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Twinning is winning

Digital twins are quickly beginning to form a key component of the digital transformation journey for enterprises across several major industries. The utility offered by creating a virtual copy of a machine, building or system helps to reduce the risk of new deployments or implementing new technologies, while offering a richer source of data for savvy businesses.

But you'd be forgiving for asking, what is a digital twin? Though the concept itself has been around since the 90s - first anticipated in David Gelernter's 1991 book *Mirror Worlds* - it became paired with product lifecycle management in 2002 at a Society of Manufacturing Engineers conference.

The name itself was, like many of the tech innovations we rely on today, popularised by NASA and Twins themselves are beginning to see particular success across four key sectors, identified in this report: Construction, healthcare, manufacturing, and transport.

The aim of this report is to break down how each of these industries is adopting Digital Twins and the impact this is having on early adopters. We look at both the functionality of the twin in action, as well as the benefits adoption is expected to bring. For this, TI turned to experts across several fields who offered their insights into digital twins. Some have created their own twins or developed simulations for other businesses, while others have adopted the technology and shared their experiences. Without them, this report could not have been written, so I want to thank them for their contributions.

We are entering a world where architects and quantity surveyors can test the impact of different materials or designs without ever laying a brick or building a physical model; where a trainee doctor can practice surgery on a virtual heart, and see the outcomes of mistakes, long before they go near a human. Digital twins offer a new, smarter way for businesses to test products or constructions with real time data analytics and insight, but none of the usual risk.

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A night cityscape with a digital network overlay. The city lights are visible in the background, and a complex web of glowing red and blue lines connects various points across the scene, representing a digital network or data flow.

Digital twins – an introduction

In today's rapidly evolving technological landscape, businesses are increasingly turning to innovative solutions to gain a competitive edge. Among these transformative technologies, digital twins have emerged as a game-changer across several industries. A digital twin, a virtual replica of a physical entity, has transcended its origins in manufacturing and is now revolutionising enterprises worldwide. This article delves into the multifaceted impact of digital twins on industries, exploring their applications, benefits, challenges, and future potential.

The concept of digital twins originated from the aerospace and manufacturing sectors, where it was initially used to simulate and optimise product design, manufacturing processes, and maintenance strategies. However, the scope of digital twins has expanded dramatically. Today, they encompass a diverse range of fields including healthcare, energy, transportation, and even urban planning. A digital twin is not merely a 3D

model; it's a dynamic, data-driven representation of its physical counterpart. This virtual replica is continuously updated with real-time data from sensors, IoT devices, and other sources. By mimicking the behaviour of the physical object, digital twins enable businesses to gain insights, optimise operations, and make informed decisions.

Applications across industries

Manufacturing: The manufacturing sector was an early adopter of digital twins, leveraging them to streamline production processes, improve quality control, and reduce downtime. By creating a digital representation of a factory, manufacturers can test various scenarios to identify bottlenecks and optimise workflows before implementing changes in the physical world. **Healthcare:** In the realm of healthcare, digital twins are transforming patient care. Personalised medicine is becoming more attainable as digital twins

Healthcare: In the realm of healthcare, digital twins are transforming patient

care. Personalised medicine is becoming more attainable as digital twins of individual patients are used to model disease progression, test treatment options, and optimise drug dosages. Surgeons can even practice complex procedures on virtual models before entering the operating room.

Energy: Digital twins are reshaping the energy sector by enhancing the efficiency of power plants, wind farms, and oil rigs. By simulating real-world conditions, operators can predict maintenance needs, optimise energy production, and minimise downtime. This proactive approach leads to significant cost savings and reduces environmental impact.

Smart Cities: As urbanisation accelerates, city planners are turning to digital twins to design and manage complex urban environments. These virtual representations help optimise traffic flow, manage infrastructure, and enhance emergency response. The result is more sustainable, resilient, and livable cities.

Aviation and Aerospace: The aviation industry benefits from digital twins by predicting aircraft performance, monitoring equipment health, and enhancing

ing safety. Airlines can optimise flight routes based on real-time weather data and fuel consumption simulations, while space agencies use digital twins to model satellite behaviour and mission outcomes.

Benefits of digital twins

The allure of digital twins lies in their capacity to provide tangible benefits across the entire business spectrum: **Data-Driven Insights:** Digital twins generate vast amounts of real-time data, offering deep insights into operational processes and performance. These insights empower decision-makers to

interconnected with physical systems, ensuring data privacy and protection becomes paramount.

Complexity and Cost: Developing and maintaining digital twins requires substantial investments in technology, infrastructure, and expertise. Organisations must carefully weigh the benefits against the associated costs.

Interoperability: As digital twins span multiple systems and technologies, ensuring interoperability between different platforms and devices can be challenging. Standardisation efforts are crucial to seamless data exchange.

Change Management: Implementing

digital twins often necessitates organisational changes, including redefining workflows and roles. Managing this transition and fostering a culture of data-driven decision-making is essential.

The Future of Digital Twins

The journey of digital twins has just begun, and their trajectory is promising: **AI and Machine Learning Integration:**

The synergy between digital twins and artificial intelligence (AI) is set to amplify their capabilities. Machine learning algorithms can process vast amounts of data generated by digital twins, uncovering patterns and insights that human analysis might miss.

Autonomous System Optimization:

Digital twins will play a pivotal role in the development and optimisation of autonomous systems. From self-driving cars to automated manufacturing lines, digital twins will enable safe testing and continuous improvement of these technologies.

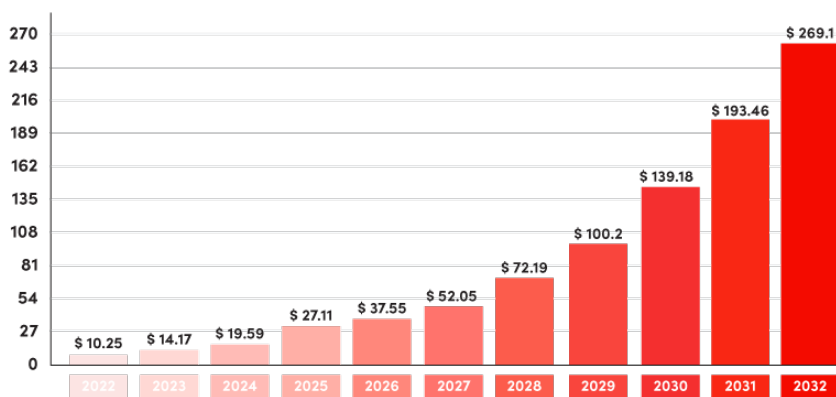
Real-Time Decision-Making: As data processing speeds increase, digital twins will support real-time decision-making. This is particularly critical in industries where split-second choices can have far-reaching consequences, such as healthcare and autonomous vehicles.

Virtual Reality (VR) and Augmented Reality (AR) Integration: The convergence of digital twins with VR and AR technologies will allow for immersive experiences. Designers, engineers, and technicians can interact with digital twins in a virtual space, enabling more intuitive problem-solving and collaboration.

Conclusion

Digital twins have transcended their origins as manufacturing tools to become a transformative force across industries. Their ability to replicate and simulate real-world entities offers unparalleled insights, predictive capabilities, and optimisation opportunities. As businesses continue to grapple with complexity, competition, and technological advancement, embracing the power of digital twins will be a defining factor in their success. The revolution is underway, and enterprises that harness the potential of digital twins will emerge as leaders in the data-driven, technology-fueled future.

DIGITAL TWIN MARKET SIZE, 2022 TO 2032 (USD BILLION)



Source: www.precedenceresearch.com

identify inefficiencies, devise targeted strategies, and optimise resource allocation.

Predictive Analytics: By leveraging historical and real-time data, digital twins enable predictive analytics. This means anticipating maintenance needs, identifying potential failures, and preventing downtime before it occurs. This proactive approach is a game-changer for asset-heavy industries.

Informed Decision-Making: With accurate and up-to-date information at their fingertips, decision-makers can make informed choices. Whether it's optimising supply chains, fine-tuning manufacturing processes, or responding to changing market demands, digital twins provide the foundation for agile decision-making.

Risk Reduction: Through simulations and scenario testing, digital twins allow businesses to assess risks without real-world consequences. From testing new product designs to evaluating the

impact of strategic decisions, the ability to experiment in a virtual environment mitigates potential pitfalls.

Collaboration and Communication: Digital twins facilitate collaboration among diverse teams by providing a common platform for data sharing and visualisation. Cross-functional teams can work together seamlessly, leading to improved problem-solving and innovation.

Challenges and Considerations
While the promise of digital twins is undeniable, several challenges must be addressed to fully realise their potential: **Data Integration and Quality:** The accuracy and reliability of a digital twin heavily rely on the quality and integration of data from various sources. Inaccurate or incomplete data can lead to erroneous insights and flawed decision-making.

Security and Privacy: Handling sensitive data within digital twin environments demands robust cybersecurity measures. As digital twins become more



Construction: Building the twinned future

By James Pearce

The construction industry, traditionally known for its intricate processes and complex challenges, is undergoing a remarkable transformation thanks in part to digital twins. When applied to construction, twins provide a holistic, real-time view of projects, from inception to completion.

Digital twins are emerging as a game changer in the design and planning phase of construction projects. Architects, engineers, and planners can create detailed virtual models of buildings, infrastructure, and entire construction sites. These virtual models enable stakeholders to visualise the project in its entirety, identifying potential design flaws, visualise and understand the project work

spatial constraints, and clash detection. With the ability to simulate different scenarios, construction professionals can test the feasibility of designs and make necessary adjustments before the physical construction commences. This not only reduces errors but also streamlines the design process, contributing to project efficiency.

As Bentley Systems director of construction Beth Buerger explains: “Digital twins offer several benefits to the construction industry compared to older manual, paper-based systems.

“Digital twins provide a detailed virtual representation of a physical asset, allowing stakeholders to work

more effectively on projects. This improves communication and collaboration among project teams. They also enable engineers to simulate and optimise designs before construction begins. They can identify and address potential issues, resulting in more efficient planning and reduced errors during construction.

“Overall, digital twins offer a more comprehensive and dynamic approach to construction management compared to traditional systems, resulting in improved efficiency, cost savings, and better project outcomes.”

Reducing risk and boosting collaboration

Construction projects are exposed to

a multitude of risks, ranging from adverse weather conditions to logistical challenges. Digital twins empower project managers to simulate various scenarios and anticipate potential risks. By integrating real-time data, such as weather forecasts and site conditions, into the digital twin, construction teams can analyse the impact of these variables on the project timeline and budget. This proactive approach allows for the formulation of contingency plans and risk mitigation strategies, ultimately leading to smoother project execution and reduced delays.

Effective communication and collaboration among project stakeholders are critical for project success. Digital twins provide a centralised platform where architects, engineers, contractors, and clients can access the virtual model and exchange information seamlessly. This enhances transparency and reduces miscommunication, as all parties have a shared understanding of the

“By integrating real-time data, such as weather forecasts and site conditions, into the digital twin, construction teams can analyse the impact of these variables on the project timeline and budget.”

project’s status and requirements. Changes and updates can be made in real-time, ensuring that everyone is on the same page. This collaborative environment fosters better decision-making and accelerates project progress.

One example of this in action was the construction on London’s Elizabeth Line, which went live in 2022. The newest train line on Transport for London’s Underground network, the Elizabeth Line spans 73 route miles

and 21 stations, coming in at a cost of £18.7 billion.

Digital Twins were used to solve the problem of siloed teams and data, explains Kingston Technology’s head of

“The Elizabeth Line digital twin uses over 250,000 models that include everything from lightbulbs to cable trays”

B2B strategic marketing Elliot Jones. “When it comes to vertical specific use cases, there are multiple examples of how a digital twin can be used to provide a clear vision of evolving requirements, and coordinate schedules to ensure on time and on cost project completion. The Elizabeth Line digital twin comprised over 250,000 models including everything from lightbulbs to cable trays, each one ‘twinned’ and labelled from database information on the Elizabeth Line’s physical assets.

“The 3D model form gave managers the ability to monitor the Elizabeth Line on various devices, once construction work began. This approach not only saved time and money, but it also meant that workers on the line could hold up a tablet for an augmented reality (AR) view of communications, water, and electricity. This could be done beneath any station wall or floor – removing all need for maps and potentially outdated models.”

Real time monitoring

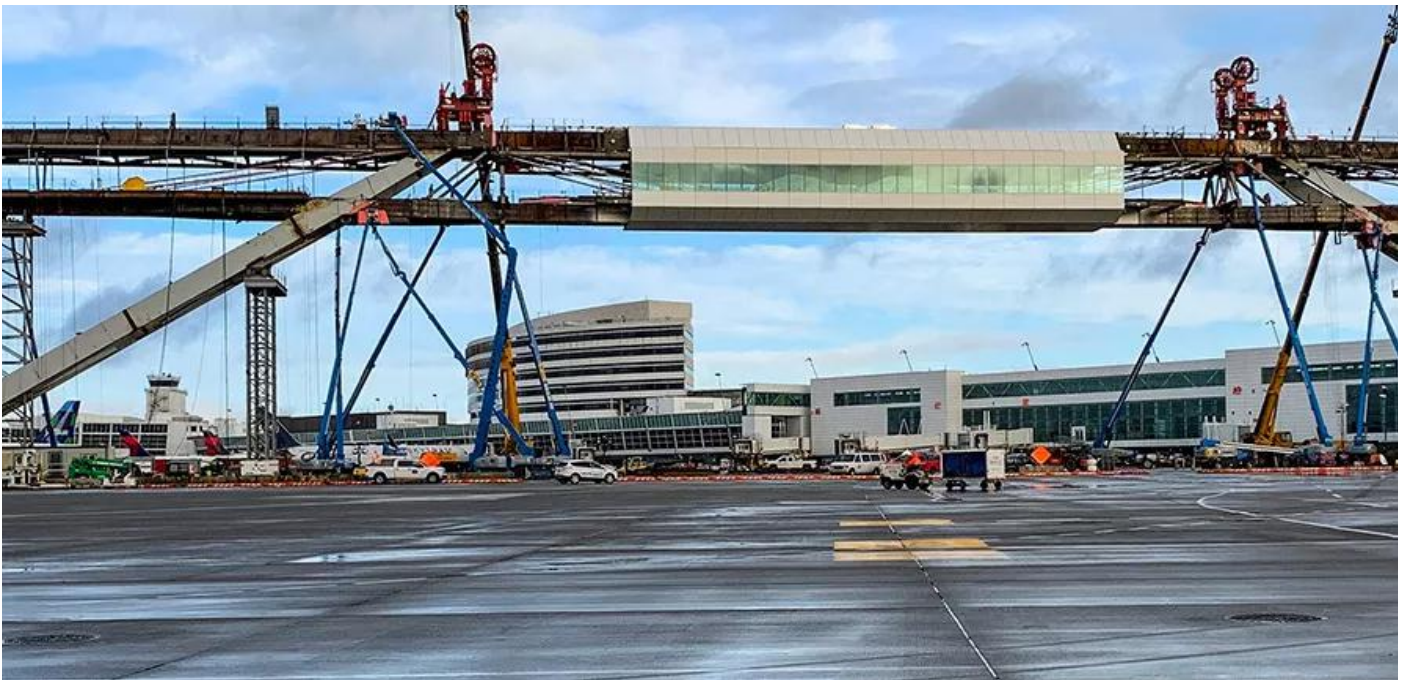
The construction process involves numerous moving parts that need to be synchronised to meet project milestones. Digital twins integrate real-time data from sensors placed on the construction site, capturing information about progress, equipment usage, and resource allocation. Project managers can monitor the construction activities in real-time against the planned schedule, identifying any deviations or delays. This level of visibility empowers deci-

sion-makers to take immediate corrective actions and optimise resource allocation, ensuring that projects stay on track.

Resource management is also a critical aspect of construction project management. Digital twins offer insights into the allocation and utilisation of resources such as labor, materials, and equipment. By analysing data within the digital twin, project managers can make informed decisions about resource allocation, preventing shortages or overages. This optimisation contributes to cost savings and ensures that resources are utilised efficiently throughout the construction lifecycle.

The benefits of digital twins extend beyond the construction phase. Once a project is completed, the digital twin continues to provide value in the maintenance and operations stages. Asset information, maintenance schedules, and performance data can be integrated into the digital twin. This allows facility managers and maintenance teams to monitor the condition of the building or infrastructure in real-time, enabling predictive maintenance and timely interventions. Ultimately, this prolongs the lifespan of assets and reduces operational downtime. In an era focused on sustainability and environmental responsibility, digital twins play a vital role in promoting sustainable construction practices. By simulating the energy performance and environmental impact of a building or infrastructure project, digital twins enable architects and engineers to optimise designs for energy efficiency and minimise the project’s carbon footprint. This data-driven approach aligns with the industry’s shift toward sustainable development.

Another example saw Clark Construction hired to build the world’s longest pedestrian walkway at the Seattle-Tacoma International Airport. The \$968 million project aimed to help the airport deal with a growing demand for international travel by expanding the 450,000sqft International Arrivals Facility. The redesign included a new connecting corridor which would feature an 85-foot high pedestrian aerial walkway linked to



Clark constructs world's longest pedestrian walkway with aid of Bentley Systems digital twin

the airport's South Satellite. Clark opted to use Bentley's Synchro application to generate a data-rich digital twin for facilities management at the airport, helping them in the construction of the structure which had to be built remotely and then hoisted on to 85-foot pier supports. It used Synchro 4D to link the BIM model to the construction schedule. This, explains Bentley's Buerger, required "meticulous planning and sequencing with no room for error". The 4D workflow twin worked, allowing Clark to successfully build and fit the walkway within of an inch, safely in place above an active airport taxi lane.

"The 4D workflow twin allowed Clark Construction to build and fit the walkway safely in place above an active airport taxi lane."

Future challenges

While the integration of digital twins in the construction industry offers numerous advantages, it's important to acknowledge the challenges associated with their implementation. The creation of accurate and detailed digital twins requires significant upfront investment in terms of technology, data collection, and expertise. Additionally, interoperability between different software platforms and data sources can be a hurdle that needs to be overcome to ensure seamless integration of information. Looking ahead, advancements in technologies such as Internet of Things (IoT), artificial intelligence (AI), and machine learning (ML) will likely enhance the capabilities of digital twins even further. These technologies will enable more sophisticated data analysis, predictive modeling, and automation within the digital twin environment, further improving decision-making and project outcomes.

For Buerger, digital twins are likely to be adopted "widely" across the sector as the technology "matures and becomes more accessible" more construction firms are expected to

recognise the benefits of the technology.

She adds: "Integrating digital twins with other technologies such as building information modeling (BIM), Internet of Things (IoT), and cloud platforms will enhance data exchange, interoperability, and collaboration among various stakeholders. "Digital twins will also leverage advanced analytics and artificial intelligence technologies to provide even deeper insights and predictions. Machine learning algorithms will help optimise construction processes, predict maintenance needs, and simulate scenarios to improve decision-making."



Healthcare: The growth of digital twins

By James Pearce

The healthcare industry is undergoing a remarkable transformation driven by technological innovations that are reshaping patient care, treatment strategies, and medical research. Among these innovations, digital twins have emerged as a groundbreaking concept with the potential to revolutionise healthcare practices. A digital twin is a virtual replica of a physical object or system, and in healthcare, it holds the power to enhance diagnostics, treatment planning, and patient outcomes. This article delves into the diverse ways in which digital twins are being harnessed to usher in a new era of personalised and data-driven healthcare.

1. Precision Medicine and Personalised Treatment

One of the most promising applications of digital twins in healthcare is the realm of precision medicine. By creating virtual replicas of individual patients, healthcare providers can simulate the patient's physiological processes, genetic makeup, and disease progression. These digital twins provide a unique platform for tailoring treatment plans to the patient's specific characteristics. Physicians can test different treatment scenarios, predict the effectiveness of various interventions, and optimise therapies for better outcomes. This personalised approach leads to more effective treatments, reduced side effects, and improved patient experiences.

2. Surgical Planning and Training

Digital twins are transforming the

landscape of surgical planning and training. Surgeons can create virtual replicas of a patient's anatomy and simulate surgical procedures before entering the operating room. This allows for a comprehensive understanding of complex cases, enabling surgeons to anticipate challenges and devise optimal strategies. Additionally, digital twins serve as valuable training tools for medical students and aspiring surgeons. They can practice procedures in a risk-free virtual environment, enhancing their skills and confidence before performing surgeries on real patients.

3. Medical Device Development and Testing

The development and testing of medical devices are critical stages in

ensuring patient safety and efficacy. Digital twins facilitate these processes by enabling manufacturers to simulate how medical devices interact with the human body. Virtual testing helps identify potential design flaws, assess the device's performance under various conditions, and optimise its functionality. This not only accelerates the development timeline but also contributes to the creation of safer and more reliable medical technologies.

4. Chronic Disease Management

Managing chronic diseases requires a comprehensive understanding of how various factors impact a patient's health over time. Digital twins provide a dynamic platform to monitor patients with chronic conditions. By integrating real-time patient data, such as vital signs, medication adherence, and lifestyle behaviours, healthcare providers can create virtual models that reflect a patient's health trajectory. This enables early detection of deviations from normal parameters, allowing for timely interventions and adjustments to treatment plans.

5. Drug Discovery and Development

The pharmaceutical industry is leveraging digital twins to optimise the drug discovery and development process. Virtual models of human organs and tissues allow researchers to simulate how potential drug compounds interact with the body. This accelerates the identification of promising drug candidates and helps predict their efficacy and potential side effects. Digital twins also enable researchers to conduct virtual clinical trials, reducing the reliance on traditional trial methodologies and expediting the path to bringing new therapies to market.

6. Rehabilitation and Physical Therapy

Digital twins are playing a crucial role in enhancing rehabilitation and physical therapy programs. For patients recovering from injuries or surgeries, healthcare providers can create virtual representations of their bodies to monitor progress and track improvements. These virtual models help therapists design personalised rehabilitation regimens, enabling patients to regain strength and mobility more effectively. Additionally, digital twins enable patients to engage in remote tele-rehabilitation programs, receiving

guidance and feedback from healthcare professionals without the need for in-person visits.

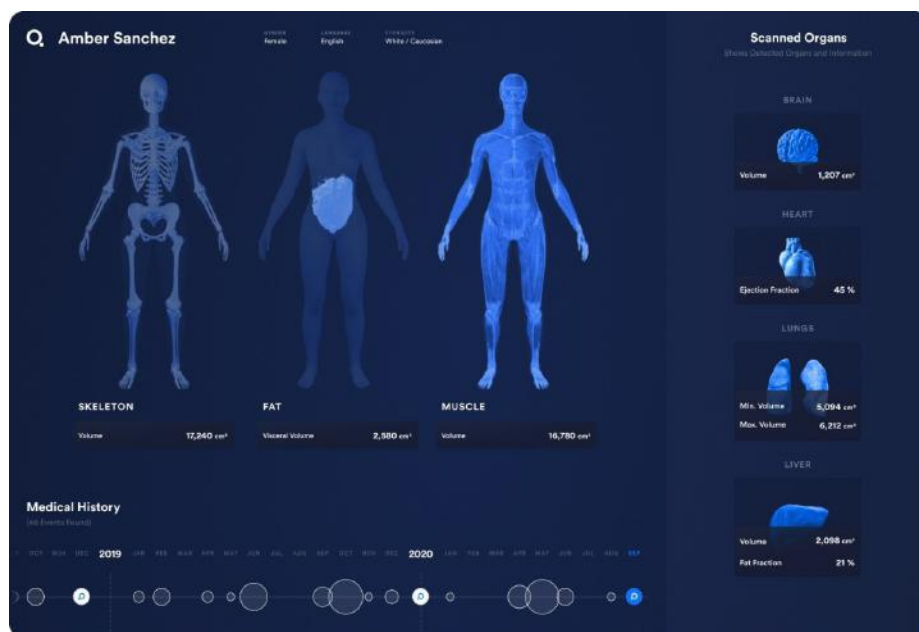
7. Mental Health and wellbeing

The integration of digital twins is extending to the field of mental health and wellbeing. Virtual models can simulate brain activity and neural pathways, providing insights into the cognitive processes associated with

time, motivating them to adhere to treatment plans and make healthier lifestyle choices.

Conclusion

The convergence of technology and healthcare is giving rise to a new era of patient-centered, data-driven medicine, and at the forefront of this transformation is the concept of digital twins. From precision med-

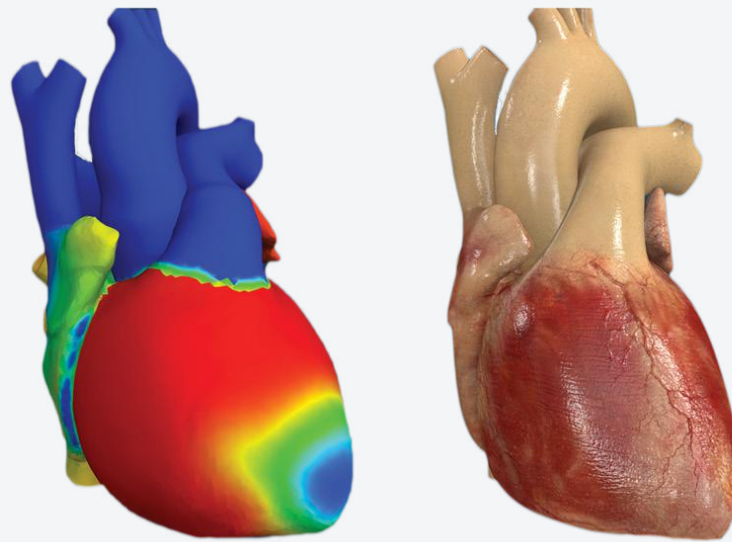


various mental health conditions. This understanding can aid in the development of personalised treatment approaches for conditions such as depression, anxiety, and cognitive disorders. Furthermore, digital twins can be used to create virtual environments for exposure therapy, assisting individuals in overcoming phobias and managing stressors.

8. Patient Education and Empowerment

Digital twins have the potential to empower patients by providing them with a better understanding of their health and treatment options. By visualising their own virtual model, patients can gain insights into their conditions, treatment plans, and the potential outcomes of different interventions. This fosters informed decision-making, as patients are better equipped to actively participate in their healthcare journey. Additionally, digital twins can help patients track their progress over

time and surgical planning to drug discovery and mental health support, the applications of digital twins in healthcare are vast and transformative. As technology continues to evolve, the potential of digital twins to enhance patient care, advance medical research, and reshape treatment paradigms is boundless. By leveraging the power of virtual replicas, healthcare is transitioning toward a future where each patient's unique needs and characteristics are at the core of their medical journey.



Case study: Living Heart Project

By Ann-Marie Corvin

Imagine we all had our own real-time 3D version of our health records, a digital twin that simulates the many systems running through our bodies and ‘crash-tests’ possible treatments, should we ever need them.

It was a young girl with a congenital heart defect that first propelled 3D software design company Dassault Systèmes into a decade-long project aimed at creating virtual twins of the human body, the fruits of which were on display at CES in January this year. For forty years the multimillion dollar French firm has been supplying its simulation systems to automobile plants to crash test car designs or to firms like Boeing, to test virtual plane parts.

Dassault became adept at creating industrial digital twins for Boeing, commercial aircraft production requiring lots of parts and companies working on virtual copies of the same machine, so that everyone can collaborate on the same representation.

“There might be a thousand different companies all working together but it all has to behave together and to fit. That’s the virtual twin,” explains Dr Steve Levine, Dassault’s senior director of Virtual Human Modelling.

The firm then had the idea to apply the

same modelling to help doctors and the healthcare sector.

Levine continues: “We thought if we could get experts to come together on our platform and use the tools we’d already developed for physical properties we could create a blue print working model of the human body.”

I meet Levine – a doctor of engineering – and his colleague, John McCarthy, a business strategy director in Dassault’s Life Sciences & Healthcare arm, at the firm’s stand at CES in Las Vegas, where an LED screen towers above us, broadcasting a visual representation of a human virtual twin.

It’s a visualisation that serves to remind us that, thanks to the progression of consumer grade AR and VR technologies, the industrial metaverse may not only transform healthcare practices, but also the experience of patients and carers using these services through a range of sensors and connected devices.

Heart of the matter

Dassault’s ongoing mission to map the human body started ten years ago. The best place to start, it was agreed, was the heart and so the Living Heart Project was born.

Heart-related diseases are still the

number one cause of death worldwide and the single biggest financial burden to the medical system globally. In the UK, for instance, a quarter of all deaths every year are from heart disease. Levine tells me later that he also had personal reasons for leading this project: his daughter was born with a rare heart deficiency.

A 3D platform that could map out the mechanics of how her heart operated would enable the engineer to understand his daughter’s heart and enable paediatricians and cardiologists to plan the best course of action to correct its faults.

“Cardiac defects are the number one congenital defect – one in every hundred people born has a heart defect. Partly we don’t know about it because children aren’t central to the medical system, because we don’t perform trials on them,” Levine explains. Levine has learned that doctors operating on newborns with a heart condition, open up the child and have about ten minutes to decide what to do.

“And in that ten minutes you dictate the child’s life,” he continues. “If we are able to have that digital twin beforehand, we can perform the surgery and optimise it before the child is born, and, once it is born, can execute that beautifully.”

To get a heart virtual twin however, Levine needed data. What followed in the early days was a labour of love that involved “a lot of getting on planes to different parts of the world” to visit cardiologists and persuade them to take part in the project.

Dassault also went on a data buying spree – acquiring healthcare database Medidata in 2019, for instance, for \$5.8bn.

To date, over 100 cardiovascular specialists are on board, as well as 30 contributing member organisations, hospitals and medical device designers. It’s a testament to the project’s medical establishment backing that, in 2014, the US Food and Drug Administration came on board as a test partner. The regulator wanted to use the project for the development of testing models to insert, place, and perform cardiovascular devices, including pacemaker leads. In 2019 this partnership was expanded by another five years, to develop a digital tool to ‘crash test’ medical devices.

Early users

The LHP is now being used by researchers, device manufacturers and doctors to develop highly accurate virtual models for reproducing conditions and testing treatment options.

Typically, its operators are bio medical engineers working in conjunction with doctors and device designers. The Boston Children’s Hospital was an early pioneer of the platform. The hospital has been using it for three years and has carried out procedures on 500 patients using the technology as a guide.

According to Levine, the hospital has just got to the point where it has enough data to start charging patients for the service. “They had to self-fund to collect the data before they could get the data to show they could save money by not having as many rehospitalisations and saving lives,” he adds. Given the magnitude of the task in hand, three years seems a relatively short period of time, although, as Levine points out, “it’s three years building on 30 years of technology development before we started and another 5 to 6 to develop the capability that they then put it into practice.”

Brain, liver & lung

Dassault’s aim is to take on the human



body, one organ at a time. Other projects are on the way. The Living Brain is still in its early stages – the firm has a representative model but it could take another decade to complete the map of the brain network, Levine adds.

Nonetheless McCarthy points out some early use cases including virtual twins of the brain that marry imaging with other patient data to pin point brain lesions in epilepsy patients that don’t always show up on regular scans. “From the procedures I’ve heard of, lesion removal surgery can now go from two hours where you are doing all that probing to something like 20 minutes because you have more precise telemetry of where that lesion is,” he says. During the pandemic Dassault also built a human lung so that it could investigate why respirators were hindering, rather than helping Covid patients. Lucid Implants utilising Dassault’s

3DExperience platform

“We learned that respirators were not very effective because they actually work against the body’s natural system. “Instead of working on negative pressure they work on positive pressure. So we now have the tools with which device manufacturers can design an improved next generation of respirators,” says Levine.

A liver project focusing on the drug toxicity of anti-cancer drugs has also launched. This project is based around the fact that the majority of anti-cancer drugs never make it to market because, while effective on some patients, they can kill others.

“If we can create virtual twins of the liver – the body’s chemical processing plant – to figure out how to deal with that and adjust the chemistry for those people who are sensitive to it, we can change the entire projection of cancer drugs – not by targeting cancer but by targeting the body and taking a more

fundamental approach,” says Levine.

A host of startups have been invited to innovate on Dassault’s 3DExperience platform as part of its 3D lab incubator. Firms on board include Belgian outfit FeOps which performs patient-specific simulations for heart interventions and is now FDA approved.

Another start up, Lucid Implants, exhibiting over in France’s Business Pavilion at CES’ Eureka Park, is focussed on creating facial bone implants for patients that have suffered injuries or lost part of their jaw to cancer. The firm is using the platform to replicate what was there before to 3D print the structures.

Connecting patients

Thanks to advances in consumer VR technology, Levine adds that virtual twins of the human body may also help patients and their carers understand what’s happening to them, bringing the industrial metaverse into the consumer realm.

“We now have that connectivity between what you feel and what your doctor is able to interpret,” claims Levine.

A patient who has just had a heart attack, for instance, can place a monitor on their chest with the data then sent to their virtual twin. They can wear a VR headset and understand what’s happening, as a lay person, in real time. As an incredibly stressed parent of a child with a rare medical condition faced with a barrage of medical acronyms, 3D may also be a way of alleviating anxiety adds Levine, whose own daughter is now a practicing medical doctor.

“When we show the parent how we are going to restore their heart, they often just break down into tears because finally they understand.

“Using VR it can take just a few minutes to comprehend what’s going on because people are able to interpret in 3D – our brains are attuned to work in 3D – so the minute you see it, you understand.”



Manufacturing: Making factories more efficient

By James Pearce

In a world where technology continually reshapes industries, the manufacturing sector finds itself on the brink of a transformative revolution. This paradigm shift, driven by digitalisation, is redefining production and supply chain management in unprecedented ways. Among the pioneering innovations driving this transformation, digital twins have emerged as a disruptive force, poised to redefine manufacturing processes and elevate standards of operational excellence.

“Manufacturers are increasingly relying on digital twins to optimise their operations and boost productivity,” explains L&T Technology Services CEO and managing director Amit Chadha.

“There are two models of manufac-

turing digital twins: one based on simulation, and another based on physical prototypes.

“While the technology is being used extensively to enhance asset reliability, Digital Twin is also being increasingly used for New Product Development, Process Improvement to optimise production line outputs and making remote preventative adjustments using predictive maintenance.”

Prototype

At the forefront of innovation, digital twins are revolutionising design and prototyping stages. Manufacturers now wield the power to craft intricate virtual replicas of products, empowering them to visualise and test various design iterations long before physical production commences. En-

gineers can scrutinise these replicas, ferreting out potential design flaws, and optimising product performance. This expedites the design-to-prototype phase, slashing development time and costs while significantly improving the likelihood of delivering a high-quality product.

Efficient production planning stands as the linchpin of manufacturing success. Digital twins allow manufacturers to simulate the entire production process within a virtual environment, preempting bottlenecks, optimising workflows, and finely tuning resource allocation. By accounting for variables such as machine capabilities, material availability, and labour efficiency, digital twins facilitate the creation of highly accurate production schedules.

The outcome? Reduced production downtime, minimised wastage, and products manufactured with unparalleled precision and consistency.

Quality or quantity

Maintaining product quality throughout the manufacturing journey is an absolute imperative. Digital twins seamlessly integrate real-time data from sensors and monitoring systems, offering insights into production parameters and quality metrics. Manufacturers can now track key performance indicators, pinpoint deviations from desired specifications, and execute corrective measures promptly. This proactive approach significantly reduces the likelihood of defects, improves yield rates, and enhances overall product quality. Equipment downtime caused by unforeseen failures can wreak havoc on production schedules and translate into substantial financial losses. Digital twins come to the rescue by facilitating predictive maintenance. They continuously monitor machinery and systems, analysing data from sensors and historical performance trends. This enables manufacturers to predict when equipment will require maintenance or repairs, allowing for proactive scheduling of maintenance activities, minimising unplanned downtime, and maximising equipment utilisation.

Optimising the supply chain

In a globally interconnected market, supply chain management is a complex and challenging task. Digital twins, however, extend their reach beyond the factory floor to optimise the entire supply chain. Through the integration of data from suppliers, logistics providers, and distributors, manufacturers can attain a comprehensive view of supply chain dynamics. This heightened visibility results in improved demand forecasting, superior inventory management, and more efficient order fulfilment. The net effect is reduced lead times and more streamlined operations. With consumer preferences growing increasingly diverse, there is an escalating demand for customised products. Here, digital twins come into play, enabling manufacturers to

offer personalised products without compromising efficiency. By creating virtual replicas of products and production processes, manufacturers can simulate different configurations and variations to meet individual customer requirements. This fosters mass customisation, where products are tailored to specific needs while still benefiting from economies of scale.

“Asset digital twins assist firms in understanding asset criticality, right down to the individual components of each piece of equipment, and then sharing that knowledge across teams within the business,” adds Chadha. “We have seen remarkable changes in data gathering, visualisation, and analysis easier by collecting and processing data throughout the industrial life cycle.”



Mr. Amit Chadha

Training and skill development

The integration of digital twins in manufacturing extends to training and skill development. Workers can undergo training in virtual environments that replicate real-world manufacturing processes. This immersive approach equips new employees with hands-on experience in a controlled setting, minimising the learning curve and reducing the risk of errors on the shop floor. Moreover, digital twins provide a platform for ongoing skill enhancement and cross-training, ensuring a versatile and adaptable workforce.

Manufacturers are now actively

embracing the concept of continuous improvement to enhance productivity and competitiveness. Digital twins play a pivotal role in this journey by offering a platform for data-driven analysis and innovation. Manufacturers harness real-time and historical data to identify patterns, trends, and opportunities for optimisation. These insights drive incremental process improvements and facilitate the discovery of breakthrough innovations that reshape entire production paradigms.

Sustainability in focus

In an era of heightened environmental consciousness, the manufacturing industry is pivoting towards sustainability to minimise its ecological footprint. Digital twins contribute to this noble endeavour by enabling manufacturers to model and analyse the environmental impact of their operations. By simulating various scenarios and evaluating factors such as energy consumption, waste generation, and emissions associated with production processes, manufacturers can identify strategies to reduce their environmental impact and adopt more sustainable practices.

Making a revolution

Digital twins are indisputably revolutionising the manufacturing industry, unlocking new dimensions of efficiency, precision, and innovation. From streamlined design and production planning to real-time monitoring, predictive maintenance, and supply chain optimisation, the applications of digital twins span the entire manufacturing lifecycle. As this technology continues to evolve and mature, manufacturers who harness the power of digital twins are poised to gain a competitive edge in an era defined by rapid technological change. The fusion of virtual and physical realms in the form of digital twins is reshaping manufacturing, paving the way for smarter, more agile, and more sustainable production processes.

Diving into undersea farming through the industrial metaverse

By Nicole Deslandes

Naples-based start-up, Nemo's Garden, launched in 2021 and grows herbs, fruits, and vegetables using underwater greenhouses. It was founded by diving equipment expert Sergio Gamberini, who was struck by the idea of growing basil underwater while he was on a stroll down the Italian Riviera. With the help of his firm Ocean Reef Group, Gamberini began testing underwater biospheres, but it was the discovery of the industrial metaverse and a partnership with German manufacturing conglomerate Siemens that helped Nemo's Garden to just keep swimming.

Industrial metaverse

Siemens has announced its plans to create an industrial metaverse: A virtual world where real machines, factories, buildings, cities, and more are mirrored in a virtual world. In this, industrial companies can design, test, and optimise their real-life products and processes in a collaborate environment, and occasionally in real-time.

Siemens's industrial metaverse will be a digital twin of the real world, with all the complexities and interactions of industrial systems accurately modelled in a virtual environment. This virtual world will allow engineers and designers to experiment with different scenarios, test new ideas, and identify potential problems before they occur in the physical world.

This metaverse will also be designed to be an open platform, allowing other companies to build their own digital twins and collaborate with Siemens and other partners. The openness will enable companies to create new business models and value chains that leverage the power of digital technologies.

Since Siemens partnered with chip company Nvidia, it was able to advance its digital twins to allow interaction in real time. So, for example, if a digital

twin of a factory senses a rise in temperature in the physical environment, the virtual twin will immediately mirror that.

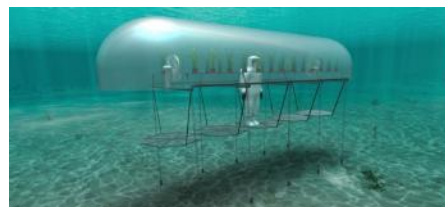
Or, if an individual machine in a factory fails, or an improved component is installed, the twin can be updated to simulate that, too.

Finding Nemo's Garden

On the surface, the idea of growing herbs, fruit and vegetables underwater sounds strange.

"There are actually three compelling reasons why you should do that," says Siemens CTO and CSO Peter Koerte. Firstly, all the CO₂ that is being absorbed by the plants is produced naturally by the ocean. Second, is that the ocean does not change temperature drastically, and thirdly, you don't need any pesticides as there won't be any creatures affecting the plants.

Plus, if food in Naples wasn't already famously delicious enough, according to Nemo's Garden, the plants grown in this environment are nutritionally richer than those grown traditionally. Despite this, constructing underwater greenhouses is no simple task: "You cannot just go downstairs and see how it works," says Koerte. Sending divers



Digital Twin of one of Nemo's Garden domes

down underwater to construct a greenhouse costs a lot of time and money, so "you really have to get it right the first time."

With a keenness to dive in to aquatic farming, Nemo's Garden sought out Siemens in order to create accurate digital twins of its greenhouse domes, so that they could build them in the metaverse, before going ahead with it in real life. With digital twin technology, Siemens modelled the greenhouse environment, virtually, to an identical match both in looks and function.

"If you can model that environment virtually before you start, you can foresee the challenges and address them in the best way," said Luca Gamberini,

Co-Founder of Nemo's Garden.

According to Nemo's Garden, the firm has seen benefits in understanding the flow of water around the shapes of its biospheres, and a greater understanding of the points of stress.

The Italian start-up also has a better idea of the solar radiation, temperature, and physical factors which act on the plants.

Sensor data

Now, while Nemo's Garden can anticipate future greenhouses, it can also take advantage of the digital twins, and implement sensor technology to monitor current greenhouses and see how they are doing through virtual reality – saving time spent sending divers down to check and collect data themselves. "The sensors give us feedback on the CO₂ levels, the oxygen levels, and the temperature so we constantly update in real-time," says Koerte.

Plus, by using existing videos of the growing cycles along with reference data, Siemens was able to train a machine-learning algorithm to monitor plant growth as well as the environmental conditions within the greenhouse domes.

As this algorithm is deployed in each of the domes' biospheres, the plants can be tracked and monitored through a dashboard throughout the season and changes can be made in real time.

Nemo's Garden is not the only environment Siemens has simulated, it has also taken up its own factory in Beijing, where it has twinned factory machines, robots, people and materials to ensure the best blend of equipment and processes.

According to Koerte, the factory is "now 20% more productive than its sister factory that is operating today."

They scored this productivity boost by simulating the production line ahead of the factory build: "By the time we built the factory, we knew this was the most efficient design," says Koerte.

"Today, I believe that this factory is going to outperform every other factory," enthuses the CTO.

Why? Because since the factory is now built with its digital twin in tow, Siemens is now able to marry other technologies such as sensors into it to create a completely accurate real-time twin.



Aerospace and transport: Twin landing

By James Pearce

In recent years, the integration of digital twins in transport industries has emerged as a transformative force, revolutionising the way products are conceptualised, developed, and maintained.

The automotive industry is undergoing a seismic shift with the integration of digital twins across the product lifecycle. From concept design to production and beyond, digital twins are optimising processes and improving outcomes.

One of the biggest shifts is when it comes to design and prototyping. Digital twins enable designers to create virtual replicas of vehicles, allowing for rapid iterations and simulations. Engineers can analyse different design variations, test aerodynamics, and optimise performance before a physical prototype is even built. This accelerates the design phase, reduces development costs, and enhances the overall quality of the end product. Digital twins also help automotive firms streamline manufacturing processes by providing a virtual mirror of the production line. This allows

manufacturers to boost assembly sequences, identify potential bottlenecks, and enhance efficiency. By simulating the manufacturing process, companies can ensure that the assembly line is well-equipped to handle variations in production volume and demand.

Connected cars

The rise of connected vehicles and the Internet of Things (IoT) has paved the way for digital twins to be integrated into the vehicle itself. Real-time data from sensors within the vehicle can be fed into the digital twin, enabling remote diagnostics, predictive maintenance, and over-the-air updates. This data-driven approach enhances vehicle reliability, minimises downtime, and provides a personalised experience for drivers. **Aerospace Industry: Soaring to New Heights**

In the aerospace industry, where safety and precision are paramount, digital twins are revolutionising how aircraft are designed, manufactured, and maintained.

Aerospace engineers can use digital twins to create detailed virtual models of aircraft components and systems. These virtual replicas are used to simulate flight conditions, analyse stress distribution, and predict the behaviour of materials. This advanced modeling enhances the design process, leading to aircraft with improved performance and safety features.

Similar to the automotive industry, digital twins are optimising aerospace manufacturing processes. By creating virtual replicas of manufacturing facilities, companies can simulate assembly sequences, identify potential clashes, and optimise production workflows. This level of virtual testing minimises errors during the assembly phase, ensuring the accuracy and safety of aircraft components.

Aircraft operators also rely on digital twins for efficient maintenance and lifecycle management. Real-time data from sensors on aircraft components is integrated into the digital twin, enabling predictive maintenance.

Airlines can identify potential issues before they lead to costly disruptions, and maintenance schedules can be optimised to minimise downtime and operational disruptions. They also extend to flight simulations and pilot training. Complex aircraft systems and flight dynamics can be accurately replicated in a virtual environment. Pilots can undergo training in realistic scenarios without the need for actual flight hours. This enhances pilot proficiency, improves safety, and reduces training costs.

Challenges and future prospects

While the benefits of digital twins in the automotive and aerospace industries are significant, challenges remain. Creating accurate and detailed

digital twins requires the integration of diverse data sources, ranging from engineering designs to real-time sensor data. Ensuring data accuracy, security, and interoperability across various systems is a critical challenge that companies need to address. Looking ahead, the future prospects of digital twins in these industries are promising. With advancements in artificial intelligence (AI) and machine learning (ML), digital twins can become more intelligent and capable of predictive modeling. This could lead to automated decision-making and even self-optimising systems, further enhancing efficiency and performance. In the ever-evolving worlds of automotive and aerospace, digital

twins are proving to be a catalyst for innovation, efficiency, and enhanced outcomes. From designing vehicles and aircraft to optimising manufacturing processes and enabling predictive maintenance, the applications of digital twins are far-reaching. As technology continues to advance, the seamless integration of virtual and physical realms promises to reshape the way these industries operate, producing safer, more efficient, and more sustainable vehicles and aircraft. The journey of the automotive and aerospace sectors into the era of digital twins is a testament to their commitment to pushing boundaries and embracing the transformative potential of technology.

How digital twins can enhance airport efficiency

By Nicole Deslandes

Throughout a passenger's journey at an airport there are multiple interaction points with different teams and services – from the check-in desk through to duty free shopping, on-board catering experiences, and land transportation once they have arrived at their destination.

An airport is essentially a passenger-processing facility and if you can process passengers more quickly without investing in new and expensive buildings and infrastructure, reasoning suggests that profits will go up while still allowing passengers to enjoy a more seamless experience.

“Every airport is kind of a business system,” acknowledges data governance lead at Heathrow Airport, Segun Alayande. “It comprises of organisations that are all trying to meet the needs of the traveling passenger.”

“With this objective, they all have to work together, and they need to communicate in order to cater to the travelling passenger's experience,” Alayande adds.

With a background in behavioural science and psychology, Corey Gray, global CEO of Smart Cities

Council says: “What we're really dealing with here are issues of human behaviour and how we can use new tools to create better outcomes for people in places.”

Smart Cities Council, a global member organisation which champions the use of science, data and technology, is also “about creating a safer, activated, resilient, sustainable spaces”, says Gray.

Among other airports, “Segun and I both agree that [London's] Heathrow airport could do a lot better,” in this aspect, Gray opines.

So how might industry 4.0 technology help improve the passenger experience at airports like Heathrow?

Taking off with digital twins

Now, with a real time virtual model of an airport – a digital twin – airports can help anticipate changes and design seamless passenger experiences before they are physically implemented.

If you can imagine a video game representation of an airport, this is what a digital twin might look like – except the machines and people are all optimised to reflect real-time events that accurately display how these moving parts act

in the space.

“The one thing that's fundamentally important is that digital twins are as good as the data that goes into them,” Gray adds.

For technology firm Vantiq, its digital twins represent what the foot traffic is like throughout the day, in different spaces in an airport.

The use of camera data meant that Vantiq could track the motion of the passengers and create a twin that highlighted areas of the airport which had too much foot traffic at certain times of the day, and other areas that were being underused.

“So now that you have a good understanding of the data coming from your team, you can start running a simulation and be able to understand what actions you can take,” adds Vantiq project manager Mark Munro.

From Gray's perspective, digital twins can help solve problems such as cost savings and risk reductions, and then can also deliver social, environmental, and governmental benefits.

However, he adds “We need to first understand who our stakeholders are, and then be really clear about what our stakeholders need, want,

and what their aspirations can be.” Frequent flyers may have noticed in the last decade that queueing systems at security is a lot more unified through allocating numbered slots at one side of the x-ray machine to allow multiple passengers to unpack electronics and liquids in one go, and then more spaces to repack their items at the other end.

A digital twin would be able to calculate and present this system before its implementation – which

not only makes the travellers experience more pleasant, but also means they can spend more time on the other side to “do more shopping, eat lunch, and have a glass of wine,” says Gray.

Heathrow’s airport management is currently looking at digital twinning at airports to facilitate the faster movement of more passengers through the airport.

Heathrow’s digital twins will also look at how best passenger luggage can be transported in a virtual twin,

under the same roof as various deliveries of airline food, equipment, in a much more efficient way.

As such, digital twin deployment may also require less staff – something which proved to be important last year, as many airports throughout Europe and the US struggled with long queues for check-in, security and luggage due to staff shortages.



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