Digital Twins in Logistics

A DHL perspective on the impact of digital twins on the logistics industry

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Preface

For centuries, people have used pictures and models to help them tackle complex problems. Great buildings first took shape on the architect's drawing board. Classic cars were shaped in wood and clay.

Over time, our modeling capabilities have become more sophisticated. Computers have replaced pencils. 3D computer models have replaced 2D drawings. Advanced modeling systems can simulate the operation and behavior of a product as well as its geometry.

Until recently, however, there remained an unbridged divide between model and reality. No two manufactured objects are ever truly identical, even if they have been built from the same set of drawings. Computer models of machines don't evolve as parts wear out and are replaced, as fatigue accumulates in structures, or as owners make modifications to suit their changing needs.

That gap is now starting to close. Fueled by developments in the internet of things (IoT), big data, artificial intelligence, cloud computing, and digital reality technologies, the recent arrival of digital twins heralds a tipping point where the physical and digital worlds can be managed as one, and we can interact with the digital counterpart of physical things much like we would the things themselves, even in 3D space around us.

Led by the engineering, manufacturing, automotive, and energy industries in particular, digital twins are already creating new value. They are helping companies to design, visualize, monitor, manage, and maintain their assets more effectively. And they are unlocking new business opportunities like the provision of advanced services and the generation of valuable insight from operational data.

As logistics professionals, we have been thinking about how digital twins will change traditional supply chains, and how the logistics sector might embrace digital twins to improve its own processes. Our objective in writing this report is to share our findings and to help you answer the following key questions:

- What is a digital twin and what does it mean for my organization?
- What best-practice examples from other industries can be applied to logistics?
- How will my supply chain change because of digital twins?

Looking ahead, we believe that the adoption of digital twins across industries will drive better decision making in the physical world. That, in turn, will drive significant changes in the operation of supply chains and logistics processes.

In the logistics industry itself, digital twins will extend the benefits of IoT already being applied today. They will bring deeper insight into the planning, design, operation, and optimization of supply chains, from individual assets and shipments to entire global supply networks.

We think there has never been a more exciting time for industries and logisticians to work together to leverage the full potential of digital twins. On behalf of us all at DHL, we look forward to collaborating with you in this exciting and potentially transformative field.

Matthias Heutger
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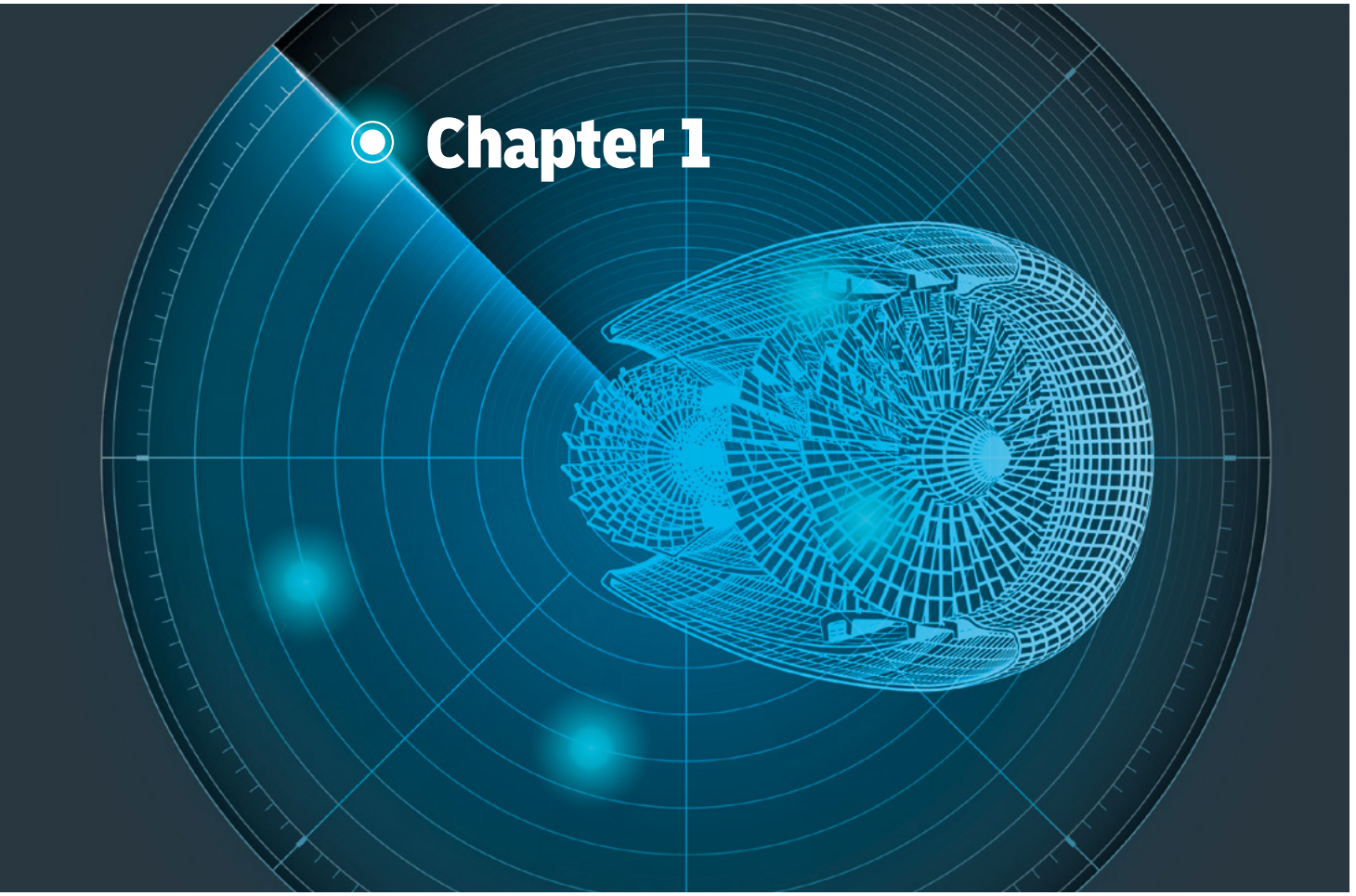


Understanding Digital Twins

1.1 THE DIGITAL TWIN COMES OF AGE

For many years, scientists and engineers have created mathematical models of real-world objects and over time these models have become increasingly sophisticated. Today the evolution of sensors and network technologies enables us to link previously offline physical assets to digital models. In this way, changes experienced by the physical object are reflected in the digital model, and insights derived from the model allow decisions to be made about the physical object, which can also be controlled with unprecedented precision.

While the digital twin concept has existed since the start of the 21st century, the approach is now reaching a tipping point where widespread adoption is likely in the near future. That's because a number of key enabling technologies have reached the level of maturity necessary to support the use of digital twins for enterprise applications. Those technologies include low-cost data storage and computing power, the availability of robust, high-speed wired and wireless networks, and cheap, reliable sensors.

The use of a high-fidelity simulation or a direct physical replica to support the operation and maintenance of an asset has a long history. NASA pioneered a pairing approach during the early years of space exploration. When the Apollo 13 spacecraft suffered significant damage on a mission to the moon in 1970, NASA engineers were able to test and refine potential recovery strategies in a paired module on earth before issuing instructions to the stricken crew. To this day, pairing - now using digital models - remains a central part of the US space agency's strategy for managing space missions.

At first the complexity and cost involved in building digital twins limited their use to the aerospace and defense sectors (see the timeline in figure 1) as the physical objects were high-value, mission-critical assets operating in challenging environments that could benefit from simulation. Relatively few other applications shared the same combination of high-value assets and inaccessible operating conditions to justify the investment.

That situation is changing rapidly. Today, as part of their normal business processes, companies are using their own products to generate much of the data required to build a digital twin; computer-aided design (CAD) and simulation tools are commonly used in product development, for example. Many products, including consumer electronics, automobiles, and even household appliances now include sensors and data communication capabilities as standard features.

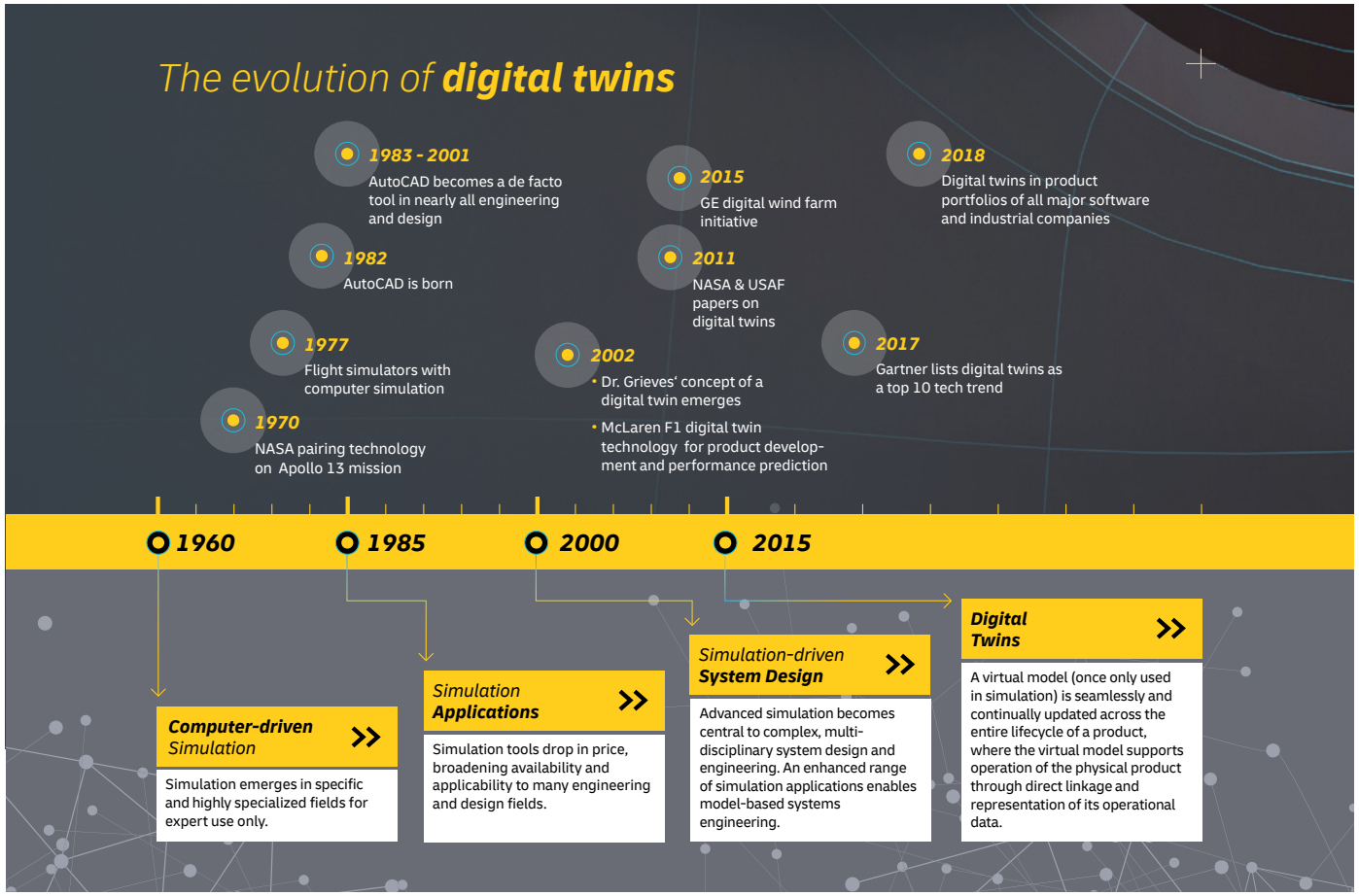


Figure 1

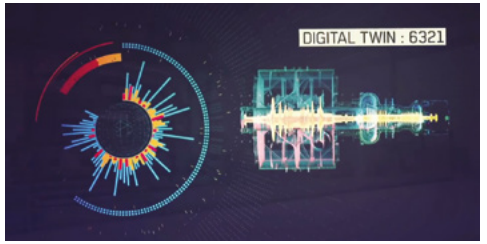


Figure 2

Figure 1: The evolution of digital twins. Source: DHL

Figure 2: GE has created a digital twin of the Boeing 777 engine specifically for engine blade maintenance. Source: GE

As corporate interest in digital twins grows, so too does the number of technology providers to supply this demand. Industry researchers expect the digital twins market to grow at an annual rate of more than 38 percent over the next few years, passing the USD $26 billion point by 2025.

Plenty of technology players have an eye on this potentially lucrative space. The broad range of underlying technologies required by digital twins encourages many companies to enter the market, including large enterprise technology companies such as SAP, Microsoft, and IBM. These organizations are well positioned to apply their cloud computing, artificial intelligence, and enterprise security capabilities to the creation of digital twin solutions. In addition, makers of automation systems and industrial equipment such as GE, Siemens, and Honeywell are ushering in a new era of industrial machinery and services built on digital twins. Also companies offering product lifecycle management (PLM) such as PTC and Dassault Systèmes are embracing digital twins as a fundamental core technology to manage product development from initial concept to end of life. Digital twin opportunities are also attracting the attention of start-ups, with players such as Cityzenith, NavVis, and SWIM.AI developing their own offerings tailored to particular niches and use cases.

1.2 WHAT MAKES A DIGITAL TWIN?

In practice with so many different applications and stakeholders involved, there is no perfect consensus on what constitutes a digital twin. As our examples show very clearly later in this report, digital twins come in many forms with many different attributes. It can be tempting for companies to ride the wave of interest in the approach by attaching a 'digital twin label' to a range of pre-existing 3D modeling, simulation, and asset-tracking technologies. But this short sells the complexity of a true digital twin.

Most commentators agree on key characteristics shared by the majority of digital twins. The attributes that help to differentiate true digital twins from other types of computer model or simulation are:

- A digital twin is virtual model of a real 'thing'.
- A digital twin simulates both the physical state and behaviour of the thing.
- A digital twin is unique, associated with a single, specific instance of the thing.
- A digital twin is connected to the thing, updating itself in response to known changes to the thing's state, condition, or context.
- A digital twin provides value through visualization, analysis, prediction, or optimization.

The range of potential digital twin applications means that even these defining attributes can blur in some situations. A digital twin may exist before its physical counterpart is made, for example, and persist long after the thing has reached the end of its life. A single thing can have more than one twin, with different models built for different users and use cases, such as what-if scenario planning or predicting the behavior of the thing under future operating conditions. For example, the owners of factories, hospitals, and offices may create multiple models of an existing facility as they evaluate the impact of changes in layout or operating processes.

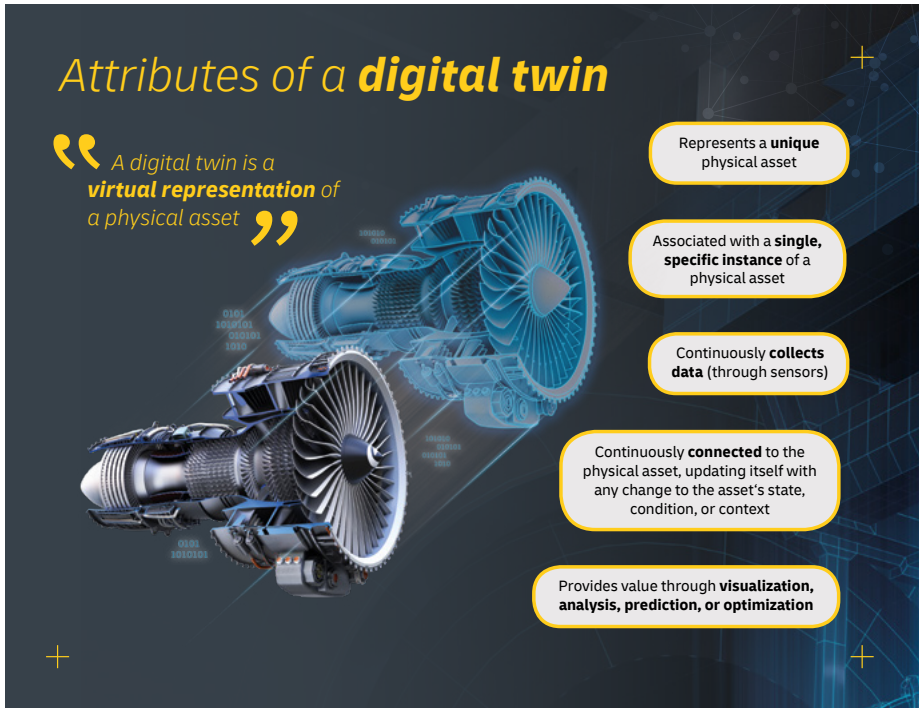


Figure 3

Figure 3: Characteristics of a digital twin. Source: DHL

Today, researchers and technology companies have built digital twins at every scale from atoms to planets. The smallest digital twin can represent the behavior of specific materials, chemical reactions, or drug interactions. At the other extreme, a large digital twin can model entire metropolitan cities. The majority of digital twins sit somewhere in the middle, with most current applications aimed at more human-scale problems, especially the modeling of products and their manufacturing processes. One notable trend is the development of larger, more complex digital twins as organizations evolve from modeling single products or machines to modeling complete production lines, factories, and facilities. Similarly, efforts are underway to create digital twins of entire cities or even of national-scale energy infrastructure and transport networks. The UK is even working on plans to develop a digital twin of the whole country to serve as a repository for multiple sources of data related to buildings, infrastructure, and utilities.

1.3 UNDERLYING TECHNOLOGIES ENABLING DIGITAL TWINS

Five technology trends are developing in a complementary way to enable digital twins, namely the internet of things, cloud computing, APIs and open standards, artificial intelligence, and digital reality technologies.

The Internet of Things (IoT). The rapid growth of IoT is one important factor driving the adoption of digital twins. IoT technologies make digital twins possible because it is now technically and economically feasible to collect large volumes of data from a wider range of objects than before. Companies often underestimate the complexity and volume of data generated by IoT products and platforms, requiring tools to help them manage and make sense of all the data they are now collecting. A digital twin is often an ideal way to structure, access, and analyze complex product-related data. Digital twins rely on a host of underlying technologies that are only now reaching the point where they can be applied reliably, cost effectively, and at scale.

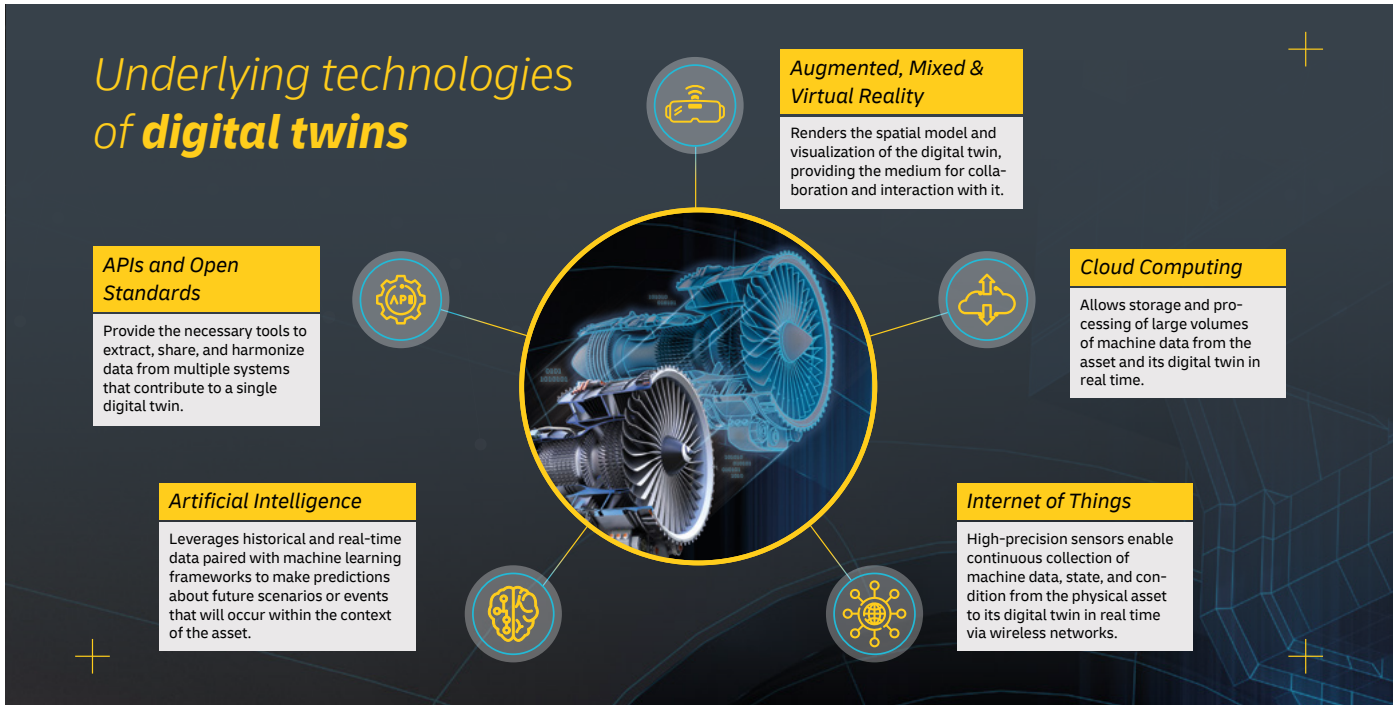


Figure 4

Cloud Computing. Developing, maintaining, and using digital twins is a compute- and storage-intensive endeavor. Thanks to the continually falling cost of processing power and storage, large data center networks with access provided via software-as-a-service (SaaS) solutions now enable companies to acquire exactly the computing resources they need, when they need them, while keeping costs under control.

APIs & Open Standards. Closed, proprietary-by-design simulation tools and factory automation platforms are increasingly becoming a thing of the past. Technology companies created and protected their own data models, requiring intensive, ground-up software development to build infrastructure from scratch for each new product.

Figure 4: Technologies behind digital twins. Source: DHL

Now the availability of open standards and public application programming interfaces (APIs) has dramatically streamlined sharing and data exchange, making it possible for users to combine data from multiple systems and tools quickly and reliably.

Artificial Intelligence (AI). Dramatic improvements in the power and usability of advanced analytical tools have transformed the way companies extract useful insights from big, complex data sets. Machine learning frameworks are enabling the development of systems that can make decisions autonomously as well as predictions about future conditions based on historical and real-time data.

Augmented, Mixed, and Virtual Reality. In order to leverage, consume, and effectively take action on the insights generated by a digital twin, it must be rendered either on a screen (2D) or in physical space (3D). To date, most digital twins have been rendered in two-dimensional space, as the conventional computing norms of today limit us to displays on monitors, laptops, and other screens. But increasingly, augmented reality is enabling us to display digital content in 3D. In addition, mixed reality allows us to interact with digital content in our existing physical environment. And virtual reality allows us to create entirely new environments to render digital twins in a highly immersive way, creating the richest consumption of and interaction with the information.

While the above technologies – IoT, cloud computing, APIs, and artificial intelligence – provide the underlying sensing and processing infrastructure required to create a digital twin, augmented, mixed, and virtual reality are the tools for visualizing digital twins and making them real to the user.

1.4 HOW DIGITAL TWINS CREATE VALUE

Digital twins can be used in different ways to add value to a product, process, user, or organization. The value available, and the investment required to capture it, are highly application dependent. Most fall into one or more of the following broad categories.

Descriptive Value. The ability to immediately visualize the status of an asset via its digital twin is valuable when those assets are remote or dangerous – examples include spacecraft, offshore wind turbines, power stations, and manufacturer-owned machines operating in customer plants. Digital twins make information more accessible and easier to interpret from a distance.

Analytical Value. Digital twins that incorporate simulation technologies can provide data that is impossible to measure directly on the physical object – for example information generated inside an object. This can be used as a troubleshooting tool for existing products and can help to optimize the performance of subsequent product generations.

Diagnostic Value. Digital twins can include diagnostic systems that use measured or derived data to suggest the most probable root causes of specific states or behaviors. These systems can be implemented in the form of explicit rules based on company know-how, or they may leverage analytics and machine learning approaches to derive relationships based on historical data.

Predictive Value. The likely future state of the physical model can be predicted using a digital twin model. One example is GE's use of digital twins in wind farms to predict power output, as depicted in figure 5. The most sophisticated digital twins do more than merely predict the issue that may occur; they also propose the corresponding solution. Digital twins will play a significant role in the development of future smart factories capable of making autonomous decisions about what to make, when and how, in order to maximize customer satisfaction – and profitability.

Figure 5

Figure 5: GE's digital wind farm project leverages digital twin technology to make predictions on power output. Source: Harvard Business Review

Early adopters of digital twins commonly report benefits in three areas:

- Data-driven decision making and collaboration
- Streamlined business processes
- New business models

Because each digital twin presents a single visualization to key decision makers, it provides a single source of truth for an asset that drives stakeholder collaboration to resolve problems expediently. Digital twins can be used to automate tedious error-prone activities such as inspections, testing, analysis, and reporting. This frees teams to focus on higher-value activities. Digital twins are a major driver of product-as-a-service business models or servitization – this is when companies abandon the one-time sale of a product to instead sell outcomes by managing the full operation of the asset throughout its lifecycle. Digital twins allow manufacturers to monitor, diagnose, and optimize their assets remotely, helping to improve availability and reduce service costs.

1.5 THE DIGITAL TWIN THROUGH THE PRODUCT LIFECYCLE

Since their inception, digital twins have been closely associated with product lifecycle management (PLM). Digital twins are now used throughout the full product lifecycle, with a product's twin emerging during the development process and evolving to support different business needs as a product progresses

Figure 6

through design, manufacturing, launch, distribution, operation, servicing, and decommissioning.

Product Development. Data from the digital twins of previous products can be used to refine the requirements and specifications of future ones. Virtual prototyping using 3D modeling and simulation allows faster design iterations and reduces the need for physical tests as depicted in figure 6. During the design phase, tests with digital twins can detect clashes between components, assess ergonomics, and simulate product behavior in a wide variety of environments. Together these measures help to reduce development costs, accelerate time to market, and improve the reliability of the final product.

Production. Digital twins facilitate collaboration between cross-functional teams in the manufacturing process. They can be used to clarify specifications with suppliers and allow designs to be optimized for manufacturing and shipping. If the organization manufactures a new digital twin with every product it makes, each model will incorporate data on the specific components and materials used in the product, configuration options selected by end customers, and process conditions experienced during production.

Digital twins of production lines as illustrated in figure 7 allow layouts, processes, and material flows to be tested and optimized before a new manufacturing facility is commissioned.

"DRIVING IMPROVED BUSINESS OUTCOMES WITH DIGITAL TWINS"

by **Sam George**, Director, Azure Internet of Things, Microsoft

For years now, Microsoft's partners and customers have been using the cloud and digital twins to create breakthrough applications for a wide variety of industries.

We've learned that most digital transformation efforts benefit from context about the physical world by creating a digital twin. For example, customers have been creating digital replicas of buildings, connecting building systems like heating and cooling, as well as electrical systems to space utilization and people within the building. Energy sector customers are modeling their distribution grid to even out usage spikes and ensure substations aren't over utilized, enabling them to avoid unnecessary, costly infrastructure updates. Digital twins support the entire lifecycle, from design time, through construction and commissioning, all the way through to operations. With these digital twins customers can then predict the future state of their models, as well as simulate potential changes. A digital twin helps bring value to the various IoT data into the model which fits their domain, and without it the IoT data has less value.

It is critical to connect to the devices and sensors in the physical world to provide real-time and operationalized data – not just the idealized state of the system. This enables customers to take advantage of replicas alive with data. By adding artificial intelligence (AI) to the mix, customers can identify trends, forecast the future, optimize and simulate changes. This enables customers to save money and improve planning, products, and customer relationships.

Figure 6: Digital twins enable faster design iterations and rapid prototyping before going into production. Source: Forbes

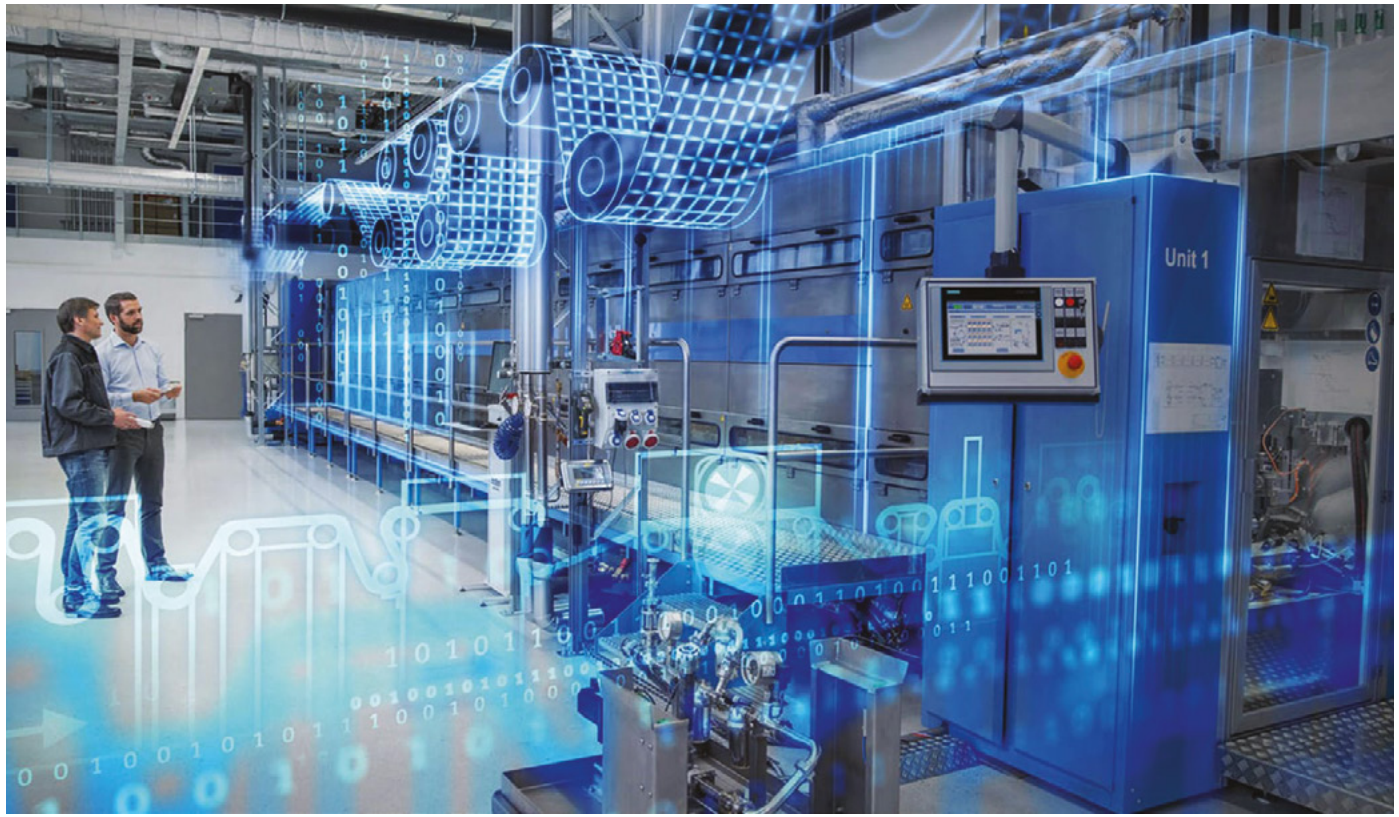


Figure 7

Operate & Service. Once the product passes into the hands of the end-user, its digital twin continues to accumulate data on its performance and operating conditions. This data helps to support maintenance planning, troubleshooting, and optimizing product performance. As products are updated and adapted or parts replaced, the digital twin is amended accordingly. Aggregate information from multiple digital twins can be analyzed to identify usage trends and optimize future designs.

End-of-life. When a product is no longer required by the user, digital twin data guides appropriate end-of-life actions. Data on the operating conditions of specific components informs decisions on whether to re-use, recondition, recycle, or scrap these items. Material data can help to determine appropriate recycling and waste streams. And the data accumulated by the digital twin during this process can be retained for future analysis.

1.6 CHALLENGES IN APPLYING DIGITAL TWINS

There are significant challenges to the widespread adoption of digital twins. Matching complex assets and their behavior digitally – with precision and in real time – can quickly exceed financial and computing resources, data governance capabilities, and even organizational culture. This section identifies the stumbling blocks that may be encountered when leveraging digital twins.

Cost. Digital twins require considerable investment in technology platforms, model development, and high-touch maintenance. While most of these costs continue to fall, the decision to implement a digital twin must always be compared to alternative approaches that might deliver similar value at lower cost. If a company is interested in a small number of critical parameters, these insights may be gathered more cost effectively via an IoT system based on sensors and a conventional database.

Precise Representation. For the foreseeable future, no digital twin will be a perfect representation of its physical counterpart. Matching the physical, chemical, electrical, and thermal state of a complex asset is an extremely challenging and costly endeavor. This tends to force engineers to make assumptions and simplifications in their models that balance the desired attributes of the twin with technical and economic constraints.

Data Quality. Good models depend on good data. That may be a difficult thing to guarantee in digital twin applications which depend on data supplied by hundreds or thousands of remote sensors, operating in demanding field conditions and communicating over unreliable networks. As a minimum, companies will need to develop methods to identify and isolate bad data, and to manage gaps and inconsistencies in product data streams.

Figure 7: Siemens is applying digital twin technology to optimize processes within its production lines. Source: Siemens

"CHANGING TASKS AND LEADERSHIP IN TECHNOLOGICAL TRANSITIONS"

by **Janina Kugel**, Board Member and Chief HR Officer, Siemens

Digital twins are likely to create a technology transition in any organization that implements them. It is of paramount importance that we look at the opportunities technology shifts like digital twins bring, rather than the pitfalls. We've got to be open for new things and leverage the opportunities afforded by technology in such a way that they help us increase the quality of life and benefit society and companies.

Today, the biggest challenge of the technological transition is the rapid pace of change. Much of what we experience now was considered science fiction 20 years ago, digital twins included. We must do some things differently than we have done in the past, and this can't happen without a culture change.

It's a journey that consists of many little steps. We need to break down silos by maintaining a global network and exchanging ideas, within our own company and beyond it. We need to flatten hierarchies and enable flexible working. Managers have to guide and support their teams, encourage them to try new things and allow errors. Therefore, managers can't just communicate with a small group, they need to collaborate openly across all parts of organizations. Collaboration is critical to leveraging the insights created by new technology like digital twins. Finally, we all have to acquire new skills on a constant basis. This form of continuing learning is a top priority at Siemens. And it's not just about upskilling but also about reskilling because – unless we retire within the next twelve months – we need to be open to learn totally new things.

In this context, the role of managers changes. Being a 'boss' is not enough, they have to play multiple roles. They may be colleagues, mentors, or coaches – or mentees who learn from others. They may have to switch back and forth between these roles several times a day depending on the situation and on the specific colleagues they're dealing with. In the digital age, soft skills are becoming more important than ever!

Interoperability. Despite significant progress in openness and standardization, technical and commercial barriers to the exchange of data remain. And where a digital twin relies on simulation or AI technologies supplied by a specific vendor, it may be difficult or impossible to replicate that functionality using alternative providers, effectively locking companies into long-term single-supplier relationships.

Education. The use of digital twins will require staff, customers, and suppliers to adopt new ways of working. That presents challenges in terms of change management and capability building. Companies must ensure users have the skills and tools they need to interact with digital twins and must be sufficiently motivated to make the necessary transition. Leveraging the new technologies required for digital twins typically requires a profound cultural shift to fully realize the value afforded by this change. For more on this topic, see the expert viewpoint on this page by Janina Kugel, Board Member and Chief HR Officer of Siemens on leadership and digital skills in times of technological transition.

IP Protection. A digital twin is a reservoir of intellectual property and know-how. The models and data incorporated into a twin include details of a product's design and performance. It may also contain sensitive data on customer processes and usage. That creates challenges around data ownership, identity protection, data control, and governance of data access by different user groups.

Cyber Security. Digital twins will be tempting targets for cyber criminals. The data links that connect physical objects to their twins provide a new point of entry for malevolent actors seeking to disrupt an organization's operations. Where digital twins play a role in the control of their physical counterparts, compromising a twin may have direct and potentially devastating real-world impact. Those characteristics make effective management of digital twin cyber security a critical priority, and one that will present new challenges to many organizations.

Every technology wave is accompanied by its own unique set of challenges and digital twins are no exception to this pattern. Industries with core offerings that depend on complex products and machinery were first to leverage the benefits of digital twins. Starting from humble beginnings in the aerospace and defense industries, digital twins are now enhancing operational value chains in the engineering, manufacturing, energy, and automotive industries. While today digital twins might seem like a far cry for the logistics industry, the next chapter examines current best practices in several different industries that logistics professionals can potentially learn from.

Digital Twins Across Industries

Digital twins can ultimately represent any physical thing, from nanomaterials all the way to entire cities. Even human beings and their behaviors have been modeled by digital twins in some cases. Organizations in multiple sectors are developing, testing, and utilizing digital twins within their operations. The following examples show how digital twins have the potential to solve a broad range of business challenges and to unlock many different sources of value.

2.1 DIGITAL TWINS IN MANUFACTURING

Manufacturing operations have been a particular area of focus for digital twin development. In part, that's because factories are data-rich environments in which core business is the production of physical assets. Companies make extensive use of automation and robotics systems on production lines and many plants are adopting IoT technologies and using digital information to optimize production performance. In high-productivity manufacturing there is plenty of value at stake. Even small improvements to throughput, quality, or equipment reliability can be worth millions of dollars.

CNH Industrial, a global producer of agricultural, industrial, and commercial vehicles, has used digital twins to optimize maintenance at its plant in Suzzara, Italy, where it produces Iveco vans. The company worked with a consultant, Fair Dynamics, and a software provider, AnyLogic, on a pilot project to improve the reliability of robot welding machines on the plant's chassis line, as depicted in figure 8.

While the project was partly intended as a technology demonstrator, CNH also hoped to solve a serious reliability challenge. Its welding robots rely on a flexible copper conductor called a lamellar pack to deliver electrical current to their welding heads. But these packs have a finite life and accumulated wear can cause a pack to melt, disrupting production and damaging the robot.

To determine the most efficient way to maintain these critical components, the company built a digital twin model of the line. Its model includes the different types of chassis and their associated welding requirements, the automatic welding stations distributed along the line, and the individual robots in each station. Data for the model is supplied by the plant's production planning systems and by condition monitoring sensors fitted to each robot. Using simulation and machine learning, the digital twin forecasts the probability of component failure. This system allows the company to run what-if scenarios comparing different operation and maintenance regimes in order to optimize maintenance and spare parts expenditure while minimizing both planned and unplanned downtime.

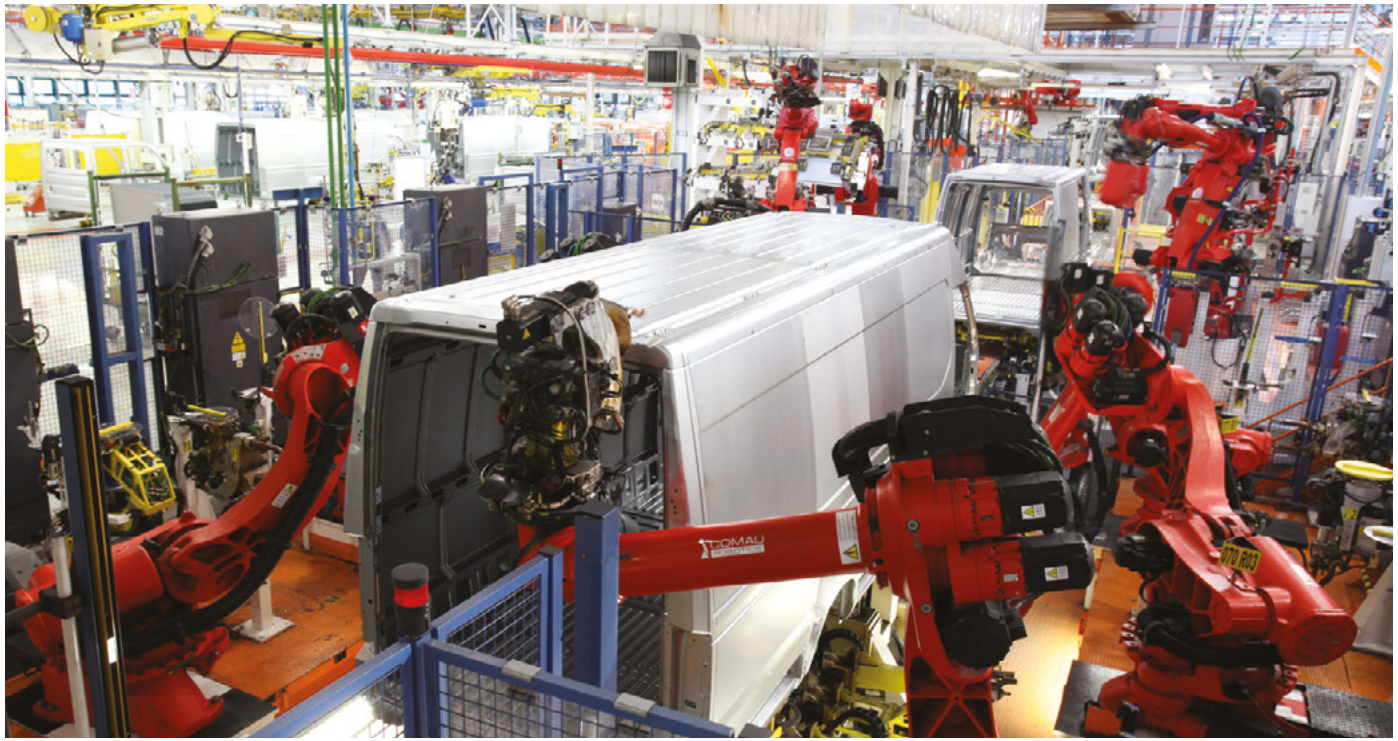


Figure 8

Figure 8: A digital twin of the Iveco manufacturing line helps drive better automated welding capabilities. Source: AnyLogic

Baker Hughes, a GE company that produces equipment for the oil and gas industry, has used technologies from its parent company to build a comprehensive digital twin of its plant in Minden, Nevada, USA. The model incorporates data from thousands of machines and processes across the facility, as well as data on component deliveries from suppliers. By providing a comprehensive real-time view of factory performance, the digital twin helps managers and staff to find improvement opportunities and react quickly to issues as they arise. Baker Hughes says that the approach has helped to improve on-time delivery at what was already a high-performing facility. Over time, the company's ambition is to double the rate at which materials flow through the plant, with the help of continued optimization through the digital twin.

"HOW DIGITAL TWINS WILL POWER THE FACTORIES OF THE FUTURE"

by **Eric Seidel**, Vice President and General Manager, Lifecycle Solutions & Technologies, Honeywell

Factories generate gigabytes of data every day, from their processes and production assets and even from the workflows of their people. Today, much of that data is locked away in disconnected systems. The factory of the future will connect all its data seamlessly, and it will extend those connections across the whole supply chain, upstream to suppliers and downstream through logistics to customers. Digital twins of factories and supply chains create three major opportunities for manufacturing organizations.

First, digitalizing the physical environment and visualizing its digital twin enables actionable insights and much faster decision-making. That will eliminate a huge amount of the variability that companies have to deal with today. In the factory of the future, every day will be your best day of performance.

Second, digital twins will empower the factory workforce, by providing dramatically improved access to data and information. This will be increasingly delivered with advanced training and operator support technologies such as virtual reality (VR) systems and augmented reality (AR) technologies that overlay information on the worker's field of view. In the factory of the future, every employee can act as a leading expert.

Once you are operating at the level of your best day every day and every employee is as effective as your leading expert, you can pursue the third, and biggest, opportunity. Companies can start to compare their own data with data from other factories around the world. You can ask 'how well does the best facility in the world perform?'. Then you can apply continuous improvement to enhance the output or the throughput of the plant until your performance matches the very best that can be achieved.

2.2 DIGITAL TWINS IN MATERIALS SCIENCE

The performance of physical products depends on the characteristics of their materials. Advances in materials science underpin many of the technologies we rely on today. Strong, lightweight materials are helping to reduce fuel consumption in cars, trains, and aircraft. And long-lasting bearings benefit from accurately formulated and processed steel alloys. But the precise characteristics of a specific piece of material is difficult to determine. Testing can be destructive or require specially prepared samples, making it hard to undertake with real parts or in the production environment.

Digital twins may provide a solution to this challenge. German software company Math2Market has developed specialized software for the simulation of a variety of material properties. The company's GeoDict software models structurally complex materials including nonwoven fabrics, foams, ceramics, and composites. Using AI-assisted image processing techniques, GeoDict depicted in figure 10 captures details of the interior geometry of these materials from computer-aided tomography (CAT) scans, electron microscopy, and similar image sources. It uses these material digital twins for a wide variety of purposes, from strength and stiffness analysis to fluid dynamics studies that model the flow of liquids and gases through filters. Customers in the oil and gas industry are also using the approach to model flows through porous rocks in underground reservoirs.

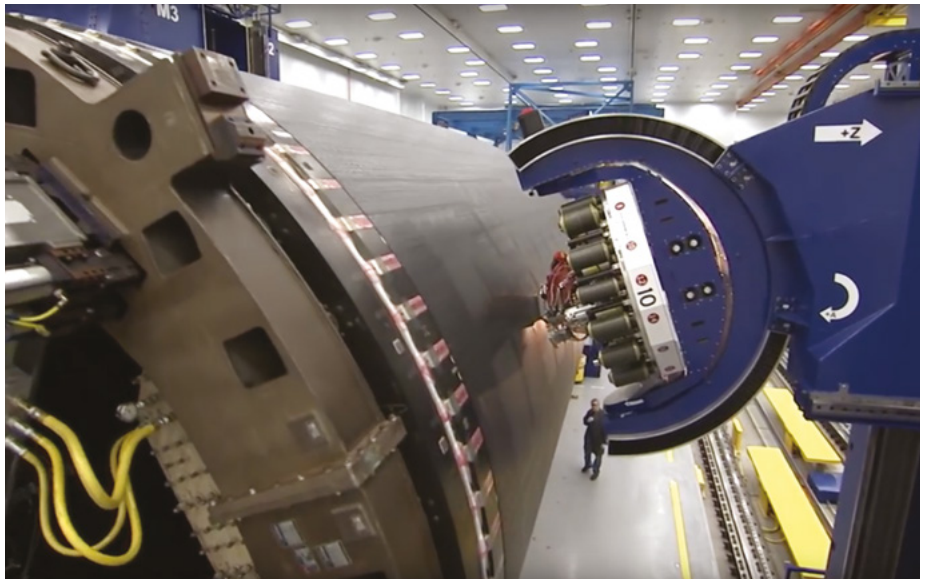


Figure 9

Meanwhile in the aviation industry, new materials are needed in the quest for increasingly lightweight, fuel-efficient, yet sturdier aircraft. Figure 9 shows how the carbon-fiber composite fuselage of a Boeing 787 passenger aircraft is effectively woven together at a production facility. Extensive digital simulation and optimization of the material composition was needed achieve the weight and robustness required by the commercial aviation industry.

Figure 9: Simulating composite material performance is critical to ensure airworthiness. Source: Spirit Aerosystems / YouTube

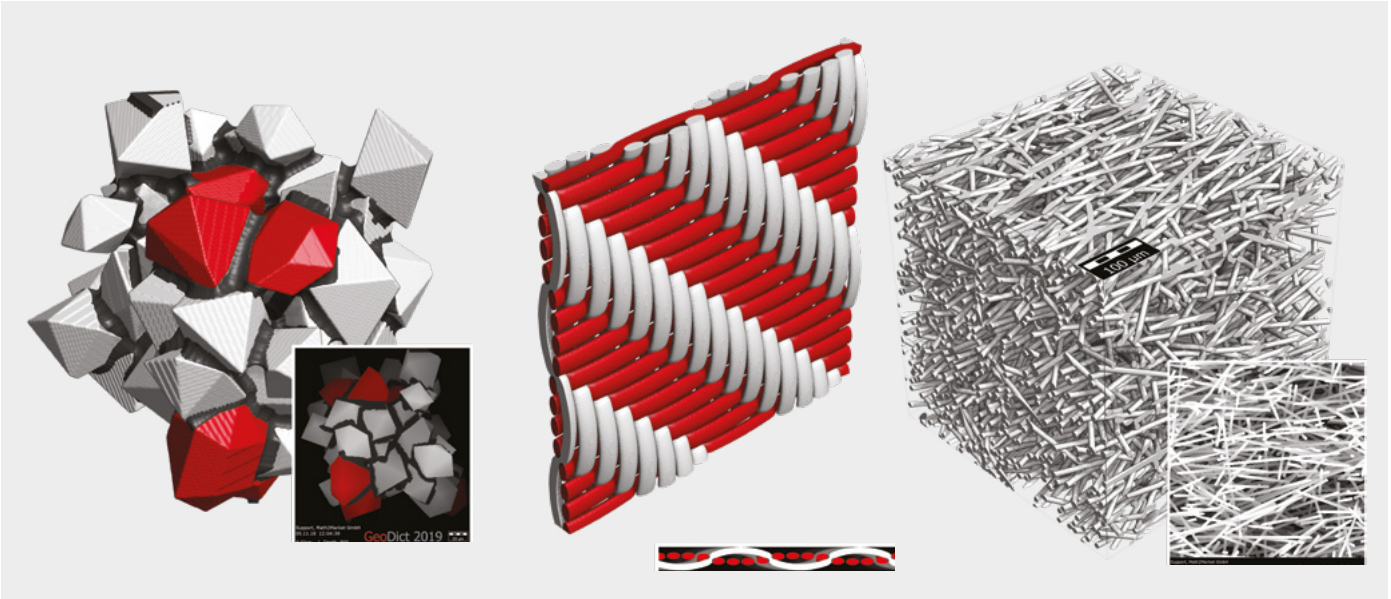


Figure 10

2.3 DIGITAL TWINS IN INDUSTRIAL PRODUCTS

Besides manufacturing, another killer app for digital twin technologies is industrial products. This is largely because the companies with these assets often pursue servitization strategies and these necessitate product uptime.

Digital twins support servitization by allowing these companies to monitor their products when they are in the customer's hands. Digital twins enable efficient maintenance strategies and remote diagnosis and repair. In some applications, customers may even be willing to pay for the data or insights generated by the digital twins of the manufacturer-owned assets.

Major aero engine manufacturers including Rolls-Royce, GE, and Pratt & Whitney are among the most advanced users of digital twin technologies today. They are applying digital twins in new product development, in manufacturing and, of course, to assist the monitoring and support of engines operating on customer aircraft.

Digital twins are also coming into use on the ground. Compressed air systems manufacturer Kaeser Compressoren in the Netherlands has worked with SAP to develop a digital twin solution encompassing its entire sales and product support lifecycle, for example. This system acts as a repository for documents and data created during the specification and tendering process for a new installation, and the platform provides remote monitoring and predictive maintenance capabilities.

Figure 11

Figure 10: Material digital twins allow in-depth simulation of material properties. Source: Math2Market

Figure 11: Digital twins accelerate the quality of MRO services. Source: MRO Network

2.4 DIGITAL TWINS IN LIFE SCIENCES AND HEALTHCARE

Researchers and clinicians across the healthcare sector are exploring the potential of digital twins, too. Much of this research focuses on modeling aspects of the human body. Such models can help doctors understand the structure or behavior of the body in greater detail, while reducing the need to perform invasive tests. Digital twins can allow complex operations to be rehearsed safely. They also have the potential to speed drug development by allowing new therapies to be evaluated 'in silico'.

Figure 12

Siemens Healthineers has developed digital twin models of the human heart like the one in figure 13. The system simulates the mechanical and electrical behavior of the heart, and uses machine-learning techniques to create unique, patient-specific models based on medical imaging and electrocardiogram data. The Siemens team is reaching the end of a six-year study in which it made digital twins of 100 patients undergoing treatment for heart failure. At this stage, the team is simply comparing predictions made by the models to the outcomes seen in the patients, but future trials could eventually result in a role for digital twins in diagnosis and treatment planning.

Medical device maker Philips has its own project underway to create a digital twin of the heart and the company is exploring a range of additional digital twin applications. In product development, for example, it is using modeling and simulation to test virtual prototypes. And it is applying artificial intelligence techniques to facilitate remote support of complex equipment such as CT scanners that perform magnetic resonance imaging (MRI) like the one depicted in figure 12. In use, a scanner may generate 800,000 log messages every day. Philips uploads that data from customers and analyses it to look for early warning signs of problems in its machines.

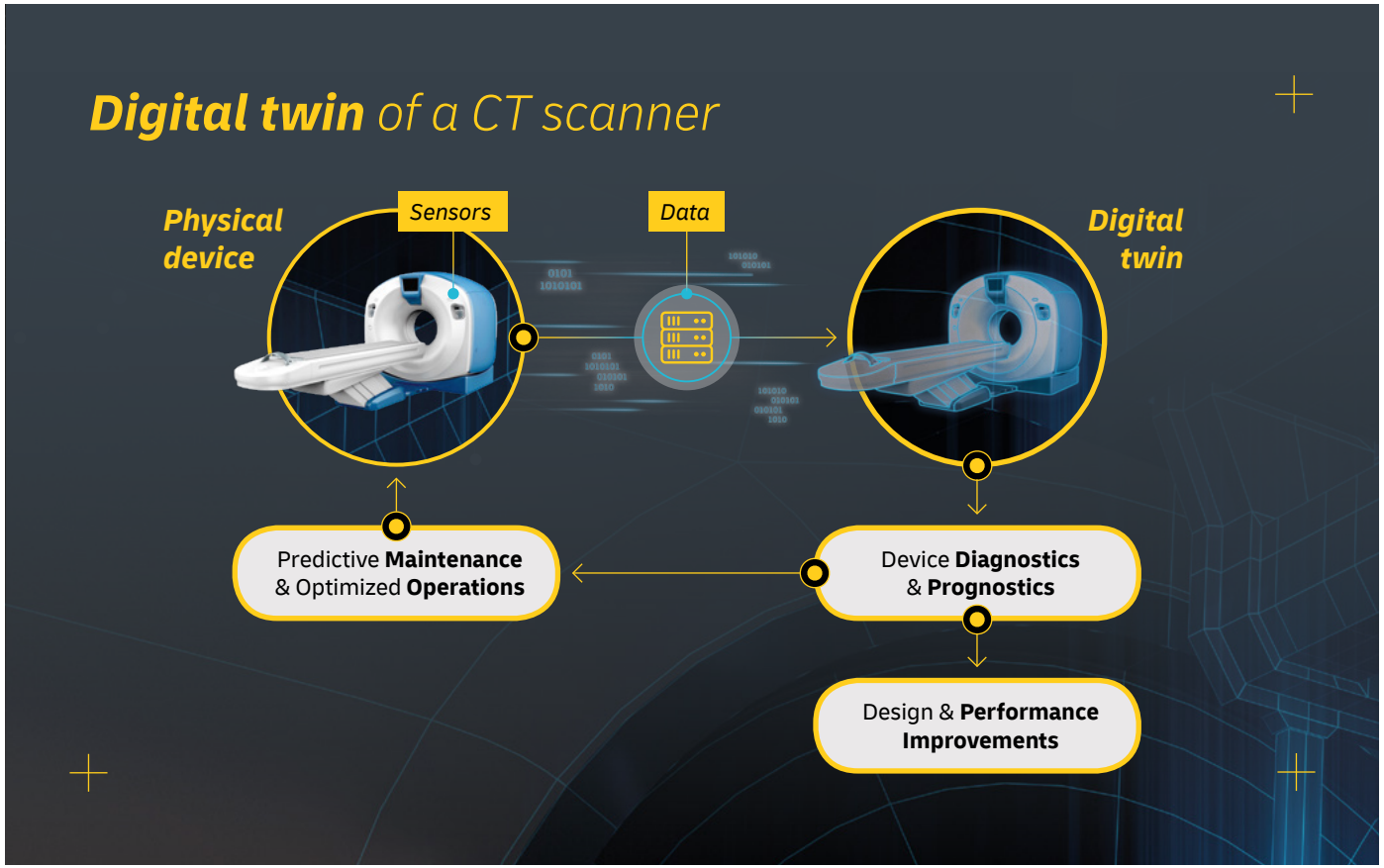


Figure 13

Figure 12: Digital twin of a CT scanner. Source: Philips

Figure 13: Using digital twins to replicate human physiology allows us to understand and test the best potential therapy conditions. Source: Siemens Healthineers

Other players are using digital twin approaches developed in manufacturing applications to improve the productivity and effectiveness of hospitals and similar healthcare settings. Mater Private Hospitals in Dublin, Ireland, for example, created a digital twin of the radiology department with the help of another team from Siemens. The group used operational data from the hospital to model the workflows of staff and patients through the department, then conducted a series of what-if analyses to examine the impact of layout modifications and changes to the nature and volume of demand. Elsewhere, GE Healthcare says the digital twin technology built into its Hospital of the Future Analytics Platform allows modeling and simulation of entire hospital workflows for the first time.

Some life sciences groups are even more ambitious. The DigiTwins initiative, a large-scale research consortium involving 118 companies and academic institutions worldwide, has set itself the goal of producing a personal digital twin for every European citizen. The project aims to develop new modeling technologies, medical informatics systems, and data sources to dramatically improve doctors' ability to diagnose illnesses and select appropriate treatments. If the project succeeds, the prize could be huge. Its founders point out that the inability to correctly predict the effects and side-effects of drugs on individual patients costs Europe's healthcare systems around €280 billion a year, 20 percent of its total budget.

2.5 DIGITAL TWINS IN INFRASTRUCTURE AND URBAN PLANNING

Measured by the size of the physical objects they represent, some of today's largest digital twins are replicas of physical infrastructure, such as energy and transport networks and urban environments.

In the UK, rail equipment company Alstom has built a digital twin to simplify the management of its train maintenance operations on the West Coast Main Line depicted in figure 14. One of Britain's busiest inter-city rail routes, the line connects London to Glasgow and Edinburgh via major cities in the English Midlands and North West. Ensuring maximum availability of the fleet of 56 Pendolino trains is a continuous challenge.

Figure 14

Alstom's digital twin includes details of every train in the fleet, along with their operating timetables and maintenance regimes. It also models the available capacity at each of Alstom's five maintenance depots. Running inside the AnyLogic simulation environment, the model uses a heuristic algorithm to schedule maintenance activities and allocate them to the most appropriate depot. Because the system is connected to live information on train locations and planned movements, it can continually adapt maintenance plans to accommodate urgent repairs. Operational issues may mean a particular train is elsewhere on the network when work is required. Maintenance planners also use the system for what-if analyses to explore the impact of changes to maintenance strategies and train timetables.

Figure 14: Alstom leverages digital twins to optimize maintenance regimes and capacity in the UK. Source: Place North West

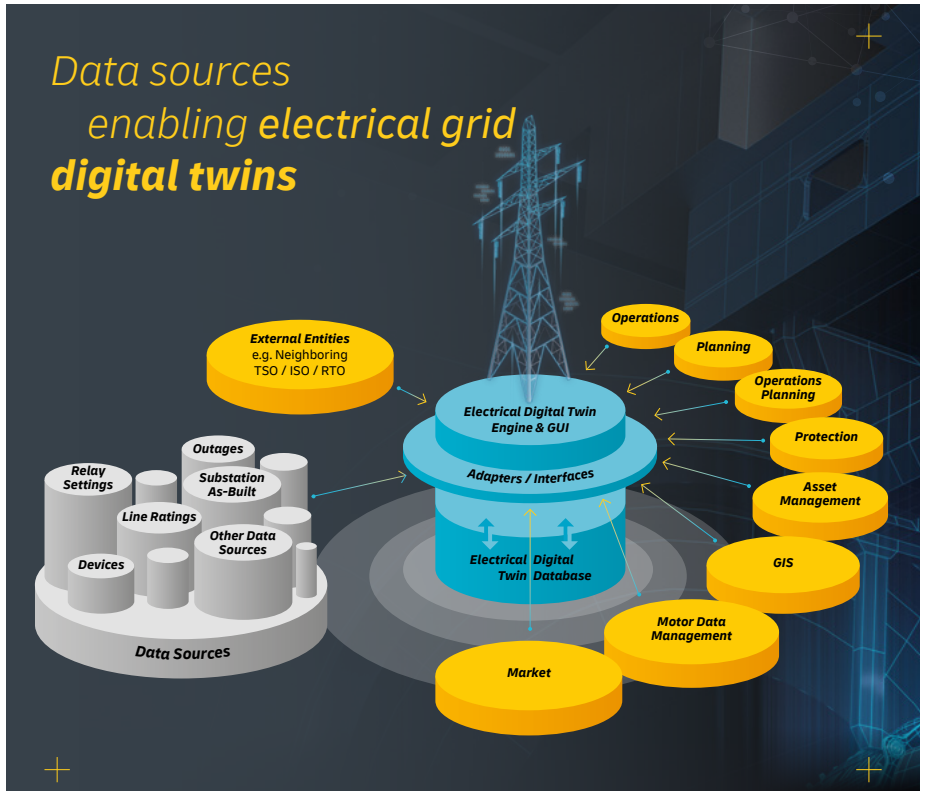


Figure 15

Figure 16

Figure 15: Data sources enabling electrical grid digital twins. Source: Siemens

Figure 16: A digital twin provides a rich single-pane-of-glass view of an urban project. Source: SmartCitiesWorld

Finnish electricity transmission system operator Fingrid worked with IBM, Siemens, and other partners to build a digital twin of Finland's power network. The Electricity Verkko Information System, or ELVIS, combines eight different systems as depicted in figure 15 into a single application, providing Fingrid with a consistent, comprehensive, and continuously updated model of its network. The digital twin is used in day-to-day grid operations, helping staff to manage power flows and protection settings to meet demand without overloading transformers or transmission lines. It also supports design and planning activities, allowing the operator to simulate the likely impact of changes to grid configuration or investment in upgraded assets.

In India, the state of Andhra Pradesh is developing a digital twin of a brand new city. Designed by architects Foster and Partners, Amaravati will serve as the new state capital, required after changes to regional borders carved off the original capital, Hyderabad, into the new state of Telangana. Amaravati has ambitions to become one the most digitally advanced cities in the world, with development planning and operations all running on a single platform.

The initial prototype of the digital twin shown in figure 16, which uses Smart World Pro software from Cityzenith, will be completed in 2019. During construction, the platform will collect data from IoT sensors to monitor environmental conditions and the progress of work.

Ultimately, the project's backers say the system will run the city's traffic management systems and automate tasks such as ensuring planning applications comply with local rules.

Figure 17

Figure 18

2.6 DIGITAL TWINS IN THE ENERGY SECTOR

Energy production, whether by fossil fuels or renewables, involves big, complex assets, often in remote locations. Those characteristics are driving the exploration and adoption of digital twins as a way to improve reliability and safety while keeping operating costs under control.

In the offshore oil and gas sector, for example, Aker BP used Siemens analytics technology in its Ivar Aasen project off the Norwegian coast, shown in figure 17. The success of the project, which reduces manpower requirements on the platform and optimizes equipment maintenance schedules, led to a strategic agreement between the two companies. Under the agreement, Aker BP and Siemens will develop digital lifecycle automation and performance analytics solutions for all future assets in the field.

Elsewhere in the North Sea, Royal Dutch Shell is involved in a two-year project to develop a digital twin of an existing offshore production platform shown in figure 18. In the Joint Industry Project, the organization is partnering with simulation company Akselos and engineering R&D consultancy LIC Engineering to implement new approaches to managing the structural integrity of offshore assets. The pilot project involves the development of a structural model of the platform, which will use data from sensors to monitor its health and predict its future condition.

Figure 17: A visualization of the digital twin technology leveraged in the Ivar Aasen project. Source: Siemens

Figure 18: Shell will develop digital twins of existing oil platforms to manage these platforms more effectively. Source: World Oil

In the wind energy sector, meanwhile, digital twin solutions are helping companies manage bigger turbines and meet aggressive reliability and cost-reduction targets. Norwegian engineering consultancy DNV GL Group, for example, has developed WindGEMINI, a digital twin package that includes physics-based models to monitor the structural integrity and predict the remaining fatigue life of turbines and components. GE is also exploring the potential of digital twins in its own wind turbine business. In one pilot project, the company built a thermal model of key wind turbine components, allowing engineers to create virtual sensors that estimate the temperature of inaccessible components based on data from physical sensors installed nearby.

2.7 DIGITAL TWINS IN CONSUMER, RETAIL AND E-COMMERCE

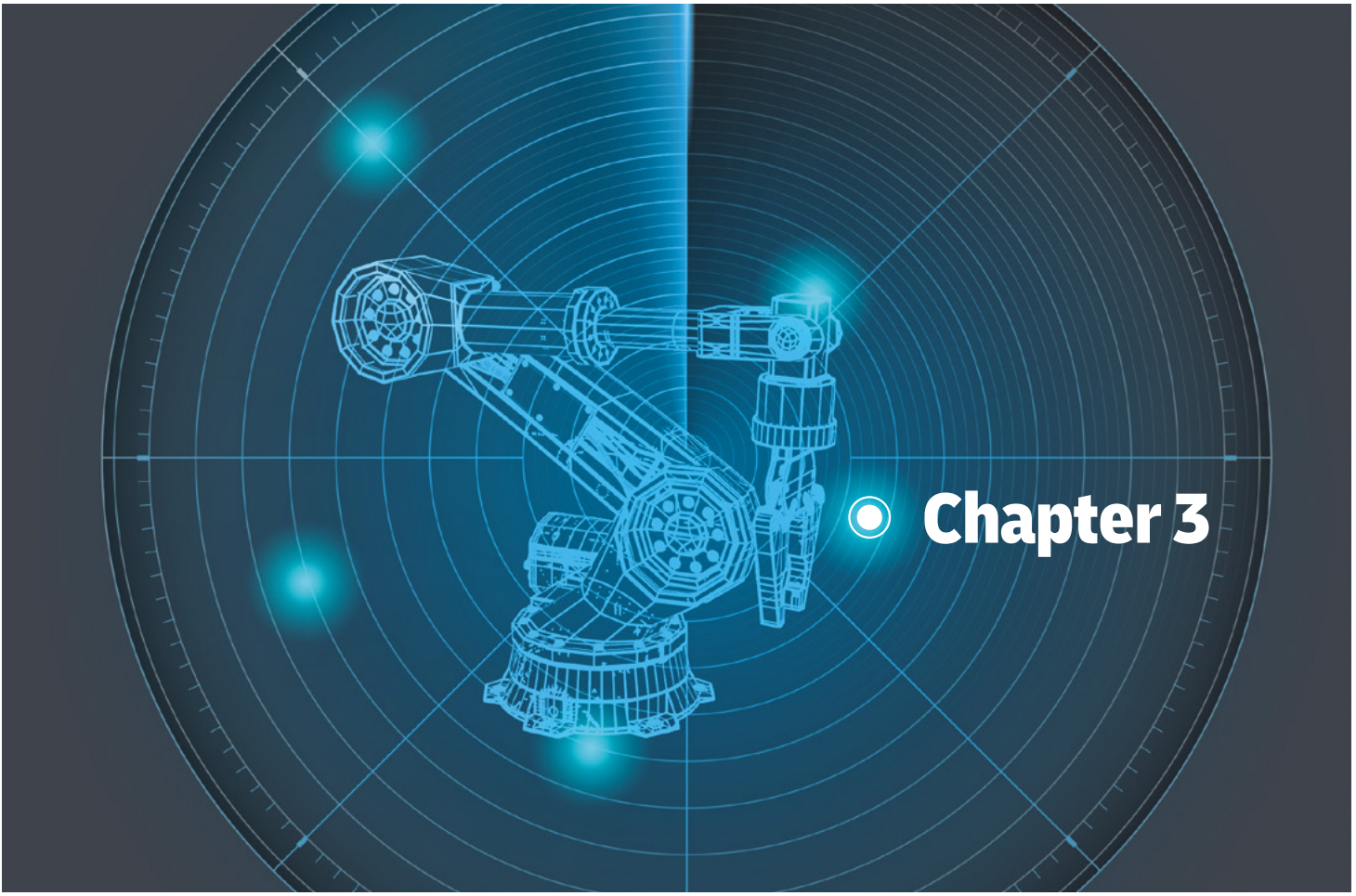
Consumer products present a different set of opportunities and challenges for digital twin technologies. Instead of a few large and complex assets, consumer markets often involve millions of much simpler objects. So players in this sector have a different focus – they are exploring the development of digital twins that track the flow of products through supply chains, for example, or building systems that can extract valuable insights from aggregated data produced by large numbers of comparatively simple models.

Dassault Systèmes, a producer of 3D modeling and digital twin technologies, has worked with retail technology company Store Electronic Systems to develop digital twins of retail stores. In the system, a 3D model of a store's layout is populated with data from electronic shelf labels like those in figure 19 to produce a detailed virtual representation of the store and its contents. Links to the store's inventory and point-of-sale systems update the model in real time to reflect the number of items stocked on the shelves. Dassault says its approach has multiple potential uses including applications that guide shoppers to the items on their list. The solution can also reduce stock-outs and help to improve merchandise layouts.

In retail and e-commerce applications, meanwhile, companies are developing increasingly sophisticated models of consumer behavior. Data on past purchases, web browsing habits, and social media activity is already being used by many companies to target advertising and promotions for specific customers and contexts. Over time, these models may evolve into consumer digital twins: complex, multi-attribute behavioral models that will attempt to predict future behaviors and proactively influence purchase decisions.

Figure 19: Electronic store labels act as critical sensors to feed the digital twins of retail spaces. Source: SES

Figure 19



Digital Twins in Logistics

While digital twins have not yet achieved widespread application in logistics, many of the key enabling technologies are already in place. The logistics sector has leveraged sensors to track shipments and more recently machinery and material handling equipment. Today the industry is also increasingly embracing open API strategies and migrating to cloud-based IT systems. Companies are applying machine learning and advanced analytics techniques to optimize their supply chains and draw new insights from historical shipment and operational data. Logistics professionals are even implementing augmented, mixed, and virtual reality applications for tasks like warehouse picking and vehicle loading as the data from these tasks is well suited to the creation of digital twins in these environments.

Bringing these and other technologies together into a full digital twin implementation is a complex and challenging endeavor, however. The cost-sensitive nature of many logistics activities may explain why few companies have so far been willing to make the necessary investments.

It is clear that the exploration of potential use cases for digital twins across the logistics space is now worthwhile. As costs fall and confidence in technology grows, the business case for some or all of the approaches described in this chapter may become compelling within the coming years.

3.1 PACKAGING & CONTAINER DIGITAL TWINS

The overwhelming majority of products that move through logistics networks do so in some form of protective enclosure. The industry employs large quantities of single-use packaging together with fleets of dedicated or general-purpose reusable containers.

Designing, monitoring, and managing packaging and containers creates a number of challenges for the industry. The growth of e-commerce, for example, is driving up demand, seasonal volatility, and packaging variety. This, in turn, produces significant waste and reduces operational efficiency through poor volume utilization.

The application of material digital twins could aid the development of stronger, lighter, more environmentally friendly packaging materials. In efforts to improve sustainability, companies are exploring the application of a range of new materials including compostable plastics and materials with a high percentage of post-consumer recycled content.

Furniture giant IKEA is even replacing plastic foam with a biological alternative grown from mushrooms.

Material digital twins such as those developed by Math2Market could help companies understand and predict the performance of new materials in packaging applications. These twins can model material behavior under the temperature, vibration, and shock loads experienced in transit.

Digital twins could also help logistics players manage container fleets more efficiently. Reusable containers are an industry standard in multiple logistics flows and modes. They include standard ocean containers, aircraft ULDs, reusable crates to transport car parts between factories, and containers for food and beverage delivery to retail stores and consumer homes.

Keeping track of reusable containers can be difficult. Not only must companies handle the movement of containers from their last destination to where they are needed next, but they must also check for damage and contamination that might compromise future loads or present a hazard to personnel or other assets.

Emerging 3D photographic technologies, such as those developed by German startup Metrilus, can rapidly create a detailed model of a container, allowing the automated identification of potential problems such as dents and cracks. That information could be combined with historical data on the container's movements to create a digital twin that informs decisions about when a specific asset should be used, repaired, or retired. Moreover, aggregating such data across a whole fleet of containers could help owners to make optimal decisions about fleet sizing and distribution, and identify trends that might indicate underlying problems such as a flaw in container design or rough handling that occurs at specific points in the supply chain.

Figure 20

3.2 DIGITAL TWINS OF SHIPMENTS

Incorporating the contents of a package or container into its digital twin is the next logical step. If a digital twin of an item to be shipped has already been created, data describing its geometry can be obtained from this pre-existing source, for example. Alternatively, the item data can be generated when the shipment is prepared, using 3D scanning and the same computer vision technologies mentioned in the previous section.

Combining product and packaging data could help companies improve efficiency, for example by automating packaging selection and container packing strategies to optimize utilization and product protection.

Figure 20: Digital twins of sensitive shipments will bring next-level visibility to the item and its packaging during transit. Source: Finnair Cargo

It is already common practice to ship sensitive, high-value products, such as pharmaceuticals and delicate electronic components, with sensors that monitor temperature, package orientation, shock, and vibration. The latest variants of these sensors, such as those developed by Roambee, Blulog, Kizy and others incorporate sensors that offer a growing host of data points that allow continuous data transmission during the progress of a shipment.

A shipment digital twin would act as a repository for the data collected by these sensors. Digital twin technologies could also allow this data to be used in new ways. A model that includes the thermal insulation and shock-absorbing characteristics of the packaging, for example, could allow conditions inside the product be extrapolated from data collected by external sensors.

3.3 DIGITAL TWINS OF WAREHOUSES AND DISTRIBUTION CENTERS

Digital twins could have a significant impact on the design, operation, and optimization of logistics infrastructure such as warehouses, distribution centers, and cross-dock facilities. These digital twins could combine a 3D model of the facility itself with IoT data collected in connected warehouse platforms (figure 21), as well as inventory and operational data including the size, quantity, location, and demand characteristics of every item.

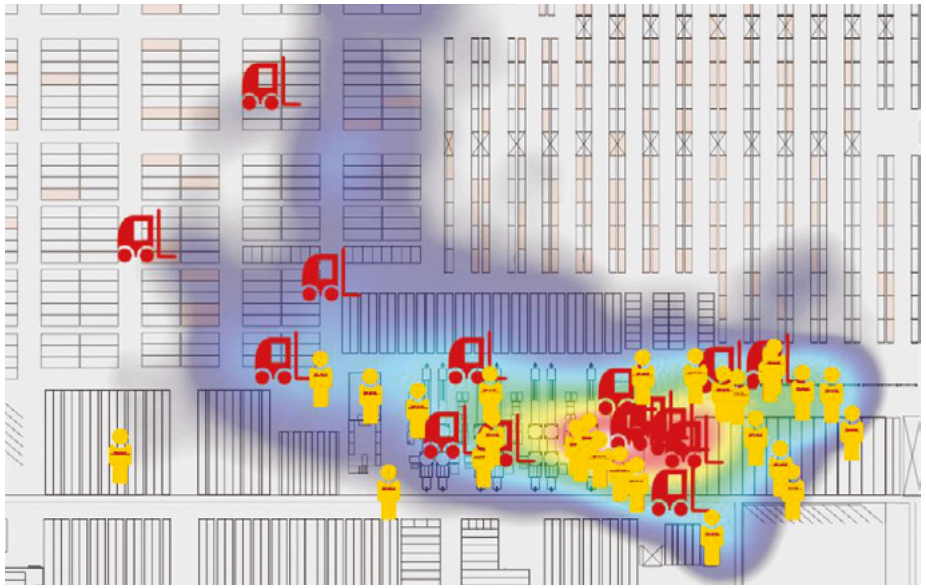


Figure 21

Figure 22

Warehouse digital twins can support the design and layout of new facilities, allowing companies to optimize space utilization and simulate the movement of products, personnel, and material handling equipment.

During warehouse operations, the digital twin can be constantly updated with data harvested from the various automation technologies that are becoming more prevalent in warehouses. These include drone-based stock counting systems, automated guided vehicles, goods-to-person picking systems, and automated storage and retrieval equipment. Digital twins will also allow further optimization of the performance of these automation systems, for example by using sensor data, simulation, and monitoring technologies to reduce energy consumption while maintaining requisite throughput levels.

Comprehensive 3D facility data can also be used to enhance the productivity of warehouse personnel. Companies can deploy virtual-reality training tools, for example, or augmented-reality picking systems using wearable devices such as Google Glass Enterprise Edition or Microsoft HoloLens – tools that are already being utilized today by DHL Supply Chain.

Figure 21: DHL uses heat maps based on internet of things technology to optimize operational efficiency and lay the foundations for safer working practices in warehouses. Source: DHL

Figure 22: Augmented and virtual reality glasses used for vision picking provide a valuable data stream to leverage in warehouse digital twins. Source: DHL

Figure 23: A visionary example of the elements involved in a digital twin of an entire supply chain network. Source: DHL

Figure 24

Perhaps the most compelling argument for using digital twins in warehouses and similar facilities is their contribution to continuous performance improvement. Comprehensive data on the movement of inventory, equipment, and personnel can aid the identification and elimination of waste in warehouse operations, from congestion in busy aisles to low productivity or picking errors by personnel. Before making changes on the ground, simulation using digital twins can enable facility managers to test and evaluate the potential impact of layout changes or the introduction of new equipment and new processes.

In environments such as e-commerce fulfillment that must accommodate rapid changes to volumes and inventory mix, digital twins can also support dynamic optimization of operations. Stock locations, staffing levels, and the allocation of equipment can be continually adjusted to match current or forecasted demand.

3.4 DIGITAL TWINS OF LOGISTICS INFRASTRUCTURE

Warehouses and distribution centers make up just a fraction of all logistics infrastructure. The flow of goods from source destination depends on the orchestration of multiple elements including ships, trucks and aircraft, order and information systems, and, above all, people.

This complex, multi-stakeholder environment can be seen most clearly at major global logistics hubs such as cargo airports and container ports. At these facilities today, the challenge of efficient operation is exacerbated by imperfect systems for information exchange, with many participants reliant on offline processes that can be subject to errors and delays.

A project is now underway in Singapore to use digital twin technologies to address these problems. The Singapore Port Authority is working with a consortium of partners, including the National University of Singapore, to develop a digital twin of the country's new mega-hub for container shipping.

The university's Professor Lee Hoo Hay shown in figure 25 is leading the initiative's technical and research development. He says that digital twin technology is finally becoming a reality thanks to a confluence of technology advancements. "Simulation-based optimization, industry 4.0, and the internet of things have been around for some time now. However it has really been the boom of artificial intelligence and its predictive capabilities that have given digital twins a big push in creating new value. In the past, creating spatial models digitally was exciting, but failed to be more than a way to visualize an object statically. Today, all the data we have from sensors, historical performance, and inputs about behavior lends itself to being linked to the spatial model and to predicting future behavior by changing different inputs. Effectively the data and prediction capabilities make the spatial model come alive."

Figure 24: The already advanced Singapore port is about to get a major upgrade with digital twins. Source: CraneMarket

Figure 25

The digital twin approach is already delivering benefits during the design phase of the Singapore project. The consortium is using its digital models to expedite the generation of potential layouts, and it is using simulation systems to evaluate different operating scenarios.

Eventually, the Port Authority hopes that the digital twin will help it optimize management of the new facility. Using simulation, for example, it will be able to choose the optimum berthing location for a vessel of any given size, taking into account the assets, space, and personnel required for loading and unloading operations, and the need to share those resources between multiple vessels at any one time.

While Singapore has a bold vision for the application of digital twins in large-scale logistics infrastructure, the ultimate success of any such initiative depends on the willingness – and technical ability – of all the stakeholders involved. A 'living' digital twin of a port or airport will require every organization using the facility to operate and maintain a digital twin of its own assets and personnel, and to share relevant data in real time with other users.

3.5 DIGITAL TWINS OF GLOBAL LOGISTICS NETWORKS

In logistics, the ultimate digital twin would be a model of an entire network including not just logistics assets but also oceans, railway lines, highways, streets, and customer homes and workplaces. The idea of such an all-encompassing twin even like the one depicted earlier in this chapter is largely an aspiration for the logistics industry for now. However, it is important to envisage where the full realization of logistics digital twins may lead.

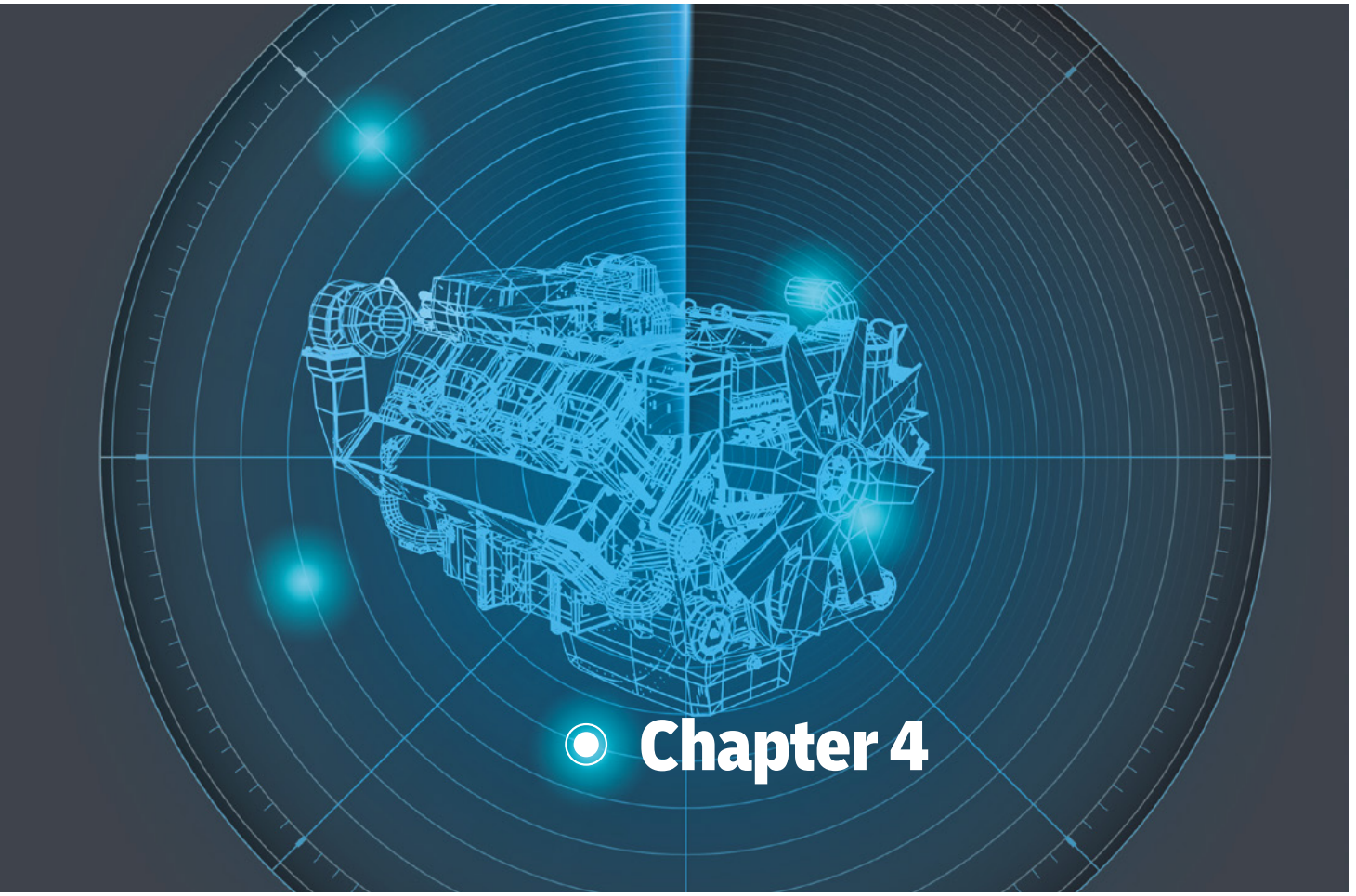
Geographic information system (GIS) technology is progressing extremely rapidly today, enabled by advances in satellite and aerial photography, and by on-the-ground digital mapping efforts. Demand for detailed geographical data has been driven by many user groups including governments, utility companies, and navigation system providers. Most recently, the development of autonomous vehicle technologies has accelerated efforts to produce extremely detailed data of the globe. Self-driving cars and trucks are already being trialed on public roads, with 11 major carmakers announcing plans to launch vehicles with autonomous capabilities over the next decade.

Autonomous vehicles will transform the availability of geographical data in two ways. They will require extremely detailed maps to operate, and they will also perform mapping functions themselves, collecting data from on-board cameras and from radio or light-based detection and ranging systems (radar and lidar methods) and then sharing that data wirelessly to continually update and improve map databases.

Modern GIS systems are much more than static digital maps. They can also incorporate dynamic data such as information on traffic speeds and densities, road closures, and parking restrictions due to accidents and repair works. They can even integrate the real-time location of specific people and vehicles. Logistics providers already make extensive use of GIS data, using it to plan delivery routes, for example, and predict arrival times based on weather conditions, congestion, and known delays at ports, airports, and border crossings. Digital twins of networks will also help providers to optimize their conventional logistics networks, for example by using rich data on customer locations, demand patterns, and travel times to plan distribution routes and inventory storage locations.

Clearly these aspirations will not be easy to fulfill and likely are still years away from full implementation. Most of today's digital twins are far less ambitious in scope but nevertheless present their users with challenges in terms of computing resource, data quality, precise representation, and governance. Here it is also important to mention that the heterogeneous and fragmented nature of the logistics industry will make it a highly adverse environment for digital twins to thrive. It is not yet clear whether those problems can be adequately addressed to enable the application of digital twins at truly global scale.

Figure 25: A digital twin to test the upcoming Tuas mega port design. Source: The Straights Times



Logistics Implications of Implementing Digital Twins

Digital twin technologies have the potential to transform almost every industry, with engineering, manufacturing, energy, and automotive leading the charge. As digital twins enter widespread use, their impact will be felt at every stage in the value chain. Detailed, real-time data on product use patterns and operating conditions will help manufacturers refine and improve their designs. Manufacturing processes will be faster and more flexible. Data on product performance will enable a more proactive approach to maintenance and support, allowing companies to offer their customers new types of service, or to intervene earlier to prevent failures and reduce downtime.

To realize these benefits, however, companies must be able to translate digital insights coming from upstream into physical actions downstream. That will require significant changes to supply chains, and to the logistics systems that manage the flow of materials, parts, and products through those chains.

4.1 INBOUND TO MANUFACTURING

Faster, more flexible manufacturing operations will place new demands on inbound material flows. Digital twins will enable more products to be configured and customized to match the specific requirements of individual customers, for example, but fulfilling that demand will increase complexity, with a greater number of component variants and more parts that must be managed in a batch size of one.

Companies will need to find ways to handle that complexity without compromising lead times, reducing transport efficiencies, or building high, costly inventories. That will require care in the choice of supplier locations, along with new approaches to transport and freight management. By pooling transport across multiple suppliers, for example, companies may be able to increase utilization even when they require frequent deliveries and small order quantities.

Closer collaboration with suppliers will also be important. Manufacturers can facilitate this by sharing demand forecasts – derived in part from digital twin data – earlier, and by working closely with suppliers to understand the capabilities and limitations of their production processes. Suppliers, meanwhile, can use approaches such as vendor-managed inventory (VMI) to provide additional flexibility and value to their customers.

Figure 26

Figure 26: Digital twins will drive greater configuration and customization, and this will require more flexibility and better quality control for fulfilling orders. Source: DHL

DHL EXPERT VIEWPOINT

Klaus Dohrmann
Vice President
Sector Development Engineering, Manufacturing & Energy
DHL Customer Solutions & Innovation

Digital twins are already changing the way our customers do business. In sectors such as aerospace, manufacturing, and industrial products, digital twins are becoming a central element of the engineering and in-field support activities of many organizations. We are now seeing the impact of these new approaches on the supply chain strategies and service requirements of those companies.

The real impact is yet to come, however. In the near future, we expect the use of digital twins to grow exponentially, from individual applications to eco-systems, connecting assets in operations and entire supply chains from end to end. That will unlock a multitude of opportunities across all industry sectors: increasing productivity, reducing waste, enabling new business models and, most importantly, delivering a new level of customer experience.

There will be a significant supply chain and logistics management component to many of these opportunities. Organizations will need their supply chains to translate upstream digital insights into physical benefits for their customers downstream. Logistics service providers will have a crucial role to play in this part of the digital twin revolution. Quite literally, it will be up to logistics professionals to deliver the full value of digital twins.

Given the complexity of the assets involved and the speed of response required, the support of digital twin-enabled assets will require the use of advanced logistics concepts such as control towers, 4PL providers, and lead logistics partners. Where digital twins enable predictive maintenance and support capabilities, for example, companies will need sophisticated service logistics solutions to deliver that support on the ground.

In every case, close collaboration between all players in the value chain will be essential to capture the full potential of digital twins. This will include the early involvement of logistics specialists in the development and implementation of digital twin concepts. Our own sector stands to benefit, too. Digital twins of supply chain assets – from containers and warehouses to trucks, ships, and aircraft – will increase the efficiency, flexibility, and responsiveness of logistics operations.

4.2 IN-PLANT LOGISTICS

The demands of digital twin-enabled manufacturing will also place new requirements on in-plant material flows. Companies may have to adapt their processes for just-in-time delivery to lineside and their kanban replenishment strategies to accommodate shorter lead times and higher product complexity. They will also need to handle material and component-related data with more rigor, to ensure that the digital twins of the products they build are associated with the correct component serial numbers or batch codes, for example.

In some cases, adapting manufacturing operations to accommodate the requirements of digital twin-driven products and business models will require new approaches to the design of workstations and plant layouts. Companies may want to switch from batch processing to single piece flow, for example, or adapt material storage and handling systems to cope with more complex and variable material requirements. Digital twin technologies could help companies to manage this additional complexity, by integrating with advanced storage and handling systems, or through the use of AR technologies to help staff locate and pick parts rapidly.

Figure 27: Digital twins will help optimize in-plant material flows. Source: DHL

Figure 27

Figure 28

Figure 29

Figure 28: Companies will need sophisticated logistics solutions to deliver support on the ground. Source: DHL

Figure 29: Visibility of assets, materials, and shipments will further improve with digital twins. Source: DHL

4.3 AFTERMARKET LOGISTICS

Digital twins have the potential to redefine the relationship between product manufacturers and their customers. With a digital twin, an OEM or a third-party service partner can monitor a product anywhere in the world. They can use that capability to offer a range of value-adding services to their customers, from remote support to predictive maintenance.

These new types of service will be highly dependent on the effectiveness of the provider's aftermarket supply chain, however. Early warning that a part is likely to fail is only useful if a replacement is available for installation at a convenient time. The supply and distribution of spare parts will become an increasingly critical element of the operating model for many companies.

To build and operate high-performing aftermarket logistics and support capabilities, companies will need to understand exactly where their customers are, which products they are using and how they operate those products. They will need to continually review the positioning and distribution of spare parts inventory to guarantee lead times that match their promises to customers.

Companies will also need to link parts distribution tightly with other elements of their aftermarket and field service operations. They may need to match component delivery windows with the arrival of service technicians at customer sites, for example, or make greater use of their dealers and distributor networks to provide after-sales services.

Aftermarket supply chains will also need to manage products at the end of their operating life, whether that is worn and broken parts removed in service operations or complete products that are no longer needed by their original users. Digital twins can help companies maximize the potential value of end-of-life equipment by helping them to identify the exact type and content of equipment. Capturing that value may call for more sophisticated reverse logistics processes, integrated with appropriate remanufacturing, recycling, and waste management systems.

4.4 ORCHESTRATING THE SUPPLY CHAIN

By offering a more complete view of the performance of products across their lifecycle, digital twins will allow companies to take a more holistic, end-to-end approach to the management of those products. Maximizing the through-life value of products and associated services will require a similarly holistic approach to supply chains.

In particular, companies will need to find smarter ways to balance inventory costs, availability, and lead times across their networks. That will increase the importance of full supply chain visibility so they understand the location and availability of parts and materials in their own inventories and those of suppliers, sales channels, and distribution partners.

Optimum supply chain set up will also be critical, with supplier and manufacturing footprints, logistics lanes, and stock locations configured to support high service levels and ensure companies can meet the availability and response time promises they make to their customers.

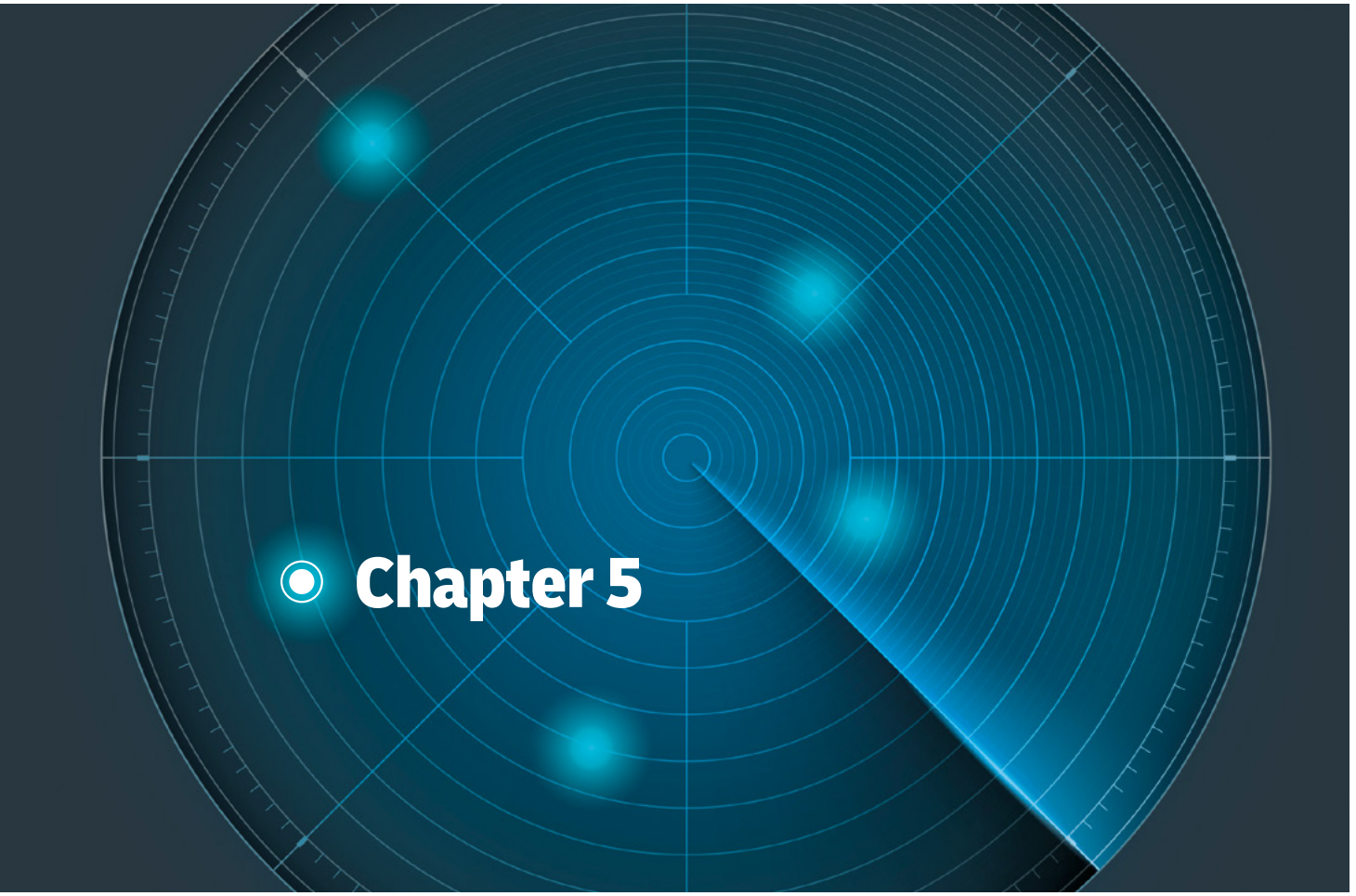
Figure 30

Finally, supply chains will need to be resilient, with the ability to maintain service levels in the face of disruption, recover quickly from major events and respond effectively to changes in demand.

Figure 30: Digital twin-enabled industrial equipment will accelerate service logistics needs. Source: DHL

Figure 31

Figure 31: Complete visibility of the performance of industrial products will drive new approaches to managing these complex assets. Source: DHL



Conclusion & Outlook

Digital twins are today coming of age. Fueled by the confluence of progress in the internet of things, big data, cloud computing, open APIs, artificial intelligence, and virtual reality, once-static digital models and simulations can now truly come alive in real time to help predict future situations, the state of physical things, and even the world around us.

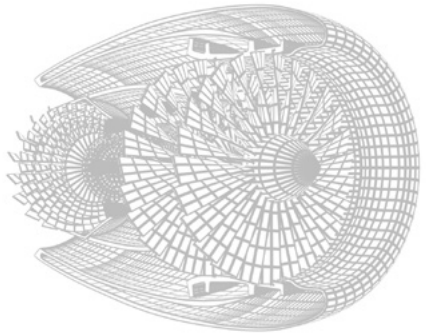
Though challenges and limitations remain in computing resources, precise representation, total cost, data quality, governance, and organizational culture, industries are evolving to overcome these obstacles. The benefits with digital twins will be improved outcomes and powerful new business models.

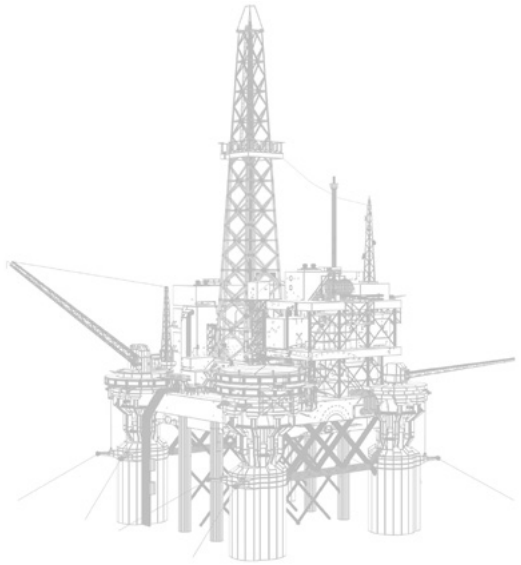
Today, the engineering, manufacturing, energy, and automotive industries are leading the way in leveraging digital twins to manage their most critical assets, followed by healthcare, the public sector, and even consumer retail. As the requisite technologies continue to become more readily accessible, the logistics sector is only just now beginning its digital twin journey and early examples of the first supply chain facilities and logisitics hubs developed using digital twins are beginning to emerge.

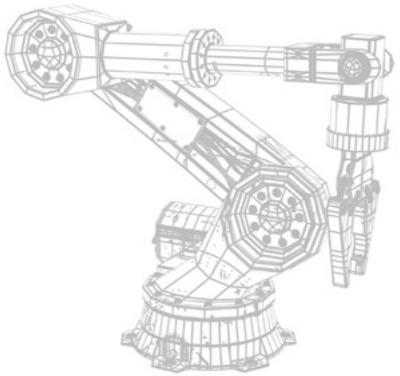
Perhaps more important for logistics professionals to consider in the near term is not how to leverage digital twins for direct orchestration of supply chain operations, assets, and facilities but rather how to evolve the supply chain. In what ways must supply chains evolve in organizations when digital twins become a core part of product, asset, and infrastructure operation?

As digital twins provide greater insight into and visibility of the current and future state of a ‘thing’ – from a material surface to a critical infrastructure – more proactive decisions can be made about managing the thing when deployed in the field. For digital twins and their physical counterparts to work together optimally, there is an accelerating need for logistics professionals to improve responsiveness, service quality, availability, and delivery accuracy to ensure the thing performs in optimal harmony with its intended design and performance.

Taking what has been provided in this report, how will you leverage digital twins in your organization? How do you see your supply chain evolving with the arrival of digital twins? At DHL we believe logistics digital twins are in their infancy and, as such, now is the time to explore and discover what challenges and opportunities might lay ahead when embracing digital twins. We look forward to hearing from you and welcome collaboration with your organization on the topic of digital twins.







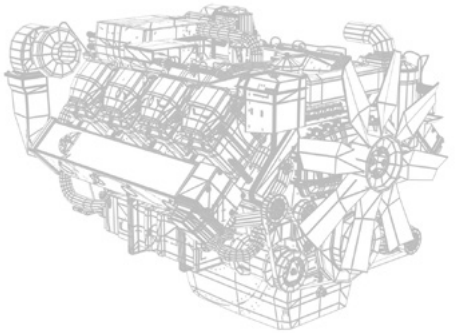


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Figure 26: DHL (2019)
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Figure 27: DHL (2019)
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Figure 28: DHL (2019)
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Figure 29: DHL (2019)
Visibility of assets, materials, and shipments will further improve with digital twins.

Figure 30: DHL (2019)
Digital twin-enabled industrial equipment will accelerate service logistics needs.

Figure 31: DHL
Complete visibility of the performance of industrial products will drive new approaches to managing these complex assets.

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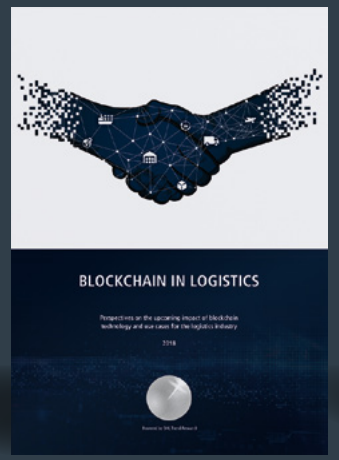

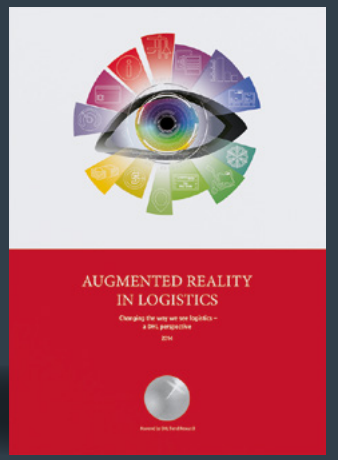

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