his rented apartment on the tablet confirms that everything is fine.

After breakfast, Paul starts his car in the underground garage. It is the first highlight of his day; only two weeks ago, he picked up his new car at the dealership, and he is still having fun exploring all the convenient features it has to offer. Using the carmaker's app that he had installed on his smartphone, he was able to track his car at every moment during its manufacture at the factory. Even when the vehicle was in the final phase of production, he was able to decide he wanted even more optional features and to order them for installation via the app. Seeing today's gloom and snow, he is glad that he went with the xenon headlights after all. Now he uses a voice command to set the four-wheel drive in the car temporarily as recommended and displayed by the onboard computer. With the aid of the sensor technology in the car and its digital twin, Paul can determine ideal driving behavior and simplify maintenance and repairs. The standardization of the digital twin also allows the insurance company to access the vehicle data, including information about driving behavior. Thanks to his safe driving style, Paul benefits from lower premiums.

His parking space app navigates him straight to a free parking space. Considering the inclement winter weather, Paul has decided not to drive to his office in the company, a packaging machine manufacturer, as it is some distance away. Instead, he goes to a co-working office. When he arrives, Paul sets up his workplace, which he has conveniently booked via an app. When people register for the app, a digital twin is created for each user; it is visible to the other users in the co-working office. Moreover, users can connect automatically via the app to other users selected on the basis of their digital twins and set up appointments for lunch or coffee. The function allows Paul to make interesting new contacts and to broaden his horizons.

His employer's use of digital twins in the production process has been the standard for almost ten years. Seamless communication between the physical facility and the digital twin allows optimization of production from anywhere, so in an emergency Paul can quickly make changes from his co-working workplace. The use of new standards also simplifies coordination with suppliers and customers.

After work, Paul goes jogging for a while despite the freezing temperatures to clear his head after a hard day's work. He puts on his running shoes and makes sure that his fitness watch is connected to the shoes. His running shoes are not some standardized mass product produced in Asia; the manufacturer promptly produced them locally in a digital factory according to Paul's specific measurements and running habits. The fitness watch continuously monitors Paul's cardiovascular values. He receives signals from the sole of his shoe indicating when he should run more slowly or faster, calculated according to his goals entered in the app, his pulse rate, and ambient conditions such as running surface and the current weather. An analysis of his runs can also be carried out on the digital twin of his running shoe, and Paul is given tips for the optimization of his running style.

Later that evening, Paul books a Mediterranean cruise for next summer. A virtual tour of the cruise ship helps him to choose the right cabin for himself and his partner. At the time he completes the booking in joyful anticipation, the cruise ship is in the shipyard for maintenance. Since the wear and tear of individual parts are tracked on the ship's digital twin, maintenance could be scheduled well before technical defects would have caused any failures. The ship is also continuously monitored during the voyage, and the mode of operation, previously optimized virtually to achieve the lowest possible and environmentally most friendly consumption of natural gas, can be implemented directly, monitored at all times, and adapted to changing weather conditions with the aid of the digital twin.

Definition of Digital Twin

At the moment, there are various definitions of digital twins in use. Among other reasons, this is a consequence of the many different perspectives found between one industry and the next. The following sources are examined more closely below:

- Fraunhofer IOSB
- Fraunhofer IPK und TU Berlin
- GE Digital
- IBM
- Gartner (März 2018)
- Detecon

Fraunhofer IOSB

For the IOSB, the term "digital twin" encompasses a concept with which products as well as machines and their components are modeled with the aid of digital tools, incorporating all geometric, kinematic and logic data. A digital twin is the image of the physical "asset" in the real factory with which the asset can be simulated, controlled, and improved. Industry 4.0 working groups discuss digital twins in conjunction with the so-called administrative shell and Industry 4.0 components. Fraunhofer IOSB's definition relates strictly to the modeling of physical objects using digital tools and does not take the life cycle of the physical object into consideration.

Source: https://www.iosb.fraunhofer.de/servlet/is/80212/

Fraunhofer IPK und TU Berlin

Fraunhofer IPK and TU Berlin define a digital twin as follows: "A digital twin is the digital representation of a unique asset (product, machine, service, ...) that changes its properties, condition, and behavior on the basis of models, information, and data." (Stark, Kind, and Neumeyer 2017). So the digital twin offers a separation of use data and models for a simulation. Changes in the asset's condition in the sense of a life cycle are also outlined.

GE Digital (General Electric)

For GE Digital, a digital twin is a software construct that acts as a bridge between physical systems and the digital world. The digital twin can serve the digital world as a proxy. Over time, it collects data on the structure of the system, its operation, and the environment in which it operates. Together with the data, intelligence is built up through analysis, physics, and machine learning. You can query the digital twin of a specific system about past and current performance, operations, early warnings, and predictions.

GE's definition establishes a connection to analytics and machine learning and goes far beyond the definition of a digital twin from other providers.

Source: https://www.ge.com/digital/blog/digital-twin-technology-and-outcomes-you-should-expect

IBM

The digital twin is the virtual representation of a physical object or system during its life cycle (design, build, operate) using real-time operating data and other sources to secure understanding, learning, reasoning, and dynamic recalibration for improved decisions. The physical object can be anything from a building to a ball bearing, whereby the system presents electrical, mechanical or software and, even more importantly, interoperability among the systems (i.e., systems of systems).

IBM's definition considers both the straightforward virtualization of a physical object and its life cycle. It continues to emphasize the interoperability among the various systems.

Source: https://www.ibm.com/blogs/internet-of-things/immersive-analytics-digital-twin/

Gartner (März 2018)

A digital twin is a digital representation of a real entity or a real system. A digital twin is implemented in the form of an encapsulated software object that reflects a unique physical entity. It relies on sensor or other data to understand the condition of the object and potentially to report on it. In addition to receiving feeds from the real entity, a digital twin can download data, software, models, and updates to the real entity or a nearby system. Data from multiple twins can be aggregated for a composite view across multiple real entities.

This definition from Gartner also expands the concept of the digital twin in the direction of an ecosystem that links data from different twins.

Detecon

Detecon, the author of this study, has decided to use the following definition in this publication:

A digital twin is the virtual representation of a physical object using operating data and other data sources to enable monitoring and dynamic control of the object. This covers the full scope from a life cycle phase to the complete product life cycle. The maturity of a digital twin is defined in dependence on the level of communication and the degree of standardization. The degree of communication describes the connection between the digital twin and the physical object. The degree of standardization reflects the modelling of the data and data sources.

Detecon Digital Twin Maturity Model

Starting from the definition of the digital twin, a possible maturity level can be considered multidimensionally. The degree of communication between the digital twin and the physical object as well as the degree of standardization relating to the modeling of the data and data sources play a role.

Detecon has developed a so-called digital twin maturity model to illustrate these relationships.It distinguishes between the communication direction and the intelligent processing of the data in determining the degree of communication. There are five levels:

0. Representative
There is no communication of any kind between the physical object and the virtual representation.

A. Simulator
Communication is unidirectional, i.e., it is limited to the direction from the physical object to the virtual representation.

B. Monitor
Communication serves the monitoring of the physical object and travels from the object to the virtual representation. In this case, sensor data are visualized first and foremost.

C. Smart Monitor
Smart monitoring is an extension of the “Monitor” level and encompasses the linking of received data and enriching these data to gain new insights (smart data) and to visualize them.

D. Digital Twin
At the digital twin level, additional communication travels from the virtual representation to the physical object, i.e., bi-directional communication that controls (for example) an actuator on the basis of the collected smart data. The interaction with the virtual model has a direct effect on the physical object.

The degree of standardization relates to the modeling of the information that will be exchanged. Depending on the degree to which a standardized information model such as OPC UA or DDS is used, the following four levels result: (see below).

The combination of the two dimensions "communication" and "standardization" is depicted in a 20-field matrix illustrating the relevant properties of the digital twins. Some fields make little sense technologically, but are included for the sake of completeness. Furthermore, the maturity level displays a tendency from 01 to D4.

1. Hands-on
There is no standardization of any kind at the hands-on level. If an information model is used, its function is proprietary, interoperability is excluded, and the development path to the next level is severely restricted.

2. Basic Model
The basic model is based on an information model and enables the exchange of data with external systems.

3. Twin of Twins
At the "twin of twins" level, the various digital twins can be linked on the basis of a standard information model.

4. World Model
A digital twin based on a world model can be fully integrated into other ecosystems. Such a digital twin uses standardized components and allows data exchange within the ecosystem

World Model	04	A4	B4	C4	D4
Twin of Twins	03	A3	B3	C3	D3
Basic model	02	A2	B2	C2	D2
Hands - on	01	A1	B1	C1	D1
	Representa-tive	Simulator	Monitor	Smart Monitor	Digital Twin

The matrix fields are interpreted as shown below:

01 **Representative / Hands-on:** This category can be compared to an analog sketch on paper. The description of a twin is not based on a standard and no data are exchanged.

02 **Representative / Basic model:** An object is modeled according to defined standards and is feasible for drawing initial conclusions about the real object.

03 **Representative / Twin of Twins:** The modelling of a real object is expanded to cover various industries so that complex processes can be simulated.

04 **Representative / World Model:** The model describes the real object in its full scope using defined information models. There is absolutely no inter action between model and real world, however. This category can be used to simulate complex production processes, for example.

A1 **Simulator / Hand-on:** The virtual image of a real object has been defined on the basis of data acquired once and can simulate the behavior of the object. There is no provision for the further processing or exchange of this data.

A2 **Simulator / Basic model:** The possible communication occurs unilaterally between the physical object and its virtual image. Information exchange with external systems on the basis of a simple information model is possible.

A3 **Simulator / Twin of Twins:** In this category the virtual images of various real objects can in addition communicate with each other using standard-ized information models.

A4 **Simulator / World Model:** The virtual image describes and simulates in its full scope the real object commensurate with standardized information models.

B1 **Monitor / Hands-on:** Captured data can be visualized with the help of a virtual image of a real object. There is no provision for the further processing or exchange of this data.

B2 **Monitor / Basic model:** A simple standardization of the collected data makes possible comparability of the data.

B3 **Monitor / Twin of Twins:** Owing to an extensive standardization of the information, the virtual image of a real object can also visualize data of other objects.

B4 **Monitor / World Model:** The virtual image describes and simulates in its full scope the real object commensurate with standardized information models. Complex sensor data can be captured and visualized.

C1 **Smart Monitor / Hands-on:** Captured data can be visualized with the help of a virtual image of a real object. There is no provision for the further processing or exchange of this data.

C2 **Smart Monitor / Basic model:** The communication travels unilaterally between the physical object and its virtual image. The captured data are processed (data analytics) and possibly enriched with external data on the basis of a standardized information model.

C3 **Smart Monitor / Twin of Twins:** The virtual image of a real object can additionally process, enrich, and visualize standardized information from other data sources.

C4 **Smart Monitor / World Model:** The virtual image describes and simulates the real object in its full scope commensurate with standardized information models. The captured sensor data are linked and enriched with the help of artificial intelligence to gain new insights and visualize them.

D1 **Digitaler Zwilling / Hands on:** A digital twin of this category is a unique prototype that captures and processes proprietary data of a physical object, thereby controlling the object as necessary.

D2 **Digitaler Zwilling / Basic model:** A simple standardization permits the digital capture and further processing of information of a real object. The goal is to control and not only monitor the real object with the help of information from the virtual image.

D3 **Digitaler Zwilling / Twin of Twins:** At this level, communication between the physical object and its virtual image is also bi-directional so that the knowledge gained through data analytics can be used to control the physical object. The use of standardized information models also makes it possible to link various digital twins.

D4 **Digitaler Zwilling / World Model:** Digital twins of this category comprehensively describe reality on the basis of globally defined, standardized information models and can interact bi-directionally with the described objects as well as with each other.

Results of the empirical survey

The study conclusions have been derived from an online survey conducted by Detecon between December 2018 and March 2019. A total of 170 participants from ten industries were surveyed. The TOP 3 sectors were telecommunications, automotive, and the public sector. The five largest industries (in terms of number of respondents) were automotive, telecommunications, travel/transportation/logistics, pharmaceutical/health care, and the public sector.

The target group of the online survey comprises the top and middle management of the corporate divisions IT, strategy, and digitalization.

Three topic areas highlighting both the current state of technology and the expected future developments of the digital twin in industry were defined for the study:

- Implementation and development of previously conducted projects on the basis of a digital twin
- Corporate strategy: opportunities and influences
- Future strategic challenges in the development and implementation of digital twins along the added-value chains

Target group and sample of the survey

As the study will later show, the digital twin has not yet become a part of day-to-day business at the surveyed companies. The primary activities at present concern the development of initial concepts that serve to identify the added value or strategically meaningful application opportunities at the management

Figure 1:
Overview of the target group for the online questionnaire

Designation	Description
COO	Chief Operations Officer
CDO	Chief Digital Officer
CTO	Chief Technology Officer
CIO	Chief Information Officer
CEO	Chief Executive Officer
IT Strategy Manager	Responsible for strategy development in the IT sector
EAM-Manager	Responsible for the company’s architecture management

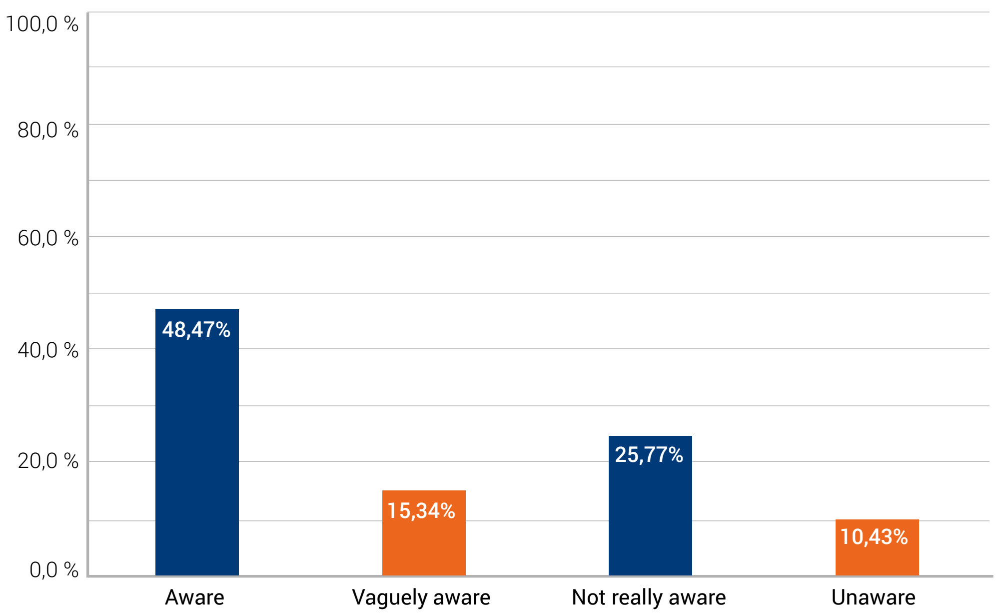
Source: Detecon

levels. This led to the definition of the survey's target group as the top and middle management level, particularly in the areas of IT, strategy, and digitalization. The questionnaire was accordingly sent to employees in the following positions (Figure 1).

Awareness of the digital twin concept

ur study shows that around 50 percent of the respondents are familiar with the concept of the digital twin. Twenty-five percent of the respondents have only a vague awareness of the concept. Around 10 percent of the respondents do not know the concept at all (Figure 2). This may be due to the fact that an in-depth digitalization of processes is still pending in these areas or that the potential inherent in digitalization has not yet been recognized. Another explanation could be the lingering skepticism about technological change from both an internal and a cross-company perspective.

Figure 2:
Is your company familiar with the concept of the digital twin?



Source: Detecon

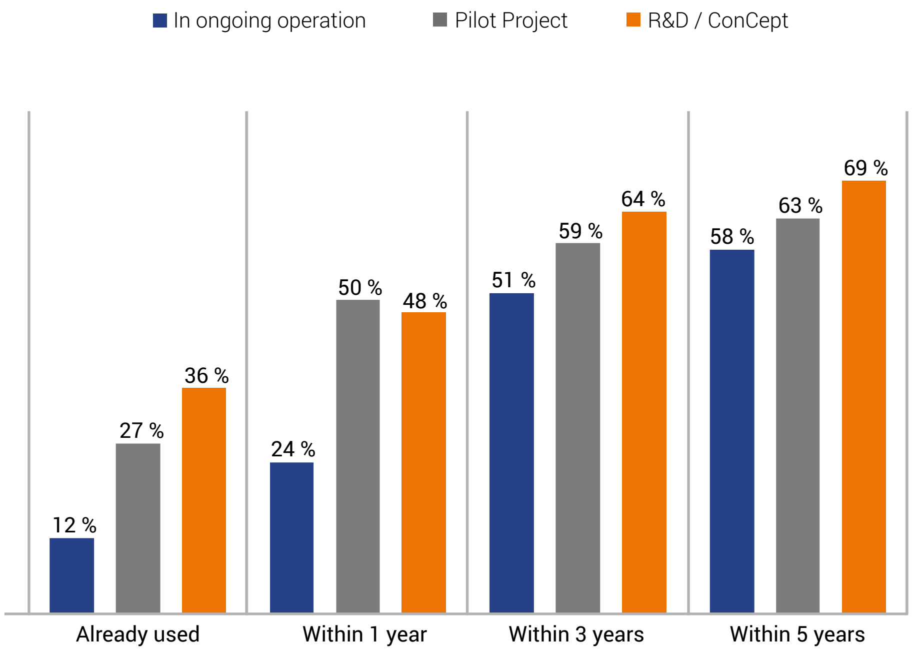
Use of the digital twin in the company

The survey shows that the concept of the digital twin is generally well known, and the following results indicate the extent to which the digital twin is already being used in companies (Figure 3).

The survey reveals that 36 percent have already implemented an initial concept, and this proportion is expected to rise to 69 percent within the next five years. As expected, use within these initial pilot projects will increase to 50 percent in the next twelve months, while integration into ongoing operation will not increase to more than 50 percent until a little later, i.e., within the next three years.

The results indicate that use in all categories should at least double over the next five years. Based on the leaps in growth for the use of the digital twin, it can also be seen that a clear trend in the degree of use is developing from the concept (already in use) to the pilot project (< one year) to ongoing operation (< three years).

Figure 3:
To what extent have you established the digital twin concept in your company?



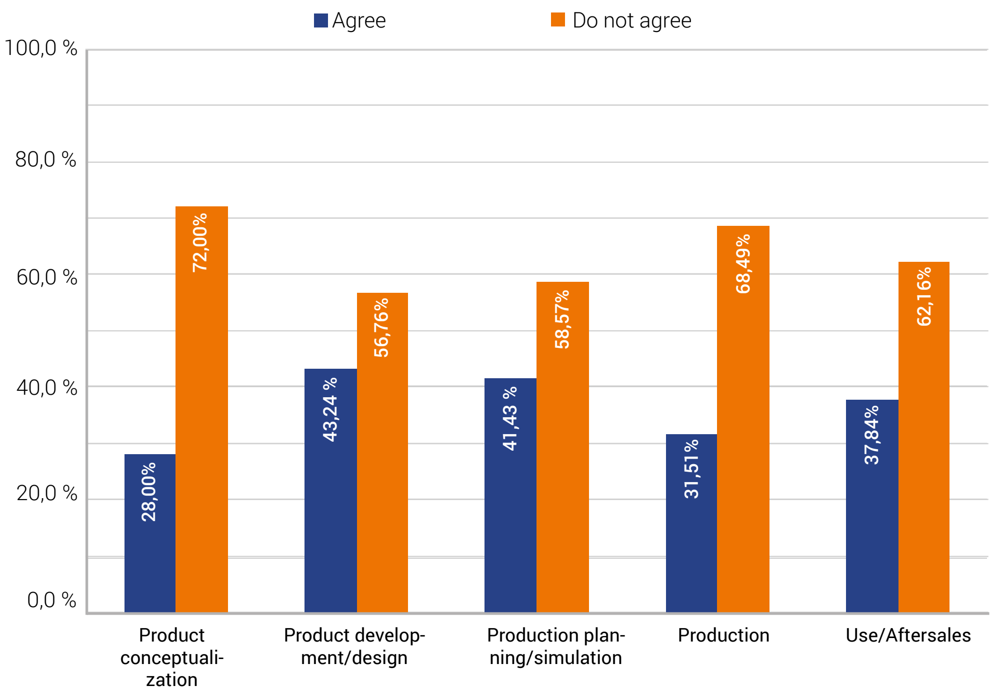
Source: Detecon

Use of the digital twin in the product life cycle

The influence of digital twins plays a fundamental role in the various phases of a product life cycle. This fact is reflected in the respondents' answers. The survey results show that digital twins have not been fully implemented in the various product life cycle phases in the company (Figure 4). There is a similar result for every single phase. When asked about specific phases, more than 50 percent of the respondents stated that, in their opinion, not one is currently covered by the digital twin in their companies. It should not be forgotten that both the basic technological know-how and the corresponding infrastructure must be in place before a concept for digital twins can be developed and implemented.

When we project the future status over the next five years, we see that the phases of product life cycles in companies examined here will be increasingly covered by digital twins. This is an indication of the high competitive potential attributed to the concept. The logical consequence is that existing added-value processes must be improved and new processes must be created, designed technologically, secured, and implemented. This is all a complex undertaking.

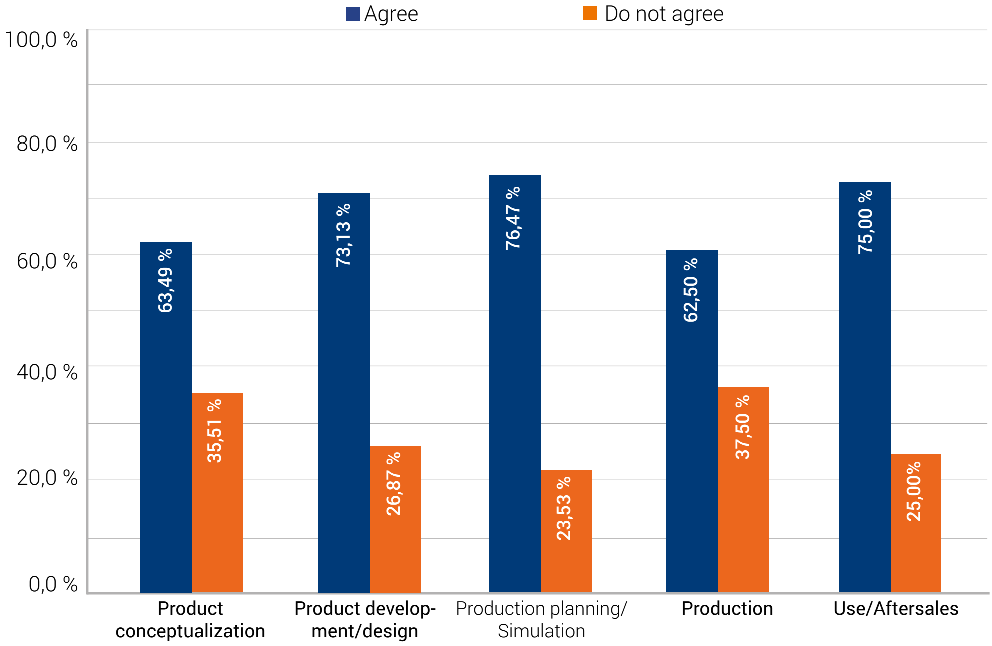
Figure 4: Which of the following product life cycle phases are currently covered by the digital twin in your company?



Source: Detecon

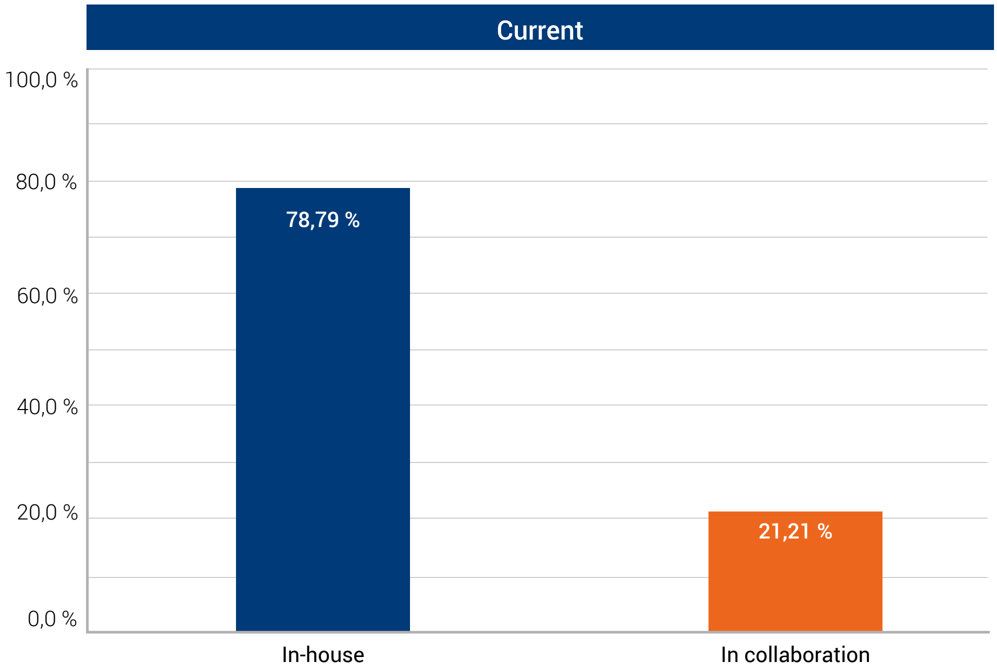
More than 60 percent of the respondents are also of the opinion that digital twins will cover all phases of the product life cycle in the future (Figure 5). Their views expect the highest degree of coverage in production planning and simulation, followed by product use and aftersales.

Figure 5: Which of the following product life cycle phases will in future (over the next five years) be covered by the digital twin in your company?



Source: Detecon

Figure 6: Is the digital twin currently used exclusively within the company or in collaboration with other companies?



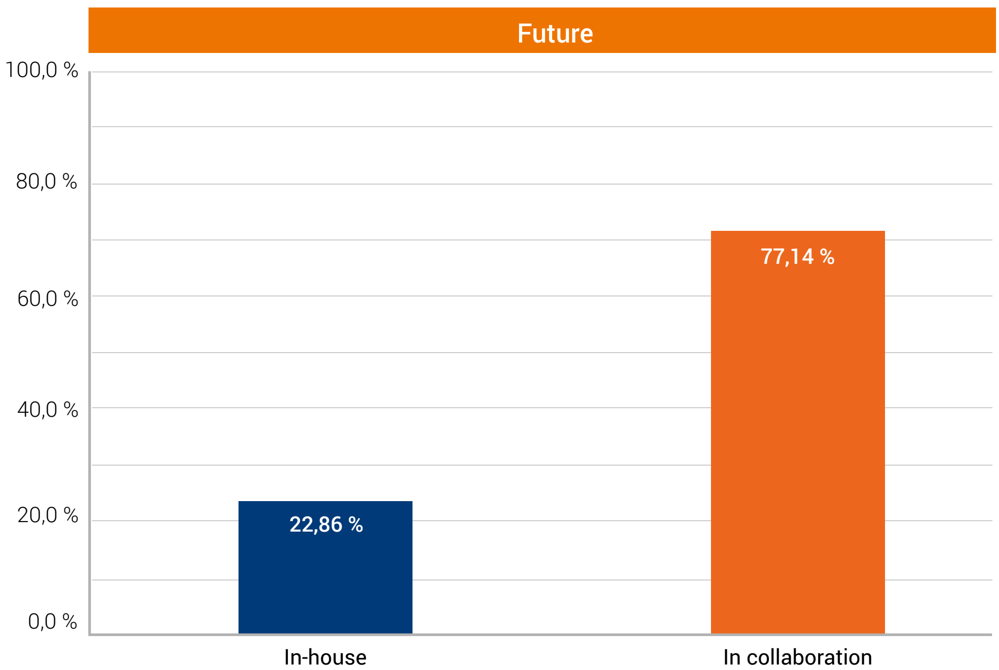
Source: Detecon

Use of the digital twin in the production ecosystem

The planned use of the digital twin in the ecosystem will strongly influence its specific features. While today almost 80 percent of the use of digital twins takes place within the company (Figure 6), 80 percent of the respondents expect a reversal of today's results within a time frame of five years so that the use of digital twins will be primarily a cross-company phenomenon (Figure 7).

One important prerequisite for the realization of this project is the use or redefinition of open standards that can ensure secure and barrier-free data exchange among all stakeholders in the added-value network. Moreover, satisfactory platform architectures must be created.

Figure 7: Will the digital twin be used exclusively within the company or in collaboration with other companies in the future?

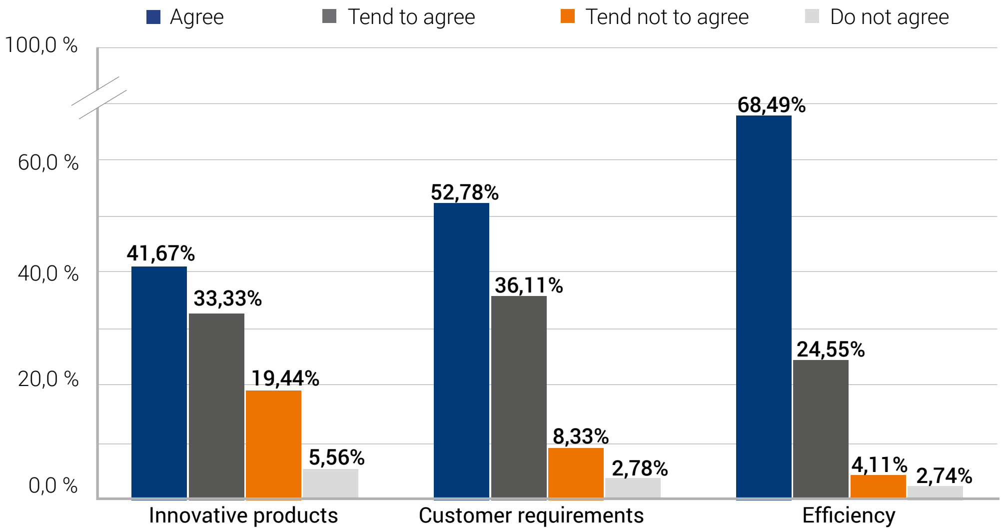


Source: Detecon

Potential of the digital twin

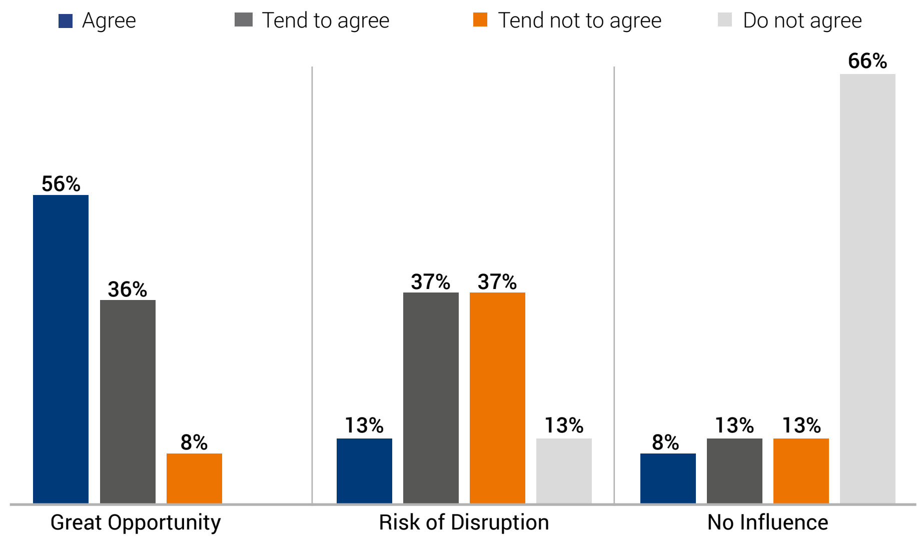
When asked about the greatest benefit or greatest opportunities inherent in the digital twin, respondents cited first and foremost efficiency, followed by the coverage of customer needs and the development of new products and associated market opportunities (Figure 8). Only just under 7 percent see little or no likelihood of efficiency gains from the introduction of digital twins. Approximately 10 percent assume little or no likelihood of improvement in the coverage of customer needs. Around one-quarter of the survey participants has little or no faith in the ability of new products to increase market potential. Overall, the results suggest that in the future digital twins will be a crucial element in competition for the vast majority of companies surveyed.

Figure 8: What do you regard to be the greatest benefit or greatest opportunity of the digital twin for your company?



Source: Detecon

Figure 9: What is your basic assessment of the effect of the digital twin on your company?



Source: Detecon

Influence of the digital twin on the company

The participants in the study were asked about their expectations regarding the influence of the digital twin (Figure 9). Most of the survey participants (92 percent) agree that the use of the digital twin represents a great opportunity. The response from 79 percent that they generally expect it to have an impact was similarly unequivocal. On the other hand, the question as to whether the digital twin can turn into a risk from disruptive, competing business models was a divisive one; exactly half of respondents agree with this statement while the other half reject it. Apparently, there is still plenty of uncertainty about the extent to which disruptive business models will develop, what effects they will have on a respondent's own company, the market, and ecosystems, and how the opportunities arising from this development can be exploited.

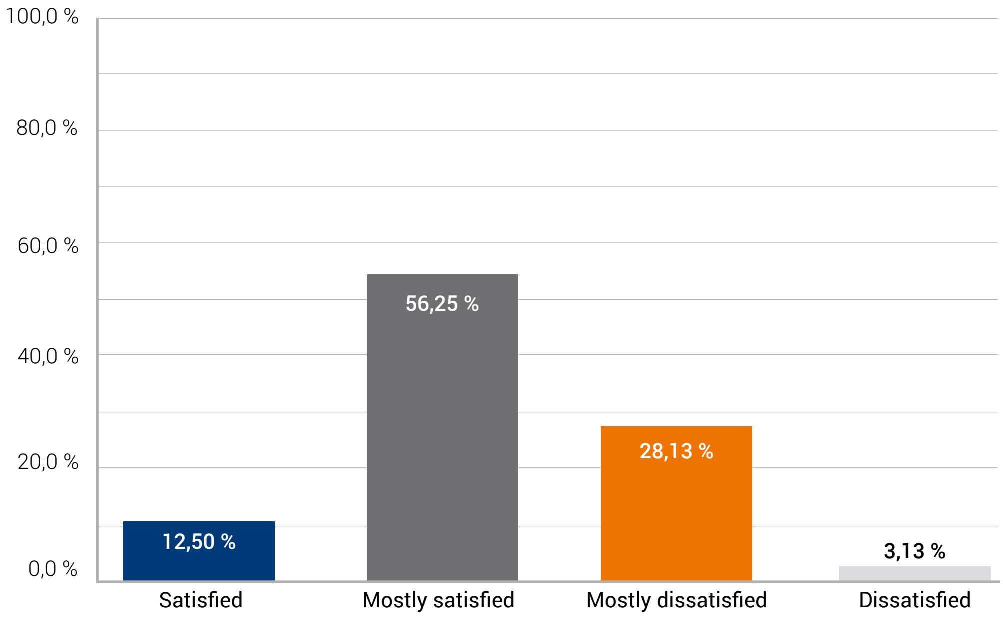
Satisfaction with project results relating to digital twins

Digital twins have become significant elements of many projects even today. We asked about project results. Almost 70 percent of the respondents declared that they were satisfied or mostly satisfied with the outcome of their projects (Figure 10). This suggests that the vast majority of companies are in a position to exploit the potential of digital twins.

Challenges in the implementation of the digital twin

We asked as well about the greatest challenges during implementation. If the categories "Agree" and "Tend to agree" are combined, approximately 78 percent of the companies lack the prerequisite expertise regarding the implementation of digital twins. Approximately 75 percent criticize inadequate standardization. Approximately 73 percent pointed to the lack of a business model. About 69 percent are aware that their IT infrastructure is inadequate, and 54 percent claim that external IT structures are poor. Data security appears to be the least of the problems or is the one that is most underestimated.

Figure 10: How satisfied are you with the results of the projects conducted in relation to digital twins?



Source: Detecon

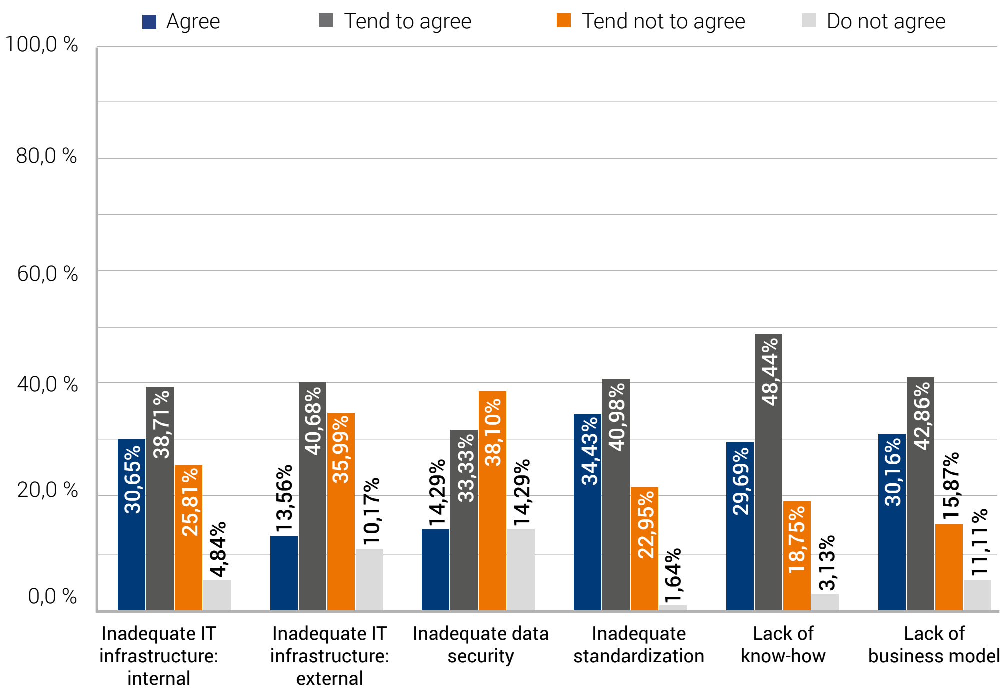
Only about 48 percent regard this issue to be a challenge (Figure 11). All in all, the survey results reveal that there are still a lot of difficulties during implementation. This is certainly another reason why many digital transformation processes are progressing so slowly.

Assessment in the Detecon digital twin maturity model

Participants were asked to assess the twin used in their organization on the basis of the Detecon digital twin maturity model so that we could obtain an overview of the general maturity level of the digital twins already in use. The combination of the two dimensions "Communication" and "Standardization" produces a 20-field matrix illustrating the relevant properties of the digital twins (Figure 12).

A significant proportion (16 percent) of the survey participants assessed their own digital twin at the lowest maturity level. If we look at the degree of standardization of the digital twin, it is striking that the majority of the use cases were assessed at the "Basic model" level.

Figure 11: What are the most significant technological and organizational challenges facing you in the implementation of the digital twin?

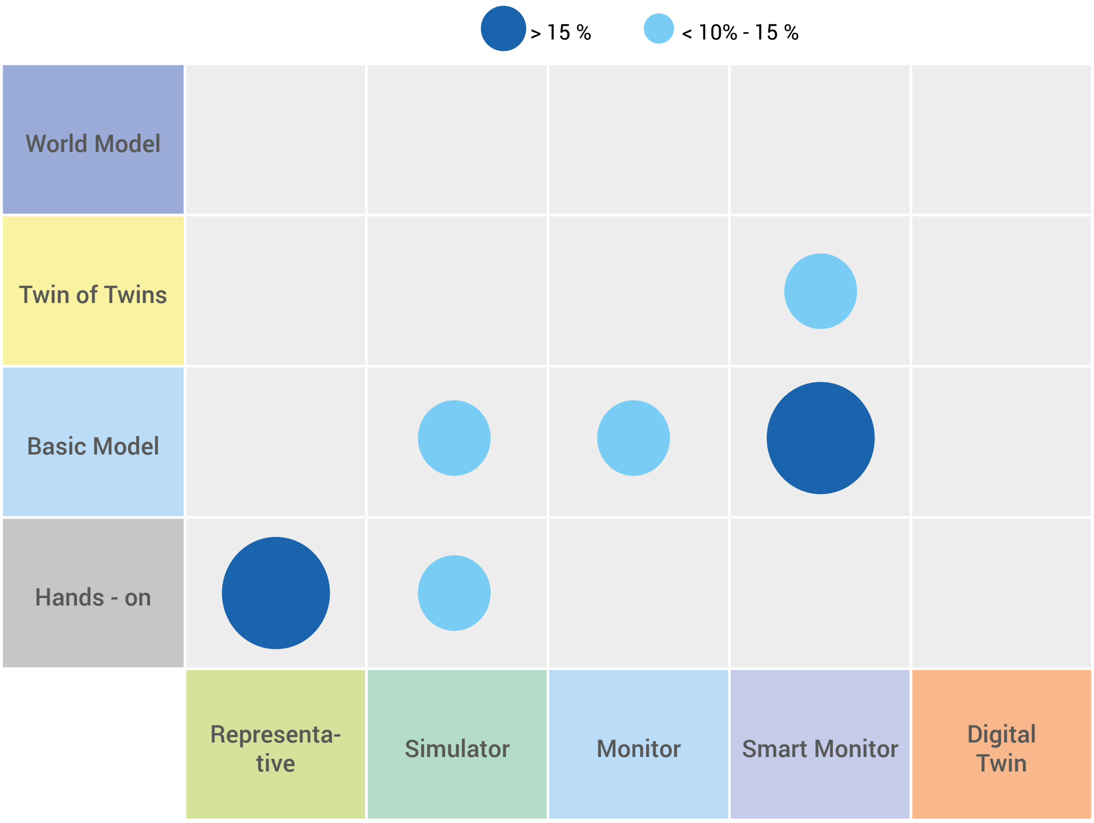


Source: Detecon

When viewed in conjunction with the degree of communication, the classification leads to clustering at the Basic model – Smart monitor levels.

As described in this category field, communication between the physical object and its virtual image is a one-way street. The captured data are processed using data analytics and, where appropriate, enriched with external data on the basis of a standardized information model. Overall, respondents indicated that the highest maturity levels in both communication and standardization have not been covered. As expected, the world model and the highest level of the digital twin have not been realized in industry.

Figure 12: Please assess the degree of communication and standardization of your digital twin



Source: Detecon

Use in practice: digital property management at the touch of a button

Digital twins should virtually simulate reality as completely as possible. They cannot achieve this without using collected data to analyze an enormous range of highly diverse influencing factors and possible changes, ideally over the entire life cycle of a product. What might a digital twin of this type look like in actual practice?

In collaboration with colleagues from the T-Systems Digital Solutions portfolio unit, a Detecon team has developed a minimum viable product (MVP) for digital property management that offers easily handled operations to the owners and managers of buildings, facilities and underground structures. Generally speaking, the management of large and diversified real estate portfolios is often complex and confusing. The practical motivation of the participants was to realize a solution that could create a detailed 3-D model of portfolio properties (some of them of historical significance) within a few days. The objective of the model was to provide a basis for professionally documenting the condition of the buildings and monitoring operating data as well as the performance of simulations. Solving these challenges in the life cycle management of real estate properties demands a platform solution that generates digital twins of buildings and infrastructures as a “single source of truth” and supports a broad range of many different use cases such as energy management, facility management, optimization of the use of floor space, predictive maintenance, and many more. Economic goals include the reduction of operating costs, process optimization, increased productivity, and new business models.

Thanks to the collaboration with other external partners such as the 3-D infrastructure specialist LocLab and the experts for product life cycle management from Dassault Systèmes, Digital Solutions was able to realize quickly the minimum viable product (MVP) “Digital Real Estate Lifecycle Management.” The basis was the 100-year-old Telekom building on Winterfeldtstrasse in Berlin, which was originally home to the first telephone exchange in the city. The first showcase demonstrations were very well received. “Potential users were impressed and thought we had been working on the visualization results for many months. In actual fact, however, it took us only 4 hours and a week of editing,” related Uwe Weber, head of Detecon’s Industrial IoT Center. A remote connection with the capital Berlin was used to demonstrate how changes in the temperature data from a sensor on Winterfeldtstrasse can be visualized in real time in the solution dashboard.

Digital twin uses specified objects

What is actually possible with the MVP “Digital Real Estate Lifecycle Management”? First of all, it saves an enormous amount of time for users. If only old plans (or even no plans at all) are available for an older building, the property can be captured in the first step by the use of a photogrammetric procedure from LocLab in just a few hours and created as a 3-D model. It is then transferred to Dassault’s 3DEXPERIENCE platform (3DX), a web- and role-based interface that provides access to all the data based on the property. Just as in building information management (BIM), precise specifications can be assigned as attributes to objects such as a fire protection door (the fire protection class, for instance). In the sense of reverse engineering, 2-D layout plans can also be extracted from the 3-D model so that seamless change management with comparability of various conditions is possible. A continuous quality assurance process results from the digitalization of the service and maintenance processes and from the sensor-supported integration of operating data. Changes in the values received from temperature sensors were graphically visualized in real time in the digital twin for this purpose. Integrated information flow makes it possible to perform predictive maintenance. Error reports or even nothing more than engine noises can be recorded continuously and analyzed for patterns. Moreover, installers can view maintenance documents and enter repair reports by means of digital exploded-view documents.

Simulation of a 5G network

Finally, the simulation of structural measures in the digital twin lays the groundwork for time- and cost-saving investment strategies. Since the twin compares all real and virtual object and operating data, simulations of heating, ventilation, and air-conditioning systems can be carried out. By including parameters such as the heat transfer coefficients of windows and doors, it is possible to calculate the energy required to achieve the desired room temperatures as well as the CO2 emissions that are produced. Visualized flow simulations of ventilation and cooling effects in rooms and on the levels of the building are also possible. Pumps from various manufacturers can be tested in virtual simulations before the decision about the purchase of the required equipment is made.

The situation for radio or 5G applications is similar: the adequacy of the transmission ranges in buildings and the floors of the building can be assured without first having to install the antennas. Electromagnetic radiation simulations of this nature in the 5G environment could fundamentally realize reachability analyses for autonomous driving – independently of the MVP actually being developed at this time – by checking radio cell transitions and the resulting latencies. It would also be possible to simulate whether the data transport would be just as fast if suddenly hundreds of people are standing alongside a road.

Or another practical scenario – in road or underground construction, digitalized construction machines can be steered in real time with 3-D and process data so that they return a digital twin with all as-built process data from roads or railways. Ultimately, the result is a holistic, virtual 3-D simulation environment that considers all aspects across industries, companies, and projects in the sense of building experience modeling (BEM) – always with the advantage that certain features can be tested virtually in advance without first having to expend time and effort to build and test them in reality.

In the future, this will lead above all to efficiency gains in many areas, but it will also be possible to come up with innovative products such as modular and standardized production.

Vision:
the digital twin as a pioneer for the global ecosystem of the future

The results of this study are not alone in illustrating the clear trend toward the cross-company use of digital twins and the consistent use of digital product models across all life cycle phases. The main drivers of this development are the prospects for competitive advantages through increased efficiency, better coverage of customer needs, and easier development of new products.

The heterogeneous IT system landscapes that have emerged over the course of decades are especially challenging for large companies. It is difficult to establish standards for the exchange of information and data across different trades because the system-specific raw data must be interpreted and standardized. Moreover, there is a lack of expert know-how. Over the next ten to twenty years, however, this problem will be significantly alleviated. There will be holistic planning approaches for new products that provide integrated, digital processes across product life cycles and ecosystems. Standards will have been established and new IT structures will be optimally aligned with them. These structures are designed by ecosystem architects. Legacy structures will have been largely replaced by the new structures. Once again, additional new, disruptive business models will be possible.

Maturity level of digital twins will rise significantly

Furthermore, the maturity level of digital twins will rise significantly in the future. As the Detecon digital twin maturity model in this study demonstrates, the digital twin at a high maturity level will process, enrich, and visualize standardized information from distributed data sources at the most innovative companies. In addition, the captured sensor data will be linked and enriched with the aid of artificial intelligence to gain and visualize new insights. In the next ten years, the AI-based capabilities will become more and more comprehensive, and it is probable that bi-directional communication between the physical object and its virtual image will be established. The knowledge gained through data analytics can then be used to control the physical object. Moreover, digital twins in ecosystems will gain the ability to communicate and cooperate with one another. All these capabilities will lead to the increased use of autonomous systems that interact intelligently with one another. The primary functions performed by human beings will revolve around monitoring, control, and repair. Cross-system information and data for use during these activities will be prepared in interactive dashboards on predominantly mobile end devices with extensive assistant functions.

Ecosystems must be able to talk to one another

If comprehensive, automated scenarios of this type are to be realized, it will have to be possible to read out the master data from the systems, devices, and components in the model. Otherwise, separate systems and components will not be able to identify one another. There are a number of questions that must be answered. What kind of system is it? What output can it deliver? What input is required? Today, this functions within a single domain, e.g., when pump A from manufacturer X is replaced with pump B from manufacturer Y in a machine. The information transfer to other domains such as development, aftersales, etc., has yet to be realized, however. The integration of the models of the separate domains into an ecosystem that is as cross-industry as possible is required to achieve this.

If the "vehicle" ecosystem is to be able to communicate with the "smart city" ecosystem, vehicle engineers, urban planners, and civil engineers must speak the same language and a relationship must be established among separate models. Since each domain is currently setting its sights on its own solutions and platforms, a later integration of the separate models through many interfaces poses an extraordinarily high challenge. One possible approach to a solution is to define standards that ensure an uncomplicated exchange of information. Possible means (among others) to establish such standards can be found in standardization, open source, or industrial collaboration. Companies need to drive interconnectivity and digital mapping of separate products and assets. Anyone who is not prepared to share information with customers, suppliers, partners, and competitors in real time runs the risk of falling behind, sooner or later. The digital twin in particular clearly reveals contexts by providing information for which all stakeholders know the origin, context, semantics, and needs. The consequence is that new added-value networks are created, some of which span the globe.

Recommendations for action

Ninety-two percent of the users of digital twins expect clear influence and new opportunities for their own digitalization projects. Related pilot projects will be launched by 50 percent of the respondents within the next twelve months. Their primary motives are the prospects for increased efficiency, better coverage of customer needs, and facilitation of the development of product innovations.

The trend is clearly in the direction of seamless digitalization of the product life cycle in the future. At least 60 percent of the study participants want to utilize the concept in all phases such as product design, development, production planning, production, use, and aftersales in the next five years.

Seventy-seven percent of the respondents are aiming to begin using the digital twin sometime in the next five years, above all in inter-company relationships.

This study has determined that the challenges during the implementation of digital twins are the lack of know-how, inadequate standards, and the identification of new business models.

- Assessing the potential for your own company will be well worth your while as it will help you to avoid suffering a competitive disadvantage in the next three to five years. Cost-benefit analyses and proofs of concept in representative sub-areas of the IT infrastructure are required. They can be followed by the development of a vision and more comprehensive architectural concepts. The Detecon digital twin maturity model will be of service in determining status and progress
- Product and application life cycle management (PLM and ALM) will continue to gain in importance in the future. The goal must be to standardize product data management within the corporate group and make it usable for all stakeholders. The first step toward this goal must be to define a uniform standard. One way to do this is to draw up a list of requirements for the PLM strategy using use case analyses. A data and information model can then be developed from this basis.
- Limiting analysis and assessment to the product life cycle will no longer be sufficient. The key is thinking in terms of ecosystems; business models arise from the synergetic interaction of all stakeholders. Conflicts of interface and interests can be avoided through the establishment of ecosystem architectures.
- The success of the project is dependent on the skills of the team. Interdisciplinary teams should be staffed with the best internal and external experts. Parallel employee training is important for the development of skills. Cross-project and cross-location communication and sharing of experience also help to establish best practices. Work must be aligned with the corporate vision and metamodel of the ecosystem at all times. The aim is to link machines, plants, and systems more closely so that their data can be used more effectively through consolidation, filtering, and intelligent analyses.

The Authors

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The Company

Detecon International is a leading management and technology consulting company operating worldwide with headquarters in Germany; for more than 40 years, it has combined classic management consulting with outstanding technological competence. The focus of its activities is on the field of digital transformation. Detecon supports companies from all areas of business as they employ state-of-the-art communication and information technology to adapt their business models and operational processes to the competitive conditions and customer requirements of a digitalized, globalized economy. Detecon's expertise bundles knowledge from the successful conclusion of consulting projects in more than 160 countries.

Detecon is a subsidiary of T-Systems International, the non-proprietary digital service provider of Deutsche Telekom. Detecon International GmbH has joined forces with T-Systems Multimedia Solutions GmbH (MMS) and the digitally oriented divisions of T-Systems Global Systems Integration (SI) to create the portfolio unit "Digital Solutions," which is one of the largest integrated digital providers in Germany.

As a member of this new alliance, Detecon is driving forward its consulting approach "Beyond Consulting," a significant evolutionary step forward in traditional consulting methods adapted to meet the demands of digitalization today and in the future. The concept features top consulting services that cover the entire spectrum from innovation to implementation. Groundbreaking digital consulting demands ever greater technology expertise and a high degree of agility that incorporates flexible, but precisely woven networks of experts for complex, digital ecosystems in particular. At the same time, it is more and more important in digital consulting to accompany clients from innovation to prototyping to implementation.

This factor prompted Detecon to found the Digital Engineering Centers for Cyber Security, Analytical Intelligence, Co-Innovation, and Industrial IoT in Berlin in 2017 as facilities that extend the added-value chain of consulting and accelerate the realization of digital strategies and solutions by means of prototypes and proofs of concept.

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