UNLOCKING THE POTENTIAL OF DIGITAL TWINS FOR THE AEC INDUSTRY

PREPARED BY

GEOSPATIAL WORLD
ADVANCING KNOWLEDGE FOR SUSTAINABILITY

PREPARED IN COLLABORATION WITH
THE AUTODESK AND ESRI JOINT CUSTOMER COUNCIL

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List of Abbreviations

2D	–	2-Dimensional
3D	–	3-Dimensional
4D	–	4-Dimensional
4IR	–	Fourth Industrial Revolution
AEC	–	Architecture, Engineering, and Construction
AI	–	Artificial intelligence
API	–	Application Programming Interface
AR	–	Augmented Reality
BIM	–	Building Information Modelling
CAD	–	Computer-aided Design
CAGR	–	Compound Annual Growth Rate
CPS	–	Cyber-physical Systems
DL	–	Deep Learning
GIS	–	Geographic Information System
IoT	–	Internet of Things
LiDAR	–	Light Detection and Ranging
ML	–	Machine Learning
OEM	–	Original Equipment Manufacturer
USD	–	United States Dollar
VR	–	Virtual Reality
WSN	–	Wireless Sensor Network

→ Foreword

Digital Twin in the AEC industry today is no more a shiny new object but a game-changing technology that promises to help to solve some significant challenges across the design, construction, operations, and maintenance phases of an asset's life. A Digital Twin is a dynamic virtual representation of the physical world, that goes beyond the collection of 3D models of the project's design phase. It combines project data from multiple sources in varied formats and across all phases to create a data-rich digital hub that enables simulations and helps track asset data from design through operations. Digital Twin mitigates the challenges which arise from analog, unclassified, and disconnected data to bring about business transformation using real-time and historical data to represent the past and present and simulate predicted futures.

In today's digital age, implementing Digital Twin technologies across the AEC project lifecycle will lead to what is defined as Construction 4.0. Construction 4.0 can drive enhanced productivity, cost savings, safety, quality control, sustainability, data-driven decision making, and collaboration to the AEC industry. By embracing digital technologies and automation, the industry can overcome traditional challenges and deliver projects more efficiently, effectively, and sustainably. With the help of technologies like geospatial, Building Information Modeling (BIM), Artificial Intelligence (AI), Machine Learning (ML), and the Internet of Things (IoT), a Digital Twin helps with everything from planning, design, and construction to operations and maintenance. It provides more business, better outcomes, significant time and cost savings, enhances collaboration and coordination within multi-disciplinary teams, and makes the construction process much more manageable. Thus, the Digital Twin could be seen as an advanced manifestation of the digital engineering environment, capitalizing on and uniting underlying technologies to create a highly responsive and simulation system.

However, while the benefits are many, there are also challenges to holistic Digital Twin implementation within the AEC industry ecosystem. One of the main obstacles of the Digital Twin implementation, as pointed out during the Autodesk and Esri Joint Customer Council Meeting, is the ability to guarantee near-real-time updates of the digital model to ensure it stays similar to the physical twin. To overcome this, there is a need to establish a data pipeline or an interface that continuously receives and processes the incoming data, enabling the integration of real-time data from the physical twin into the digital model. Depending on the complexity and requirements of the system, this integration can be achieved through APIs, streaming platforms, or custom-built solutions.

Moreover, concerns regarding data security, data residency, data interoperability, along with capacity development cause resistance amongst AEC stakeholders to adopt and implement Digital Twin in their workflows, and need to be mitigated to accelerate adoption as the technology continues to mature.

In this context, Geospatial World, in collaboration with the **Autodesk and Esri Joint Customer Council**, is excited to release this white paper on **Unlocking the Potential of Digital Twins for the AEC Industry**. The white paper presents an unbiased view on the drivers, benefits and key risks behind the adoption of Digital Twins for the AEC industry, the purview of owners, and the next steps required to drive the implementation of Digital Twin sustainably and holistically across an asset's lifecycle. I thank all **Autodesk and Esri Joint Customer Council** members for their support. We hope this comprehensive, research-based white paper helps AEC firms navigate and accelerate their Digital Twin journey globally.

Yours Sincerely
Ananyaa Narain
Vice President - Consulting
Geospatial World

⟶ Acknowledgement

The architecture, engineering, and construction (AEC)industry is critical to the global economy. This sector is highly complex and fragmented – vertically and horizontally resulting in major interface frictions and hostile environments. The AEC industry is transforming from following traditional practices towards increased sustainability, adopting modern building methods, and changing the construction lifecycle holistically. It is at an inflection point, wherein bricks and mortar are giving way to digitally enabled processes and tools that are changing the face of the industry.

Digital Twins have gained considerable attention in recent years, particularly in the AEC industry, as they have the ability to transform project delivery, enhance sustainability, and improve the operational efficiency of infrastructure assets. Digital Twin technology involves creating a virtual replica of a physical asset or system, which can be used to simulate, monitor, and optimize its performance throughout its lifecycle. In this context, this white paper, Unlocking the Potential of Digital Twins for the AEC Industry, is a result of a thought-provoking discussion amongst the members of the Autodesk and Esri Joint Customer Council.

The white paper presents an unbiased view of the industry on the advancement of Digital Twin, its adoption and implementation, and the challenges stakeholders face in adopting next gen solutions across the AEC lifecycle. The white paper also illustrates the industry's transition towards a more sustainable and holistic approach to building, known as Construction 4.0, that is accelerating the digital transformation of the AEC industry.

This white paper would not have been possible without the timely and active guidance and support of Kathleen Kewley, Director, Global Business Development – AEC, Esri and Eric DesRoche, Director Infrastructure Business Strategy, AEC Design Solutions, Autodesk. Additionally, Geospatial World would like to acknowledge each member organization of the Autodesk and Esri Joint Customer Council, as mentioned below, for providing us with valuable inputs that proved to be extremely instrumental in the compilation of this comprehensive research-based white paper.

- Golder
- Black & Veatch
- Mott MacDonald
- VHB
- HNTB
- CDM Smith
- Wood Rodgers
- Atkins
- Gannett Fleming
- Burns McDonnell
- Jacobs
- Bechtel
- Parsons
- AECOM
- GHD

We hope this comprehensive research-based white-paper motivates readers to act on their digital transformation journeys.

Yours Sincerely
Ananyaa Narain
Vice President – Consulting
Geospatial World

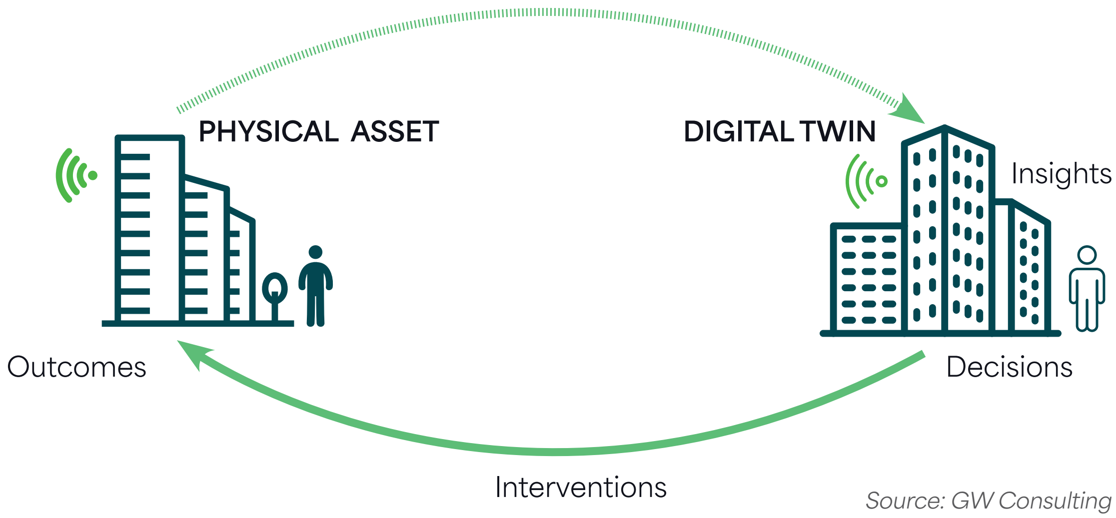
THE AGE OF DIGITAL TWINS

Digital Twins are at the center stage of digitalizing the Architecture, Engineering and Construction (AEC) industry. Regarded as one of the industry's most exciting recent developments. Digital Twin technology uses multiple data sources and machine learning algorithms to in a dynamic way, going beyond a simple collection of 3D models of the design phase of a project.

From a definition standpoint, buildingSMART International (bSI), an organization that promotes open standards and digital transformation in the construction industry, defines a Digital Twin as "a digital representation that mirrors a physical entity, process, or system in the built or natural environment. It is a dynamic and interconnected model that provides a real-time, virtual replica of the physical object or system, allowing for data exchange and communication between the physical and digital realms."

Digital Twins can offer design, build and operational efficiencies, generating significant savings. In addition, they are also a means to achieve greater safety, sustainability and resilience through improved simulation, accurate resource planning, predictive maintenance and holistic lifecycle management.

How a Digital Twin Works?



Source: GW Consulting

In today's digital age, implementing Digital Twin technologies across the AEC project lifecycle will accelerate the transformation of the industry, leading to what is often called Construction 4.0, characterized by the integration of advanced technologies like geospatial, Building Information Modeling (BIM), Artificial Intelligence (AI), Machine Learning (ML), and the Internet of Things (IoT). In this context, a Digital Twin becomes an advanced manifestation of the physical environment, capitalizing on and uniting underlying technologies to create a highly responsive simulation system. For the AEC industry, a Digital Twin is a dynamic model, which means it is responsive in near-real time and continues evolving with the physical twin changes. The model continues to evolve as data is supplied, enabling simulations to predict different possible outcomes, resulting in better decisions based on real-world conditions of infrastructure assets.

Digital Twins provide multidimensional perspectives of an asset's design and performance, including site inspections, routine maintenance, and real-time monitoring. They are also a way to explore **"what-if" scenarios,** such as the effects of design modifications, inclement weather, and security incidents. A genuine Digital Twin has the operational and behavioral awareness to model, forecast, and guide decisions based on actual circumstances or future scenarios. Moreover, the Digital Twin's data collection covers the asset's entire lifecycle, which can benefit future projects too.

Digital Twin Technology Application is Aligned with —

Considerable increase in adoption and implementation of BIM and enhanced convergence of BIM and GIS across the AEC project lifecycle.

Significant advancements in related technologies such as Internet of Things (IoT), Artificial Intelligence and Machine Learning, Immersive Solutions (AR/VR), Real-time sensors, and Wireless Sensor Networks (WSN).

Ilustrating how digital technologies and associated initiatives can make a significant contriubution to a more sustainable future

Digital Twins provide multidimensional perspectives of an asset's design and performance, including occupant behaviour, use patterns, space utilization, and traffic patterns.

Global Growth of Digital Twin

$73.5 B

The Global Digital Twin market size is projected to reach USD 73.5 billion by 2027 at a CAGR of 60.6 percent during 2022-2027

MARKETSANDMARKETS

31%

As a result of COVID-19, 31 percent of respondents use DTs to improve employee or customer safety, such as the use of remote asset monitoring

Gartner

40%

By 2027, over 40 percent of large companies worldwide will use Digital Twin in their projects to increase revenue

Gartner

89%

Up to 89 percent of all IoT Platforms will contain some form of Digital Twinning capability by 2025

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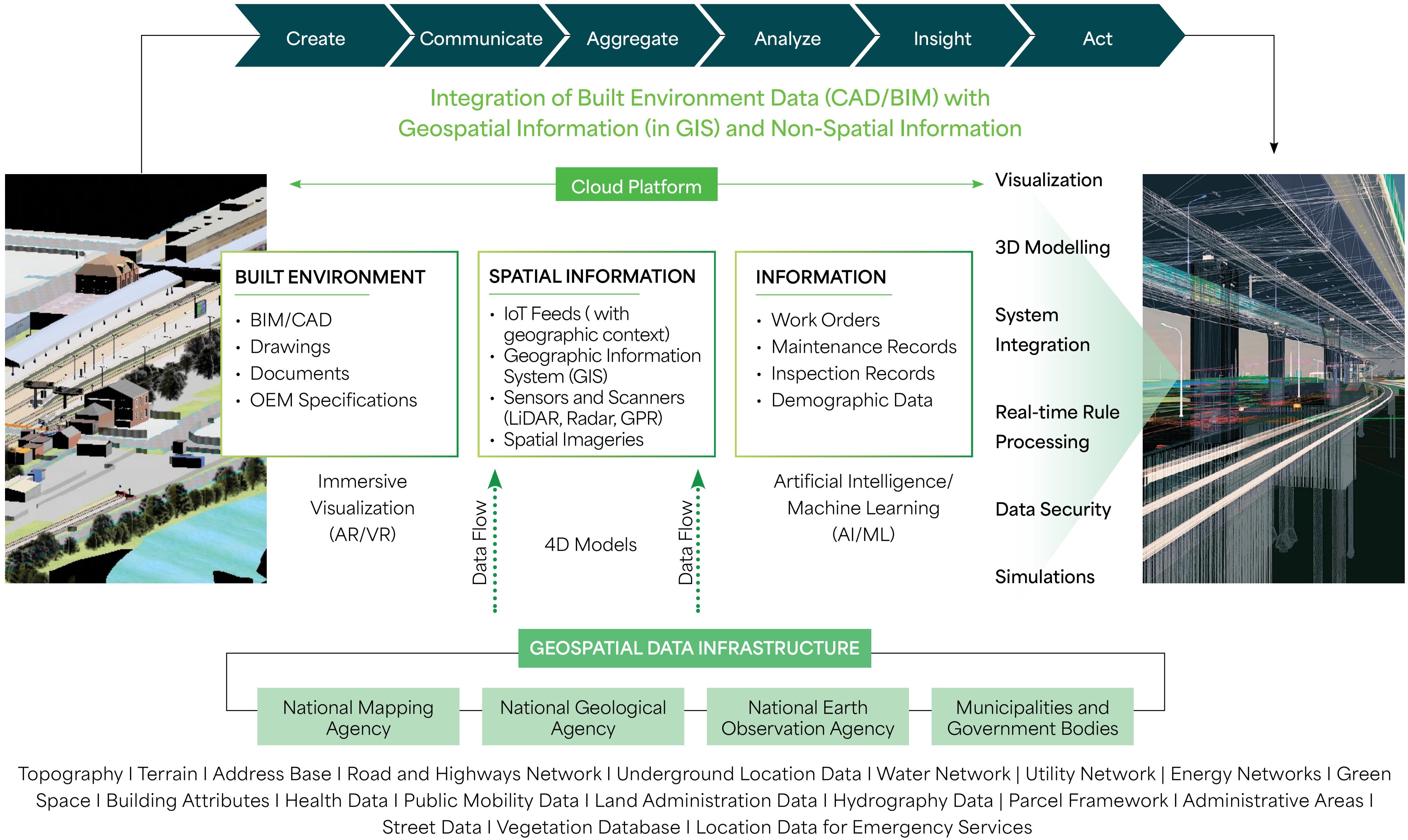
Digital Twin Technology Infrastructure

Global trends are showing how industry and society are rapidly embracing increased automation, data interoperability, data exchange, and manufacturing technologies. Digital Twin technology lies at the core of this new "4th Industrial Revolution", taking inputs from a combination of technologies, including CAD/BIM, GIS, geospatial data, sensors, scanners, the Internet of Things (IoT), and AI/ML, to name a few. The BIM processincorporates built environment data created during the planningand design phases, making it the most efficient path to creating an accurate, high-value Digital Twin. Digital Twin uses the data created in the BIM process and extends it to the construction and operational phases. Additionally, GIS technology links spatial contexts to information systems, models, and behaviors of real objects, enriching the Digital Twin model to create holistic digital representations of environments, assets, and networks. On top of that, Internet of Things (IoT)sensors providing geographic context are criticalto continue the feedback loop of data in near real-time between physical and virtual twins, enabling simulations and extending the benefits to the asset's operational and maintenance stage.

The 4th Industrial Revolution embraces automation, data interoperability, data exchange, and manufacturing technologies. Digital Twin technology lies at the core of this new paradigm and is developed using many technology solutions, including CAD/BIM, GIS, geospatial data, sensors, scanners, the Internet of Things (IoT), and AI/ML.

Macro-level Digital Twin Technology Infrastructure for Civil Infrastructure Projects



Source: Netherlands Geolocation Economy Report; GW Consulting Analysis

Key Characteristics of a Digital Twin

Digital Twin technology is revolutionizing the way industrial facilities operate by providing a virtual replica of a physical plant or system that can be used to monitor, control, and optimize its operations. However, to maintain and optimize operational efficiency it is quite important that a Digital Twin possesses the following key characteristics

Fidelity and Frequency

Fidelity refers to the level of accuracy and detail in the representation of the physical asset within the Digital Twin. It encompasses the completeness and precision of the virtual model in capturing the asset's geometry, properties, behavior, and interactions with its environment. Frequency (or speed), on the other hand, refers to the rate at which data is collected and updated within the Digital Twin. It determines how often the virtual model reflects the real-time conditions and changes of the physical asset. The frequency of data updates depends on the nature of the asset, the available data sources, and the desired level of real-time monitoring and analysis.

Interoperability

Interoperability refers to the ability of a Digital Twin to seamlessly integrate and communicate with other systems, software, devices, and data sources. It involves the establishment of standardized protocols, interfaces, and data formats to enable the exchange of information and interoperability between different components of the Digital Twin ecosystem. Interoperability is crucial because it allows for the integration of diverse data sources, sensors, IoT devices, and software applications that contribute to the Digital Twin's functionality. Further, it enables the Digital Twin to receive data inputs from various sources, such as building automation systems, sensors, weather stations, or maintenance databases, and to provide data outputs to other systems for further analysis or control.

Connectivity

A Digital Twin should be able to seamlessly connect all the systems, machines, devices, and sensors within the physical plant or system to enable real-time monitoring, control, and optimization of its operations. This requires a robust and reliable network infrastructure that can handle large amounts of data and support secure communication between different components of the system.

Security

A Digital Twin should be designed with a strong focus on cybersecurity to protect against cyber threats, data breaches, and other security risks in the physical plant or system. This requires a comprehensive cybersecurity strategy that includes measures such as network segmentation, access controls, data encryption, and regular security assessments.

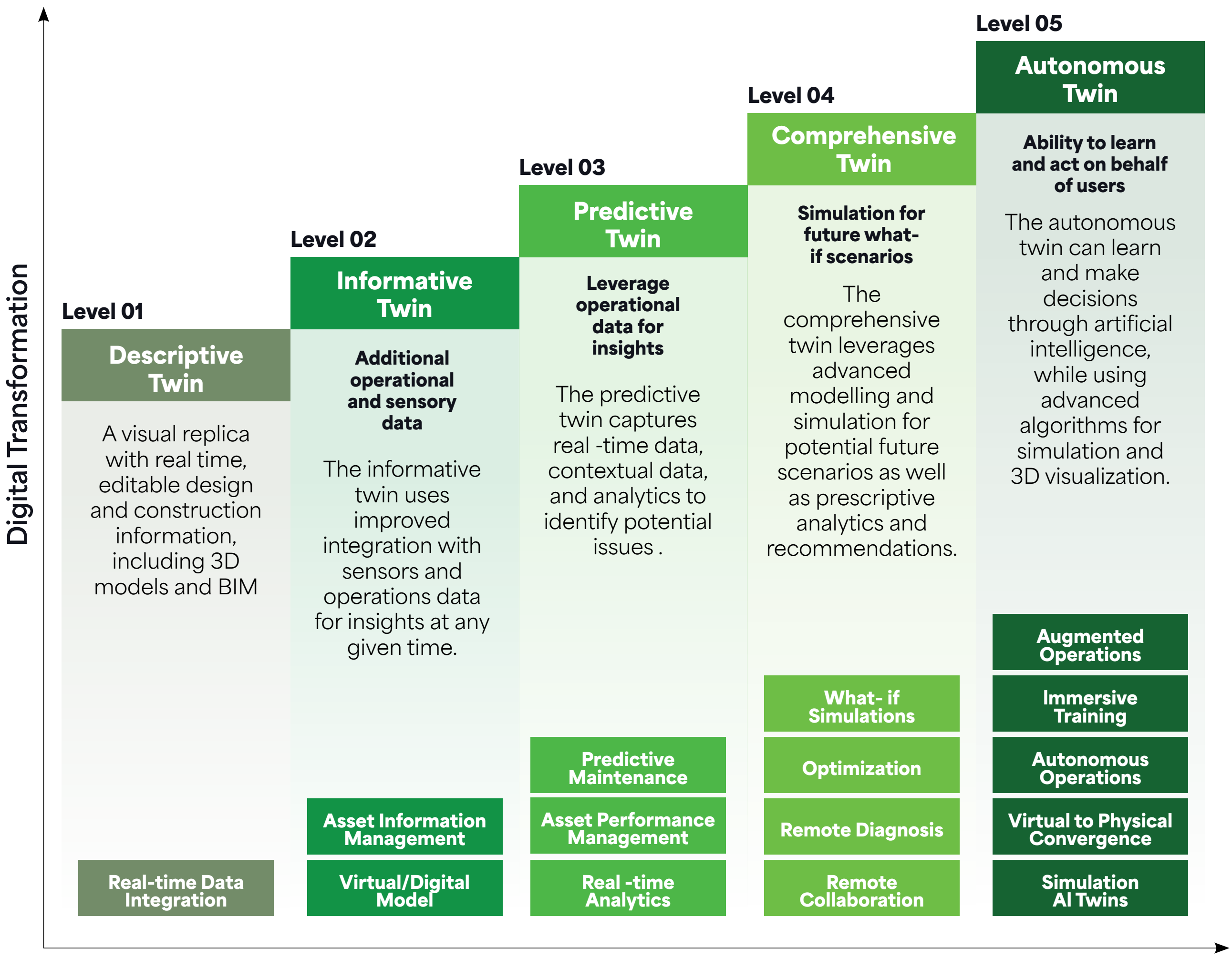
Synchronization

Synchronization, as a characteristic of Digital Twins, refers to the process of maintaining consistent and up-to-date data between the physical asset and its digital representation. It ensures that the Digital Twin accurately reflects the current state and behavior of the physical asset in real-time.

Digital Twin Maturity Model

Research and Innovation thought leaders Verdantix proposed a five-step maturity model for Digital Twins, which outlines the business value and outcomes of its implementation across infrastructure assets. The following image captures the characteristics of these five levels of the Digital Twin Maturity Model.

Digital Twin Maturity Model in AEC Project Life-cycle



Source: Inspired by the Verdantix's five-level maturity model

To fully reap the advantages of a Digital Twin in AEC projects, organizations can adopt a gradual approach based on their digital maturity and the readiness of their workforce. This approach involves five stages that act as stepping stones towards the ultimate goal of achieving the full benefits of Digital Twins, namely the autonomous twin. By following this step-by-step approach, AEC firms can pragmatically and organically create long-term value for the ecosystem, leading to improved efficiencies, productivity, and compliance.

DIGITAL TWIN ADOPTION & IMPLEMENTATION IN AEC INDUSTRY

In a world where digital transformation is racing ahead at unprecedented pace, the AEC industry faces both the benefits and challenges of embracing this new reality. Digital Twin technology plays a vital role in this transformation by developing digital replicas of existing assets, processes, and systems. By integrating real-time data, communication and automation, Digital Twins align with emerging paradigms like Cyber-Physical Systems (CPS) and Industry 4.0, enabling a meaningful integration between the physical and digital worlds. This facilitates the integration of smart decision-making, improved performance, and increased efficiency using advanced analytics. The possibility of using Digital Twin to attain these highly desirable outcomes have made them highly relevant in the AEC industry, where stakeholders are increasingly recognizing the value of investing in maturing their adoption journeys, which could guide Digital Twin implementation across the AEC project lifecycle.

Digital Twin Drivers across AEC Ecosystem

Digital Transformation: Advancements in technology, such as Geographic Information Systems (GIS), Building Information Model (BIM), Artificial Intelligence/Machine Learning, Internet of Things (IoT), and cloud computing have made it easier to implement Digital Twins in the AEC sector. The maturity of this transformation today provides the essential infrastructure and tools to gather, analyze and visualize data, increasing the value proposition of each individual technology in isolation.

Environmental Priorities: Digital Twins can help to address sustainability goals in the AEC industry in two ways: impact of historical decisions and using the digital model as a predictive guide to the simulate present and future (what-if scenarios) for key sustainability metrics such as energy consumption, material usage and environmental impacts. These capabilities allow stakeholders to identify opportunities for energy efficiency, waste reduction and sustainable design, contributing to a greener built environment.

Economic Climate and Efficiency: Digital Twins optimize resource usage, streamlining workflows, reducing rework, and unlocking substantial cost savings. Stakeholders can use the digital representation of assets, processes, and systems to identify key risks, optimize interventions and improve productivity, unlocking substantial cost savings and shortening project timelines.

Asset Lifecycle Focus: A fundamental driver of implementing Digital Twin technology is its use across the AEC project lifecycle, from design and construction to operation and maintenance. By capturing data and information at every stage, stakeholders are able to monitor performance, anticipating maintenance needs and continuously updating management plans and strategies, which results in extended asset life and significant operational efficiencies. Furthermore, it can also deliver smoother data handovers, and competitive differentiation to deliver increased project value.

Data- Driven Context: Digital Twins offer value by leveraging spatial and non-spatial data for informed decision-making, enabling easy access to near-real-time asset lifecycle insights. This helps AEC firms to simulate scenarios, identifying potential issues and making proactive decisions to enhance performance, mitigate risks and deliver better outcomes for customers. In this new reality, owners, operators and AEC firms can recognize the total value of data to support the right decisions at the right time.

Next Gen Collaboration: Digital Twins facilitate connections and productive dialogue between multiple stakeholders across the AEC industry, including architects, engineers, contractors, and owners/operators. Through the provision of a common virtual platform, Digital Twin implementation leads to 'long-term value delivery' instead of static commoditized projects, providing end users with enhanced efficiencies in project delivery through real time communication, coordination, and data exchanges.

Benefits of Digital Twin Adoption

The concept of a Digital Twin can mean different things to the diverse stakeholder groups operating in the AEC industry. A certain level of confusion exists across the stakeholder ecosystem, especially concerning 3D Data Models. Those owners and operators who understand the value of a Digital Twin foresee it as a technology that maximizes value while reducing operational expenditure. They also look at Digital Twins as a vital tool for simulating outcomes and deriving risk mitigation, sustainability, and resiliency benefits.

Additionally, the AEC firms, who are broadly involved in delivering Digital Twin technologies, foresee Digital Twin technology to drive business opportunities and create diversified business models. At the same time, AEC firms realize that if they do not invest in Digital Twin technology, they are risking becoming stagnant in their project delivery capabilities and could struggle to compete in the global market in the long run. AEC firms also feel that if they are too late in adopting the benefits of the Digital Twin, their data and process would continue to be siloed. This could impact their ability to attract emerging talent and data-driven innovation, which could inevitably become a barrier to future growth. These negatives associated with the delay in Digital Twin technology adoption will also be a differentiator in Digital Twin adoption and implementation in the AEC project lifecycle.

According to the study titled "**Drivers for Digital Twin Adoption in the Construction Industry: Systematic Literature Review"** published by MPDI, the benefits of Digital Twin adoption in the construction industry can be categorized into four main areas, as explained in the below graph.

Benefits of Digital Twin Adoption across AEC Project Life-cycle

Phases of Construction: Design and Engineering | Construction | Operations and Maintenance | Restoration and Refurbishment

Concept-oriented

- Optimised overall design process
- Effective design collaboration
- Sustainability in project design
- Improved design information delivery
- Ensure effective project planning
- Ease transition to digital transformation
- Improved materials selection
- Real-time data visualization

Product-oriented

- Optimised construction process
- Reduced construction cost
- Enhanced prefabrication of assets
- Reduced non-fatal injuries
- Safety risk management
- Improved product quality
- Effective stakeholder collaboration
- Better project management

Operational-success

- Real-world accurate asset management
- Improved project operations' efficiency
- Enhanced predictive maintenance
- Reduced operational costs
- Enhanced environmental monitoring
- Enhanced energy management
- Continued asset monitoring and management

Preservation-oriented

- Enhanced building retrofit
- Improved renovation works
- Accurate preservation of cultural heritage

Benefits across phases of construction

Inspired from: https://doi.org/10.3390/buildings12020113

Stakeholder-wise Capabilities of Digital Twin in AEC Industry

A Digital Twin gives a multi-dimensional view of how a facility is designed, built, and is performing throughout its lifecycle. Whether you're an architectural practice, engineering consultant, road contractor, facilities manager or an owner, Digital Twin technology will transform the built asset lifecycle. –The following graph captures the different capabilities of Digital Twins enjoyed by different stakeholders associated with an AEC project and a brief description of benefits that they can enjoy owing to these capabilities.

Stakeholder-wise Capabilities of Digital Twin

Stakeholder	Capabilities	Outcomes
Owner	• Predictive Analytics • Immersive Visualization • Asset Planning and Management • Construction Management • Energy Management	Digital Twin creates an integrated design and construction process leading to lower costs, improved productivity, efficiency, and compliance. The analytics derived from Digital Twin simulations allows owners to achieve practical and financial goals while simultaneously mitigating risks.
Architects Engineers and Contractors	• Immersive Visualization • Dynamic Simulation • Energy Efficiency Analysis • Structural Analysis and Simulation • Construction Planning and Visualization • Digital Facility Handover	Digital Twins bring project data of varied formats together from many sources and from across phases to create a data-rich digital model that presents data in a single pane view with analytics and insights in near-real time to make informed decisions.
Operations and Maintenance	• Real-time Monitoring of Assets • Predictive Maintenance • Remote Operations and Control • Energy Management • Compliance and Regulatory Monitoring	The Digital Twin when connected to a built assets system continuously collects asset performance data and system model to perform simulation. Owners and Operators are able to use the Digital Twin platform to monitor and perform facility management, tune energy consumption and carbon emissions and realize the asset's lifetime value.

Challenges in Digital Twin Adoption in the AEC Industry

Undoubtedly, Digital Twins offer significant benefits that are driving the AEC industry to actively explore the technology's adoption. However, there are challenges associated with implementing Digital Twin for owners, operators, and AEC firms. One key challenge is ensuring the continuous updating of the digital model to accurately reflect the physical Twin. This requires near real time updates to monitor, simulate and optimize the asset through its entire lifecycle. At the same time, stakeholders struggle to keep up with managing the constant data feeds from IoT sensors, GIS and BIM to maintain an accurate replica of the physical asset. Another critical challenge faced by AEC firms, owners, and operators is the learning curve associated with implementing Digital Twins for frontline staff, due to their complexity and technology-intensive nature, which often results in AEC stakeholders not having the technical competencies and digital skills required to successfully implement Digital Twin technologies.

The main challenges of Digital Twin implementation is the ability to guarantee the system's capacity to continuously update the digital model to ensure that it stays similar to the physical Twin.

Challenges in Digital Twin Adoption

Challenges	Description
Digital Skills and Expertise	Lack of awareness and working knowledge of the advanced technologies required across the AEC project lifecycle inclusive of Internet of Things (IoT)-based connected sensors, lights, and meters, geospatial technologies such as LiDAR, remote sensing, drones, photogrammetry, and 4IR technologies such as AI/ML/DL **Proposed Mitigation:** AEC firms should invest in training and up-skilling programs to build Digital Twin expertise. Providing resources and training opportunities to professionals, including architects, engineers, and contractors, to enhance their understanding of Digital Twin technologies and their practical application will be the first step towards mitigating the digital skill and expertise challenge AEC firms face today.
Unscalable and Complex IT Infrastructure	Unavailability of high-speed internet connectivity and flexible IT/OT infrastructure poses significant challenges for adopting Digital Twins in construction projects. As a result, managing the associated processes as well as multiple sensors, cameras, and actuators , to name a few of the most commonly used devices, becomes difficult. Moreover, the current shortage of skilled professionals adds to this complexity, further hindering the adoption of Digital Twins. **Proposed Mitigation:** AEC firms need to prioritize deploying scalable and adaptable IT infrastructure to accommodate diverse Digital Twins with their varied project types, sizes, and complexities. This will ensure that Digital Twin technologycan be effectively deployed across various projects withinthe AEC industry.
Financial Constraints	Digital Technology implementation is often challenging due to financialconstraints of Project owners and clients, as it requires significant investmentin technology, people, and processes. Skeptics are hesitantin investing in Digital Twin technology due to the unavailability of insights on the actual return on investment generated. **Proposed Mitigation:** AEC firms need to conduct comprehensive cost-benefit analysis to assess the potentialreturn on investment (ROI) of implementing Digital Twins. Understanding and reviewing the long-term benefits and outcomes, such as reduced rework, enhanced operational efficiency, and cost savings in maintenance and operations, will be helpful in justifying the initial investment.
Lack of Collaboration	Collaboration among multiple stakeholders and adopting a structured approach are essential in the successful implementation of Digital Twins. However, working with diverse groups, each with their own responsibilities and views, can be a a challenge, and can lead to disjointed collaboration and coordination. **Proposed Mitigation:** AEC firms need to collaborate with regulatory bodies to ensure that regulations and codes align with the use of Digital Twinsin the AEC industry. Additionally, they need to work towards establishing guidelines and frameworks that enable the adoption of DigitalTwins while adheringto legal and regulatory requirements.
Data Security and Privacy	Since Digital Twins involve the collection and usage of vast amounts of data from multiple sources, ensuring this data is private and secure from unauthorized access or misuse is paramount. This is resulting in rising regulatory scrutiny of the practices used to secure and manage data across interconnected systems, which may be challenging for organizations. **Proposed Mitigation:** AEC firms need to establish a comprehensive data governance framework that outlinesdata ownership, access controls, data handling procedures, and privacy protection measures. This framework should be aligned with relevant regulations, such as data protection laws, to ensurecompliance.

Impact of Investment in Digital Twin across AEC Industry

Implementation of Digital Twins, while still being at an early stage, is being adopted gradually in the AEC sector and is already adding value. For example, Corgan, a leading architecture and design firm, integrated Digital Twin technology into the construction workflow for the LAX airport project, improving performance and productivity. This digital transformation is accelerated by rising demand, growing complexity, and the availability of advanced design tools. The following graph captures the positive and negative impacts related to investment in Digital Twins by AEC firms, classified according to a few identified impact characteristics.

Impact of Investment in Digital Twin on the AEC industry

Positive Impact of Investing in Digital Twin

- New market share capture and revenue
- Better understanding of client's operation needs
- Potential new business opportunities and services
- Position as a cutting edge/forward thinking and thought leadership company
- Improve client relationship and transparency
- Shift from commoditized to value delivery
- Improve collaboration and integration
- Better predictable outcomes
- Digital resiliency
- Increased efficiency, productivity and compliance
- New business models
- Authoritative stakeholder management
- Outcome-focused approach/ lean processes
- Increased sustainability

Digital Twin Impact Characteristic

- Market Share and Revenue
- Innovation Culture
- Collaboration
- Value-based Approach
- Efficiency, Productivity, and Compliance
- Specialization
- Business Models
- Sustainability and Resiliency

Negative Impact of NOT investing in Digital Twin

- Unable to compete in the digital transformation market
- Lack of culture of innovation
- Potential for errors and emissions
- Siloed processes
- Stagnant growth
- Unable to keep up with new industry business models
- Lack of connected data
- Increased liability
- Increased cost
- Reduced knowledge transfer
- Lack of holistic problem solving
- Reduced resiliency and sustainability

Impact of Investment as identified by Autodesk and Esri Joint Customer Council Members

Future of Digital Twin

Digital Twins have revolutionized how we utilize data in everyday life, from buildings to utilities or transportation. This digital revolution has made data easily accessible to AEC firms, owners, and operators. In the near future, full implementation of an Autonomous Digital Twin across the AEC project lifecycle might includethe following components as part of its solution package.

Predictive Analysis and Simulation: Digital Twins will leverage data collected from sensors and other sources to enable predictive analysis and simulation. This will allow stakeholders to model various scenarios, assess performance, optimize designs, and identify potential issues before they occur. It will facilitate data-driven decision-making and improve project outcomes.

Lifecycle Integration: Digital Twins will play a central role in integrating the entire lifecycle of a built asset, from design and construction to operation and maintenance. A single, comprehensive Digital Twin model will capture and connect data throughout the asset's lifespan, enabling better-informed decision-making, efficient maintenance, and improved performance.

Advanced Analytics and AI: Digital Twins will leverage advanced analytics and artificial intelligence to extract actionable insights from vast amounts of data. Machine learning algorithms will enable predictive modeling, anomaly detection, and optimization, leading to more efficient designs, better resource allocation, and enhanced operational performance.

Digital Twin Standards: For the future advanced implementation of Digital Twin, technology companies need to collaborate and invest in developing infrastructure Digital Twin standards. Technology providers should work collaboratively with AEC firms, owners, and operators to define and optimize the benefits of deploying Digital Twin standards.

Conclusion

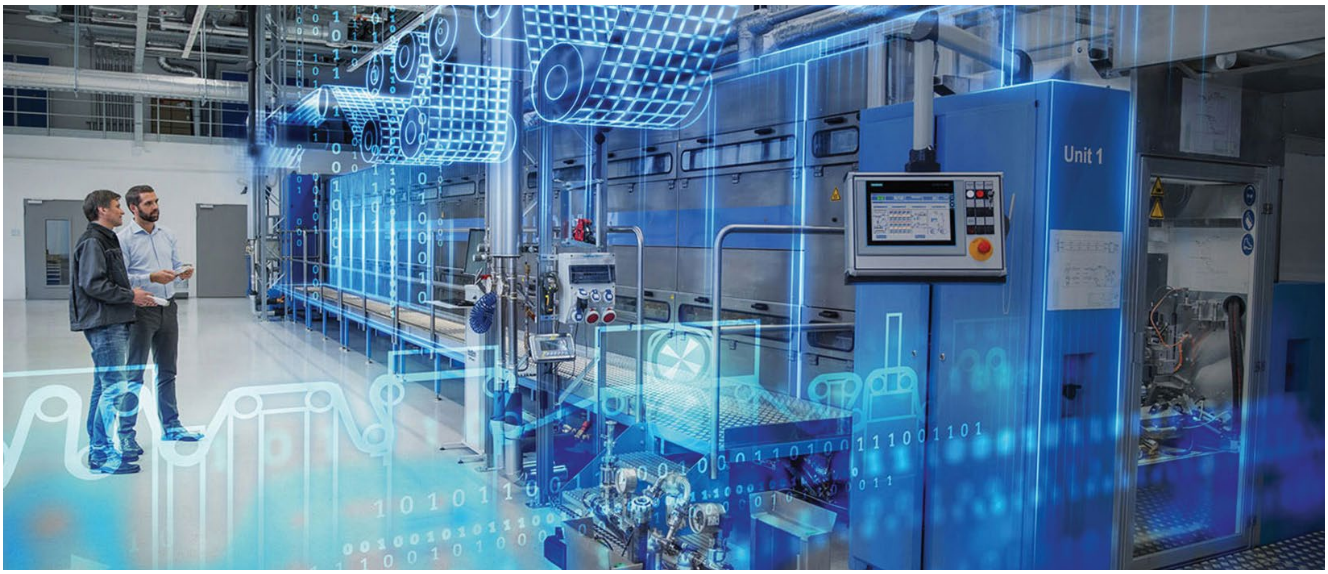
The AEC industry is actively embracing digital transformation, with a focus on modelling information relating to assets over its lifecycle. Many firms are investing in digital technologies, including “Digital Twin” to build more resilient, innovative and sustainable infrastructure. Digital Twin technologies are leading the digital-first strategyof many AEC firms, enabling a deeper understanding of the AEC workflow, from plan and design to operations and maintenance. By leveraging Digital Twin technologies, AEC firms can transform passive assets into data-centric systems, improving the flow of information and driving efficiency and sustainability into their processes and operations.

Digital Twin technology is becoming increasingly essential in the multidisciplinary aspects of infrastructure design, construction, operations, and maintenance. Today, Digital Twin provides Owners, Clients, and Operators with simulation capabilities that enhance operational efficiency and enable transformation toward smart infrastructure development. They provide a holistic view of all processes, products, services, and usages, strengthening infrastructure planningand development. At the same time, Digital Twins benefit the AEC sector by:

- Developing long-lasting, agile, resilient, and sustainable infrastructure assets
- Promoting innovation and collaboration among all stakeholders
- Highlighting opportunities for carbon reduction and climate change mitigation/adaptation
- Optimizing infrastructure assetsfrom design to operations and maintenance.
- Supporting a circular economy

The time is right for AEC firms to adopt Digital Twin as a fundamental technology in their workflows. Although the main advantage of using Digital Twin technology still rests in the fact that AEC firms can build digitallybefore building physically, additional simulation and optimization workflows in the operations and maintenance space can also add significant additional value, Digital Twin technology has the potential to become a game-changer for infrastructure projects, unlocking capabilities to deliver world-class infrastructure projects while achievingsustainable development goals.

A Digital Twin gives a multi-dimensional view of how infrastructure assets are designed, built, and operated. Digital Twin technology transforms the fundamental characteristic of the built asset lifecycle from improving operational efficiency to informing future design and construction decisions. It empowers AEC firms, owners, and operators to start digital, stay digital, and deliver digital.



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