



# W/P

WHITE PAPER  
**Digital Twin**

Fostering antifragility for business resilience.





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# 01 Intro

**In our increasingly complex world, intricately interconnected ecosystems transcend borders, impacting nations and organizations alike.**

Enterprises are swiftly embracing digitalization, unlocking the potential of data to enhance performance and even rethinking business models. However, this digital transformation unfolds within dynamic ecosystems where decision outcomes (as well as unplanned events) can yield unforeseen consequences.

The world we live in is continually faced with complex challenges, stemming from interconnected actors



pursuing diverse objectives. Recent global dynamics have significantly disrupted pretty much all businesses and organizations. Even before the era of COVID, uncertainties were prevalent, but their impact was often not as transformative as what we are currently witnessing.

**These days, organizations must strengthen their organizational and technological capabilities to navigate the complexities they face.** To be able not only to sustain unplanned events but to actually learn from them becomes essential. This concept is known as "antifragility," a term coined by Taleb.

**Organizations today requires scenario planning, enhanced visibility, and increased agility.** The complexity of our environment is determined by three key factors: the number of potentially interacting elements (**Multiplicity**), the level of interconnectedness among these elements (**Interdependence**), and the diversity of these elements (**Diversity**). Complexity arises from the relationships between different actors, experiences, and moments in time. To navigate these intricacies, advanced technologies and approaches have become essential. These enabling

technologies are crucial in elevating technology into tangible benefits. However, this complexity not only increases the complexity of decision-making but also amplifies the accompanying responsibilities.

**Fortunately, a set of technologies is at our disposal to facilitate quicker and more informed decisions.**

Realizing the full potential of these technologies requires a shift in perspective, commencing with process mapping and simulations. This will require taking the utilization of technology to the next level as well as elevating the quality of organizational conversations.

**The Digital Twin concept introduces two parallel realms: one dedicated to strategic scenario planning and the other to real-time operational management.** This powerful technology enables real-time dynamic tracking and the acquisition of a comprehensive global perspective. Consequently, Digital Twins have become indispensable for managing complex processes.

In this multifaceted world, decision-makers rely on Digital

Twins to grapple with complexity, attain a dependable overview of their business, and make informed choices, whether on a strategic or operational level.

In the past, the focus was on optimization, but today, optimization is just one of the challenges we must address. Balancing this with the concept of antifragility is crucial, particularly in the business realm, where transformation and sustainability are vital for adapting to an ever-changing market. Companies must confront the uncertainties arising from the complexity of our world. Focusing solely on prediction is insufficient, as unpredictable "black swan" events will always occur.

**It's essential to equip companies to manage complexity, developing their internal "muscle" of antifragility.**

So in conclusion the ultimate goal is not merely to endure impacts but to learn from them and emerge stronger. To develop antifragility, guarantee sustainability and continuously transform, **companies should not only withstand impacts but also thrive through them, achieving something greater.**



# Key concepts & benefits

**A Digital Twin is a near-real-time digital copy of a product, process, service or system. So information that may be obtainable from a physical asset can be also obtained from its Digital Twin.**

Both the **physical entity and its digital copy** evolve together through their entire lifecycle. The coupling of the physical and digital world enable you to monitor both systems, prevent issues, develop new opportunities and simulate future outcomes.

**It provides a reliable, risk-free, environment where one can assess optimal operational conditions.**

Think of how we use navigation tools who can remodule our routes by taking into account our needs (bypass tolls or restricted ahead) and reacting close to real time to actual events in the physical world (Accidents, Queues).

The concept of “Digital Twin” was originally formed in 2002 at the university of Michigan in the context of Product Lifecycle Management (PLM). Though the terminology has changed over time (e.g. “3S” standing for Sensors, Software and Service), the concept remained fairly stable. It is based on the idea that a digital information construct about a physical system could be created as an entity on its own. This digital information would be a “twin” of the information that was embedded within the physical system. The two remain tightly coupled through the entire lifecycle and evolve together.

Therefore, the definition of Digital Twin can be given as a set of virtual information constructs that fully describes a potential or actual physical product, system or process from the micro to the macro level. At its optimum, any information that could be obtained from inspecting a physical asset can be obtained from its Digital Twin.

Digital Twins can be implemented at different scales:

- **micro or machine level** (CNC machine, Gas turbine, Engine, etc.)
- **meso or factory level** (Assembly line, Power plant, Tanker, etc.)
- **macro or organizational level** (Supply chain, Electricity delivery network, Transport fleet, etc.)



Though different implementation scales of Digital Twin indicate various levels of complexity, the main concepts, features and challenges remain almost unchanged.

In a nutshell, Digital Twin could be described as a near-real-time digital image of a physical system that helps in monitoring and optimization of business performance.

One of the founding concepts of Digital Twin is that of Multi agent simulations. Basically a system is expressed by describing its components rather than the rules that govern the system. This is referred to as Agent Based (ABMS) simulation and modelling technique. The behaviour of these components (agents) is simulated as they interact with each other and their environment and can capture the evolution of complex dynamical systems as macro level behavior emerges from the micro decisions made by the individual entities.





# 1

## Continuous improvement

The Digital Twin concept integrates diverse technologies for foundational business enhancements.

# 2

## Predictive Modeling

Using simulation-based, mathematics, or data-based modeling, the Digital Twin predicts asset states and disruption impacts.

# 3

## What-if Analysis

Through user-friendly interfaces, the Digital Twin facilitates scenario simulations for optimal actions on the physical twin.

# 4

## Visibility

The Digital Twin enhances transparency in machine and asset operations, spanning interconnected systems like manufacturing plants or airports.

# 5

## Insight

The Digital Twin serves as a communication tool to understand and explain the behaviors of individual machines or collections.

# 6

## System Integration

Designed correctly, the Digital Twin integrates with backend applications, optimizing supply chain operations.

# 7

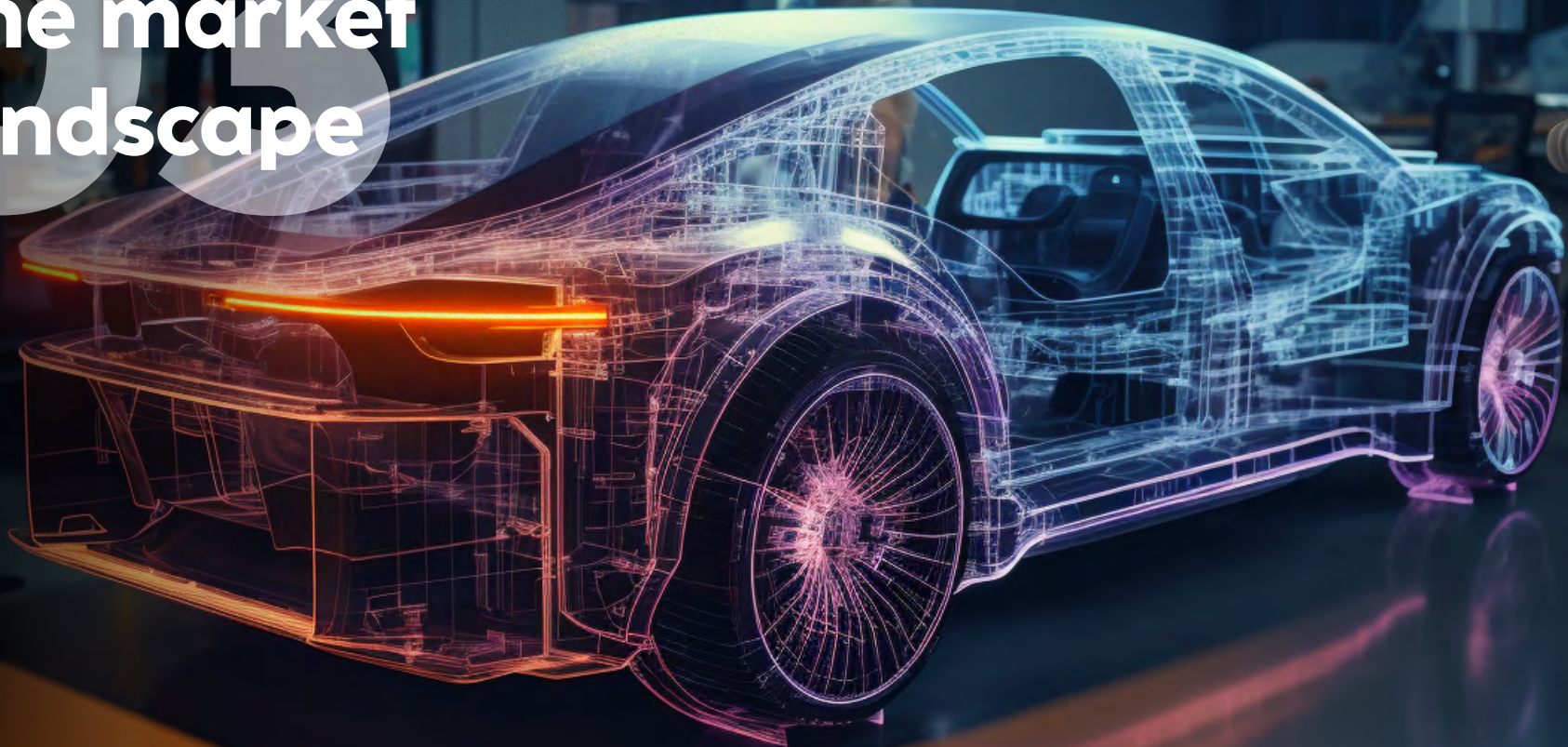
## Disruptive business models

Beyond traditional models, the Digital Twin expands value chains, creating new mechanisms like data-driven or product-as-a-service models, fostering revenue opportunities in an evolving ecosystem.





# 05 The market landscape



The market landscape



## As we look ahead to 2025 and beyond, the adoption of Digital Twin technology continues to gain momentum, reshaping industries in profound ways.

In the era of a highly automated world, we anticipate the increasing integration of Digital Twins into enterprise solutions. Their reach extends to learning and training systems, user assistance, simulations, testing, design, and coding. This integration marks a significant step toward democratizing digital technology, making it accessible to businesses of all sizes.

In an era characterized by relentless digital advancement, Digital Twins are poised to be indispensable. **They have the**

**potential to revolutionize content creation, technological development, and our approach to learning, work, production, and life.**

One sector experiencing exceptional growth through the embrace of Digital Twin is Manufacturing, but the impact of these virtual replicas extends to other industries.

Let's deep dive into the **six most promising industries** shaping the future of this remarkable technology:

- **Manufacturing** - leading the pack is the manufacturing sector, where Digital Twins have found extensive application. They are making their presence felt in the creation of the 'Factory of the Future.' These digital counterparts offer a virtual window into highly automated production lines, enabling manufacturers to envision the impact of automation and optimization on their operations. In the field of light-off factories, Digital Twins can be used to steer production by providing decision-makers with insights into the current state of the factory and predicting how it will respond to changes. This allows them to make adjustments to

production schedules, machine settings, and other factors to optimize output and quality.

- **Healthcare** - the healthcare industry is witnessing a digital transformation with the integration of Digital Twins. These sophisticated replicas facilitate real-time monitoring of patient health and enable physicians to devise personalized treatment plans. From virtual simulations of complex surgeries to the optimization of medical device development, Digital Twins are ushering in a new era of precision medicine, improving patient outcomes, and enhancing the efficiency of healthcare delivery.
- **Transportation** - in the realm of transportation, Digital Twins are contributing to the development of intelligent and sustainable mobility solutions. Whether it's the design and simulation of autonomous vehicles or the optimization of traffic management systems, these digital replica are instrumental in shaping the future of transportation. They offer insights into improving safety, reducing environmental impact, and enhancing the overall mobility experience.

- **Energy** - the energy sector is embracing Digital Twins to revolutionize the management of power grids, renewable energy generation, and resource optimization. By creating virtual replicas of intricate energy systems, stakeholders can monitor, control, and fine-tune their operations for maximum efficiency. Digital Twins play a crucial role in achieving sustainable energy production, grid resilience, and effective resource allocation.
- **Retail** - Digital Twins are also finding their way into the retail industry, where they are enhancing customer experiences and optimizing supply chains. These virtual representations of products, stores, and logistics networks empower retailers to analyze consumer behavior, refine inventory management, and streamline the entire retail process. By fine-tuning the shopping experience and improving operational efficiency, Digital Twins are propelling the retail sector into the future.
- **Augmented City** - The Digital Twin is an ally in city development. By creating accurate digital models of

neighborhoods, infrastructure, and services - including transportation, water networks, and buildings - and by collecting and analyzing heterogeneous data, solutions can be studied to optimize energy and water consumption, reduce pollution to improve traffic, and ensure better resource management. It serves as a valuable tool for sustainable urban planning and for preventing and managing the consequences of natural phenomena and extreme weather events.

The current landscape of Digital Twins is marked by diverse applications across various sectors, promising innovative solutions and efficiency improvements.

As we delve deeper into the whitepaper, we will explore the future of Digital Twins, envisioning a world where they converge with technologies like the industrial metaverse and generative AI to bring about **a new era of possibilities.**







# 04

## Our approach

We empower our clients by simulating and **addressing their business challenges, minimizing the risk of uncertainties, and amplifying their path to success.**

Our specialization in Digital Twin applications enables managers to make informed decisions, leveraging a detailed digital replica of their business.

Through the synergy of **Advanced Analytics, Simulation, and Machine Learning techniques**, we not only identify corrective actions for unforeseen events but also, more significantly, predict and optimize overall business performance.

## Unlocking actionable insights across your connected value chain.

With a focus on the digital transformation of the manufacturing and transportation sectors, IXG is the global division of the Engineering Group specialized in designing, building and delivering holistic technology solutions covering the end-to-end lifecycle and supply chain of all industrial products and processes.

**19**

IndX Hubs in 11 Countries & 4 Continents

**1500+**

Global IndX Projects Delivered

**725+**

IndX Transformation Specialists

**Global**

Delivery & Customer support

**30+**

Markets, covering all Discrete & Process Industries



We adopt **a comprehensive end-to-end approach to the Digital Twin**, covering **strategic, tactical, and operational dimensions** within an organization's ecosystem. Leveraging our methodological approach, we proficiently deliver on all the promised benefits of this cutting-edge technology.

We have developed a specialized method to transform standalone simulation models into essential tools for enterprise decision-making. Initially, **we map and collect constraints** in our client's business ecosystem (e.g., volume, frequency, equipment). Subsequently, understand **how to enhance performance** (e.g. by exploring automation, adapting to technology changes, and ensuring flexibility).

This results in **two key outcomes**:

- **Strategically**, dynamic simulation serves as a valuable tool for investment planning decision-making. This enables us to test various solutions and evaluate their ROI in alignment with corporate strategy;
- **Operationally**, dynamic simulation serves to create a Digital Twin of operations, connecting the simulation to real-time processes. This enhances areas such as warehouse planning and scheduling.

Our goal is to execute **real projects, starting small to yield tangible results and scaling up**, empowering clients through collaborative, lasting solutions within a specific framework.

## 01 – Setting the environment



Core team & modeling community



Modeling standards & guidelines



Training & support

## 02 – Scaling Use Case



Model creation



Model adaptation



Model monitoring & updating

**Digital Twins, commonly applied in the Digital Industry sector, streamline supply chain decision-making across various levels.**

**1**

### **Tool or Workcenter**

Supporting tool configuration and enhancing cycle times, machine utilization, and throughput rates.

**2**

### **Manufacturing site**

Preventing production bottlenecks, optimizing workforce allocation, analyzing product mix changes, and making capacity planning decisions.

**3**

### **Internal supply chain**

Overcoming silos across the value chain to enhance overall performance.

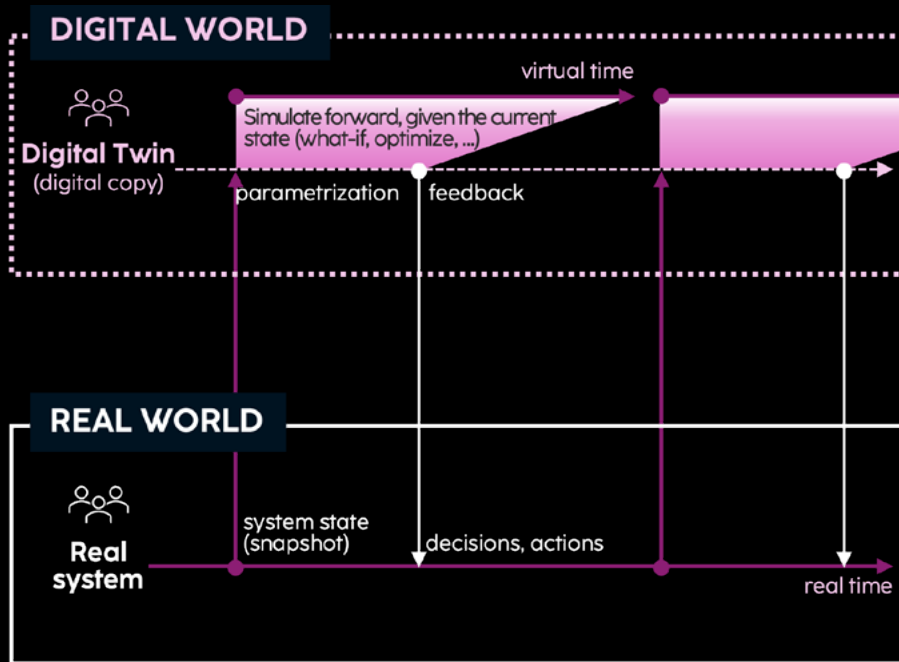
**4**

### **End-to-end supply chain**

Analyzing the impact of demand shifts, supplier disruptions, transportation delays, and evaluating different supply chain network configurations.



# HOW THE DIGITAL TWIN WORKS



1

## Digitalize

The DT receives **data from the real world** with a certain frequency. Through this data it can **recreate the state of the system** at a certain time, by setting the proper parameters (parameterization) of the model to which it refers.

2

## Simulate

Given the current state, the DT **simulates the evolution of the system**, in virtual mode (i.e. as fast as possible), over a given time horizon.

3

## Return feedback

In case the simulation identifies possible critical issues or a **misalignment from the desired state**, the DT can return a **warning message** back to the decision maker (e.g. by displaying it in a control room).

4

## Decide

When a criticality occurs, the DT can be used to **evaluate ex-ante different corrective solutions**, (i.e. what if). Also, having identified levers to act on, the DT can automatically return multiple scenarios showing the state of the system when certain conditions occur.



# 05 Our projects

Our projects

## CASE STUDY

### New Supply Chain Simulation for Pharmaceutical Leader

Our team of experts designed a simulation model to analyze and predict the behavior of a global pharmaceutical company's supply chain network. This company, one of the top 20 pharmaceutical firms worldwide, is conducting clinical trials for a dengue fever vaccine and needs to be prepared for large-scale production and distribution if approved. The current approach relies on an outdated spreadsheet that can't offer the granularity required for decision-making. Our solution combines agent-based and discrete event modeling, allowing for maximum flexibility and scenario analysis. Every production and inventory phase is modeled individually, with the entire supply chain network constructed modularly. This modular approach facilitates easy parameter definition for each element, accommodating the forecasted market demand over the simulated timeframe, providing valuable support for decision-making, visibility into the supply chain, and enhanced flexibility.



## CASE STUDY

### Digital Twin in the Caspian Sea

We supported operations for exploiting the largest oil field discovered in the last 40 years.

Our partner, a purpose-driven entity, faced enormous technical challenges in this endeavor.

The field is situated in the Caspian Sea, with extremely shallow waters, significant weather-related concerns, high H2S content, and the necessity of artificial islands for operations. The project ranks among the costliest in history. Time is of the essence because the sea is drying up at a rate of 10 cm per year, rendering the area inaccessible. ENG was brought in to develop a simulation model that optimizes the fleet of ships and equipment, providing flexibility for testing various alternatives and extreme scenarios to choose the most cost-effective logistics configuration.

The solution's extreme flexibility, time and cost optimization, and logistical support for operations proved indispensable.





CASE STUDY

**Digital Twin for Aeronautical Plant Redesign**

Through advanced simulation, we transformed a global aerospace manufacturer's structure from an Original Equipment Manufacturer (OEM) to an Maintenance, Repair & Operations (MRO) aeronautical facility. The client sought to validate design decisions by creating a model to visualize future scenarios through "what-if" analyses. Using simulation software, we virtually recreated the client's entire process, enabling analysis of minimum resource requirements for future workloads. Our team employed Siemens Tecnomatix Plant Simulation to construct a 3D simulation model that transitioned the existing production facility into an aircraft maintenance and repair structure. It identified bottlenecks and improvement opportunities, resulting in increased efficiency in product design and engineering, improved efficiency and productivity in the future aircraft repair facility, reduced capital investment risks, optimized production resources, and enhanced visibility and communication between business systems.



CASE STUDY

**Enhancing Traveler Experience with Crowd Mgmt**

We provided an end-to-end crowd management solution for a rail operator facing the challenge of integrating crowd management for new station access points, assessing impacts, and mitigating overcrowding conditions. Our solution focused on a major railway station, including commercial galleries, access control areas, and track spaces.

The model we developed allowed simulations with various parameters, such as gate configurations, passenger data, train technical specifications, and timetables, offering predictions of occupancy, dwelling times, congestion alerts, and evacuation times.

This precision in simulation enabled better station organization based on data, resulting in better predictions of critical situations, more accurate system impact simulations, precise tracking of traveler flows, and overall station organization improvements.



CASE STUDY

**Advantages of Digital Twins for Emerson Electric**

In an ongoing partnership, we helped Emerson Electric create Digital Twins for their HVAC and Automation & Control divisions in North America. Emerson Electric, a global energy company, sought to enhance productivity and profitability, acquire data on inefficiencies, improve data accuracy, and reduce data acquisition times.

Our team designed and built comprehensive simulation models for future HVAC production lines and Automation & Control facilities. The Digital Twins have been instrumental in identifying optimal layouts, equipment, and container purchases.

The results included increased operational productivity and overall profitability, improved order scheduling and completion date forecasting, enhanced data accuracy and data acquisition capabilities, and detailed insights into product storage inefficiencies and downtime.



Our projects





# Why choose us

Why choose us

## End-to-End approach

Encompassing the entire lifecycle of products and assets, from initial design through production and operation, IXG excels in supply chain strategy, decision science, planning, and execution.

Their seamless integration of digital and physical processes optimizes operations.

## Cutting-Edge advantages

Fueled by an extensive network of global technology partners, IXG gains exclusive access to the latest software solutions. We focus on understanding the customer's needs, presenting tailored options, and guiding them to the best technology that aligns with their organization's goals, requirements, and unique digital transformation vision.

## Fit-Tailored solutions

Leveraging profound expertise in Industry 4.0, Digital Supply Chain, and the Digital Twin domain, IXG navigates the complex technological landscape, deploying unique proprietary methodologies.

## Global Reach

With 19 IndX Hubs located in 11 countries across 4 continents, we offer extensive global coverage to cater to your needs and projects, ensuring a truly international presence.

## Access to expertise

Our team boasts more than 700 IndX Transformation Specialists, each contributing their extensive knowledge and experience to provide you with top-tier support and innovative solutions for the digital transformation journey.





# 07 How will it evolve

How will it evolve



## **Digital Twin technology is charting a transformative course that promises to reshape the landscape of industries and redefine how organizations conduct their operations.**

As we gaze into the horizon of possibilities, we discern the emergence of three distinct metaverse types, each on its unique journey to maturity.

These metaverses encompass the Personal Metaverse, elevating individual immersive experiences, the Enterprise

Metaverse, which harnesses mixed reality to enhance professional tasks, and the Industrial Metaverse, where the potential of Digital Twins shines brightly, replicating and optimizing industrial and manufacturing operations. The Industrial Metaverse is particularly intriguing, maturing at a pace that surpasses its counterparts. Forward-thinking companies have already begun embracing Digital Twin technology, setting the stage for a future where comprehensive interconnected simulations drive enterprise-wide optimization. Various studies corroborate the surging importance of Digital Twins in modern industries, emphasizing the growing significance of this groundbreaking technology.

**One of the noteworthy facets of Digital Twin's future is their role in revolutionizing the training of deep reinforcement learning algorithms.**

As the demand for extensive datasets to train these algorithms escalates, advanced AI and GANs (Generative Adversarial Networks) embedded in Digital Twins step in as valuable generators of synthetic data.





This synthetic data contributes significantly to algorithm training, enhancing their decision-making capabilities, and ultimately optimizing operational processes.

Furthermore, Digital Twins are poised to act as virtual sensors, effectively addressing the challenges posed by data gaps in complex systems. Consider an example within the automation industry. In an automated manufacturing process, where precise pressure data may be missing, Digital Twins, driven by GANs, AI, and real-time correlations between variables like volume and temperature, can seamlessly approximate the missing pressure data. This not only enhances data integrity but also offers **intelligent solutions to optimize manufacturing processes, ensuring quality, and resource efficiency.**

A pivotal transition on the horizon is the shift from local optimization to a global approach. Rather than focusing solely on the efficiency of isolated plant operations, organizations are recognizing the transformative potential of holistic enterprise-wide optimization. As illustrated

in the journey towards the Industrial Metaverse, where interconnected Digital Twins of different components and systems contribute to overall optimization, the future is in managing the complexity of the entire enterprise.

This approach promises to **unlock new levels of efficiency, resource utilization, and performance across the organization, making it a key driver of Digital Twin technology's evolution.**

In conclusion, the future of Digital Twins is marked by their pivotal role in enabling seamless enterprise-wide optimization, serving as virtual data generators for AI training, and **offering solutions to bridge data gaps in complex systems.**

Backed by a multitude of studies, Digital Twins are poised to lead organizations into **a new era of efficiency, innovation, and interconnected decision-making.** This technology stands as the cornerstone for navigating the digital age's vast landscape of opportunities and **ensuring businesses can thrive in an ever-evolving ecosystem.**



How will it evolve



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