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Digital Twin as a Methodology for Improving Operational Performance in Industrial Organizations - Presenting some Leading International Experiences -

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Summary: The study aims to explore the role of Digital Twin technology as an effective tool for improving operational performance in industrial organizations, by enhancing efficiency, predictive maintenance, and data-driven decision-making. The effectiveness of Digital Twins relies on the integration of IoT, cloud computing, and advanced analytics, alongside employee training and management readiness for change.

The study has found that developing a structured roadmap for adopting Digital Twin technology, starting with pilot projects, investing in digital infrastructure, fostering partnerships between universities, research centers, and industrial organizations, establishing clear frameworks for data governance and cybersecurity, and adapting lessons learned from international experiences to local contexts, significantly enhances operational performance, flexibility, and future readiness. The study recommends that organizations implement these strategies to ensure the effective use of Digital Twins and maximize their potential in improving operational processes and driving industrial innovation.

Keywords: Digital Twin Technology, Operational Performance, Predictive Maintenance, Industrial Innovation.

Jel Classification Codes : O33; L60 ; M 15.

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I- Introduction :

The advent of the Fourth Industrial Revolution (Industry 4.0) has fundamentally redefined the landscape of industrial operations. Amidst the convergence of physical and digital systems—fueled by advancements in the Industrial Internet of Things (IIoT), Artificial Intelligence (AI), and cloud computing—organizations are under immense pressure to achieve unprecedented levels of efficiency, agility, and sustainability. The traditional model of reactive decision-making is no longer sufficient to maintain a competitive edge in a hyper-connected, volatile global market. To navigate this complexity, industrial enterprises require innovative, data-driven methodologies that offer predictive capabilities and comprehensive real-time visibility.

The rapid digital transformation observed across industrial sectors has intensified the need for advanced technologies capable of enhancing operational efficiency, minimizing downtime, and enabling data-driven decision-making. Among these technologies, the *Digital Twin* has emerged as one of the most innovative and influential paradigms. A Digital Twin is a virtual, dynamic digital replica of a physical asset, process, or production system that allows real-time monitoring, simulation, prediction, and optimization of industrial operations.

At the heart of this operational transformation lies the Digital Twin (DT). This is where Digital Twin emerges as a pivotal methodology. Digital Twin acts as a bridge between the physical and virtual worlds, providing a live digital model of assets and processes, fed with real-time data. In recent years, major international industrial organizations have adopted Digital Twin models to improve production flexibility, reduce operational risks, and enhance product quality. These applications have demonstrated the transformative potential of Digital Twin technology in revolutionizing manufacturing processes, predictive maintenance strategies, and resource allocation.

Research Problem:

Industrial organizations—particularly in developing countries—face growing challenges related to rising operational costs, fluctuating productivity levels, and increasingly complex industrial processes within the constraints of limited technological resources. In this context, Digital Twin technology has emerged as an advanced solution capable of supporting continuous improvement in operational performance through simulation, real-time monitoring, and predictive analytics. However, the adoption of this technology remains limited in developing countries compared to advanced economies, raising the need to understand how it can be effectively implemented and what lessons can be learned from successful international experiences. Accordingly, the problem of the study can be formulated in the following main question: How can Digital Twin technology contribute to achieving continuous improvement in the operational performance of industrial organizations in developing countries, and what lessons can be drawn from selected global experiences in this field?

Sub-Questions:

To help answer the main problem, the following sub-questions are posed.:

- What are some of the most successful international experiences in implementing digital twin technology within industrial organizations?
- What organizational, technical, or economic challenges might hinder the adoption of digital twin systems?
- How can industrial organizations develop a practical framework for adopting digital twin technology based on leading international experiences?

Significance of the Study:

The significance of this study lies in its focus on Digital Twin technology as a fundamental pillar of industrial transformation in the era of Industry 4.0, due to its substantial potential to enhance operational efficiency, improve product quality, and reduce downtime and costs. The study is also important because it analyzes leading international experiences, providing opportunities to learn from global best practices and understand the mechanisms that contributed to the successful implementation of this technology in advanced industrial organizations. This study holds particular relevance for industrial organizations in developing countries seeking to adopt modern technologies, as it offers a knowledge framework to comprehend the concept of Digital

Twin, assess its potential benefits, and address the challenges associated with its implementation, thereby supporting competitiveness and continuous improvement in operational performance.

Objectives of the Study:

This study aims to achieve the following:

- Clarify the conceptual framework of the Digital Twin and demonstrate its role as a modern tool within the technologies of the Fourth Industrial Revolution (Industry 4.0).
- Review and document the leading and selected global experiences in applying Digital Twin technology across various industrial sectors.
- Extract and generalize best practices and lessons learned from successful international experiences to identify the critical success factors (CSFs) for Digital Twin implementation.
- Propose and present a strategic and applied framework (Roadmap) that industrial organizations can adopt to ensure the continuous and predictive improvement of their operational performance based on the Digital Twin.

II- Literature Review:

II.1. Digital twin history and evolution:

The concept of the Digital Twin was first introduced in a 2002 presentation by the University of Michigan titled "Conceptual Ideal for PLM." Although the presentation focused on Product Lifecycle Management, it included fundamental characteristics of Digital Twins that have remained largely unchanged—specifically, the existence of a "real space" and a "virtual space" connected through the exchange of data and information. Several years later, in 2010, the term "Digital Twin" appeared in NASA's widely cited definition as an "integrated multi-physics, multiscale, probabilistic simulation of a vehicle or system that uses the best available physical models, sensor updates, fleet history, etc., to mirror the life of its corresponding flying twin." A more recent definition in the context of manufacturing describes a Digital Twin as "a digital representation of an active, unique product […] or product–service system […] that incorporates its selected characteristics, properties, conditions, and behaviors through models, information, and data across one or multiple life cycle phases. (J. Trauer, 2020, p. 759)

NASA used an early form of a twin to replicate space conditions and conduct tests in preparation for missions—an approach also reflected in hardware models such as the Airbus "Iron Bird." Emerging initially within the aerospace sector, the Digital Twin methodology began to expand into the manufacturing industry around 2012. This raises the question: why did it take nearly a decade for the concept to gain widespread implementation? The answer lies in the rapid technological advances that occurred in the following years. Breakthroughs in cloud computing, the Internet of Things (IoT), and big data paved the way for major developments in multiple fields, including Industry 4.0, the Physical Internet, cyber-manufacturing, Made in China 2025, and cloud-based manufacturing models. Industry 4.0, in particular, witnessed a transformation driven by digitalization, interconnected devices, and large-scale data availability. With digital data storage becoming the norm and sensors increasingly embedded across industrial environments, the implementation of digital twins became practical, revitalizing the concept. Additionally, the emergence of advanced simulation capabilities and the significant growth in computational power made it possible to conduct realistic virtual testing, further enabling the adoption of Digital Twin technology (Angira Sharma and al, 2022, p. 3)

II.2. Concept of Digital Twins:

Presented below are a number of prominent definitions that describe the concept of the Digital Twins:

Digital twins are exact virtual replicas of physical objects, processes, or systems. Their purpose is to simulate and predict the behavior of their real-world counterparts. A digital twin is configured by a computer system that processes the same variables as its physical counterpart and produces identical results. Unlike simulators, which typically focus on specific aspects or behaviors under specific conditions, digital twins provide a comprehensive and dynamic simulation. They are constantly updated with real-time data, allowing them to accurately reflect the current state of the physical object. (Latorre, L., Rego, E., & de Leo, L., 2024, p. 6)

Digital twins is a methodology that involves developing a virtual replica of a specific physical object or process, enabling continuous real-time monitoring, analysis, and evaluation. The primary objective of digital twinning is to enhance operational performance, anticipate potential issues, and generate actionable insights to optimize processes and improve overall efficiency. (Khadidja, 2025, p. 301)

The Digital Twin is a virtual representation of an object or system that reflects its changes over time. Its implementation involves the process of twinning, which refers to synchronizing the virtual and physical states so that they remain equivalent. (Helena Solman and al, 2022, p. 272)

The Digital Twin is a virtual construct that represents a physical counterpart, integrates several data inputs with the aim of data handling, data storing, and data processing, and provides an automatic, bi-directional data linkage between the virtual world and the physical one. Synchronization is crucial to the Digital Twin to display any changes in the state of the physical object. Additionally, a Digital Twin must comply with data governance rules and must provide interoperability with other systems. (Andrea Matta, and Giovanni Lugaresi, 2024, p. 4)

From the previous definitions, it can be said that A Digital Twin is a virtual copy of a real object, system, or process that uses real-time data to show how it works and changes. It helps organizations monitor performance, predict problems, and improve operations.

II.3. Benefits of Digital Twins:

Digital twins provide a comprehensive set of advantages capable of transforming the way organizations. design, develop, operate, and maintain their products, processes, and systems. (Latorre, L., Rego, E., & de Leo, L., 2024, pp. 8-9)

- **Enhanced design and development:** Digital twins allow for the system's performance before its physical creation or implementation, enabling early detection and correction of potential issues. This leads to a more streamlined design process and products of higher quality.
- **Better decision-making:** Through the integration of real-time data and the use of advanced analytical tools, digital twins generate meaningful insights that support informed decision-making at all organizational levels—from day-to-day operations to long-term strategic planning.
- **Predictive maintenance:** By forecasting wear patterns and potential component failures, digital twins facilitate a shift from reactive to predictive maintenance, minimizing unplanned downtime and prolonging asset longevity.
- **Improved operational efficiency:** Digital twins support the optimization of operations by enabling the simulation and evaluation of processes across multiple scenarios. This capability enhances planning accuracy, ensures more effective resource allocation, and decreases operational costs.
- **Safe environment for innovation:** Digital twins offer a risk-free platform for experimentation, allowing organizations to test new concepts and ideas without endangering physical assets or interrupting current operations—thereby promoting continuous innovation.
- **Customization and adaptability:** Digital twins support the tailoring of products and services to meet specific customer requirements and enable faster adaptation to market changes or evolving consumer preferences.
- **Lifecycle management:** By providing a holistic view of a product's lifecycle—from initial concept to end-of-life—digital twins facilitate detailed monitoring and continuous improvement throughout every stage.
- **Sustainability enhancement:** Through optimized design, improved process efficiency, and reduced resource consumption, digital twins contribute to lower energy use and waste generation, supporting broader corporate sustainability goals.

II.4. Types of Digital Twins:

The types of Digital Twins include the following: (Phipps, 2025)

- **Product Digital Twin**: A product digital twin is a virtual replica of a physical product throughout its entire life cycle. It allows testing, optimization, and performance monitoring of the product before and after actual production. This type is widely used in industries such as automotive and aerospace.

- **Process Digital Twin**: A process digital twin models industrial or logistical processes to enhance efficiency and productivity. It simulates complex workflows to identify bottlenecks and test different improvement strategies. It is an essential tool in manufacturing and logistics.
- **System Digital Twin:** A system digital twin represents a network of interconnected assets and processes, such as a factory or an energy grid. It enables overall system optimization and continuous monitoring. This type is commonly applied in the energy and infrastructure sectors.
- **Organizational Digital Twin**: An organizational digital twin simulates the entire operation of a business by integrating internal interactions and key processes. It helps assess and improve overall performance, including talent management, financial flows, and operational efficiency. It plays a crucial role in corporate digital transformation initiatives.
- **Environmental Digital Twin:** An environmental digital twin models natural or urban environments to analyze the impact of human activities. It is used for natural resource management, climate monitoring, and urban planning. This type is particularly important in smart city projects and sustainable environmental management.

II.5. Concept Operational performance:

Operational performance represents the quantifiable outcomes of an organization's processes, including elements such as reliability, production cycle duration, and inventory turnover. This level of operational efficiency subsequently influences broader business performance indicators, such as market share and customer satisfaction (MD. AZIM1, HELALUDDIN AHMED,and A.T.M. SHIBBIR KHAN, 2015, p. 64)

Operational performance refers to the level of effectiveness and efficiency of manufacturing operations, as reflected through a set of shop-floor non-financial performance measures. These measures encompass product quality, customer satisfaction, on-time delivery, employee morale, and efficiency and utilization. (Abdullatif Mohamed Basheikh and Ahmed Abdel-Maksoud, 2008)

Operational performance refers to a company's capability to meet customer needs by ensuring fast delivery, maintaining high product quality at minimal costs, and demonstrating flexibility in its operational processes. It can also be described as the degree to which a company efficiently manages the flow of materials, products, and information to deliver goods and services to its customer customer satisfaction. (Hadikusu, Steven; Siagian, Hotlan, 2022, pp. 76-77)

From the previous definitions, we can define operational performance as the overall effectiveness and efficiency of an organization in executing its core business processes. It encompasses the company's ability to deliver high-quality products or services on time, at competitive costs, and with the flexibility to adapt to changing customer demands and market conditions. Operational performance also involves the smooth and efficient management of resources, including materials, information, and human capital, to ensure a continuous and optimized flow of goods and services. High operational performance directly contributes to customer satisfaction, organizational competitiveness, and long-term business success.

II.6. Digital Twin and Operational Performance — How They Interact:

In this section, we map how implementing DT impacts specific dimensions of operational performance in industrial organization

Table 01: Contribution of Digital Twin to Different Dimensions of Operational Performance

Performance Dimension	Contribution by Digital Twin
Process Efficiency & Throughput	Simulation and monitoring help identify bottlenecks, optimize workflow, reduce setup/change-over times, and improve overall throughput.
Downtime Reduction & Maintenance Efficiency	Predictive maintenance reduces unexpected breakdowns, stabilizes production schedules, and reduces maintenance costs.
Product Quality & Consistency	Real-time monitoring detects deviations; virtual testing ensures adherence to specifications, reducing defects.
Cost Reduction	Fewer physical prototypes, optimized

	resource/energy usage, and reduced waste result in lower costs.
Time-to-Market / Market Responsiveness	Faster design iterations and process changes accelerate product development and market release.
Flexibility & Adaptability	Ability to simulate alternative scenarios enhances organizational agility.
Sustainability & Resource Efficiency	Optimization of resource consumption, waste reduction, and energy management support sustainability goals.

Source: Compiled by the author based on the literature on Digital Twin applications in industrial organizations (Longo, F.,and al, 2022) , (Viola, J., & Chen, Y, 2020); (Fantozzi, I. C., and al, 2025)

Table 01 highlights the contribution of Digital Twin technology to various dimensions of operational performance. It enhances process efficiency and throughput by identifying bottlenecks, optimizing workflows, and reducing setup times. Downtime and maintenance efficiency improve through predictive maintenance, which minimizes unexpected breakdowns and stabilizes production schedules. The technology ensures product quality and consistency via real-time monitoring and virtual testing, reducing defects. It also supports cost reduction by lowering the need for physical prototypes, optimizing resource and energy usage, and minimizing waste. Time-to-market and market responsiveness are accelerated through faster design iterations and process adjustments. Moreover, Digital Twins increase flexibility and adaptability by allowing simulation of alternative scenarios, and promote sustainability and resource efficiency through better resource management and energy optimization.

III- Case Studies on Digital Twin Implementation for operational performance:

III.2. General Electric (GE), United States: General Electric (GE) is considered one of the world's pioneers in applying Digital Twin technology, particularly through its Predix industrial platform. GE developed advanced digital twins for gas turbines, jet engines, and large-scale manufacturing systems. These twins integrate real-time sensor data, machine learning models, and predictive analytics to simulate the behavior and lifecycle of physical assets. The adoption of digital twins enabled GE to significantly enhance operational performance by reducing unplanned downtime by up to 30%, improving turbine efficiency, and increasing the reliability of industrial operations. Through early fault detection and data-driven maintenance strategies, GE succeeded in optimizing asset performance and minimizing operational risks

III.2. Siemens, Germany: Siemens has implemented one of the most sophisticated and comprehensive Digital Twin frameworks within its global manufacturing network. The Amberg Electronics Plant in Germany represents one of the best examples of a fully integrated product–process–system digital twin model. Siemens uses digital twins throughout the entire manufacturing lifecycle, from product design and process simulation to real-time production monitoring and optimization. This approach has resulted in outstanding operational outcomes, including achieving a production accuracy rate of 99.98%, reducing defects, and increasing overall manufacturing efficiency. The seamless synchronization between virtual and physical environments has allowed Siemens to achieve high production flexibility, faster decision-making, and continuous process improvement

III.3. Boeing, United States: Boeing employs Digital Twin technology extensively in aircraft design, assembly, and predictive maintenance. The company integrates 3D modeling, IoT-enabled sensors, and simulation tools to create a virtual representation of aircraft components and systems. By utilizing digital twins, Boeing has significantly improved its operational efficiency by reducing design time by up to 40% and minimizing the need for physical prototypes. The technology also enhances assembly precision and reduces rework, leading to substantial cost savings. Moreover, digital twins support safety and reliability improvements by enabling early detection of structural anomalies and optimizing maintenance strategies based on real-time aircraft condition

III.4. NASA, United States: NASA is among the earliest adopters of Digital Twin concepts, using them for spacecraft health monitoring, mission simulation, and anomaly detection. Digital twins

allow NASA to simulate thermal loads, structural stresses, and operational conditions that spacecraft encounter during missions. This capability enhances the reliability of mission-critical systems, reduces operational risks, and improves mission planning efficiency. Through virtual replication of spacecraft systems, NASA engineers are able to test scenarios that would be impossible or extremely costly to replicate physically. As a result, digital twins have become a vital element in ensuring the safety and success of space mission.

III.5. Singapore Smart Nation, Singapore: Singapore has developed one of the world's most advanced large-scale digital twin projects as part of its Smart Nation initiative. The city-scale digital twin integrates data on transportation, infrastructure, environmental conditions, and public utilities to support real-time monitoring and long-term urban planning. This virtual model helps government agencies predict traffic congestion, improve emergency response, optimize energy consumption, and enhance the delivery of public services. The implementation of this digital twin has significantly improved the operational performance of Singapore's urban management systems by enabling more informed decision-making and efficient resource allocation.

III.6. Ferrari, Italy: Ferrari uses Digital Twin technology within its Formula One operations to simulate car performance under various track and environmental conditions. The digital twin allows engineers to test aerodynamic configurations, engine behavior, and mechanical responses before rM2aces, reducing the need for costly and time-consuming physical testing. This approach has greatly improved the team's operational performance by enabling rapid optimization of racing strategies, enhancing the reliability of race cars, and supporting real-time decision-making during competitions. As a result, digital twins have become a critical tool in maintaining Ferrari's competitive M2advantage in motorsports.

Dubai Electricity and Water Authority (DEWA), UAE: The Dubai Electricity and Water Authority (DEWA) has implemented a sophisticated Digital Twin system to manage its electricity and water networks. By integrating smart meters, real-time monitoring technologies, and AI-based forecasting tools, DEWA uses digital twins to enhance network stability, predict system failures, and optimize energy and water distribution. This has led to significant improvements in operational performance, including reductions in resource losses, enhanced asset reliability, and improved maintenance scheduling. DEWA's digital twin strategy demonstrates how utility providers can use advanced technologies to achieve higher efficiency and better service delivery

Toyota – Supply Chain and Manufacturing Optimization (Merged Version): Toyota has adopted Digital Twin technology as a core tool to enhance the performance of its supply chain and manufacturing systems, strengthening both its legendary production system and global supply chain resilience. The company has developed detailed virtual models of its end-to-end operations, encompassing raw material flows, logistics networks, inventory movements, and the intricate workings of its production facilities. These digital twins allow managers to run sophisticated "what-if" simulations instantaneously—for example, assessing the impact of a disruption in a specific region or a sudden spike in consumer demand. On the factory floor, the twin optimizes assembly line throughput by simulating material flow, identifying bottlenecks, and resolving production issues virtually before they occur. By integrating real-time data from IoT-enabled sensors installed across factories, Toyota can monitor machine performance, predict production delays, and improve equipment utilization. This proactive, data-driven approach has enabled Toyota to achieve greater operational efficiency, reduce waste, optimize inventory levels, enhance lean manufacturing practices, and respond more agilely to market volatility. Overall, Digital Twin technology reinforces Toyota's flexibility, accelerates its response to market changes, and supports its global leadership in automotive production.

Rolls-Royce: Predictive Maintenance in Aerospace (Final Academic Version): Rolls-Royce is recognized as a global leader in the adoption of Digital Twin technology within the aerospace sector, particularly for predictive maintenance of aircraft engines. Each physical engine produced by the company is paired with a highly detailed virtual twin that continuously receives real-time data from thousands of embedded sensors monitoring temperature, pressure, vibration, fuel efficiency, thermal behavior, and structural integrity. Using advanced analytics, AI, and machine learning, the digital twin accurately simulates the engine's current condition, evaluates wear levels, and predicts future performance. This enables Rolls-Royce to detect subtle anomalies well before they develop into failures, allowing maintenance to be scheduled proactively rather than according to fixed intervals. Consequently, unplanned ground time is significantly reduced, engine

availability is increased, and overall flight safety is enhanced. This data-driven approach underpins the company's "TotalCare" and "Power-by-the-Hour" service models, reinforcing operational excellence and delivering substantial value to airline customer.

Smart Buildings: Energy Efficiency and Facilities Management (Merged Version): Digital Twin technology is increasingly being adopted in smart buildings, particularly large commercial and office complexes, to enhance energy efficiency and optimize facilities management. A building's digital twin integrates real-time data from all critical systems, including HVAC, lighting, security, and occupancy sensors, creating a unified virtual model that provides a holistic operational view. Through this platform, building managers can simulate different energy usage scenarios, detect inefficiencies, and predict maintenance needs for essential systems. The technology enables dynamic adjustments, such as optimizing HVAC operations based on actual occupancy rather than fixed schedules, and adapting lighting levels according to natural light availability. By modeling energy consumption patterns under various environmental and occupancy conditions, digital twins help identify the optimal balance between operational cost and occupant comfort. The adoption of digital twin solutions in smart buildings results in significant reductions in energy consumption—often reported up to 30%—lower maintenance costs, improved indoor comfort, extended asset lifespan, and more reliable facility management. Overall, this technology supports sustainability goals while enhancing operational performance and resource.

VI- Conclusion:

Digital Twin technology has emerged as one of the most significant innovations of the Fourth Industrial Revolution, playing a central role in the transition toward data-driven and intelligent industrial systems. This article explored the conceptual foundations of Digital Twins, their historical development, core mechanisms, and the diverse industrial sectors that have adopted them. It also examined leading international experiences that have contributed to positioning Digital Twin technology as a strategic tool for enhancing industrial performance and strengthening organizational competitiveness.

The study makes it clear that the Digital Twin is not merely a supportive digital tool but a comprehensive framework that integrates modeling, analytics, information synchronization, and interactive simulation. This unique capability to bridge the physical and virtual worlds enables organizations to better understand their operations and optimize them more effectively. Based on the study, several conclusions have been reached:

- The results show that Digital Twin technology plays a significant role in improving operational performance by providing accurate virtual models of physical assets and processes. These models support real-time monitoring, predictive analytics, and scenario simulation, helping organizations reduce downtime, enhance product quality, optimize resource utilization, and strengthen decision-making. This confirms that Digital Twins improve efficiency, flexibility, and responsiveness across industrial operations, making them a critical element of modern digital transformation strategies.
- The analysis of international experiences demonstrates the strong positive impact of Digital Twins on industrial performance. Global leaders such as General Electric, Siemens, Boeing, NASA, and Toyota have achieved measurable improvements in reliability, production accuracy, and cost reduction through their Digital Twin initiatives. These cases show how organizations can leverage real-time data synchronization and advanced simulation tools to enhance maintenance strategies, accelerate product development, and optimize manufacturing systems and supply chains.
- the findings indicate that leading international applications—across aerospace, manufacturing, energy, utilities, and smart cities—provide clear evidence of the effectiveness of Digital Twin technology. However, the study also identifies major challenges hindering broader adoption, particularly in developing countries, such as limited digital infrastructure, skills shortages, high implementation costs, data governance issues, and internal resistance to technological change. The study finally concludes that developing a practical adoption framework requires a phased implementation approach, strong investment in digital capabilities, workforce training, and the adaptation of global best practices to local industrial contexts.
- Understanding how Digital Twins function, recognizing the requirements for their implementation, and drawing lessons from global best practices are essential for industrial

organizations—particularly in developing countries—to leverage this technology as part of their digital transformation efforts. Ultimately, Digital Twin technology provides significant opportunities for building smarter, more adaptable, and future-ready industrial environments.

Recommendation:

There is a need to develop a national and industry strategy for adopting digital twins within the framework of Industry 4.0, which can be achieved through the following measures:

- Investing in digital infrastructure, particularly in the Internet of Things (IoT), cloud computing, and advanced data analytics.
- Training and developing human resources in digital modeling, data management, and predictive analytics.
- Fostering a culture of digital transformation within organizations and addressing resistance to change.
- Implementing pilot projects to evaluate effectiveness before widespread adoption of digital twins.
- Establishing clear frameworks for data governance and cybersecurity specific to digital twins.
- Leveraging international experiences and adapting lessons learned to the local industrial context.
- Encouraging partnerships between universities, research centers, and industrial organizations to accelerate technology transfer.
- Developing a comprehensive roadmap to guide industrial organizations in their gradual transition toward adopting digital twins.
- Integrating digital twin solutions as a core part of operational and strategic planning to enhance efficiency, reliability, and decision-making.
- Ensuring effectiveness by implementing IoT sensors and robust data collection systems to provide high-quality, real-time data.
- Applying digital twins not only to individual assets but across supply chains, production lines, and facilities for a comprehensive view of operations.
- Providing training for employees and managers to effectively utilize digital twins for decision-making, simulation, and problem-solving.
- Regularly updating digital twins with real-time data and adapting them to changing operational conditions to maintain accuracy and effectiveness.

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