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**ỨNG DỤNG CÔNG NGHỆ DIGITAL TWINS TRONG QUẢN LÝ KHO HÀNG:
NGHIÊN CỨU SO SÁNH TRƯỜNG HỢP DHL VÀ AMAZON VÀ ỨNG DỤNG
ĐỐI VỚI VIỆT NAM**

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Tóm tắt

Nền kinh tế số của Việt Nam đang phát triển nhanh, làm gia tăng nhu cầu về các giải pháp quản lý kho tiên tiến trong lĩnh vực logistics. Công nghệ Digital Twins đã trở thành công cụ quan trọng trong quản lý kho thông minh nhờ khả năng hiển thị theo thời gian thực, tối ưu hóa quy trình và hỗ trợ ra quyết định dự báo. Nghiên cứu này phân tích việc ứng dụng công nghệ Digital Twins trong quản lý kho thông qua so sánh hai trường hợp DHL và Amazon. Dựa trên dữ liệu thứ cấp và nghiên cứu tình huống, bài viết chỉ ra cách tiếp cận tập trung vào vận hành của DHL nhằm cải thiện hiệu quả, an toàn và năng suất lao động, cũng như chiến lược dựa trên hệ sinh thái của Amazon, tích hợp điện toán đám mây, robot và mô phỏng dựa trên vật lý để tối ưu hóa thiết kế

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kho và tự động hóa. Từ các thực tiễn này, nghiên cứu đánh giá hàm ý đối với ngành logistics Việt Nam, đồng thời xác định các thách thức trong việc áp dụng Digital Twins, bao gồm chi phí đầu tư cao, hạn chế hạ tầng số, thiếu hụt kỹ năng và sự kháng cự trong tổ chức. Bài viết đề xuất triển khai theo giai đoạn, hợp tác dựa trên nền tảng đám mây và nâng cao kỹ năng nguồn nhân lực phù hợp với Chương trình Chuyển đổi số Quốc gia của Việt Nam.

Từ khóa: DHL, Amazon, quản lý kho hàng, digital twins, công nghệ digital twins

DIGITAL TWINS TECHNOLOGY IN WAREHOUSE MANAGEMENT: A COMPARATIVE CASE STUDY OF DHL AND AMAZON WITH IMPLICATIONS FOR VIETNAM

Abstract

Vietnam's rapidly expanding digital economy has increased the demand for advanced warehouse management solutions within the logistics sector. Digital Twins Technology has emerged as a key enabler of smart warehouse management by providing real-time visibility, process optimization, and predictive decision-making. This study examines the application of Digital Twins Technology in warehouse management through a comparative analysis of DHL and Amazon. Using secondary data and case study analysis, the paper highlights DHL's operational-focused approach to improving workflow efficiency, safety, and labor productivity, and Amazon's ecosystem-driven strategy that integrates cloud computing, robotics, and physics-based simulations for end-to-end warehouse design and automation optimization. Drawing on these global practices, the study evaluates the implications for Vietnam's logistics sector, identifying key adoption challenges such as high investment costs, limited digital infrastructure, skill shortages, and organizational resistance. The paper proposes phased implementation, cloud-based partnerships, and workforce upskilling as practical pathways to support Digital Twins adoption in alignment with Vietnam's National Digital Transformation Program.

Keywords: DHL, Amazon, warehouse management, digital twins, digital twins technology

1. Introduction

In the National Digital Transformation Program by 2025, with an orientation toward 2030, the Government of Vietnam identified logistics as one of the eight priority sectors for comprehensive digital conversion to enhance national competitiveness (VietnamPlus, 2025). As the digital economy continues to flourish, the logistics sector is expected to contribute 5-6% to Vietnam's GDP by 2025 (Vien Nhu, 2021). However, traditional warehousing remains a

significant bottleneck, characterized by manual labor-intensive processes and a lack of real-time visibility, which leads to high operational costs which currently account for nearly 16.8% of the country's GDP (Minh, 2024). To bridge this gap, Digital Twins Technology is emerging as a transformative solution, offering a virtual mirror of physical assets to optimize warehouse operations, reduce errors, and predict future disruptions through real-time data.

Global leaders such as DHL and Amazon have been pioneers in integrating Digital Twins into their warehousing ecosystems. DHL utilizes Digital Twins to optimize process flows and labor productivity across its global network. On the other hand, Amazon leverages its AWS IoT TwinMaker platform to test warehouse designs, enhance robotic automation integration, and optimize productivity before implementation in physical facilities.

Drawing lessons from a comparative analysis of how DHL and Amazon apply Digital Twins Technology, this report aims to analyze the feasibility and strategies for implementing Digital Twins Technology in Vietnam's warehouse management. Thus, Vietnamese logistics and e-commerce enterprises can consider adopting similar digital twins-based systems to enhance operational efficiency aligned with the country's National Digital Transformation Program.

2. Literature review

2.1. The trend toward developing smart warehouse management

As optimizing warehouse operation has become a strategic priority for various businesses, the transition toward developing smart warehouse management systems (SWMS) has emerged as an effective approach to enhance operational efficiency and decision-making process. In a study conducted in 2018, Žunić et al. highlighted that the application of AI and optimization algorithms within SWMS could improve picking route planning and task sequencing, resulting in shorter travel distances, lower picking time and higher order fulfillment accuracy. Additionally, the contribution of automated identification technologies is further emphasized by Rashid et al. (2019), who demonstrate that RFID-integrated SWMS significantly improves receiving, put-away and dispatch operations by automating item identification and data entry. As a result, human errors are minimized and processing time across key warehouse operations is significantly reduced. Furthermore, a research conducted by Yerpude and Singhal (2018) had shown that IoT-based SWMS could enhance inventory visibility and accuracy by enabling real-time monitoring and continuous updates of stock information, thereby reducing discrepancies between physical inventory and system records. Moreover, Khan, Huda and Zaman (2022) found that IoT-based

flows could also improve the coordination of inbound and outbound activities by facilitating real-time information exchange between warehouse assets and management systems. Through SWMS, warehouse managers are able to respond more quickly to operational changes and reduce delays caused by fragmented information flows.

2.2. Application of Digital Twins Technology in warehouse

In recent years, the rapid development of Industry 4.0 technologies has significantly transformed warehouse management practices, with Digital Twins Technology emerging as a core component of smart warehouse management systems. In the study of Braglia et al. (2019), the authors illustrated that by integrating RFID technology with discrete-event and agent-based simulation, a warehouse Digital Twins can continuously capture real-time information on the locations of goods and handling equipment. Through the stimulation of alternative operational scenarios, the Digital Twins can support routing optimisation, space allocation and congestion reduction, thereby lowering overall handling costs. Similarly, in a research in 2024, ZarinchangMokalla showed that a Digital Twins model along with optimization algorithms can dynamically optimize order-picking processes in warehouse management. Employing the Digital Twins Technology can reduce order throughput time by up to 15.2%, thus improving traveling time and distance while significantly enhancing safety and rack stability by over 90%.

With its ability to create adaptive warehousing plans based on real-time data analysis, the integration of Digital Twins with IoT-enabled AI could improve demand forecasting and proactive inventory control, resulting in substantial gains in warehouse efficiency and inventory optimization at around 30% (Devi et al., 2023). In addition, the Digital Twins Technology had shown strong potential in maximizing the space utilization and throughput efficiency of the large-scale automated high-rise warehouses (Leng et al., 2021). Furthermore, the strategic application of Digital Twins beyond operational efficiency was emphasized by Elbouzidi et al. (2025), who embedded a bottom-up carbon accounting framework into the Digital Twins Technology. Their findings demonstrated that Digital Twins can support sustainable decision-making via the evaluation of alternative low-carbon operational scenarios. It can therefore be seen that Digital Twin Technology not only enhances key warehouse activities such as picking efficiency and inventory control but also contributes to more resilient and sustainable warehouse management systems.

Although previous studies have explored several aspects of Digital Twins Technology application in the warehouse sector, existing literature has reflected a significant research gap. Despite the increasing global adoption of Digital Twins Technology, there is still limited research on Digital Twins Technology for Vietnam's warehouse management systems.

3. Theoretical framework

3.1. Warehouse Management

Warehouse management (WM) is defined as a set of planning and control procedures aimed at efficiently and effectively coordinating all warehouse processes and activities (Faber et al., 2013). These activities include the management of inbound flows, storage operations and outbound order fulfillment, with the objective of meeting customer demand while ensuring operational effectiveness.

As supply chains become increasingly centralized and warehouses show a strong growth in scale and complexity, warehouse management has gained greater importance in both academic research and practice. Prior research suggested that effective warehouse management contributes to lower operational costs and improved overall warehouse efficiency, particularly through better coordination of inventory management and storage location assignment (Van den Berg and Zijm, 1999). These improvements are especially critical in environments characterized by high product variety, frequent order picking and short response times.

Warehouse management is commonly conceptualized as an integrated system of planning and control decisions. Faber et al. (2013) propose that the core characteristics of warehouse management can be captured through three key dimensions: planning activities, decision rules complexity, and control systems. This framework emphasizes that warehouse performance depends not only on physical layout or automation, but also on the structure and sophistication of managerial decision-making and information flows. Therefore, warehouse management can be viewed as a coherent managerial system that aligns operational planning and control mechanisms to ensure efficient and reliable warehouse operations.

3.2. Digital Twins Technology

Recognized as a transformative digital innovation, Digital Twins Technology has recently gained increasing attention across various industries, including manufacturing, logistics and infrastructure systems. The concept of Digital Twins was initially introduced by Grieves in the early 2000s in the context of product lifecycle management, referring to a virtual representation

that mirrors a physical object throughout its lifecycle (Grieves, 2016). With advances in digitalization and data analytics, the Digital Twins concept has evolved from a static representation into a dynamic and continuously updated system. According to IBM (2020), Digital Twins can be defined as a digital representation of a physical object or system that uses real-time data to enable monitoring, analysis and optimization of real-world operations.

Digital Twins Technology can be understood through a set of interconnected functional components. Boyes and Watson (2022) identify four essential components of a Digital Twins: digital coupling, digital representation, tools and functional outputs. The process begins with digital coupling, which establishes communication between the physical entity and the digital domain by capturing and exchanging state data. These data are then structured and maintained within the digital representation, which models the physical entity and stores relevant operational and temporal information. Based on this representation, tools such as analysis, simulation, and presentation mechanisms operate to process and interpret system behavior. The outcomes of these tools are delivered through functional outputs, which allow user interaction as well as configuration and control of the Digital Twins.

Digital Twins Technology is now increasingly applied as an effective approach to enhancing operational performance by allowing for predictive maintenance, process optimization and risk mitigation, thereby improving efficiency and reducing operational costs (Mihai et al., 2021). At the same time, by facilitating continuous data exchange and structured digital modeling, Digital Twins support more informed and data-driven decision-making for managers (IBM, 2020). However, the implementation of Digital Twins Technology also poses several challenges to businesses. High development and system integration costs, together with data quality concerns and cybersecurity risks, may hinder effective adoption (Boyes and Watson, 2022). These challenges suggest that although Digital Twins offer considerable potential benefits, their successful implementation largely depends on technological readiness and organizational capability.

4. Analysing and discussing DHL and Amazon’s Application of Digital Twins Technology

4.1. DHL Case Study

4.1.1. Overview of DHL

Table I: Descriptive Profile of DHL

Company name	DHL
Year established	1969
Place of origin	San Francisco, California, United States
Headquarter	Bonn, Germany
Current Ownership	Deutsche Post AG
Vision	To be a post office for Germany and a logistics company for the world.
Mission	<ul style="list-style-type: none">● We make our customers, employees and investors even more successful;● We always show respect while achieving high scores;● We facilitate and simplify the lives of our customers;● We contribute to making our world better.

Source: DHL’s Official Website

4.1.2. DHL’s current application of Digital Twins Technology

DHL has applied Digital Twins Technology in its warehousing operations as part of its digitalisation strategy to improve efficiency, visibility, and real-time decision-making. One of the most prominent implementations is the one created in collaboration with Tetra Pak in 2019 - which is the first smart warehouse in Asia Pacific to deploy the Digital Twins Technology (DHL, 2019).

Efficiency gain with reduced congestion and processing time

The Digital Twins Technology provides a detailed virtual mapping of the warehouse layout, including aisles, docks, picking zones, and traffic flows. In detail, data is collected through a sensor network consisting of approximately ten sensors covering four aisles and more than one thousand picking locations. Real-time operational data from forklifts, automated guided vehicles (AGVs),

and warehouse workers is continuously mirrored in the virtual environment. By simulating movement patterns and visualizing them through heat maps, DHL is able to identify congestion hotspots and bottlenecks, enabling targeted interventions to optimize workflow and material movement. Moreover, A DHL control tower also supervises the flow of inbound and outbound goods to maintain time efficiency, ensuring goods are correctly shelved within 30 minutes of receipt, and delivery-bound goods are ready for shipment within 95 minutes (DHL, 2019).

Live site access monitoring

The Digital Twins Technology is also used to enhance live site access monitoring within DHL warehouses. Restricted and sensitive zones, such as hazardous goods storage areas or high-value inventory sections, are digitally replicated in the virtual warehouse model. Access rules and authorization parameters are embedded directly into the Digital Twins systems (DHL, 2019). Through the integration of sensors and wearable devices, the system tracks who enters these restricted zones and records the timing of access events. This capability supports improved control, compliance, and traceability by allowing managers to monitor access behavior in real time and respond promptly to unauthorized or unsafe entries.

Monitor temperature systems

For temperature-controlled warehouse operations, DHL applies Digital Twins Technology to monitor environmental conditions more effectively. Temperature-sensitive zones, including cold storage and pharmaceutical handling areas, are modeled within the Digital Twins environment. IoT sensors continuously feed real-time data on temperature, humidity, and equipment status into the virtual system (DHL, 2019). This enables the Digital Twins not only to reflect current environmental conditions but also to support predictive monitoring by identifying potential temperature deviations before they occur. As a result, DHL can proactively manage risks related to product quality.

Full traffic visibility for slotting optimisation

Digital Twins Technology further provides DHL with full traffic visibility to support slotting optimization decisions. All moving assets within the warehouse such as forklifts, AGVs, pallets, and workers are tracked in real time and visualized in the Digital environment (DHL, 2019). This comprehensive visibility allows DHL to analyze movement density and flow patterns across different warehouse zones. Through these simulations, DHL can evaluate potential improvements without disrupting live operations, thereby enhancing space utilization and operational efficiency.

Real time operational data

Another key application of the Digital Twins Technology is the integration of real-time operational data from multiple systems. Live data streams from the Warehouse Management System (WMS), including order processing and inventory levels, are combined with inputs from material handling equipment systems, sensors, and scanning devices (DHL, 2019). This integrated visibility supports informed decision-making, enables more effective team coaching, and contributes to continuous improvement in workforce productivity and overall warehouse performance.

Enhanced MHE safety

Finally, DHL uses Digital Twins Technology to enhance safety related to material handling equipment. Forklifts and AGVs are digitally represented, incorporating data on speed, load, and proximity to other assets and workers. The system monitors unsafe behaviors such as speeding, sharp turns, and near-miss incidents. AI-based models are used to simulate potential accident scenarios, allowing DHL to assess risks and evaluate preventive measures. Heat maps are also employed to identify areas with high worker concentration, enabling the implementation of additional safety requirements where necessary (DHL, 2019). Through these capabilities, Digital Twins Technology supports a proactive and data-driven approach to warehouse safety management.

4.2. Amazon Case Study

4.2.1. Overview of Amazon

Table II: Descriptive Profile of Amazon

Company name	Amazon.com, Inc.
Subsidiary	Amazon Web Services (or AWS), Amazon Robotics
Year established	1994
Place of origin	Seattle, Washington, United States
Headquarter	Seattle, Washington, United States
Current Ownership	Publicly listed company (NASDAQ: AMZN)
Vision	We strive to be Earth's most customer-centric company, Earth's best employer, and Earth's safest place to work.
Mission	<ul style="list-style-type: none">● Customer obsession rather than competitor focus,● Passion for invention,● Commitment to operational excellence,● Long-term thinking

Source: Amazon's Official Website

4.2.2. Amazon's current application of Digital Twins Technology

Amazon's application of Digital Twins Technology in warehouses is a long and complex project that involves both its 2 subsidiaries and other tech-based partners. In this ecosystem, Amazon Robotics is responsible for designing and operating the physical robots and automation systems used in fulfillment centers, while Amazon Web Services (AWS) provides the cloud infrastructure and Digital Twins framework that integrates real-time warehouse data, large-scale simulations, and analytics. To enable high-fidelity virtual modeling, NVIDIA Omniverse serves as the Digital Twins platform for creating realistic 3D warehouse environments, and NVIDIA Isaac Sim supports physics-based robot simulation and AI training.

End-to-end simulating warehouse operations

Amazon applies Digital Twins Technology to create full-scale virtual replicas of its fulfillment centers, allowing performance to be analyzed before construction or operational changes are implemented. Using NVIDIA Omniverse and ProModel-based simulations, Amazon can model the entire warehouse flow from receiving to shipping, rather than isolating individual processes (AWS, 2024). This end-to-end approach captures real operational complexity such as order variability, equipment downtime, ensuring that future-state designs reflect real-world conditions rather than idealized assumptions.

Data-driven warehouse design and layout optimization.

Through Omniverse-powered Digital Twins, Amazon visualizes warehouse layouts with full-fidelity realism, including storage pods, robot traffic, picking zones, and human workstations. RTX-accelerated ray tracing, physics, and material modeling allow Amazon Robotics to test alternative layouts and automation configurations virtually. In parallel, ProModel simulations convert current operational performance into benchmark metrics such as throughput, space utilization, labor productivity, and equipment efficiency, which are then compared against future designs (AWS, 2024). This allows Amazon to optimize layout decisions while minimizing costly redesigns after construction.

Enhanced robotic intelligence through synthetic data and perception training

Another critical application is the training and improvement of autonomous robotic systems. When real-world issues arise such as perception failures caused by reflective packaging materials, Amazon generates physically accurate, photorealistic synthetic data within the Digital Twins environment. These datasets are used to retrain computer vision and perception models, significantly reducing retraining time and improving accuracy without disrupting live operations. This accelerates the deployment of reliable robotic picking and sorting solutions at scale.

Optimised human–robot interaction and sustainability performance

Beyond automation, Amazon applies Digital Twins to simulate human–robot workstations and evaluate ergonomic improvements for employees. By modeling worker movement, task sequencing, and equipment interaction, Amazon identifies opportunities to reduce physical strain while maintaining high productivity. Additionally, ProModel simulations allow sustainability metrics, such as energy usage and CO₂ emissions, to be tracked alongside traditional KPIs (AWS,

2024). This enables Amazon to align operational efficiency with environmental performance, reinforcing its sustainability objectives.

4.3. Comparison and evaluation of Digital Twins Technology applications at DHL and Amazon

4.3.1. Comparison of Digital Twins Technology applications at DHL and Amazon

a. Objectives and scope of implementation approach

DHL's strategy is primarily operational-centric, reflecting its role as a logistics service provider responsible for managing complex physical flows of goods across existing logistics infrastructures. As seen in the 2019 Tetra Pak collaboration, DHL focuses on digitizing existing warehouses to better manage human-machine interaction and operational complexity. Their digital twin environment functions as a real-time decision support system that helps eliminate immediate bottlenecks and manage restricted zone access (DHL, 2019). In practice, this system also improves warehouse traffic coordination, worker safety monitoring, and real-time inventory visibility, enabling managers to detect congestion points and optimize material-handling operations. This approach reflects DHL's need to continuously optimize ongoing logistics operations across facilities that are already built and operating.

By contrast, Amazon adopts a more ecosystem-centric and design-driven approach, consistent with its role as an e-commerce platform that operates and constantly expands a large fulfillment network. Leveraging infrastructure from Amazon Web Services and simulation technologies such as NVIDIA Omniverse, Amazon builds physically accurate virtual replicas of fulfillment centers to analyze performance before facilities are constructed (AWS, 2023). These simulations allow engineers to test warehouse layout design, robotic workflows, storage density, and material flow efficiency in advance. While DHL mirrors real-world operations to improve current logistics performance, Amazon primarily simulates future-state fulfillment ecosystems to prevent inefficiencies from occurring in the first place and to support rapid scaling of its global e-commerce infrastructure. This difference highlights how digital twin adoption is shaped by each firm's core business model: DHL focuses on optimizing logistics services within existing networks, whereas Amazon uses the technology to design, scale, and continuously innovate its fulfillment ecosystem.

b. Technological foundations

DHL's system is built on a large-scale IoT sensor network that continuously collects operational data within the warehouse environment. By attaching smart sensors to material-

handling equipment and wearable devices used by workers, movement and activity data are transmitted to a centralized control tower. This enables managers to monitor warehouse flows through real-time dashboards and heat maps, helping identify congestion areas, track equipment utilization, and improve the visibility of inventory movements across different warehouse zones.

Amazon, by contrast, relies on a cloud-native physics simulation engine. Instead of simply tracking movements, Amazon's digital twin simulates the laws of physics using technologies such as NVIDIA Isaac Sim. This allows the company to generate synthetic operational data and replicate complex warehouse scenarios within a virtual environment. As a result, Amazon can perform deeper predictive modeling and test operational conditions such as robot navigation, storage density, and peak-demand workflows more effectively than DHL's sensor-based mirroring approach

c. Integration with Robotics and Automation

At DHL, the Digital Twins platform functions primarily as a supervisory layer that supports the coordination between human workers and automated machines. The system monitors forklifts, automated guided vehicles (AGVs), and other material-handling equipment to detect localized operational issues such as traffic congestion in high-density warehouse zones. In this sense, the technology serves as a management tool that enables human supervisors to oversee machine operations, improve workflow coordination, and enhance workplace safety.

For Amazon, Digital Twins operate as a training and optimization environment for AI-driven robotics. Engineers use the virtual warehouse environment to train and retrain robotic systems before deployment in live fulfillment centers. For example, robots can be trained to handle challenging tasks such as recognizing reflective or transparent packaging without disrupting real warehouse operations (NVIDIA, 2025). This simulation-based approach helps improve robotic picking accuracy, automation reliability, and overall warehouse operational efficiency.

4.3.2. Evaluation of Digital Twins Technology applications at DHL and Amazon

a. Strengths

Improved Efficiency and Transparency

Both firms demonstrate that Digital Twins Technology provides a systematic leap in productivity. DHL's integration of live WMS data with DT mirrors allows for the 30/95-minute Rule goods shelved in 30 mins; shipped in 95 mins (DHL, 2019). By having a digital mirror, DHL can hold operations to a strict, granular timeline that was previously impossible to track manually.

Amazon's end-to-end simulations capture complexities like equipment downtime and labor constraints, ensuring that warehouse designs are based on realistic stress tests, thus minimizing costly physical redesigns (AWS, 2024).

Transition to Proactive Safety and Sustainability

A significant strength is the move from reactive to proactive management. DHL's ability to digitally border restricted zones and monitor MHE behaviors ensures high compliance and worker safety (DHL, 2019). Amazon extends this logic to human health and the environment. By modeling human-robot workstations, they identify tasks that cause physical strain and adjust them virtually. Furthermore, they track environmental KPIs, such as energy usage and CO2 emissions, within the simulation. This allows Amazon to align high-speed productivity with modern ESG standards (AWS, 2024).

b. Potential challenges for DHL, Amazon and future adopters

Data reliability and the "Garbage In, Garbage Out" risk.

The primary vulnerability remains the accuracy of the source data. If a sensor in a DHL cold-storage zone fails or provides an incorrect temperature reading, the virtual twin will mirror a false reality, leading managers to make incorrect interventions. As seen in other high-tech sectors, an immutable digital record is only useful if the input is verified. Without strict data governance and independent audits, the real-time insights of a Digital Twins can become a legal or operational liability (KPMG, 2024).

High Financial Barriers and Legacy Integration

The high-fidelity systems used by Amazon require massive capital investment and a specialized workforce that many smaller companies cannot afford. For future adopters, the biggest challenge is legacy integration. Most warehouses run on old Warehouse Management Systems (WMS) that were never designed as a 3D simulation engine. Achieving full synchronization across a global supply chain is often blocked by the varying digital maturity of different partners; if a supplier's data is still paper-based, the end-to-end Digital Twins remain incomplete (Gartner, 2023).

5. Recommendations

5.1. Overview of warehouse management and logistics industry in Vietnam

Vietnam's warehouse management and logistics industry has expanded rapidly over the past decade, driven by strong economic growth, the rise of e-commerce, and regional integration

through trade agreements such as CPTPP and RCEP. The logistics sector has recorded an average annual growth rate of 14-16%, contributing approximately 4.5-5% to GDP and ranking 43rd in the Logistics Performance Index, placing Vietnam among the top five ASEAN countries in 2023 (Van, 2025). However, the industry continues to face a major structural challenge in the form of high operational costs, which account for around 16-18% of GDP which is significantly higher than the global average (Lê Nguyễn, 2024).

Warehousing plays a central role within this logistics ecosystem, underpinning inventory management, order fulfilment and supply chain visibility. Vietnam's modern warehouse market grew at an estimated annual rate of 23% between 2020 and 2023 and is projected to continue expanding at approximately 7% per year through 2027. Key logistics hubs have emerged in Binh Duong, Dong Nai and Bac Ninh, supported largely by foreign investors such as Mapletree, BW Industrial and SLP (Phuong Hien, 2024).

5.2. Challenges in adopting Digital Twins Technology in Vietnam's warehouse sector

Although the Digital Twins Technology has a great potential to improve the efficiency, visibility, and decision-making of the warehouse, it is hindered by several structural and operational issues that impede its uptake in the warehouse industry in Vietnam.

5.2.1. High initial investment and financial constraints

The major impediment to adoption is the large initial investment to implement Digital Twins systems (Tao et al., 2019). In the case studies of DHL and Amazon, the successful implementation is dependent on dense sensor networks, Internet-of-things devices, the cloud computing platform, advanced simulation platforms, and AI-based analytics. Nevertheless, a big percentage of logistics firms in Vietnam is small to medium sized in line with limited financial resources. To them, the expenses incurred in hardware installation, software licensing, system integration and long term maintenance may be prohibitive in nature especially when long run gains on investment are not certain (Sustainability Directory, 2025).

5.2.2. Limited digital infrastructure and data integration capabilities

Digital Twins demand real-time quality data of interconnected devices like warehouse management systems, transportation management systems, IoT sensors, robotics, and environmental monitoring instruments (Kritzinger et al., 2018). Most of the warehouses in Vietnam still have fragmented or semi-digital systems, where information is stored in different platforms and handled manually. Lack of compatibility between data architecture and

interoperability prevents the development of a solid online version of the physical warehouse processes. In the absence of regular and precise data flows, Digital Twins models might turn into lifeless simulations instead of being used as dynamic decision-supporting devices (Saranya, 2024).

5.2.3. Shortage of skilled human resources

The other major difficulty is associated with lack of access to qualified staff that can design, operate, and maintain Digital Twins systems. Subsequently, the case of Amazon presented, the successful implementation of this process requires the skills of data analytics, modeling simulations, artificial intelligence, robotics, and cloud computing. The logistics employees in Vietnam are mostly focused on operational implementation as compared to managing the digital system, a factor that renders them a skills gap, creating additional reliance on the external technology service providers, thereby raising costs of implementation and slowing knowledge transfer within the organisations (Toobler, 2025).

5.2.4. Cybersecurity and data governance risks

Since Digital Twins systems will absorb large volumes of operational and real-time information, the issues related to cybersecurity and data privacy will gain greater importance. Many Vietnamese logistics companies now do not have strong cybersecurity systems and detailed data governance strategies, which increases the risk of information theft, data breakage, and unintentional leakage of confidential business data. These weaknesses can, by extension, deter companies from adopting well interconnected digital systems (Huang et al., 2024).

5.3 Lessons learned and recommendations for Vietnam

The case studies of DHL and Amazon provide some insightful information to Vietnamese stakeholders interested in using the Digital Twins Technology to modernize the management of the warehouse, yet at the same time, address the local limitations.

5.3.1. Apply warehouse layout Digital Twins in major logistics hubs first

Big logistics operators located in Binh Duong, Dong Nai, and Bac Ninh ought to deploy operational warehouse Digital Twins that recreate the storage layouts, picking paths, and movement of different parts of the inventory before it can be substantiated in the real world. Similar to the approach used by DHL, businesses may turn to such technology vendors as Siemens or Dassault Systemes and local cloud providers like Viettel Cloud or FPT Smart Cloud to optimize warehouse efficiency and reduce operational congestion.

5.3.2. Deploy transportation Digital Twins for e-commerce logistics

Transportation Digital Twins should be implemented by logistics companies that support e-commerce platforms to simulate the route of delivery, traffic, and demand variability. These systems are able to optimize the last-mile delivery and fleet usage in accordance with the Amazon logistics model. Partnership with technology companies, like GrabMaps, Viettel AI, or AWS, can be used to enable real-time integration of data and optimization of routes.

5.3.3. Develop cloud-based Digital Twins for SMEs in shared warehouses

In order to reduce the financial strain, logistics companies of small and medium size need to use cloud-based Digital Twin systems to track inventories and manage the capacity of warehouses within common warehouses. These simplified systems may be integrated with simple IoT sensors with warehouse management systems and be offered on a Software-as-a-Service basis created by Vietnamese technology firms like FPT Software or VNPT.

5.3.4. Implement infrastructure Digital Twins for energy and equipment management

Large-scale automated warehouses need to install infrastructure Digital Twins to track the energy usage, temperature, and equipment functionality. Similar to the smart warehouses of Amazon, these systems would be able to forecast the maintenance needs and optimize the use of energy. Logistics companies can also cooperate with the industrial technology providers like Schneider Electric or IBM in order to adopt such solutions.

CONCLUSION

The case studies of DHL and Amazon demonstrate that Digital Twins Technology can be effectively applied across different levels of warehouse complexity and technological maturity. While DHL adopts a pragmatic and incremental approach focused on optimizing existing operations, labor productivity, and safety, Amazon represents a more advanced, ecosystem-driven model that integrates cloud computing, robotics, and physics-based simulations to support end-to-end warehouse design, automation testing, and human–robot interaction. Together, these cases confirm that Digital Twins can generate substantial value, ranging from operational efficiency improvements to strategic planning and innovation. For Vietnam, although the logistics and warehousing sector faces challenges such as high investment costs, fragmented digital infrastructure, skills shortages, and organizational resistance, the experiences of DHL and Amazon suggest that a gradual and context-appropriate adoption strategy is more feasible than replicating highly sophisticated models. By prioritizing high-impact use cases, leveraging cloud-based solutions and partnerships, and investing in workforce upskilling aligned with national digital transformation policies, Digital Twins Technology can become a key driver of efficiency, resilience, and global competitiveness in Vietnam’s logistics sector.

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