reflecting reality

DIGITAL TWINS: ADDING INTELLIGENCE TO THE REAL WORLD

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Capgemini RESEARCH INSTITUTE

Introduction

In Chattanooga, in the US state of Tennessee, information from 500 different sources, including traffic cameras, 911 emergency-call data, radar detectors, and weather stations, feeds into the city's digital twin.
Upon conducting experiments in traffic-congestion relief using the twin, the city has shown an improvement of up to 30% in traffic flow, resulting in greater energy efficiency as well as reduced passenger delays.[1] In another example, Nanyang Technological University (NTU) in Singapore, using digital twins, was able to create 31% savings in energy use and a reduction of 9.6 kilotons in carbon emissions.[2] These examples not only illustrate the scale of today's digital twins and the efficiencies they bring but also highlight the sustainability benefits they can provide.

A digital twin is a virtual replica of a physical system that can model, simulate, monitor, analyze, and constantly optimize the physical world. It aims to bridge the "physical-digital" gap at the right frequency and fidelity, thereby improving performance and sustainability. It establishes a closed-loop approach to unlock value, bringing synergies across data, technologies, and business processes, and is at the core of Intelligent Industry[3] transformation. Through its ability to answer questions such as "what is best?", "what if…?", and "what next?", a digital twin can not only provide visibility on how dynamic, real-world systems are currently performing and propose how to improve them, but also predict how they will perform in different scenarios. A product or a system can have one or more than one digital twin depending on the stage of the lifecycle that requires it.

There are various ways in which digital twins can help organizations attain their sustainability goals and facilitate easier collaboration with the extended ecosystem. During the conception phase, a digital twin for design can aid the design effort and testing of new features as well as bring greater efficiency to production processes, consequently

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saving costs and reducing time to market. During the build phase, a twin can aid virtual training and commissioning. Later, when the product/asset/system is being operated and maintained, another twin can make processes more efficient by reducing downtime through predictive maintenance and improved performance via optimization. In addition, they also aid organizations in introducing new business or operating models.

As a result, organizations are increasingly investing in digital twin solutions. The market size for digital twins, which exceeded $5 billion in 2020, is expected to grow at over 35% CAGR between 2021 and 2027.[4]

To understand how leading companies are integrating digital twin technology into their digital transformation programs, we surveyed over 1,000 organizations, spread around the world and across industries, including: life sciences, consumer products, energy & utilities, discrete manufacturing, and infrastructure owners/operators. To get a first-hand account of the value derived from and the challenges faced during digital twin implementation, we focused largely on organizations with an ongoing digital twin program (which form 80% of our sample), while the rest are planning to start one. We also conducted in-depth interviews with industry executives and academics.

Introduction

This report, which is part of our series on Intelligent Industry,[5] aims to answer the following questions:

01 Are organizations adequately prepared to deal with changing trends?

02 How can digital twins drive higher performance and sustainability?

03 How can digital twins add value throughout the value chain?

04 Which are the organizations that have successfully deployed digital twins?

05 How can organizations accelerate their digital twin journey?

Executive Summary

Changing customer preferences, growing regulatory pressures, and increased concerns around carbon emissions are compelling organizations to accelerate digital innovation. At the same time, the growing convergence of products, software, and services is creating an opportunity for the next big transformation across industries. We call this new era of transformation "Intelligent Industry." While technologies such as AI, cloud, 5G, and edge computing are key catalysts of this journey, digital twins are at the core of the transformation. A digital twin can optimize the *design* and *operate* and *serve* phases of any system – be it a product, its related services, a production line, infrastructure, a logistic network, or even a system of systems. It enables collaboration all along the system's life cycle and across ecosystems, thereby optimizing operations and even helping organizations reinvent their business models. How are organizations harnessing this technology, and to what end? What challenges do they face and how can they overcome them?

Our research reveals that digital twin deployments are being driven by both top and bottom lines, as well as safety, sustainability, and brand reputation. Organizations working on digital twins have already seen, on average, a 15% improvement in metrics such as sales, turnaround time, and operational efficiency, as well as an improvement upwards of 25% in system performance. Further, digital twins will provide digital and flexible ways of working to mitigate risks and extend collaboration, allowing operations to be virtual before they become physical, and enabling a closed-loop feedback. As a result, organizations are set to increase the deployment of digital twins by 36% on average over the next five years. Digital twins also provide a unique opportunity to reconcile profitable growth and sustainability. Organizations have realized an average improvement of 16% in sustainability owing to the use of digital twins. However, the path to successful digital twin deployment is still not without hurdles; nearly half of organizations lack a clear vision, managerial commitment, and the necessary investment, as well as the right skillset within their workforces.

Executive Summary

We also found that 13% of organizations surveyed excel in six areas that allow them to be the frontrunners in digital twin deployments: vision, leadership, ecosystem empowerment, system capabilities and intelligent system development, digital practices, and collaborative platforms deployment. Compared to the rest, these organizations realize at least 65% higher benefits in the form of increased sales, improved customer satisfaction, reduced costs, and improved sustainability.

With digital twins still being an emerging technology, it requires a value- and integration-driven stepwise transformation. To move forward progressively in this transformation, companies need to organize themselves to support digital twins in terms of capabilities, road map, and governance, while anticipating end-to-end integration. Based on these elements, we highlight five key areas organizations need to work on to implement successful digital twin deployments.

Foremost among these is a stepwise long-term road map that integrates safety and sustainability goals. Additionally, in order to deploy digital twins at scale and obtain full benefits from the system, a set of capabilities will be required to design, build, and operate digital twins, from system engineering and distributed architecture through simulation to machine learning. A digital twin architecture that provides for end-to-end integration in terms of connectivity, data models, distribution, and access is key to scaling up. However, since a digital twin is connected to a number of systems and consequently opens access to inordinate amounts of sensitive information, organizations must also ensure reinforced data security and privacy measures prior to at-scale deployment. The greatest value of a digital twin comes from being able to predict or simulate the impact of a particular change on the entire ecosystem. Therefore, on-boarding critical partners to the digital twin vision and deploying collaboration platforms with these partners will greatly augment the benefits such a project can offer.

A digital twin is a virtual replica of a physical system that can model, simulate, monitor, analyze, and constantly optimize the physical world.

01

Organizations feel ill equipped to face major industry trends

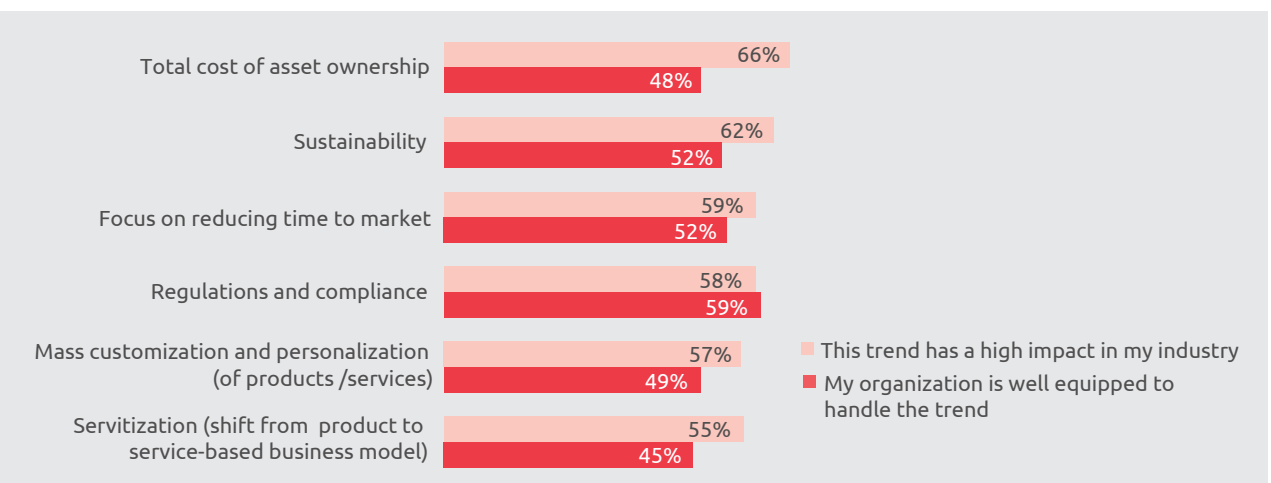
Servitization (a shift from products to service-based business models), sustainability, and regulatory compliance impact almost all organizations today, either directly or indirectly.

At the same time, organizations also need to continuously optimize total cost of ownership, time to market, and customer experience. However, our research shows that fewer than half of organizations feel they are able to meet these market demands. As many as 66% of organizations surveyed, for example, agreed that optimizing total cost of ownership of assets is an important factor impacting them; however, only 48% claimed to be well equipped to do so themselves.

Among the industries surveyed, the energy & utilities industry is struggling most to adapt to servitization and mass customization, with only 27% and 22% of respondents in this industry suggesting they are prepared to handle these trends, respectively.

Fig.1

Less than half believe they are equipped to tackle the major trends impacting them



Source: Capgemini Research Institute, Digital Twins survey, September–October 2021, N=1,000 organizations.

Regarding the areas of sustainability and total-cost-of-ownership (TCO) optimization, the life sciences industry is lagging, with only 26% and 28% of life sciences companies being confident of their maturity in these respective trends.

The consumer products industry is most heavily impacted by almost all of these market factors (with the exception of servitization and regulations and compliance) but is still lacking maturity, with just 36% of respondents saying they are well-equipped to handle them.

We also found that organizations are planning to dive deeper into the servitization trend in the next three years. Organizations estimate that the approximate share of revenue derived from service-based businesses is going to rise from the current 41% to 53% in this period. In a related projected trend, our research finds that 29% of systems within organizations today are smart and connected, with an expected increase in this trend to 35% within three years.

02

How digital twins drive higher performance and sustainability

Our research shows that organizations are looking to digital twins as a way to address the various challenges with which they are dealing.

A digital twin is a real catalyst for profitability and sustainability. It can function as a tool that allows experimentation with different scenarios and the opportunity to assess the impact of each decision without any real-world risks, thereby positively impacting key business metrics. This ensures effective decision-making and deployment of strategies that maximize profitability, maintain reliability, and improve sustainability.

Fig.2

Digital twin investments are driven by top and bottom lines as well as safety, sustainability, and brand reputation

Source: Capgemini Research Institute, Digital Twins survey, September–October 2021, N=1,000 organizations.

Digital twins positively affect both top and bottom lines

Digital twins allow organizations to improve on a number of metrics, such as costs, operational efficiency, turn-around times, and sustainability. Our research shows that organizations have realized a 13% decrease in costs, on average, across the various use cases of digital twins and a 15% increase in operational efficiency (see Figure 3).

Cost reduction, followed closely by technological advancement, are the top drivers of digital twin investments – with 79% and 77% of organizations, respectively, citing them as such. For the construction of Italian sports-car manufacturer Maserati's Ghibli model, the car's digital twin helped provide developers with information for continuous optimization, which, in turn, helped them reduce both the costs and the time required for development by an impressive 30%.[6] Acciona, a Spanish conglomerate working in infrastructure management and renewable energy, is developing a digital twin to improve water treatment in one its Middle Eastern desalination plants. The digital twin will enable testing of operational data in the process control system before implementation. This makes the process validation simpler and allows optimization of system operations.[7]

Clarifying the importance of digital twins, Surjya Kanta Pal, Professor of Mechanical Engineering and Head of the Advanced Manufacturing Technology CoE at IIT Kharagpur, says: *"A digital twin gives you complete, real-time visibility of your system. It affords greater reliability of your systems and equipment, as it can identify faults and predict availability and remaining useful life. This, in turn, allows you to increase your system's performance and reduce downtime, resulting in increased production rates and reduced costs."*

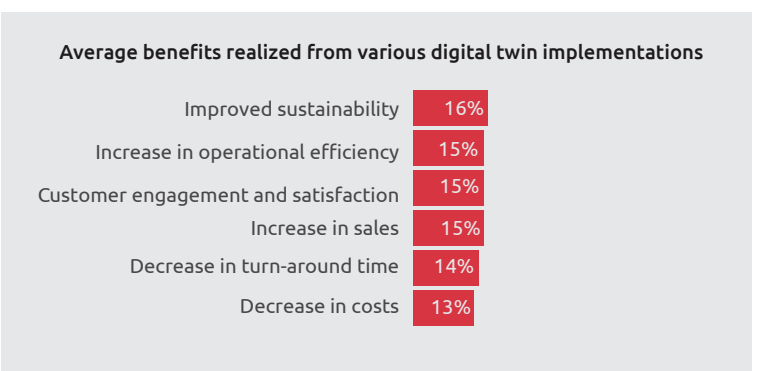
Digital twins can also greatly reduce time to market, which is the third-most cited driver of adoption, at 73%. With the use of digital twins, processes required to assemble cable harnesses for the Airbus A330 could be carried out in one-fifth of the time previously required.[8] This was achieved because the digital twin could provide the seed for automatically generating manufacturing instructions so that, through tablets and augmented reality (AR) glasses, operators were able to assemble products following the instructions on the devices. Digital twins also allow virtual testing, checking for errors before manufacturing, and improving designs and services – further reducing development time.[9]

Another important driver for digital twin implementations is increased operational efficiency. An executive from an industrial aluminum manufacturing organization, echoes this sentiment:

"We measure any new digital twin implementations against two basic KPIs. The first is whether it helps the customer, such as through improved quality, which reduces the rate of rejection. And the second is whether it brings operational excellence, which includes reducing unplanned downtime. These two focus areas help in our return on capital employed."

Fig.3

Organizations realize a multitude of benefits from their digital twin implementations



Source: Capgemini Research Institute, Digital Twins survey, September–October 2021, N=800 organizations with ongoing digital twin programs, benefits averaged across the various use cases.

"A digital twin gives you complete, real-time visibility of your system. It affords greater reliability of your systems and equipment, as it can identify faults and predict availability and remaining useful life."

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Digital twins enable new business models

As seen in Figure 2, introducing new business models is another major driver of digital twin investments. In an instance of a cross-industry relationship driving new business models through digital twins, Canadian mining start-up The Metals Company (TMC), in collaboration with Swiss construction engineering company Allseas, is developing a deep-sea nodule-collection system to responsibly recover polymetallic nodules[10] from the sea floor and transfer them to an onshore processing plant.[11] In advance of testing this initiative, TMC and Norway-based Kongsberg Digital are jointly creating a digital twin to enable 3D visualization of deep-sea operations in a dynamic dashboard for review by various stakeholders. While polymetallic nodules sit on the seafloor in complete darkness at depths of up to 4 km, the digital twin will allow TMC to collect polymetallic nodules in clear sight under laboratory conditions. The project is expected to be the "world's first operational and environmental industrial work surface for deep-sea polymetallic nodule collection."[12]

Digital twins also allow organizations to reshape their business models. Through advanced digital twins, organizations can employ "platform-as-a-service" (PaaS) models, which allow them to deliver value to customers in new ways. For instance, Germany-based compressed-air specialist, Kaeser Kompressoren, is using a simulation-based digital twin system to enable the company to digitalize its sales process.[13] To increase the efficiency of its "configure, price, and quote" system, Kaeser has introduced "simulation-as-a-service" (SimaaS) for the technical verification of customers' proposed configurations. While the customer benefits from a convenient view of their product configuration and greater surety of purchase experience, Kaeser derives lower cost of sales from its digital twin implementation.

How digital twins bridge physical and virtual worlds

According to Kari Tammi, Associate Professor at the School of Engineering at Aalto University, *"Digital twins can be the missing business use case for intelligent and connected systems. They can harness the power of data collected from the connected systems to tune capacity, optimize production, or make products more efficient in the real world."*

As a virtual replica of a physical system, a digital twin is a reliable tool for bridging the "physical-digital gap," allowing risk-free, low-cost system improvement.

A digital twin offers a single place for collaboration. Moreover, the modifiable virtual replica of a physical system allows continual monitoring and optimization along the system's lifecycle and across ecosystems. In this context, a 'system' could refer to a product and its related service, a production line, an infrastructure, a logistic network, and beyond that, a system of systems.

Digital twins offer a platform for the physical world to intersect with the digital. The following three key channels enable this bridging of the physical and the virtual:

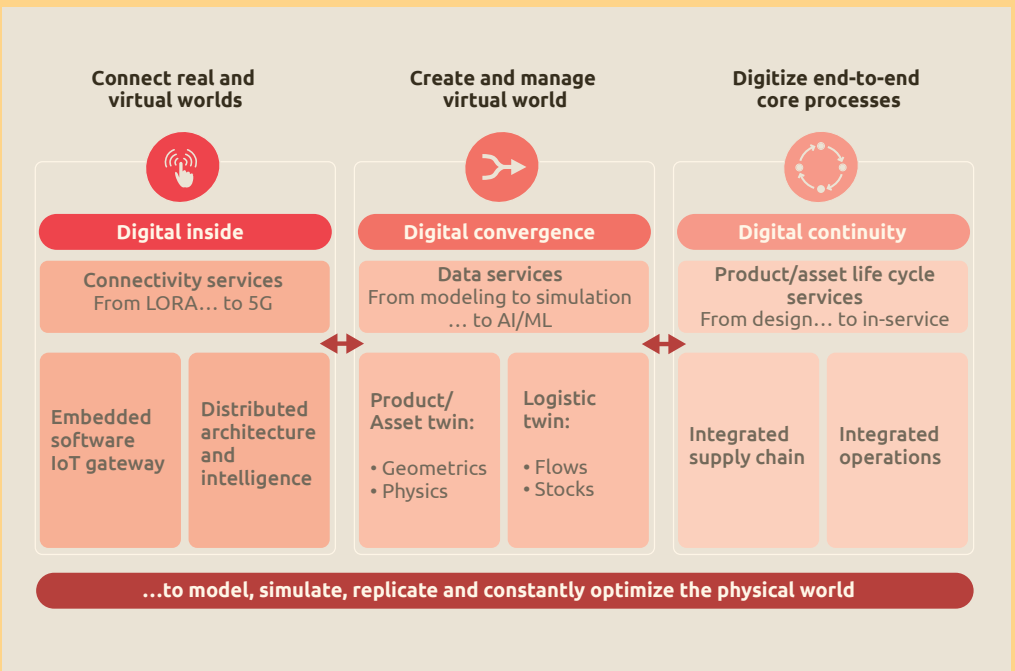
+ **Digital Inside** is vertical integration through technologies harnessing the full power of distributed architecture and intelligence: software, connectivity, and security.

+ **Digital Continuity** is the horizontal integration of processes that use the power of ever maturing cloud-enabled platforms supporting end-to-end processes such as product/asset lifecycle management, supply chain management, and asset or after-sales management.

+ **Digital Convergence** is the integration of system modeling, simulation, monitoring, and analysis into ever-more powerful systems.

Fig.4

Digital twins connect the physical and virtual worlds



Source: Capgemini.

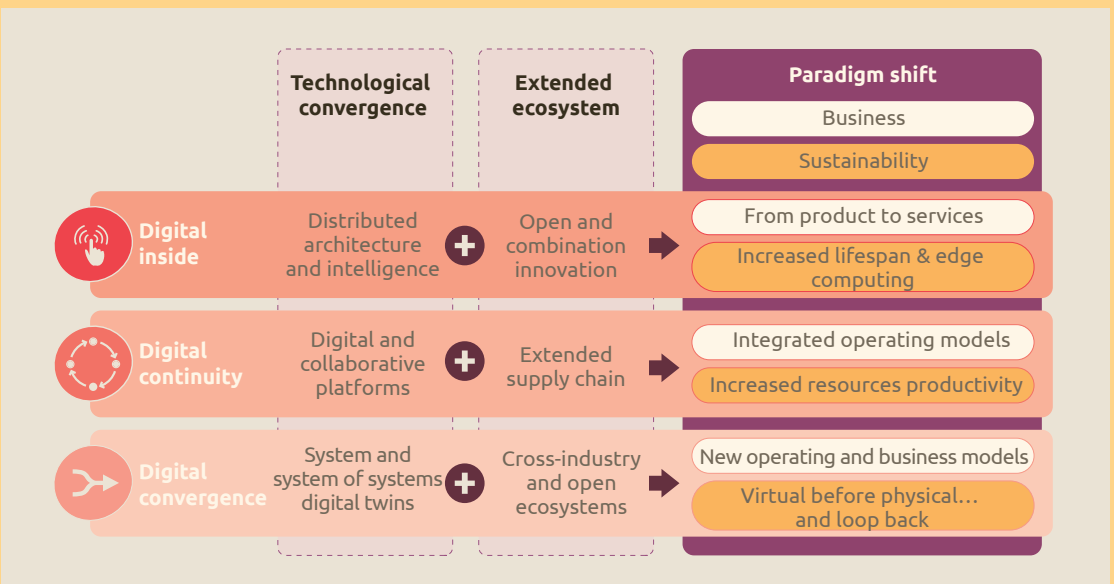
Open ecosystems and combination innovation[14] will allow organizations to take full advantage of distributed architecture and intelligence to drive servitization strategies. They will also help extend hardware lifespans and facilitate edge computing (in which data is processed as close to the source as possible) for improved sustainability.

Digital continuity will make extended supply chains a reality and optimize operating models through seamless intra- and inter-company collaboration, while increasing resource productivity. It will also allow recycling of scarce resources and sharing of operational resources such as transport, as well as optimization of load rates.

Meanwhile, digital convergence will enable the development of new and sustainable business and operating models, such as end-to-end mobility, integrated supply chain, and circular economies. This is made possible by empowering cross-industry and open ecosystems around a system, while optimizing existing capabilities all along the value chain.

Fig.5

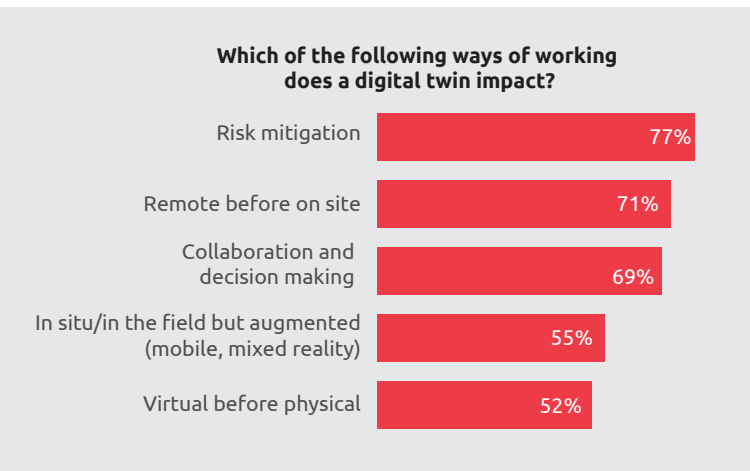
Extended ecosystem and technological convergence together drive intelligent industry



Source: Capgemini.

Fig.6

Digital twins provide a digital and flexible way of working



Source: Capgemini Research Institute, Digital Twins survey, September–October 2021, N=1,000 organizations.

Digital twins augment employee experience by improving safety, allowing collaborative ways of working, and supplementing training

Nearly four-fifths of the organizations surveyed mentioned that risk mitigation is a key factor that digital twin technology influences (see Figure 6). Digital twins allow organizations to reduce health and safety risks for employees in addition to reducing supply-chain risks.

Digital twins can increase employee safety by supporting remote operations and removing the need for direct human involvement in physically dangerous work situations. Sixty-four percent of surveyed organizations cite increasing employee safety as a driver of their digital twin investments. Through its digital twin Echo, Equinor, an international energy company, has been able to achieve a reduction of up to 50% of offshore man hours at its Johan Sverdrup oil field, cutting down significantly on employee exposure to risks.[15] According to an executive working with a multinational energy firm, *"The energy industry is one of the most advanced in the adoption of digital twins, because it can be unsafe. If you have a platform where you have people and there is a strong physical risk of accidents, the processes on that platform are the first that you want to automate. Not just that, you also want to control the risk variable. For us, that is one of the strongest implementations of digital twins."*

Digital twins also allow teams to work in a flexible manner, enabling remote access and collaboration. Shawn Sehy, General Manager at Nissan Motor Corp., speaks to this benefit: *"Design and engineering are very mature areas in terms of digital twin implementations, and the pandemic actually expedited that a lot. While designers couldn't physically meet each other, they could sit in their own homes with Oculus glasses [virtual reality headsets] on and go into a digital space with other executives and inspect the entire car. It does eliminate the need to travel and to get people in a single room to be able to work on design and engineering aspects."*

Royal Dutch Shell is constructing a digital twin of its Pulau Bukom manufacturing site in Singapore. Upon planned completion in 2024, the organization is expecting approximately 25% improvements in levels of productivity, reliability, and safety. Shell has dubbed this project a means by which "to transform the ways to work." XR – including AR, virtual reality (VR), and mixed reality (MR) – along with connected tablets, will allow real-time collaboration. Narayanan Valayaputtur, Projects and Engineering Manager, comments: *"Shell Bukom's digitalization plans, anchored by the digital twin, constitute a shake-up of the plant. With the setting up of a virtual plant through the digital twin, and by equipping staff on site with tablets, we are creating a new culture of remote work, with the provision of complex data at employees' fingertips. This is an exciting time, as we are not just building digital assets, but also a new digital culture. We are telling our staff to pursue their interests in becoming data scientists or software engineers, all while working in a manufacturing plant with our playground of data."*[16]

The digital twin system has brought the concept of efficiency by design much closer to becoming a reality.

Digital twin-enabled XR proves to be useful for another key area – that of industrial training. Equipped with accurate, detailed, and true-to-life data from digital twins, XR tools can precisely replicate scenarios workers may find themselves in, and help them "learn by doing" in a safe environment. Honeywell's Immersive Field Simulator, a VR and mixed reality-based training tool that incorporates a digital twin of the physical plant, uses this concept to provide targeted, on-demand, skill-based training for workers.[17]

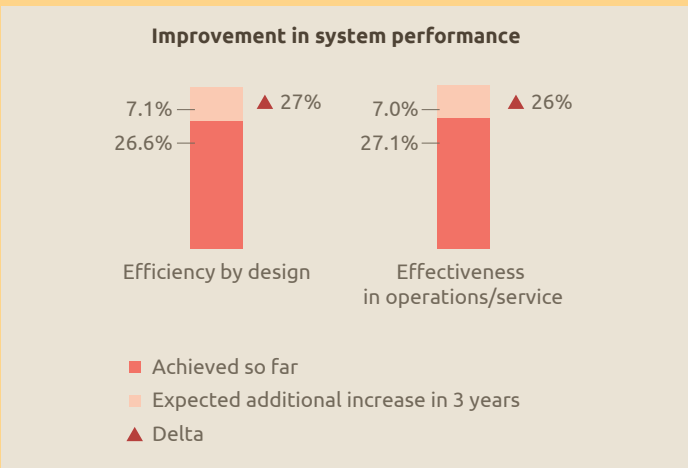
Organizations are targeting a further increase of 25%+ in system performance

Driven equally by efficiency by design, and increased effectiveness of operations and services, organizations hope to improve performance of their systems by a further 25% or more, taking the overall improvement to more than 30%.

The digital twin system has brought the concept of efficiency by design much closer to becoming a reality. Digital twin technology essentially allows operational efficiency to be fully tested at the digital design stage, reducing the need to review and rework a prototype, saving time and financial costs. Generating a virtual simulation of new products and systems before creating physical versions creates the possibility of "getting it right first time." According to our research, 67% of organizations believe simulation is an impactful data service offered by a digital twin, justifying its use.

Fig.7

Organizations hope to improve overall performance by 25%, equally driven by efficiency by design and operational effectiveness

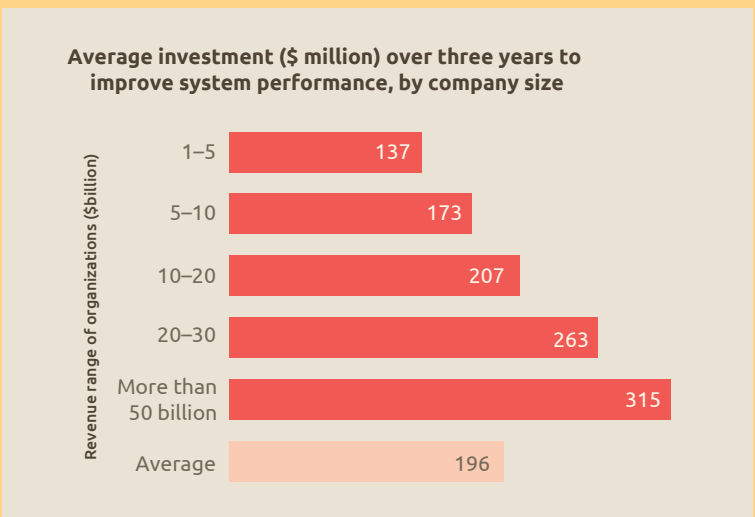


"Delta" represents the differential in what has been "achieved so far" and the overall increase expected in next 3 years. Source: Capgemini Research Institute, Digital Twins survey, September–October 2021, N=1,000 organizations.

Towards the effort to improve system performance, on average organizations plan to invest nearly $200 million over the next three years. The size of investment planned is directly proportional to the size of the organization, with organizations with enterprise-level revenue greater than $50 billion setting aside more than $300 million on average for these investments.

Fig.8

Organizations are planning to invest nearly $200 million on average over three years



Source: Capgemini Research Institute, Digital Twins survey, September–October 2021, N=1,000 organizations.

Digital twins are enabling a sustainable future

Digital twins can help organizations understand and quantify the impact of decisions already taken, as well as compare various scenarios that can help forecast the outcome of different decisions. As such, they can help reduce waste, increase efficiencies, propose interventions, and possibly automate change – helping organizations and societies become more sustainable as they become more digital.

Moreover, profitable growth and sustainability have, to date, mostly been governed by distinct agendas that are more parallel than convergent. However, since digital twins are powered by intangible assets like data and collaboration, they provide a unique opportunity to increase profitability, while limiting the use of resources along the value chain. This is made possible through digital twins' ability to be virtual before physical, allow remote before in-situ, be in situ but augmented, and provide a closed feedback loop.

Some use cases of digital twins that can be implemented in different industries to secure a more sustainable future – environmentally, socially, and economically – are shown in figure 9.

Digital twins provide a unique opportunity to reconcile profitable growth and sustainability.

01

Energy & utilities
Digital twins reduce the need for personnel to be present at risky onshore fields by enabling remote operations, thereby improving employee safety

02

Automotive
Digital twins can aid the design and testing process and reduce waste by enabling modeling and ensuring physical versions are right the first time

03

Aviation
Utilizing data from an electric propulsion system, digital twins used in the design phases of new aircraft can optimize in-service performance and lifetime robustness

04

Manufacturing
Digital twins provide models of "the best way" to run a process in a given environment, resulting in reduced product waste

Fig.9

Digital twins help advance sustainability initiatives across industries

05

Smart cities
Among various uses, digital twins can reduce emissions by managing traffic, make cities safer by identifying disease hotspots, and monitor energy efficiency

06

Buildings
By integrating real-time data and information received from sensors, digital twins can identify areas where energy is being wasted

07

Healthcare
Digital twins support more extensive research and quicker therapy development by accurately simulating the human body

08

The Earth
Work is under way to create a digital twin of the Earth to help combat climate change by simulating the atmosphere, oceans, and human systems

Source: Capgemini

Digital twins are enabling a sustainable future

Digital twins help advance both environmental sustainability (through efficiency by design and operational efficiency) and social sustainability (through drug development, personalized medicine).

+57%

Agree that one of the key drivers of their digital twin investments is improving sustainability efforts

Benefits range from process efficiencies cutting down on emissions and waste, to the ability to test the viability of new, sustainable materials

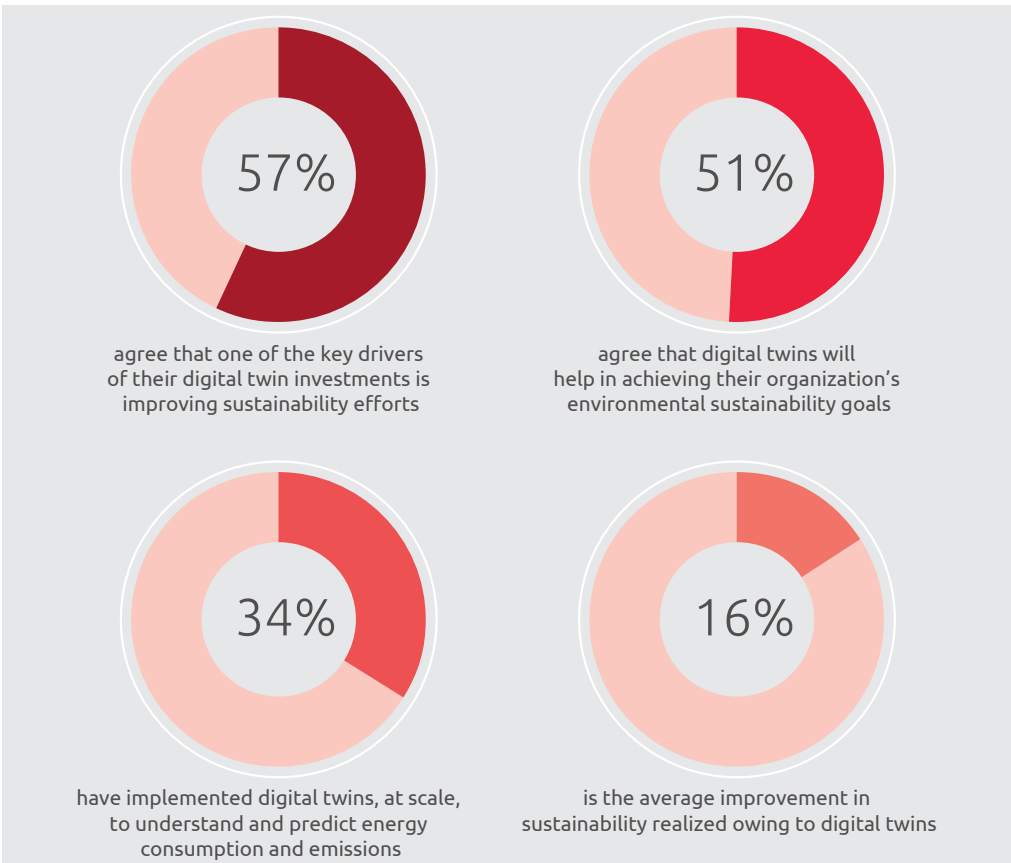
Organizations are largely convinced of the advantages digital twins can provide to advance their sustainability efforts; 51% of digital twin implementers surveyed agree that digital twins will help in achieving their organization's environmental sustainability goals. Moreover, 57% say that improving sustainability efforts is one of the key drivers of their digital twin investments.

Many organizations are already invested in their quest to use this technology to advance their sustainability agendas, with 34% having implemented digital twins at scale to understand and predict their energy consumption and emissions. The consumer products and energy & utilities industries are leading in implementations for this use case, with 52% and 50% of surveyed organizations in these industries, respectively, utilizing digital twins for sustainability.

Even at these initial stages, organizations have begun seeing an average improvement of 16% in their sustainability metrics through digital twin implementations across various use

Fig.10

More than half of the surveyed organizations lean on digital twins to improve their sustainability, and a few are already reaping the benefits



Source: Capgemini Research Institute, Digital Twins survey, September–October 2021, N=800 organizations with ongoing digital twin programs.

cases. With increased uptake of more complex digital twins, this percentage is expected to increase.

A number of organizations are already benefitting from the sustainable edge that digital twins provide.

Urban planning: Singapore's digital twin, called Virtual Singapore, is being used to identify where best to build solar panels by assessing light and temperature variation across the country. *"In this way, modelling and simulation help us optimize the amount of clean energy we can harness from the sun, in land-scarce and heavily built-up Singapore,"* explains Tan Kok Yam, Deputy Secretary (Smart Nation and Digital Government) of the Prime Minister's Office.[18]

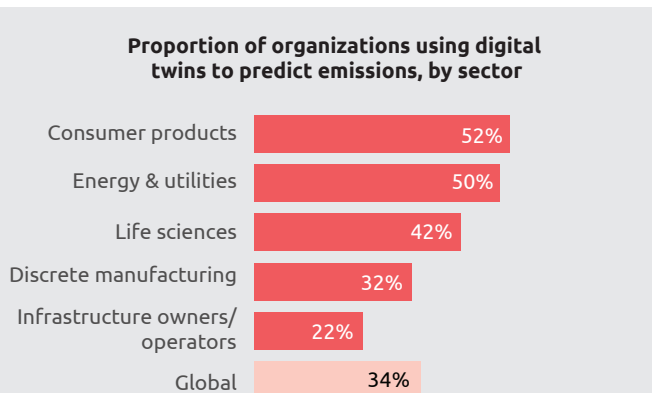
Infrastructure: Digital twins can be used to help owners of commercial buildings dramatically reduce carbon emissions. They can also significantly improve efficiencies and lower operating costs as seen in the NTU's example. The predictive nature of the digital twin can also be used to test the suitability of new materials. Construction company Lendlease recently built a digital twin to test and determine the viability of building a multistorey complex in Melbourne, Australia from sustainable timber.[19] While this timber had been used previously in construction, it had not been tested in high-rise buildings (in this case, a 29-story apartment tower).

Siemens, in one of its projects with a German city of about 200,000 residents, modeled the city's energy demand and infrastructure using a digital twin and found that cutting emissions by 70% by 2035 would be a perfectly feasible target.[20]

Energy & utilities: The development of five digital twins of platforms operated by Neptune Energy, an international oil and gas exploration and production company with a regional focus on the North Sea, North Africa and Asia Pacific, is expected to enable engineers and integrity specialists to carry out an estimated 4,100 hours of work from onshore locations, improving efficiency and cutting carbon emissions associated with offshore travel. Additionally, digital twins of two new platforms have also recently been developed, which will support planning of Neptune's major carbon capture and storage (CCS) project in an area capable of storing

Fig.11

Consumer products, energy & utilities, and the life sciences industries lead implementation of digital twins to understand and predict energy consumption and emissions



Source: Capgemini Research Institute, Digital Twins survey, September–October 2021, N=800 organizations with ongoing digital twin programs.

more than 50% of the carbon dioxide volumes being targeted by the Dutch industrial sector.[21]

Aviation: Rolls-Royce's digital twin-enabled platform has helped it extend the time between maintenance for some aircraft engines by up to 50%, thereby enabling it to reduce dramatically its inventory of parts and spares. Perhaps more importantly, it has also greatly improved the efficiency of its engines through this platform. *"Since 2014, we've helped one of our airlines avoid 85 million kilograms of fuel and over 200 million kilograms of carbon dioxide,"* says Stuart Hughes, Chief Information and Digital Officer at Rolls-Royce.[22]

Automotive: In Capgemini Research Institute's discussion with Renault CIO Frédéric Vincent,[23] he revealed how the car-crash safety test, which was earlier conducted "by throwing the car into a wall… multiple times," could become more efficient through the use of a digital twin of the car in the cloud to simulate the crash and update, upgrade, and change required parameters.

Healthcare: With reference to the social aspect of sustainability, GSK and Siemens are collaborating to digitalize the vaccine development and production process in an effort to shorten development times for vaccines, allowing them to reach people faster and with optimum quality.[24]

In the life sciences sector, digital twins are being applied in medical-device manufacturing as well as in drug development and personalized medicine. Gerd Hoefner, Senior Vice President at Siemens Healthineers, comments: *"[Digital twins] can be used not only for diagnosis but also for testing the safety of treatments. For example, we could assess the effectiveness of certain cardiac drugs on a digital twin's heart. Digital twins can also be used to digitally simulate cardiac catheter interventions and heart surgery in advance, to determine if there's a realistic chance of success."*[25]

Another effort, named the Living Heart Project, is attempting to develop and validate highly accurate personalized digital models of the human heart, which will establish a unified foundation for cardiovascular in silico medicine and serve as a common technology base for education and training, medical device design, testing, clinical diagnosis, and regulatory science – creating an effective path for rapidly translating current and future cutting-edge innovations directly into improved patient care.[26]

Consumer products: Kim Kirkconnell, Vice President, IT Global Digital Supply Chain, Kimberly-Clark, speaking to their sustainability efforts, commented: *"We are using technology and innovation in various areas. For instance, in North America, the Huggies brand introduced diapers made with plant-based ingredients. We are already using sensor analytics to track our energy and water consumption to monitor our footprint. In the future, we will be looking at opportunities to apply digital twin technology in making our products more sustainable."*[27]

In another example, Unilever is making use of digital twins at a facility in Brazil to make production more efficient. The company used a digital twin to set manufacturing parameters; for example, the temperature at which soap is pushed out before being cut into bars. The project resulted in a saving of $2.8 million by reducing energy usage and improving productivity by 1–3%.[28]

Organizations will significantly increase digital twins' deployment

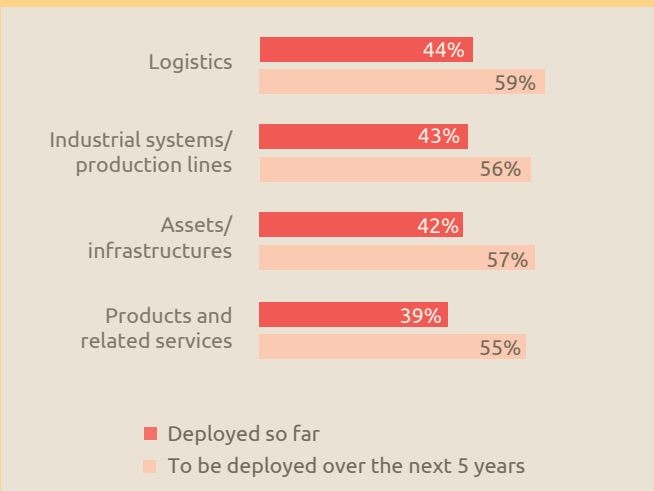
Digital twin implementations are set to increase by 36% on average over the next five years

Organizations aspire to increase digital twin deployments in the near future. Of every 100 physical "systems" within an organization with digital twin implementations, on average 42 are already using a digital twin. In the next five years, this number is projected to increase to 57, a growth of approximately 36%. Since our survey uses a targeted sample of organizations already having a digital twin program, the base numbers are higher than the absolute market adoption numbers.

The deployment of digital twins is fairly balanced between greenfield, brownfield, and a mixture of the two, with about 30% of organizations marking each as their preferred method. The energy & utilities industry has the highest percentage of brownfield deployments across all industries, with 40% of implementers within the sector classifying their digital twin deployments as brownfield, and 33% adopting a mix of greenfield and brownfield.

Fig.12

Organizations already working on digital twins are set to increase their deployments



Source: Capgemini Research Institute, Digital Twins survey, September–October 2021, N=800 organizations with ongoing digital twin programs.

"In the future, we will be looking at opportunities to apply digital twin technology in making our products more sustainable."

Kim Kirkconnell

Vice President, IT Global Digital Supply Chain, Kimberly-Clark

03

Digital twins add value throughout the value chain

A digital twin, in its simplest form, is a virtual twin of a single component or a single unit of equipment, such as a robotic arm. This is a unit-level digital twin. By architecting and connecting such simpler twins, a system-level digital twin can be constructed. This will augment the efficiency gains realized from the individual twins. For example, a digital twin of a production line, a system-level twin, can be created by connecting digital twins of multiple machines. Extending this further, a digital twin of a factory or even of a network can be created by connecting multiple production lines/factories together (a system-of-systems digital twin).

When we look at what the digital twin is being used to simulate, broadly, it can be categorized as a product, asset, or network twin. In fact, a product or a system can have multiple digital twins – for instance, one twin covering the design, one twin covering the production, and one for the maintenance part. Depending on whether we are looking at the twin of a product or an asset or a logistics network, there are a variety of ways in which value is derived or added. A digital twin can, based on use case, be broadly classified into the following categories:

Product twin that allows faster time to market and improved system operations

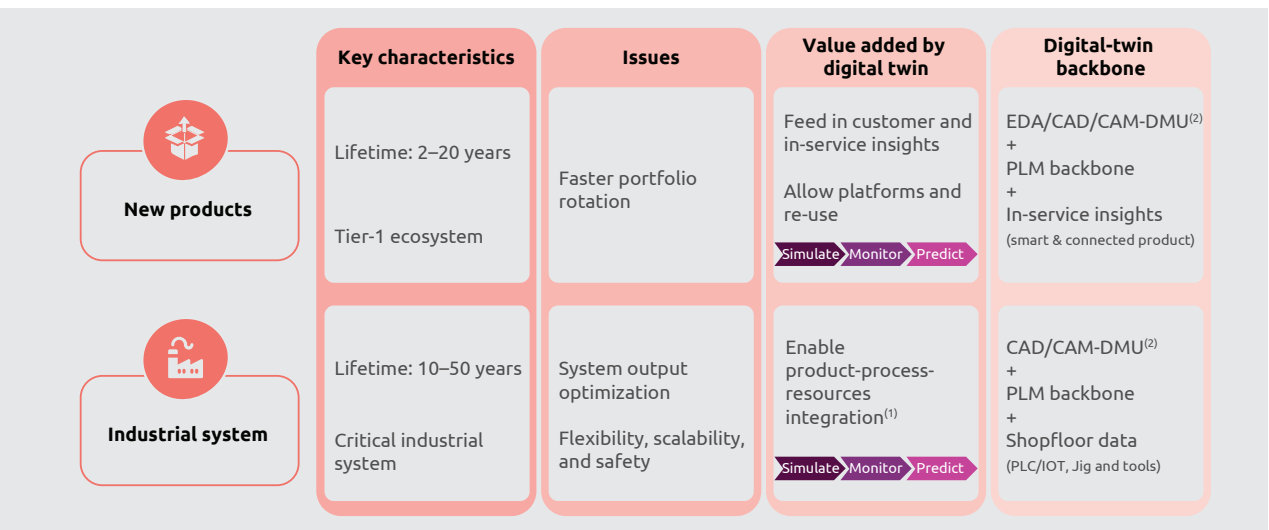
+ **New product:** during the design and development of new products, digital twins can be used to improve product design and reduce time to market and can also maintain engineering-manufacturing continuity.

+ **Industrial system:** digital twins of industrial systems allow integration of products, processes and resources, thereby improving the system output and providing scalability.

The automotive industry has been using digital twins, not necessarily under that name, in their design (such as the design of assembly lines) and engineering departments for more than a decade. Over the years, the applicability of digital twins has expanded and, today, digital twins can help automotive manufacturers achieve end-to-end digital continuity and thereby provide additional value to customers. Tesla, for example, relies on digital twins to improve its customer experience. It creates a digital twin of every car it sells; data from the sensors is fed into each car's simulation and, using AI, Tesla can determine whether the car requires maintenance or if it is working as intended. Further, Tesla can even update the car's software through over-the-air updates.[29]

Fig.13

Issues solved and value added by a product digital twin



(1) Manufacturing continuous processes will require dedicated design and simulation tools (2) CAD/CAM: Computer-aided design / manufacturing; DMU - Digital mockup; EDA – Electronic design automation.
Source: Capgemini analysis.

Extending the previous use case of Tesla further, digital twins can even be used to optimize the design of future products through generative design. Based on the data obtained from the products already in the field, digital twins, coupled with generative design, could be used iteratively to modify product design and simulate lifetime performance under real-world conditions.[30]

Talking about the predictability benefits, an executive working with the energy and utilities business of an Indian conglomerate, says, *"In the power industry, we essentially need to submit our power-generation schedule, in terms of how much power we are going to provide to the grid, and at what frequency, and our [back-up] plan if we are unable to do so. Through the use of digital twins, we now have a more predictable generation schedule, with very minimal potential deviation or variance, thereby avoiding the stringent regulatory and financial penalties characteristic of our industry."*

Figure 13 shows the key characteristics of a product twin, the business issues it can solve, and the value added.

Logistics twin that provides agility and resilience through simulations in addition to optimization

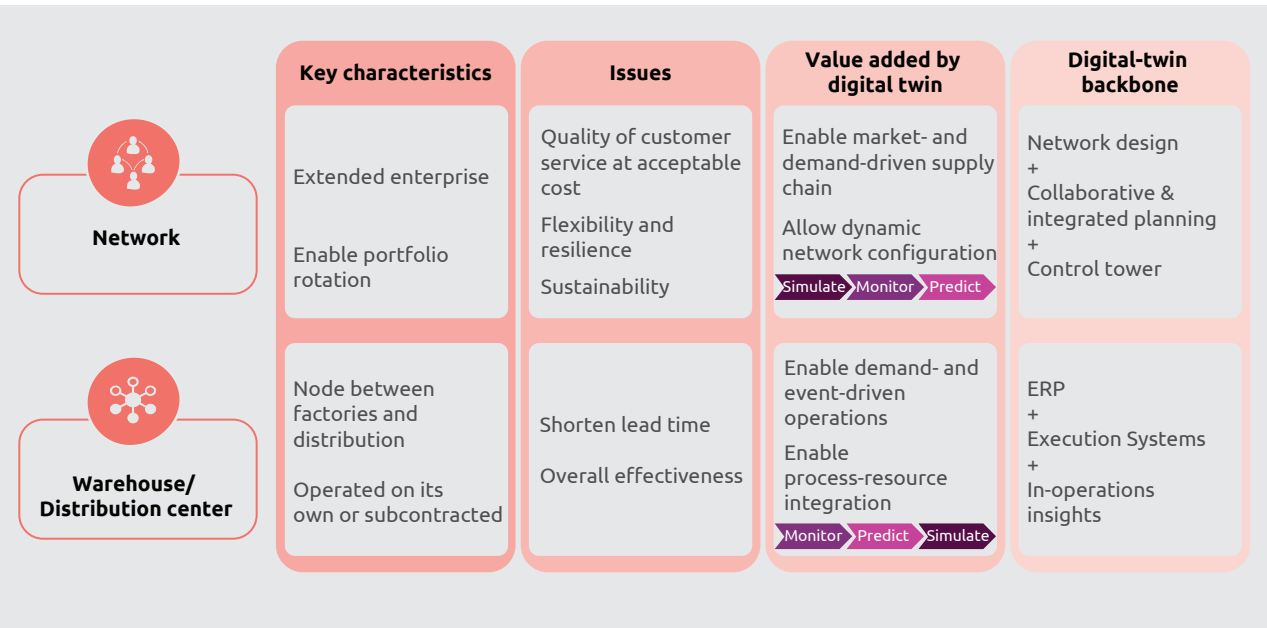
+ **Networks:** digital twins provide simulation of supply and demand networks, allowing organizations to improve performance, resilience, and sustainability for augmented customer centricity.

+ **Warehouse/ distribution center:** digital twins allow effective process resource integration in a warehouse or distribution-center context.

Philip Morris International (PMI) has created a digital twin of its global manufacturing footprint. This allows the company to assess the impact of changes in product portfolio, market regulations, and even business disruption. The solution allows PMI to run forward-looking optimization scenarios considering manufacturing cost, import/export duty, and transportation costs across the network. The company has consequently reduced the use of spreadsheet simulations by 90% and was able to decrease the time required for scenario evaluation from weeks to hours.[31]

Fig.14

Issues solved and value added by a logistics digital twin



Source: Capgemini analysis.

Asset twin that extends the lifetime of assets and moderates the total cost of ownership

+ **Existing assets/ infrastructure:** digital twins can lower the total cost of ownership (TCO) of existing infrastructure or assets by providing a single source of truth, as well as a data layer, allowing teams to collaborate in a seamless manner.

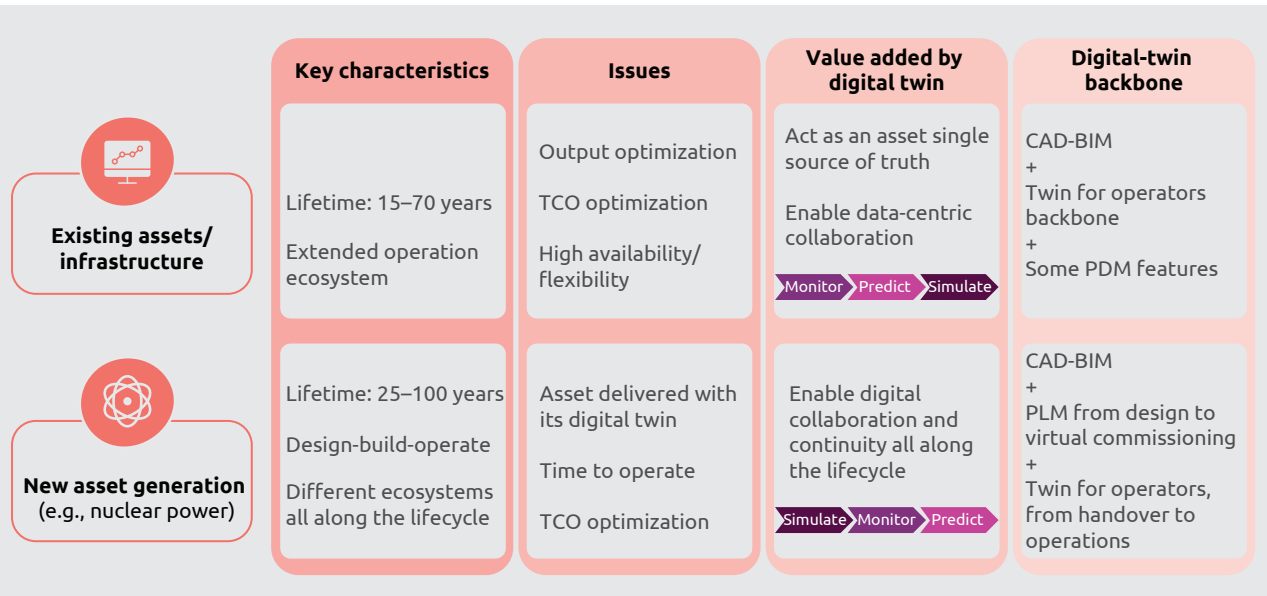
+ **New asset generation:** for new assets, digital twins will reduce the time to operate and also optimize the TCO.

BMW Group announced the design of a digital twin of an entire factory, which it can use to simulate the operation of 31 of its existing physical sites. Milan Nedeljkovic, Member of the Board of Management for BMW AG, says, *"All elements of the complete factory model — including the associates, the robots, the buildings and assembly parts — can be simulated to support a wide variety of AI-enabled use cases, such as virtual factory planning, autonomous robots, predictive maintenance and big data analytics."* This approach is expected to produce 30% more efficient planning processes.[32]

Neara, an Australian software company, enables utilities companies to design, simulate, and manage their assets (such as power lines). Daniel Danilatos, Founder and CEO, elaborates: *"In the past, if you wanted to look at a utility pole and understand how it behaves and if it needs replacing, it will take a lot of effort to make that decision accurately. If you wanted to make that decision across millions of assets [in this case, poles], you couldn't do it quickly. [Our software] mitigates the trade-off between the depth of understanding and the scalability [of the task]."*[33]

Fig.15

Issues solved and value added by an asset twin



Source: Capgemini analysis.

Digital twin systems allow data-driven decision-making all along the lifecycle and across ecosystems

Digital twins allow teams to collaborate on different kinds of data service. The greatest impact of digital twin technology comes from its ability to provide rapid access to the required data, as mentioned by 71% of the organizations in our survey. The quantum and the complexity of data is rapidly increasing day by day, and digital twins help designers, engineers, and analysts make sense of this data in an intuitive manner and gain valuable insights. An executive from a global energy organization says, *"An important way that digital twins help large organizations like theirs – that have large portfolios of assets around the world – is through standardization of data. Digital twins can help consolidate information and drive a common criterion in the way you save and read data. Apart from helping data management, this can also aid in breaking silos within the organization and working in a more integrated manner."*

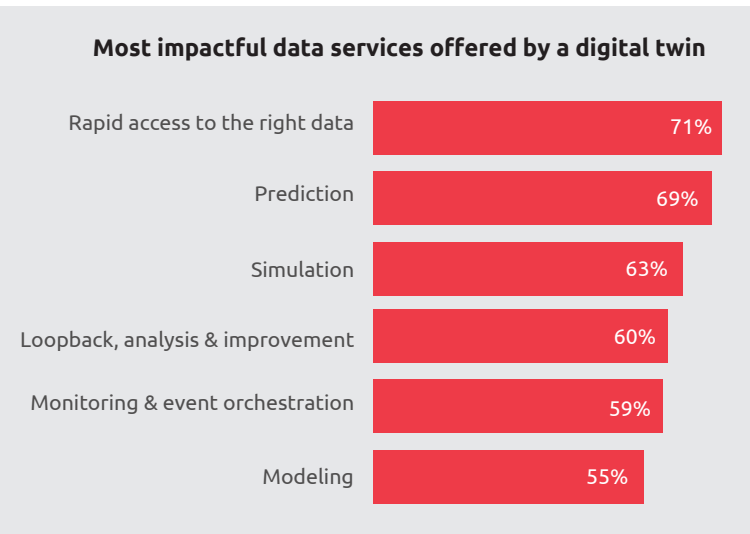
The second-top-rated use case is its ability to predict, with 69% ranking this as the most impactful service. As illustrated in Figure 16, digital twins also allow simulation and provide inputs to be fed back into design and development.

+69%

rank "Prediction" as the most impactful data service offered by a digital twin

Fig.16

Digital twins allow insight to be extracted from data in real time



Source: Capgemini Research Institute, Digital Twins survey, September–October 2021, N=800 organizations with ongoing digital twin programs.

digital twin

A product or a system can have multiple digital twins – for instance, one twin covering the design, one twin covering the production, and one for the maintenance part.

The path to successful digital twin deployment is not hurdle-free

Although organizations have realized the benefits and applications of digital twins, there are a number of challenges to successful deployment. We identified the following four major areas of challenges that are slowing digital twin deployment.

I: Overcoming a lack of strong vision, management support, and well-balanced governance

A lack of management support, coupled with operational problems, is, in some instances, causing digital twin implementation to fail.

- Even though 55% of organizations consider digital twins a strategic part of their digital transformation, around half of them (42%) lack a clear vision as to how to deploy them.
- While 59% of organizations claim to have drawn up a long-term (five years or more) roadmap to develop a digital twin system, about half of organizations (43%) report a lack of managerial commitment to digital twin initiatives and 49% face the challenge of a lack of investment in the concept.
- 56% of organizations are dealing with a lack of digital continuity across systems and processes, and 55% report a lack of cross-functional collaboration.
- The reported lack of strong governance also leads to inefficient program management: at one-third of the organizations surveyed, digital twin governance has not been formalized or is completely lacking.

II: Development of core business and collaborative skills

Further, digital twin implementation requires a specific skillset, the lack of which poses a challenge for many organizations. Figure 17, highlights the core business skills required for digital twin implementation and maintenance. Additionally, cross-functional collaboration is another critical skill (as cited by 58% of respondents); however, only 50% confirm that they have this skillset available within the workforce.

III: Deployment and integration of a secured end-to-end architecture

Additionally, a number of technological challenges are hindering organizations from realizing the full potential of digital twins within their specific contexts. With digital twins having to "speak" to many systems, including legacy systems, API integration, connectivity, and other measures are necessary to collect data. Inadequate internal digital infrastructure is further hindering progress in this respect; 67% of organizations say that insufficient cloud deployment and API integration constitute a major challenge for them.

IV: Empowerment of the ecosystem remains a significant challenge

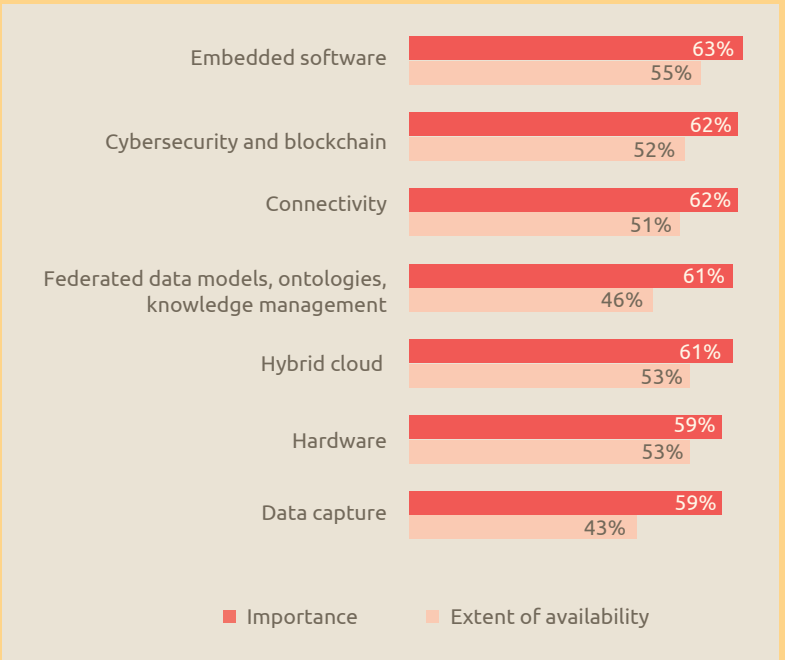
Large organizations find themselves dealing with hundreds or even thousands of suppliers. In order to work with these suppliers and other partners in a more efficient manner, collaboration platforms are essential. However, as shown in Figure 19 below, fewer than half have deployed such a platform for collaborative use with their partners (albeit, on average, this is projected to increase to 58% within the next three years).

+61%

organizations agree that federated data models and ontologies are necessary for digital twin implementation

Fig.17

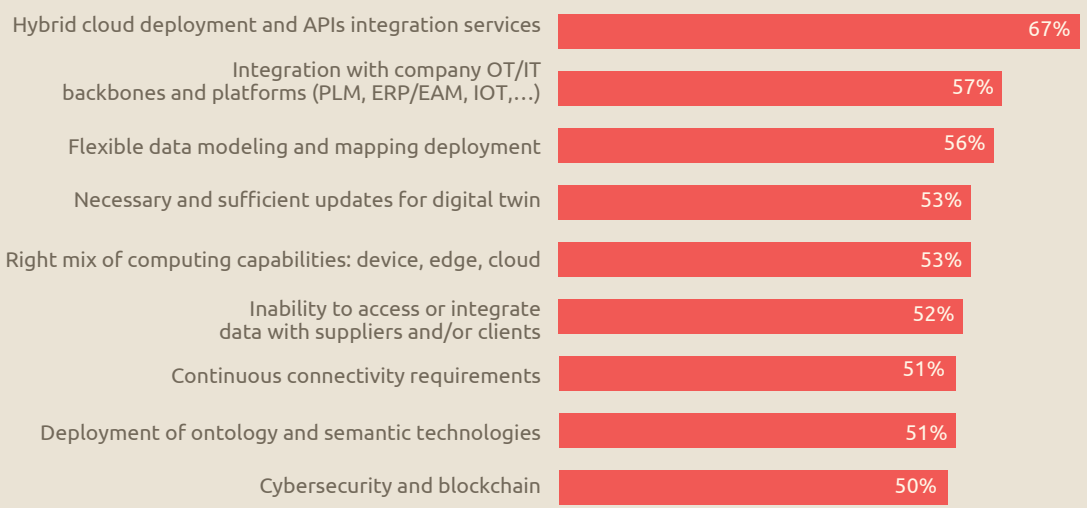
Core business skills necessary for digital twin implementation



Source: Capgemini Research Institute, Digital Twins survey, September–October 2021, N=800 organizations with ongoing digital twin programs.

Fig.18

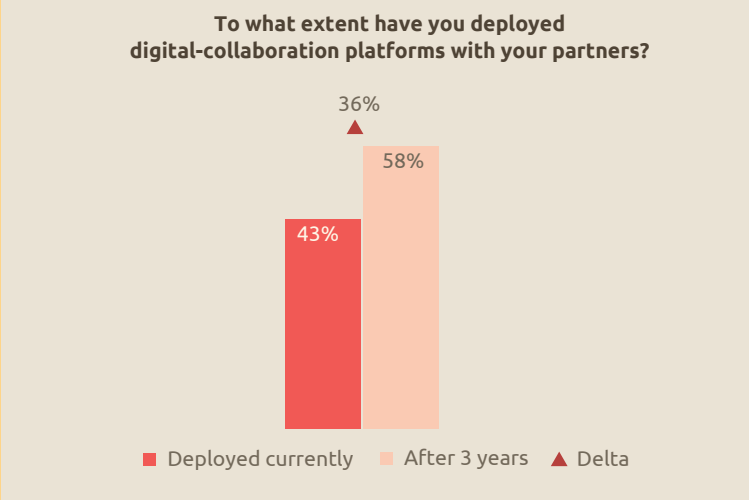
Technological challenges that impede the progress of digital twin deployment[34]



Source: Capgemini Research Institute, Digital Twins survey, September–October 2021, N=800 organizations with ongoing digital twin programs.

Fig.19

Collaboration within ecosystems and deployment of collaborative platforms will increase by more than 35%



Source: Capgemini Research Institute, Digital Twins survey, September–October 2021, N=800 organizations with ongoing digital twin programs.

“ {Digital twins} can be used not only for diagnosis but also for testing the safety of treatments.”

- Gerd Hoefner, Senior Vice President at Siemens Healthineers

04

Frontrunners in the digital twin journey win the greatest benefits

Who are the frontrunners in this digital twin transformation?

While digital twins allow organizations to enjoy a multitude of benefits, organizations do need to have certain elements in place in order to capitalize fully on the systemic enhancements. We analyzed the organizations in six affected areas:

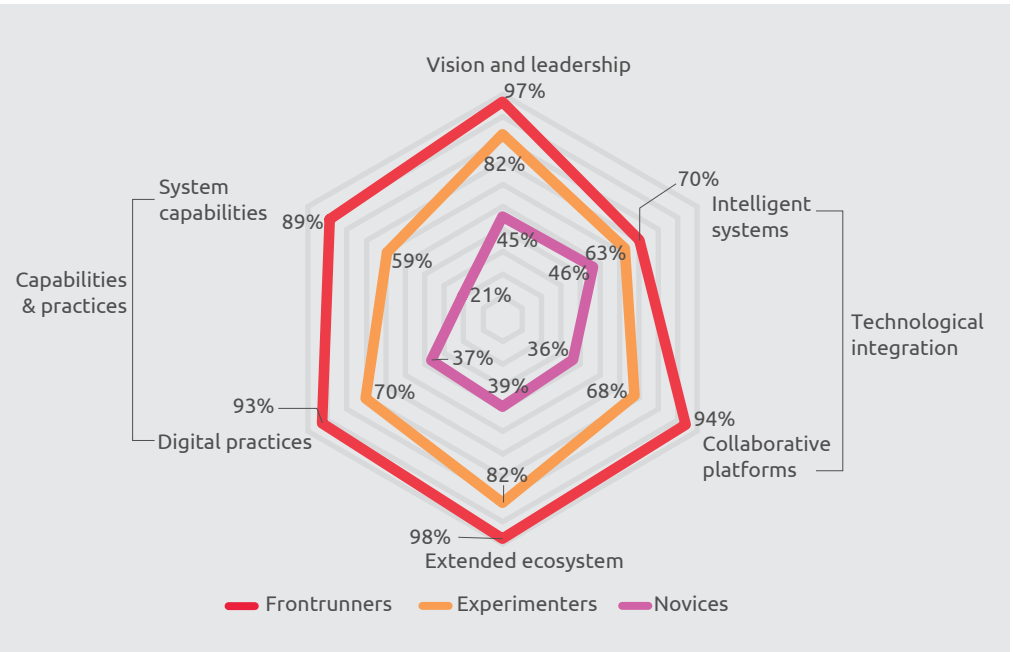
- Vision and leadership
- Technological integration
  - collaborative platforms
  - intelligent systems: smart, connected, and sustainable
- Capabilities and practices
  - system capabilities available
  - digital practices – data-driven and digital ways of working – within the organization
- Extended ecosystems

Based on the above, three cohorts emerged:

- **Frontrunners:** perform well in all areas (13% of the surveyed organizations)
- **Experimenters:** perform well in some of these six areas (10%)
- **Novices:** perform poorly in all areas (77%)

Fig.20

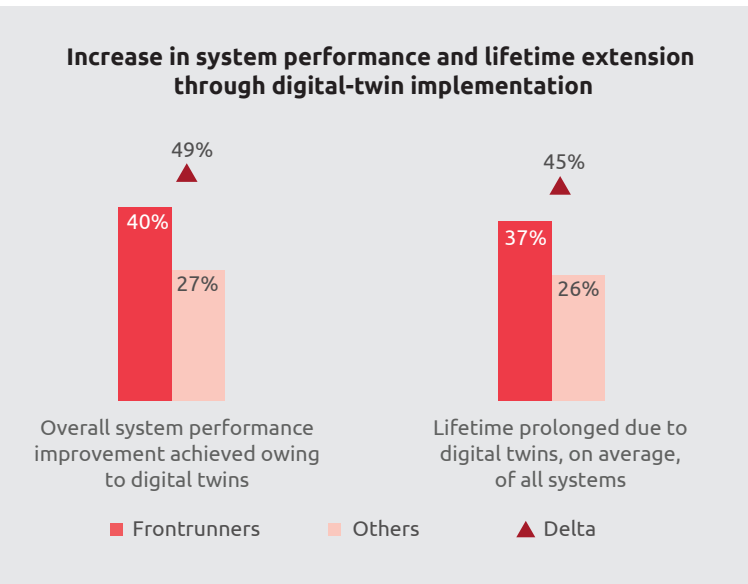
Frontrunners outperform others in all six areas of transformation



Note: Scores on each axis are rated from 0 to 100%, with 100% being a perfect score.
Source: Capgemini Research Institute, Digital Twins survey, September–October 2021, N=1,000 organizations.

Fig.21

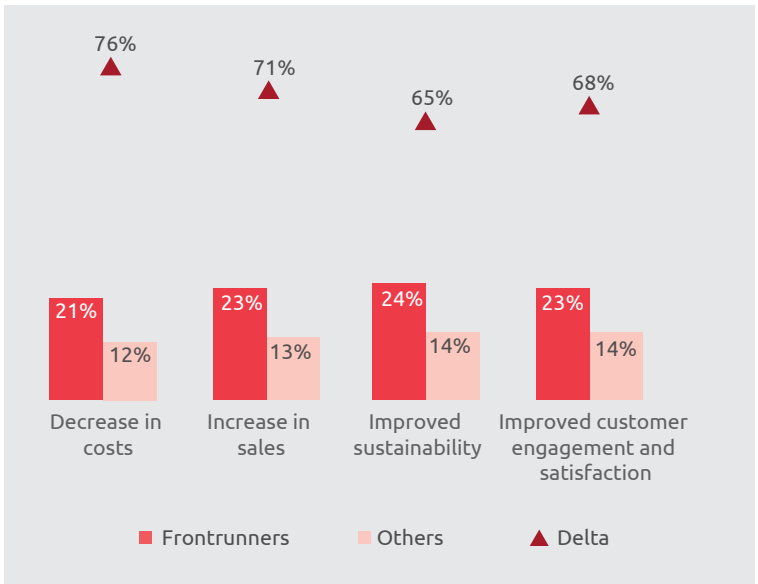
Frontrunners realize an additional 40%+ improved system performance and extended lifetime compared to others



Benefits are averaged across the five categories: products and related services, industrial systems/production lines, assets/infrastructures, logistics, and after-sales support and services. "Delta" represents the differential in improvement attained by the frontrunners.
Source: Capgemini Research Institute, Digital Twins survey, September–October 2021, N=131 frontrunners, N=869 other organizations.

Fig.22

Frontrunners realize anywhere between 65% and 75% higher benefits compared to others



"Delta" represents the differential in benefits attained by the frontrunners.
Source: Capgemini Research Institute, Digital Twins survey, September–October 2021, N=131 frontrunners, N=869 other organizations.

Frontrunners are able to realize significantly higher benefits

In our analysis, we found that frontrunners are in a position to realize higher benefits. Owing to digital twins, frontrunners on average report a 40% improvement in overall system performance, compared to 27% realized by others. One of the reasons for this is that frontrunners are able to utilize efficiency by design and achieve operational efficiency to a much greater degree.

Similarly, frontrunners report a 76% greater reduction in costs and 68% greater improvement in customer engagement compared to others (see Figure 22).

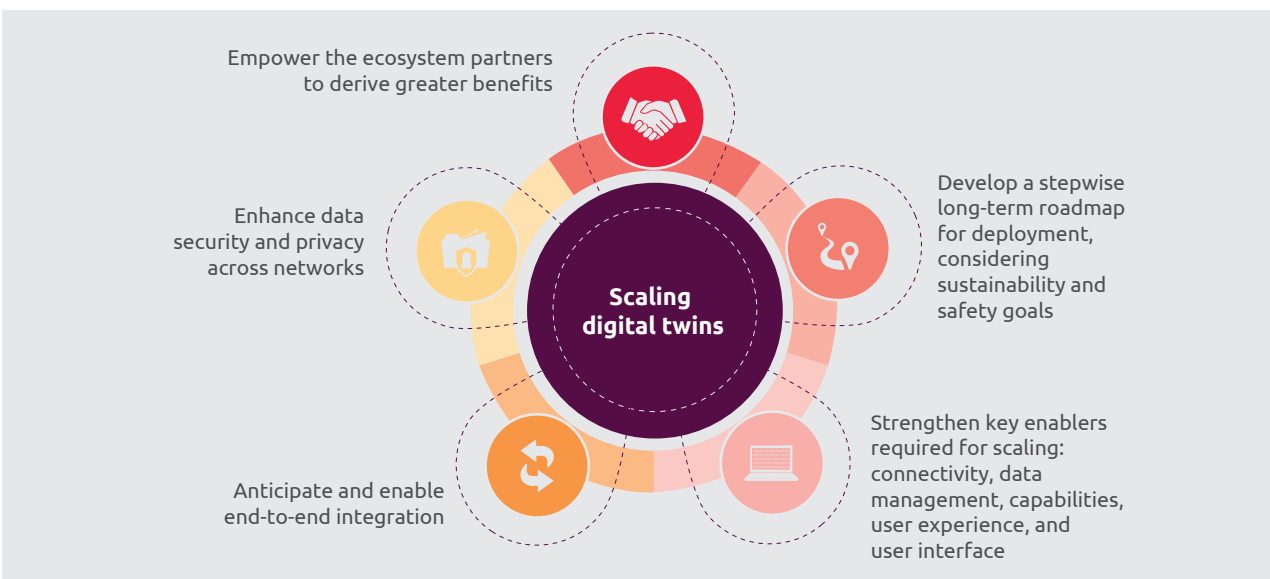
05

How to accelerate transformation through digital twins?

Organizations across industries are relying on digital twins to reduce time to market, improve their operational efficiency, meet their sustainability agendas, and improve their customer experiences. However, many are yet to install the required infrastructure to scale digital twins successfully and thereby enjoy the complete spectrum of benefits on offer. Drawing on the best practices employed by early adopters, our survey results, and our market experience, we have identified the following areas in which organizations need to invest to drive their digital twin transformation at scale.

Fig.23

Accelerating digital twin transformation



Source: Capgemini Research Institute analysis.

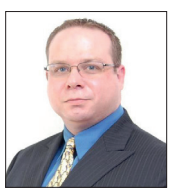
Develop a stepwise long-term roadmap for deployment, considering sustainability and safety goals

Organizations typically start their digital twin journeys with a pilot or proof of concept. It is important, however, to have a roadmap for scaling digital twin deployment. As many as 97% of frontrunners have a long-term roadmap (five years or more) for digital twins, compared to just 58% of others. A roadmap helps the organization identify the gaps in each function of the organization and the enablers (data management, skillsets, etc.) required to plug those gaps. The roadmap also ensures that the necessary funding is channeled towards these initiatives. While working with limited budgets for digital transformation and other on-going projects, organizations might also consider the safety benefits that digital twins bring, through virtual, remote, and augmented on-site approaches (see Section 2), as well as the sustainability benefits through optimal resource utilization, operational-efficiency improvements, and cost savings along the entire value chain. Another important point that organizations need to consider while deciding on the business case for digital twins is that not only do digital twins help with existing systems, but they also allow organizations to introduce new business models and unlock revenue opportunities.

Deploy use cases that will address repetitive pain points or strategic issues first

Full-scale digital twin deployment requires significant investment in terms of the software, time for deployment, skilled resources, and budget. So, once proof of concept is out of the way, it is advisable to take up the use cases where a digital twin has already proven beneficial, and where its application will address some pain points or strategic issues. Elaborating on their digital twin initiatives, Amy Sausen, former Global Director, Digital Technology at Kimberly-Clark, comments:

A well-thought-out design of your digital twin is critical – it is the compass needle, and you want to be going in the right direction from the beginning. ”



Sacha Porges

Global Director, Customer Quality & Programs at GKN Automotive

"The [digital twin] technology is not yet ready to help us in product innovation, because using fluid dynamics in a digital environment (for example, trying to model how a Kleenex tissue or a Huggies diaper absorbs moisture) can become very complex. However, using a digital twin to create an environment where a system can be monitored in real time, learning from that, and converting those insights into predictive or prescriptive actions is a stronger application because of the vast amount of data available within manufacturing operations. We are piloting the predictive maintenance use case for a machine currently, to understand when the machine might break down and the reason for breakdown."[35]

Address quick wins to convince employees of the value addition

Whatever the type of digital twin, the value can be unlocked only when employees interacting with the twin are able to use the application for analysis, course correction, or prediction. Working on quick wins such as tracking the flow of assets on a shopfloor, for instance, will help convince the employees of the value and also act as a lighthouse project.

A well-defined governance structure also helps establish which entity within the business owns the data generated from each digital twin and which entities are responsible for maintaining data hygiene (i.e., synchronization of the digital twin with the physical source, data quality, prevention of unauthorized changes to the data, etc.).

A key consideration for the governance team is ensuring that the employees who would be using the digital twins are aware that the digital twins can augment their work and aid in further decision-making. This means ensuring that the immersive experience provided to the employees is consistent with their operations. Organizations can achieve this by providing employees with the required platforms and tools to test the applications, while simultaneously learning in a supportive culture that encourages employees to upskill and innovate.

Strengthen key enablers required for scaling

In order to deploy digital twins at scale and obtain full benefit from the system, organizations must ensure certain foundations are in place.

+ **Secured connectivity:** Systems, organizations, and processes are ever more closely connected in today's business environment. Connectivity and security are required to ensure continuity of information from edge to cloud and from design to operations and services, all along the supply chain. Only then can the full benefits of the system be realized.

+ **Data management:** In order for the digital twins to model, simulate, predict and monitor effectively, data continuity and integration with multiple data sources is necessary. For digital twins to mimic operational behaviors, quick computation is critical. Further, the data from the various systems needs to be analyzed and interpreted. This can be accomplished in a speedy manner by setting up data interoperability a priori through an ontology or a series of ontologies. This can help manage the complexity of digital

Setting up data interoperability a priori through an ontology or a series of ontologies helps manage the complexity of digital twins.

"Using a digital twin to create an environment where a system can be monitored in real time is a stronger application because of the vast amount of data available."

Amy Sausen

Former Global Director, Digital Technology at Kimberly-Clark

twins and make relationships explicit. Some ontologies can also help in data modeling and address issues such as missing data and data security. Frontrunners recognize these challenges, with 95% mentioning that a unified data platform is essential to successful implementation of a digital twin, compared to just 54% of others who suggest the same.

As the digital twins scale, this challenge becomes even greater, and organizations must determine how to develop these ontologies, whether to use any current ones or to create new ones, and how these are going to be validated and maintained. To benefit fully from digital twins, organizations must design and deploy a data-management strategy. Digital twins can also be computationally very intensive, so organizations would also need to scale their infrastructures and scale up their cloud systems.

+ **Capabilities:** Organizations will also need to strengthen certain skillsets in order to design and operate digital twins.

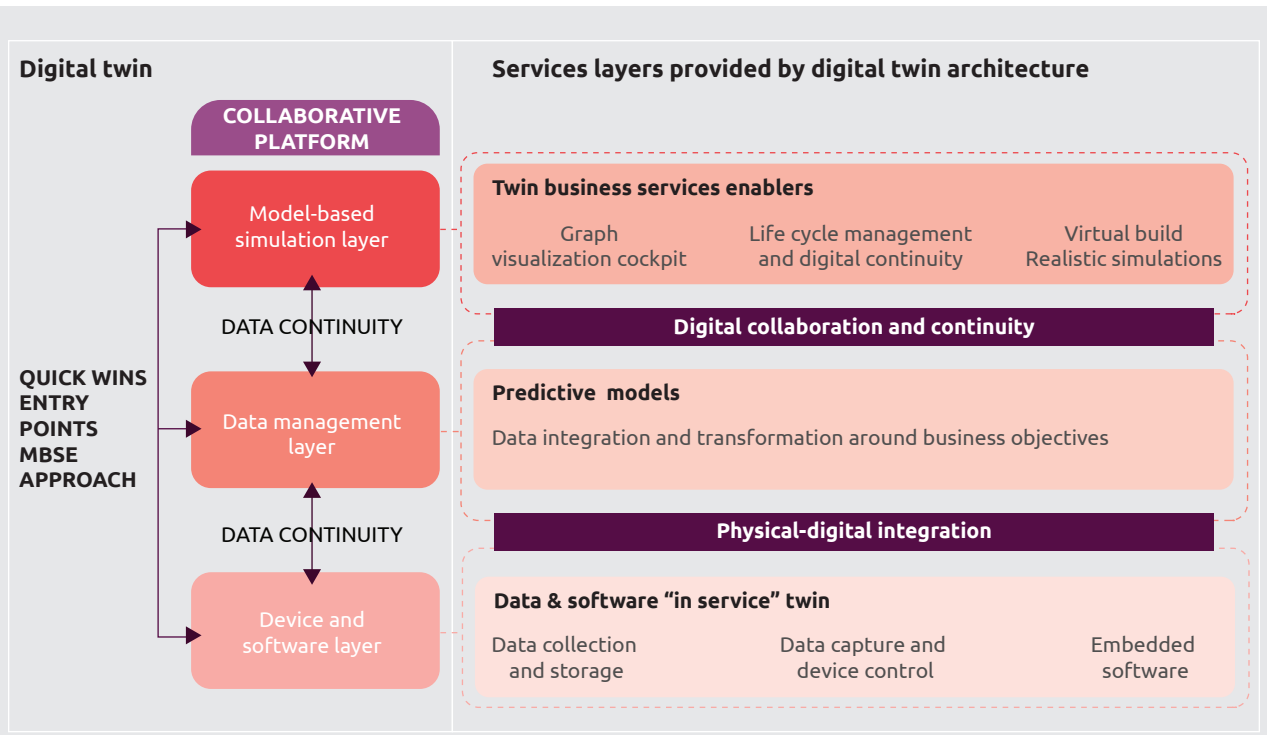
Design capabilities: Skillsets such as systems engineering, modeling, and multi-dimensional simulation are necessary in designing the digital twin system
Operate and serve capabilities: These include data capture, distributed architecture, artificial intelligence/machine learning, as well as event-management capabilities
Collaborative skills: All along the value chain, across both internal and external ecosystems

+ **User experience and user interface:** Finally, an intuitive UX/UI is necessary to exploit the full potential of smart, connected systems and processes in the field. Employees using digital twins must be able to use, navigate, and immerse themselves in the application and, in order to achieve this, the UX as well as the UI must be well-thought-out and intuitive for the users.

Sacha Porges, Global Director, Customer Quality & Programs at GKN Automotive, underlines the importance of these enablers: *"A well-thought-out design of your digital twin is critical – it is the compass needle, and you want to be going in the right direction from the beginning. You need to know the enabling technology to be able to integrate the physical assets with the digital twins: how you would*

Fig.24

A high-level digital twin architecture



Source: Capgemini.

connect the physical to the virtual, and what technology would you need to do that. Similarly, to enable real-time flow of data from the IoT [internet of things] devices and integration with operational and transactional data from other enterprise systems, you must define the types of devices and software needed."

Design and implement a digital twin architecture

A digital twin architecture helps deliver the digital twin initiatives in a smooth manner. Figure 24 shows a high-level architecture with three major technology foundations required for delivery, along with the services that a digital twin enables.

As explained in the previous recommendation, a data-management layer allows for easy analysis of data. A device and software layer allows for employees and teams to interact with the twin. For simple use cases or quick wins, all these three layers can be addressed separately or through model-based systems engineering (MBSE). MBSE also provides the interoperability among these three layers that is required for complex use cases.

The figure also shows the service layers that the digital twin architecture provides. It allows physical-digital integration by means of data collection and storage, data capture and device control, and through embedded software. Further, digital collaboration and continuity is enabled through data integration. In order to realize all these successfully, organizations should focus on lifecycle management, digital continuity, realistic simulations, and cockpit & dashboard services.

The bottom layer shown in Figure 24 provides for data collection in order to build a single and up-to-date source of truth federating

+47%

of organizations are considering strategic partnerships for digital twins initiatives

+38%

of organizations are willing to work with new/existing partners towards digital twin implementation

"cold" (historical system specifications and models etc.,) and "hot" (IOT, OT, real-time events) data, as well as "descriptive" (GIS, BIM, CAD/CAM, etc.) and "transactional" (PLM, ERP, MES etc.) data. The modelling of a digital twin should be flexible and be able to offer advanced data services, such as modeling and simulation, intuitive visualization, analytics and AI/ML, and event-orchestration, to manage predictive/preventive alerts and real-time incidents efficiently.

However, a single source of truth does not necessarily mean that all data sources and computing activities need to be centralized in one place; data consistency and performance would not be manageable in such a scenario. Therefore, striking the right balance in terms of data-sizing, synchronization, and computing is critical to scaling up.

Enhance data security and privacy across networks

Since a digital twin is connected to a number of systems and consequently opens access to inordinate amounts of sensitive information, hacking into an unsecured digital twin allows immediate access to the internal data of the entire business system.

Ensuring only authorized access to system facilities and data is paramount in protecting the confidentiality of business and personal information.

In addition, unauthorized modification or destruction of data/operations while being processed, in transit, or in storage must also be prevented. The integrity of the system must be maintained to preserve confidence in the reliability of the data it produces and to ensure non-repudiation and authenticity of commands/actions. Obviously, this requires secure communication between the digital twin and its physical counterpart.

An adversary affecting a digital twin or its physical counterpart can introduce divergence in the behaviors or states of the two entities. Given the bi-directional link between the two, an attacker may negatively affect both through changes in either.

The privacy and security risks associated with digital twin deployment are manifold. Reinforced data security and privacy measures are, therefore, indispensable prior to digital twin deployments – a sentiment echoed by 69% of surveyed organizations, who plan to effect major changes in their end-to-end cybersecurity.

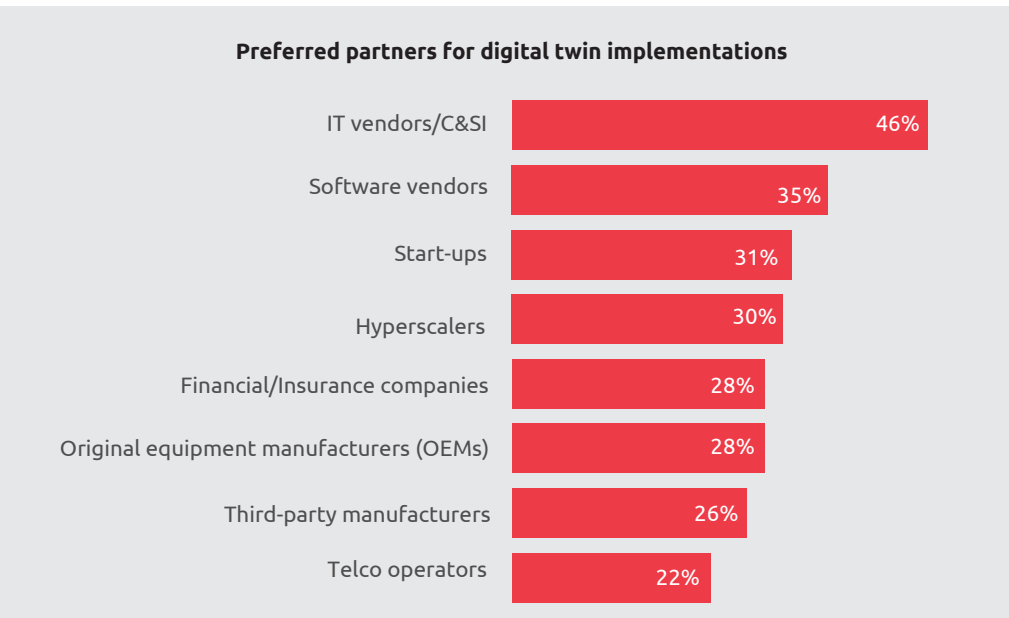
Collaborate with partners to derive greater benefits

The greatest value of a digital twin comes from being able to predict or simulate the impact of a particular change on the entire network of partners. This can be made possible only by feeding data or inputs from/about partners into the digital twin. In order to build such complex twins, which extend far beyond the boundaries of the individual organization and into the wider ecosystem, organizations need to on-board their critical partners to the digital twin vision and deploy collaboration platforms.

Organizations also realize that they need to collaborate or partner with technology companies to drive digital twin implementations. Johnson Controls, HVAC (heating, ventilation, and air conditioning) and security equipment manufacturer for buildings, for example, announced an integration between the Azure Digital Twins IOT platform and its own OpenBlue Digital Twin platform to maximize efficiency while managing physical spaces.[36] Beyond suppliers and customers, organizations are working with a variety of partners, which may include IT vendors or consulting and system integrators (C&SI), software firms, startups, hyperscalers, financial institutions, original

Fig.25

C&SI partners and software firms remain the top preferred partners for digital twin initiatives



Source: Capgemini Research Institute, Digital Twins survey, September–October 2021, N=800 organizations with ongoing digital twin programs.

equipment manufacturers (OEMs), and telco operators. Further, 47% of organizations are considering strategic partnerships for digital twin initiatives, while another 38% are willing to work with new/existing partners towards digital twin implementation. Among the various potential partners, 46% of organizations rank IT vendors/C&SI as being among their top-three preferences, followed by software vendors (see Figure 25).

The energy & utilities sector is keen to harness the potential of digital twins. However, while they are focusing on small-scale twins, building digital twins for an electric grid or a nuclear reactor is definitely complex, and it is often difficult for the organizations to develop these advanced twins on their own. As a result, we see organizations collaborating with software vendors and equipment providers. E.ON, for example, is working alongside multiple industry partners through a consortium to create a digital twin that monitors asset health and performance of its 110 kV power transformers.[37] Separately, French utilities giant EDF is also planning to deploy digital twins for its fleet of 56 nuclear reactors – in collaboration with various academic and industry partners.[38]

Similarly, consortiums play a role in the design and development of digital twins. They help in the adoption of standard formats and provide resources or guidelines to organizations, thereby increasing the scale of adoption. For instance, Digital Twin Consortium, which counts Microsoft, GE Digital, and Northrop Grumman among its founders, is working on advancing best practices and standards requirements. The members aspire to drive consistency in the vocabulary, architecture, security, and interoperability of digital twin technology.[39]

+ Partner with Capgemini for transformation with digital twins

We propose a set of digital twin solutions to deliver value at speed

A complete and agnostic immersive remote platform, for assistance and acceptance, providing digital continuity of 3D models

Federated data model integrating natively 1D-3D, geographical information and IoT data for augmented operations

From secured sensor and OPCUA connectivity to end-to-end OEE management

+ Research Methodology

To understand how leading companies are approaching digital twin transformation, we carried out extensive research with both qualitative and quantitative components.

In-depth interviews

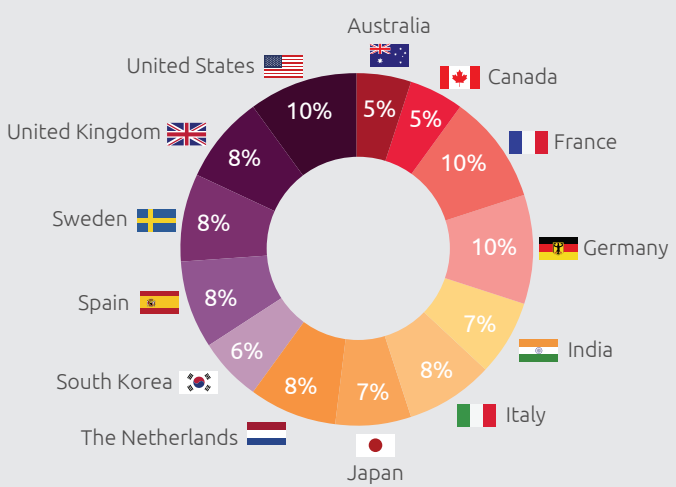
We conducted 14 in-depth interviews with industry experts, academics, and think tanks from various organizations and universities.

Executive survey

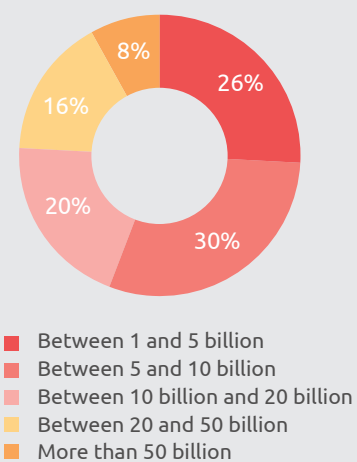
We surveyed 1,000 organizations, 80% of which have an ongoing digital twin program, with the rest planning to start one. The distribution of selected respondents and their organizations is provided in the following figures.

The study findings reflect the views of the people who responded to our online questionnaire for this research and are aimed at providing directional guidance. Please refer to the methodology for details of respondents and get in touch with a Capgemini expert to understand specific implications.

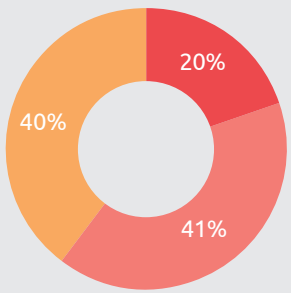
Country of headquarters of organization



Annual revenue of organization (in USD)

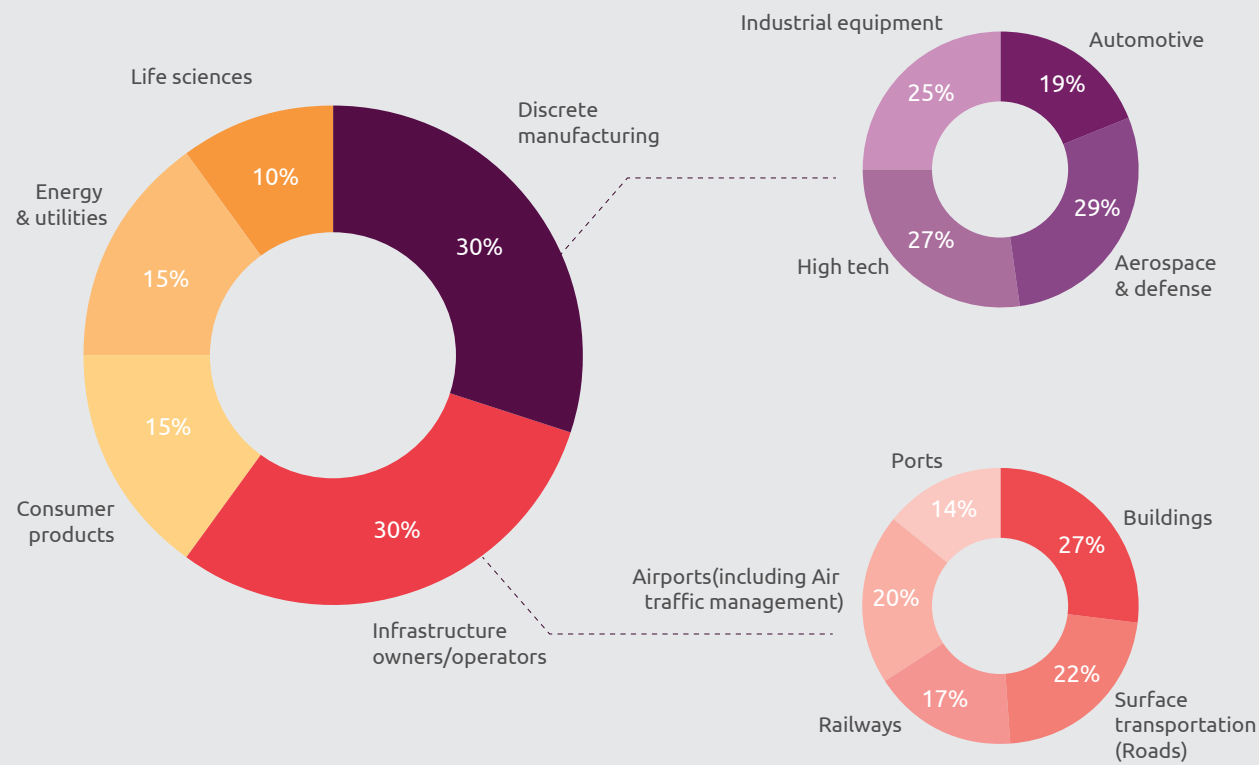


Digital twin implementation journey



- We are planning to start to implement a digital twin within the next 12 months
- We have an ongoing digital twin program focused on one specific part of the value chain
- We have an ongoing comprehensive digital twin program across the whole value chain

Sector distribution of organization



Source: Capgemini Research Institute, Digital Twins survey, September–October 2021, N=1,000 organizations.
*The study findings reflect the views of the people who responded to our online questionnaire for this research and are aimed at providing directional guidance. Please refer to the methodology for details of respondents and contact a Capgemini expert to understand specific implications.

Research methodology

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- Conversations for Tomorrow #3: Intelligent Industry: The Next Era of Transformation, December 2021, https://www.capgemini.com/research/conversations-for-tomorrow/conversations-for-tomorrow-3/.
- Next Destination: Software, September 2021, https://www.capgemini.com/research/software-the-new-battleground-of-the-automotive-industry/.
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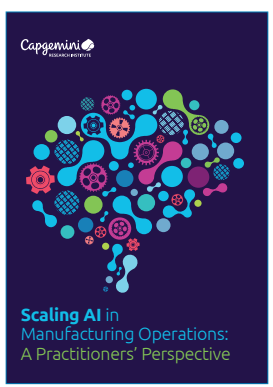

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