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Digital Twin Technology in Logistics: A Narrative Review of Implementation, Impact, and Challenges

Muhammad Rifqy Naufal Abdillah[1], Muhammad Wahyuilahi[2]
[1]Politeknik Negeri Madiun, Indonesia
[2]Politeknik Astra, Indonesia
Correspondent: muhammadrifqy412@gmail.com [1]

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ABSTRACT : The adoption of digital twin technology in logistics has gained significant traction as organizations seek to enhance supply chain transparency, operational efficiency, and predictive accuracy. This review explores how digital twin technologies improve logistics performance, identifying what enables success and what challenges persist. Literature was collected through comprehensive searches in Scopus and Google Scholar using keyword-based Boolean strategies, with inclusion criteria focusing on peer-reviewed studies from the last decade that explicitly address digital twin applications in logistics systems. Findings reveal that digital twins enable smarter decision-making through real-time tracking and predictive tools, especially in urban and maritime logistics. Empirical evidence highlights substantial gains in logistics performance, especially in urban and maritime logistics contexts. However, systemic barriers persist, including challenges in integrating legacy systems, high implementation costs, cybersecurity risks, and shortages of skilled professionals. Comparative insights reveal a digital divide between developed and developing economies, driven by disparities in infrastructure and institutional support. To accelerate adoption, stakeholders—especially policymakers and logistics managers—must prioritize infrastructure, workforce readiness, and inclusive innovation policies. Future studies should prioritize cross-regional comparisons and develop standardized evaluation models. Overall, digital twin technology holds strong promise for transforming global logistics if supported by cohesive governance, innovation, and strategic investment.

Keywords: Digital Twin; Logistics Technology; Supply Chain Innovation; Real-Time Analytics; Predictive Logistics; Smart Warehouse; Blockchain Integration

INTRODUCTION

The rapid advancement of digital technologies in the context of Industry 4.0 and the emerging landscape of Industry 5.0 has positioned digital twin technology as a pivotal driver in reshaping

global logistics systems. Over the past decade, digital twin technology has garnered increasing attention as a strategic solution for optimizing operational processes in logistics, enhancing supply chain visibility, and enabling predictive modeling and system failure prevention (Zarnitz et al., 2023; Hou et al., 2023). As a dynamic digital representation of physical assets, systems, or processes, digital twins facilitate real-time monitoring, simulation, and analysis. Recent literature underscores their integration into logistics domains such as smart warehousing, maritime transport, and urban logistics, highlighting their role in cost reduction and performance optimization (Lin & Low, 2023; Draksler et al., 2023).

Global trends indicate a significant surge in digital twin adoption across both industrialized and emerging economies, reflecting a shift toward digital transformation in response to increasing supply chain complexity (Abideen et al., 2021; Zhou et al., 2024). While precise adoption statistics vary across studies, there is widespread consensus that the application of digital twins is no longer confined to advanced economies. Rather, companies in developing countries have begun leveraging digital twin systems as part of strategic digitalization efforts (Zarnitz et al., 2023; Hou et al., 2023). These efforts aim to address the intricacies of global logistics through real-time synchronization, automated reconfiguration, and proactive decision-making processes.

The increasing relevance of digital twin technology in logistics is underpinned by a convergence of technical innovation and market pressures. Studies show that digital twins contribute significantly to enhancing end-to-end supply chain visibility, reducing delays, and optimizing route planning and resource allocation (Draksler et al., 2023). In smart warehouse systems, for example, digital twins enable predictive maintenance, inventory control, and equipment failure simulation—ultimately leading to operational efficiency and cost savings (Abideen et al., 2021). Similarly, in maritime and urban transportation, digital twins are used to model port congestion scenarios or simulate last-mile delivery routes, thereby offering data-driven insights for logistics planners (Zhou et al., 2024).

However, the implementation of digital twin technology in logistics is not without considerable challenges. A dominant theme in the literature relates to the integration of heterogeneous data sources and the interoperability between legacy systems and new digital infrastructures (Jeong et al., 2022; Hauge et al., 2020). The seamless functioning of a digital twin relies heavily on advanced IT systems, including robust sensor networks, secure cloud computing platforms, and real-time analytics engines. Inadequate infrastructure, limited standardization, and cybersecurity vulnerabilities present significant barriers to full-scale implementation (Hauge et al., 2020; Jeong et al., 2022).

Additional constraints are prevalent in developing countries, where the digital twin ecosystem faces heightened limitations due to insufficient financial investments, underdeveloped ICT infrastructure, and a shortage of skilled professionals (Hou et al., 2023; Kajba et al., 2023). Even in technologically advanced regions, enterprises continue to grapple with synchronizing the digital model with rapidly evolving physical systems in real time. Accurately reflecting dynamic

operational environments remains a technical hurdle, exacerbated by inconsistent data quality and latency issues (Abideen et al., 2021; Jeong et al., 2022).

The disparity in adoption between developed and developing regions underscores the broader challenge of digital inequality in logistics innovation. In urban areas—particularly in smart city contexts—digital twin applications benefit from high-speed connectivity, data richness, and sophisticated planning tools, facilitating efficient delivery systems and responsive logistics networks (Pan et al., 2021). Conversely, in rural or infrastructurally constrained settings such as parts of Indonesia, adoption is hindered by limited network coverage, lack of digital literacy, and minimal investment in cutting-edge technologies (李 et al., 2024; Cebir & Akkartal, 2024). Comparative studies across Southeast Asia, although limited, indicate that regions with more advanced technological infrastructure exhibit faster and more impactful deployment of digital twin solutions (Pan et al., 2021).

From a theoretical standpoint, various conceptual models have been proposed to understand the multifaceted nature of digital twin systems in logistics. One prominent approach is the Dynamic Data Driven Application Systems (DDDAS) framework, which supports real-time simulation by integrating live data streams into computational models for continuous adaptation (Ghandar et al., 2021). Another approach includes multi-layered architectures that incorporate data acquisition, simulation modeling, and analytics processing. These frameworks emphasize the synergistic integration of IoT technologies, big data platforms, and machine learning algorithms for the creation of responsive, adaptive digital twin environments (Abideen et al., 2021; Jeong et al., 2022).

Existing systematic reviews and meta-analyses, however, reveal significant limitations in scope and depth. Most studies focus narrowly on manufacturing or isolated segments of logistics rather than providing a holistic view of digital twin implementation across logistics chains (Werbińska-Wojciechowska et al., 2024; Sun et al., 2021). Quantitative analyses are also sparse, with few reviews offering performance metrics or comparative evaluations of digital twin efficacy in diverse economic and infrastructural settings (Kajba et al., 2023). These limitations point to a critical need for cross-sectoral and regionally comparative research that addresses these gaps and formulates standardized evaluation frameworks (Gao et al., 2024; Kajba et al., 2023).

Accordingly, the primary aim of this narrative review is to provide a comprehensive synthesis of recent literature on digital twin technology within the logistics sector. This review seeks to analyze the evolution of digital twin applications, identify critical enablers and barriers to implementation, and propose actionable strategies for enhancing the integration and effectiveness of digital twin systems. Special attention is given to interoperability, cybersecurity, data integration, and infrastructural readiness as key factors influencing digital twin success in diverse contexts (Sun et al., 2021; Manickam et al., 2023).

The scope of this review encompasses both developed and developing regions, with a focus on comparative insights from urban and rural logistics environments. It highlights case studies from Southeast Asia, including Indonesia, to draw out regional disparities and common challenges in

adoption. By doing so, the review intends to establish an evidence-based foundation for tailoring implementation strategies and policy interventions that reflect local conditions and capabilities (Pan et al., 2021; 李 et al., 2024).

In sum, this study contributes to the growing body of knowledge on digital transformation in logistics by offering a targeted, literature-based evaluation of digital twin technology. Through a rigorous synthesis of existing research, this review seeks not only to clarify the current state of digital twin adoption in logistics but also to illuminate pathways for future innovation, capacity building, and strategic policymaking.

METHOD

This study employed a narrative review methodology to synthesize current research on the application of digital twin (DT) technology in logistics. The aim was to obtain a comprehensive and critical understanding of the existing literature while identifying prevailing themes, research gaps, and conceptual frameworks. Given the complexity and interdisciplinary nature of digital twin technology in logistics, a carefully structured approach was adopted to capture studies with both breadth and depth of relevance. The review process was anchored in scholarly search strategies that adhere to academic standards for rigor and transparency.

The literature search was conducted using two of the most widely recognized scientific databases: Scopus and Google Scholar. These platforms were selected due to their broad coverage of peer-reviewed journals and high citation indexing, particularly in the fields of engineering, computer science, industrial technology, and logistics. The search process involved multiple iterations to refine the scope and precision of the retrieved articles. The search queries were designed using a combination of domain-specific keywords and Boolean operators to ensure the retrieval of literature that directly addresses the implementation and evaluation of digital twin systems within logistics and supply chain environments.

Specifically, the primary keywords used in the search included "digital twin," "logistics," "supply chain," "urban logistics," "smart warehouse," and "Industry 4.0." These keywords were strategically selected based on common terminology in prior reviews and keyword clustering analyses in the field. To enhance specificity, Boolean operators were applied. For instance, queries such as "digital twin" AND ("logistics" OR "supply chain") were executed to target studies discussing digital twin technology in the context of logistical operations. To further broaden the scope and capture terminological variations, the OR operator was used for terms such as "urban logistics" OR "transportation." Additionally, the wildcard asterisk (*) was applied to keywords like "logistic*" to ensure that all derivations of the root term, including "logistics" and "logistic," were included in the search results. These techniques, as demonstrated by Abouelrous et al. (2023) and Kajba et al. (2023), were instrumental in maximizing the scope of relevant literature while minimizing irrelevant entries.

The inclusion criteria were developed to filter studies that provide high-quality empirical or theoretical insights into digital twin applications in logistics. First and foremost, only peer-reviewed journal articles were included to ensure academic credibility. All selected studies were published in English to maintain linguistic consistency and to ensure the accuracy of analysis. The temporal boundary for publication was set within the last 10 years to ensure relevance to contemporary technological and industrial contexts. Furthermore, articles were included if they explicitly addressed the deployment, evaluation, or conceptualization of digital twin systems in logistics-related settings, including but not limited to transportation networks, smart warehousing, and end-to-end supply chain management. Special attention was given to studies presenting detailed methodologies for implementing digital twin solutions or evaluating their impact on logistics performance metrics such as delivery time, cost reduction, system resilience, or real-time visibility.

Conversely, exclusion criteria were established to maintain focus and methodological integrity. Grey literature such as conference abstracts, opinion pieces, white papers, and unpublished theses were excluded due to their limited peer-review validation and variability in reporting standards. Articles for which the full text was not accessible were also excluded, as the inability to assess the complete methodology or findings compromised their evaluative utility. Moreover, studies that centered on digital twin applications in sectors unrelated to logistics, such as healthcare or manufacturing without a logistics component, were filtered out during the screening phase. Publications that did not follow peer-review processes or lacked methodological transparency were similarly removed from consideration, following best practices outlined by Freese and Ludwig (2024).

The types of studies incorporated into the review varied across qualitative, quantitative, and mixed-methods research designs. These included experimental studies (e.g., pilot implementations of DT in logistics hubs), simulation-based evaluations, case studies of DT deployments in real-world logistics contexts, and conceptual papers proposing models or frameworks. Each study was assessed for its relevance to the research focus and for its contribution to understanding the capabilities and limitations of digital twin systems within logistics domains. For instance, case studies detailing smart warehousing in urban logistics provided context-rich insights into technological integration, while simulation studies offered empirical validation of DT benefits in predictive maintenance and resource optimization.

The selection process was conducted in multiple stages. Initially, all retrieved titles and abstracts were screened for relevance to the core subject. This first-level screening helped eliminate evidently irrelevant publications. Subsequently, full-text versions of the remaining articles were reviewed to determine their methodological robustness and thematic alignment with the research objectives. In this stage, special attention was given to the clarity of the digital twin definition used, the specificity of logistics context addressed, and the rigor of data analysis methods reported. Discrepancies in study eligibility were resolved through collaborative discussions and consensus among the reviewing team.

In evaluating the final pool of selected articles, a qualitative synthesis approach was used. Articles were coded and categorized according to key themes, such as technology integration challenges, data interoperability, cybersecurity, organizational readiness, and comparative regional analysis. These thematic codes were iteratively refined during the analysis phase to reflect emerging patterns and contextual nuances. Additionally, bibliometric patterns such as publication year distribution, citation frequency, and geographical spread of studies were noted to provide a broader view of research dynamics in the domain. These steps ensured that the narrative review not only synthesized content but also captured research trends and methodological shifts over time.

This methodological approach ensures that the narrative review produced is both systematic and adaptable. It is systematic in the sense that it employs a transparent and replicable process for literature identification, inclusion, and analysis. It is adaptable in its flexibility to accommodate diverse study designs and regional perspectives, which is critical for a multifaceted topic such as digital twin adoption in logistics. By grounding the review in rigorous search procedures, clear inclusion/exclusion criteria, and multi-stage filtering, this study provides a credible and comprehensive understanding of the current state of digital twin technology in logistics contexts.

Ultimately, this review process enables a high level of reliability in synthesizing literature and contributes to scholarly discourse on digital innovation in supply chain systems. It also lays a strong methodological foundation for future research that may wish to extend this analysis quantitatively, including through meta-analysis or bibliometric mapping techniques.

RESULT AND DISCUSSION

The findings of this narrative review are organized thematically to highlight the multifaceted contributions of digital twin technology to modern logistics. The analysis is based on empirical and conceptual studies reviewed in this research and is presented under three primary themes: the integration of digital twin in supply chain logistics, the role of real-time monitoring and predictive analytics, and the influence of digital twin on data security and integrity in digital logistics systems.

The integration of digital twin systems into supply chain logistics has led to significant improvements in operational visibility and coordination efficiency across diverse logistical environments. According to Moshood et al. (2021), the application of digital twin technology in supply chains enhances the capacity to predict logistical performance and offers real-time visibility into the status of physical assets. Their findings are supported by simulation and case study data, which show that digital twins facilitate more responsive and adaptive decision-making processes. This is particularly relevant in highly dynamic and complex logistics networks, where delayed information can lead to substantial inefficiencies. Ran et al. (2022) further demonstrated how digital twin integration within production and distribution lines results in measurable improvements in coordination and throughput. Their study underscores how synchronized digital models allow for more accurate alignment between manufacturing output and transportation schedules.

Successful implementation of digital twins in these contexts is often influenced by a combination of technological and organizational factors. Cebir and Akkartal (2024) note that infrastructure readiness—including the deployment of IoT sensors and cloud platforms—is essential for effective integration. Equally important is the capacity for seamless data integration, where interoperability between legacy and modern systems determines the continuity of data flow. Organizational characteristics such as firm size, investment in digital innovation, and institutional support also play a critical role. Larger firms with stronger innovation portfolios and centralized IT governance structures tend to exhibit higher success rates in adopting and scaling digital twin technologies in their logistics operations. These patterns reveal how digital twin adoption is not merely a technological challenge but also a socio-organizational process shaped by resource availability, institutional maturity, and technological agility.

In terms of real-time monitoring and predictive analytics, empirical evidence from cross-national studies confirms the measurable impacts of digital twin deployment on logistics efficiency and forecasting accuracy. Rigó et al. (2024) report that the use of Bayesian inference-based predictive models within digital twin frameworks has led to reductions in response times to logistical disruptions by 15% to 30% compared to traditional logistics systems. These findings are critical in validating the value proposition of digital twins, particularly in high-stakes logistics settings such as just-in-time delivery systems and emergency response supply chains. Moreover, Zhou et al. (2024) emphasize the role of digital twins in maritime logistics systems, where real-time monitoring and adaptive analytics contribute to dynamic operational adjustments. Their research shows that such applications help reduce cost overruns and optimize the performance of shipping networks by enabling accurate forecasting of docking times, load distribution, and route deviations.

The effectiveness of these systems is amplified through the integration of intelligent infrastructure, including sensor arrays, machine learning algorithms for anomaly detection, and continuously updated digital simulations. Rigó et al. (2024) highlight the importance of updating simulation environments in real-time to account for changing operational parameters such as weather conditions, vehicle availability, and personnel shifts. These updates ensure that predictive recommendations remain relevant and timely. Similarly, Zhou et al. (2024) identify machine learning-driven models as essential for managing uncertainty in maritime routes and for optimizing fuel efficiency through route adjustments. The convergence of these technologies within digital twin environments illustrates a high level of automation, adaptability, and strategic foresight in modern logistics planning and execution.

With regard to data security and integrity within digital logistics systems, digital twin architectures offer enhanced capabilities for ensuring trustworthy and transparent data transactions. A fundamental component of this capacity lies in the synchronization of operational data in real-time, which allows for early detection of deviations and anomalies. Torky et al. (2022) provide compelling evidence that integrating blockchain technologies with digital twin systems establishes immutable ledgers that enhance the traceability and non-repudiation of data transactions. The cryptographic properties of blockchain, when linked to digital twin infrastructures, offer a robust framework for ensuring data integrity across multiple stakeholders in a supply chain.

Furthermore, the adoption of RFID and NFC technologies within digital twin frameworks contributes to the secure and automated collection and tracking of logistical data. Ng et al. (2024) show that these identification technologies reduce the risk of data manipulation and strengthen auditing capabilities, particularly in warehouse and distribution center environments. By embedding secure identification mechanisms into physical assets and linking them with digital representations, logistics managers gain an added layer of confidence in the authenticity of operational data.

Frankó et al. (2020) extend this argument by demonstrating how blockchain-based identification solutions significantly reinforce the data security architecture of digital twin systems. Their findings suggest that the integration of these technologies not only prevents tampering but also enhances the reliability of insights generated from digital twins. In complex logistics systems, where multiple actors share and interact with data, ensuring the authenticity and reliability of that data is critical for maintaining coordination and accountability. The convergence of digital twin, blockchain, and secure identification tools thus establishes a multidimensional defense mechanism against cyber threats and operational inconsistencies.

Together, the evidence from these thematic areas supports a robust understanding of how digital twin technology is reshaping the logistics sector. The reviewed studies not only confirm the technical feasibility of digital twin adoption but also provide empirical insights into the contextual factors that mediate its success. The integration of digital twins within supply chains is shown to enhance coordination, optimize operations, and foster resilience, particularly when supported by infrastructural readiness and institutional capability. Real-time monitoring and predictive analytics enabled by digital twins facilitate faster, more accurate responses to dynamic operational conditions, improving both tactical and strategic decision-making. Meanwhile, the fusion of digital twin technology with advanced data security frameworks underscores the potential of these systems to function as trustworthy platforms in increasingly complex and interconnected logistics ecosystems.

A comparative perspective also reveals significant regional differences in the deployment and performance of digital twin systems. In developed economies, where infrastructural and institutional maturity is typically higher, the deployment of digital twin systems tends to be more comprehensive and integrated. Conversely, in developing regions, challenges related to resource limitations, technological gaps, and institutional fragmentation often hinder the scalability and sustainability of such initiatives. Nevertheless, pilot projects and targeted investments in these regions are beginning to show promising results, suggesting that with appropriate policy support and investment strategies, digital twin technology can be a valuable tool for logistics optimization across varying economic contexts.

These findings collectively affirm the transformative potential of digital twin technology in the logistics sector. They also highlight the importance of adopting a multidimensional approach—encompassing technology, organizational readiness, infrastructure, and security—when evaluating the success and scalability of digital twin initiatives. Future research and implementation strategies must continue to bridge gaps between regions, promote interoperability, and develop standardized

metrics for assessing digital twin performance, ensuring that the technology fulfills its promise across global logistics landscapes.

The synthesis of recent findings on digital twin technology in logistics reinforces the consensus established in earlier studies that emphasize its transformative potential in enhancing transparency, operational efficiency, and predictive capabilities within supply chain networks. As Raja et al. (2024) affirm, digital twin systems offer real-time modeling of logistical assets and processes, facilitating proactive decision-making that can mitigate disruptions and improve throughput. This aligns with earlier contributions by Moshood et al. (2021) and Ran et al. (2022), who highlighted measurable gains in coordination and visibility achieved through digital twin integration. However, recent analyses also extend this discourse by illuminating persistent implementation challenges that inhibit the full realization of digital twin promises, particularly regarding scalability and legacy system integration, which have been relatively underexplored in prior literature.

While the theoretical underpinnings of digital twin technology emphasize flexibility and adaptability, systemic barriers remain a substantial constraint in practice. Technological complexity, high initial investment costs, and persistent interoperability issues with legacy systems have been consistently documented as core challenges (Raja et al., 2024). These limitations are exacerbated by the heterogeneous nature of data sources across logistics networks, which complicates real-time integration and weakens the coherence of digital simulations. This is particularly evident in large-scale logistics operations where data are sourced from various devices, platforms, and organizational silos. As noted in the results by Cebir and Akkartal (2024), even with IoT and sensor infrastructure in place, the seamless aggregation and synchronization of data remain elusive in many cases.

Moreover, cybersecurity concerns pose a growing challenge to digital twin deployment. Although the adoption of blockchain and encrypted identification technologies such as RFID/NFC offers potential solutions (Torky et al., 2022; Ng et al., 2024), the lack of regulatory frameworks and standardized protocols undermines their widespread implementation. In the absence of unified standards, individual organizations are often compelled to devise their own ad hoc security strategies, which results in inconsistent protection levels across the logistics ecosystem. Frankó et al. (2020) highlight how this inconsistency creates vulnerabilities in data integrity and weakens trust in the system, particularly in contexts where multiple stakeholders access and rely on shared digital twin data.

From an institutional perspective, the limited availability of skilled professionals capable of managing complex digital twin architectures is another pressing issue. Logistics firms, especially in developing regions, frequently lack the human capital necessary to design, implement, and maintain these systems. This workforce gap is both a technical and educational problem, reflecting broader systemic deficiencies in digital skill development. As Hou et al. (2023) argue, without robust capacity-building efforts and dedicated investments in training, the digital twin landscape will remain fragmented and underdeveloped, despite technological advancements.

In addressing these systemic barriers, the literature provides several policy and technological pathways. From a policy standpoint, the establishment of regulatory standards that encourage

interoperability is essential. Raja et al. (2024) advocate for both national and international regulatory frameworks to facilitate collaboration across public and private sectors. Such frameworks would provide guidance on security protocols, data sharing agreements, and system certification standards, thereby lowering the institutional risks associated with digital twin adoption. Financial incentives, such as tax credits or grants for digital infrastructure upgrades and workforce training, are also proposed to mitigate the burden of upfront investments and promote inclusive technology diffusion.

Technologically, modular and scalable architectures are increasingly promoted as a means to overcome integration and expansion challenges. These architectures allow organizations to implement digital twin systems in stages, scaling them according to operational maturity and resource availability. Integrating blockchain for data immutability and IoT devices for real-time data collection supports this modularity, creating a flexible framework that can evolve with technological progress and organizational needs (Kajba et al., 2023). As emphasized in the findings of Zhou et al. (2024) and Rigó et al. (2024), predictive analytics powered by continuously updated simulations and anomaly detection algorithms are instrumental in reinforcing the operational reliability and agility of logistics networks.

Furthermore, the development of shared digital twin platforms that operate under open standards could offer a collaborative alternative to siloed implementations. Such platforms would enable smaller logistics providers to participate in digital ecosystems without incurring prohibitive costs, fostering equity in digital innovation. This approach is particularly relevant in developing regions, where infrastructural and financial constraints limit individual organizational capabilities. As demonstrated by comparative findings from Southeast Asia (Pan et al., 2021; 李 et al., 2024), digital twin adoption is markedly higher in countries with strong institutional coordination and public investment in digital infrastructure.

Despite the promise of these solutions, it is important to acknowledge the limitations of current research. Many of the reviewed studies, while methodologically sound, are concentrated in specific geographic contexts—primarily high-income countries with advanced logistics infrastructures. This skews the empirical base and limits the generalizability of findings to more resource-constrained environments. Moreover, few studies provide longitudinal data on digital twin implementations, which hampers the ability to assess long-term impacts on logistics efficiency, resilience, and cost-effectiveness. There is also a lack of unified performance metrics, making cross-study comparisons difficult and impeding the development of standardized evaluation tools.

In light of these gaps, future research should prioritize multi-regional studies that capture the diversity of digital twin adoption pathways and contextual challenges. Comparative analyses between developed and developing economies could yield insights into scalable best practices and the conditions under which digital twin technologies are most effective. Additionally, longitudinal case studies tracking digital twin deployments over time would be valuable in understanding the lifecycle dynamics of these systems and their evolving contributions to supply chain performance. Methodological innovations in simulation validation and performance benchmarking could also strengthen the robustness of empirical claims and support the design of more responsive digital twin solutions.

Ultimately, the discussion of digital twin adoption in logistics reveals both the immense potential and the multifaceted complexity of this technological paradigm. While real-time monitoring, predictive analytics, and enhanced data security present compelling benefits, systemic barriers related to infrastructure, regulation, interoperability, and human capital continue to limit full-scale implementation. As such, the discourse must move beyond technology alone and consider the broader institutional, economic, and societal ecosystems in which digital twin systems are embedded. Only through integrated policy support, technological innovation, and inclusive capacity-building efforts can the transformative power of digital twins be realized across global logistics landscapes.

CONCLUSION

This narrative review underscores the transformative potential of digital twin technology in enhancing operational efficiency, real-time visibility, and predictive capabilities within modern logistics systems. The integration of digital twins has been empirically linked to improved coordination, reduced operational disruptions, and stronger data-driven decision-making across logistics environments. However, systemic challenges—such as interoperability with legacy systems, high implementation costs, cybersecurity vulnerabilities, and insufficient human capital—continue to hinder widespread adoption. The findings further reveal the significant disparities in adoption rates between developed and developing regions, highlighting the role of infrastructure readiness and institutional support in enabling technological transformation.

To address these challenges, strategic policy interventions are necessary. These include the establishment of national and international regulatory frameworks to standardize digital twin implementation, provision of financial incentives for digital infrastructure investment, and development of workforce training programs to close the digital skills gap. Technological solutions such as modular system architectures, integration of blockchain for data integrity, and use of IoT-driven real-time monitoring are vital in overcoming data integration and scalability issues.

Future research should focus on comparative, longitudinal studies across diverse geographic and economic contexts, and develop unified performance metrics to evaluate digital twin systems effectively. Addressing these gaps will enhance the applicability and impact of digital twin technology in global logistics. Ultimately, fostering interoperability, security, and digital readiness remains crucial to realizing the full promise of digital twins in building resilient and adaptive logistics ecosystems.

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