

DIGITALIZATION OF WAREHOUSE MANAGEMENT IN MODERN LOGISTICS

Fourat ANDERI, Vytautas Magnus University, Agriculture Academy, Faculty of Bioeconomy Development,
email: fourat.anderi@vdu.lt

Abstract

Digitalization is a big reason why today's logistics systems are faster and more competitive. Warehouses have changed thanks to new technologies like Warehouse Management Systems (WMS), RFID, automation, and real-time data tracking. These tools help companies keep better track of their stock, make fewer mistakes, and run their storage and shipping more smoothly.

This article looks at how digitalization is changing the way warehouses work and how it affects logistics performance. The research is based on a review of scientific studies about digital logistics and warehouse tech. What the studies show is that using digital tools in warehouses makes things more efficient, cuts down on processing time, and makes the whole supply chain easier to follow. These systems also help managers make better decisions by giving them accurate, up-to-date info on what's happening in the warehouse.

In short, digitalizing warehouse management is now a key part of modern logistics. It helps companies stay competitive and plays a big role in their growth and success.

Keywords: digitalization, logistics, warehouse management systems, supply chain, automation.

Introduction

In recent years, digitalization is no longer a bonus, but it became crucial and one of the most important changes shaping the development of logistics. Its rapid growth and the complexity of supply chain obliged the companies to improve the efficiency and the flexibility of their logistics operations. As a result, many organizations implemented digital solutions to optimize and improve logistics processes.

Warehouse management is one of the most impacted areas by this digital transformation. It plays a crucial role in the supply chain due to its role in storing products, inventory management and in preparing the goods for distribution. Despite its importance most warehouse work was done by hand which often cause problems like inefficiency, mistakes in tracking and delays in preparing orders then digital technology appears and most of these tasks become easier and automated.

Technologies such as Warehouse Management Systems (WMS), barcode scanning, radio-frequency identification (RFID), and automated storage systems allow companies to monitor inventory in real time and improve the accuracy of warehouse operations. These digital tools enable better coordination between warehouse activities and other supply chain processes, including transportation and inventory planning. According to research in logistics management, the implementation of digital technologies in warehouses can significantly increase operational efficiency and reduce operational costs.

Even though more warehouses are using digital technologies, it's still not fully clear how to use these tools to improve overall logistics performance. Most studies look at one technology at a time or focus on specific uses, but few give a broad picture of how different digital tools work together to make warehouses more efficient and better connected to the rest of the supply chain. That's why a closer look at digitalization in warehouse management is needed to really understand what role it plays and why it matters in today's logistics word.

Research aim: To analyse the role of digitalization in warehouse management and its contribution to logistics efficiency.

The following **objectives** have been set to achieve the aim:

1. To analyse the concept of digitalization in logistics and warehouse management.
2. To identify the main digital technologies used in modern warehouse operations.
3. To examine how digital warehouse technologies contribute to logistics efficiency.

Research object and methods

The object of this research is the digitalization of warehouse management in modern logistics systems. The study focuses on how digital technologies are applied to improve warehouse operations and overall logistics performance.

The research is based on qualitative methods, primarily a systematic analysis of scientific literature. Academic articles, industry reports, and conference papers related to warehouse digitalization and logistics technologies were collected from scientific databases such as Google Scholar, ScienceDirect, and MDPI.

The literature search focused on publications from the period 2016–2024 in order to ensure the relevance of the analysed material. Keywords used in the search process included “warehouse digitalization,” “warehouse management systems (WMS),” “RFID,” “warehouse automation,” and “logistics efficiency.”

A selection of relevant sources was made based on their direct relation to the research topic, scientific credibility, and contribution to understanding digital warehouse technologies. In total, the most relevant studies were analysed to identify key technologies and evaluate their role in improving warehouse operations.

In addition, a comparative analysis was conducted to examine the functions, advantages, and limitations of different digital technologies used in warehouse management. This approach allowed for a structured comparison of technologies and their contribution to logistics efficiency.

Research results and discussion

An analysis of academic research shows that digitalization plays an important role in improving how warehouses and logistics operate. Technologies such as Warehouse Management Systems (WMS), RFID, barcode scanning, and automation help companies track inventory more effectively, monitor operations in real time, and improve accuracy in daily tasks (Winkelhaus & Grosse, 2020; Ivanov, Dolgui & Sokolov, 2019). Studies also show that using digital systems reduces human mistakes, improves coordination across supply chains, and helps businesses respond more quickly to customer demands (Tarudin, Latif, and Adlan, 2025).

The Concept Of Digitalization In Warehouse Management

Digitalization means using digital technologies to run business operations. It change old manual ways of working into automated systems that rely on data. This helps improve efficiency, performance, and decision-making (Acuna, Disalao, Emano, Listahan, Payla, Pogoy, & Teh, 2025). It marks a big shift in how organizations work, helping businesses communicate better, speed up processes, and make smarter choices by having access to real-time information. In supply chain and logistics, digitalization involves using digital tools to make every stage of logistics more efficient and automated. It goes beyond just scanning documents to creating fully connected digital workflows (Smerichevska, Prodanova, & Yakushev, 2024).

From a broader logistics perspective, supply chain activities should be considered as interconnected systems rather than isolated functions. Effective supply chain management depends on the coordination of material and information flows across all stages (Christopher, 2016). Digitalization facilitates this integration by enabling real-time information exchange, improving coordination between different actors, and supporting more effective decision-making. Technologies such as Artificial Intelligence (AI), the Internet of Things (IoT), and Big Data provide tools to forecast demand, optimize routes, track goods, and enhance operational efficiency across the supply chain (Smerichevska, Prodanova, & Yakushev, 2024).

Within warehouse management, digitalization is reflected in systems such as Warehouse Management Systems (WMS), barcode technologies, and digital tracking tools. These technologies replace manual processes, reduce human errors, optimize storage and picking operations, and provide continuous inventory visibility. As a result, warehouse operations become more efficient, accurate, and responsive to changing demand conditions (Acuna, Disalao, Emano, Listahan, Payla, Pogoy, & Teh, 2025; Smerichevska, Prodanova, & Yakushev, 2024). Digital workflows also enable faster documentation processing and improved operational monitoring, supporting managers in evaluating and improving warehouse performance (Smerichevska, Prodanova, & Yakushev, 2024).

The value of digitalization comes from both operational and strategic benefits. Companies that embrace digital solutions can cut down on mistakes, speed up order processing, improve service quality, and stay competitive in the market. Digitalization also helps different business functions work together more smoothly and makes logistics processes more efficient. This is why it plays a key role in driving better performance and competitiveness in today's supply chains and warehouse operations (Smerichevska, Prodanova, & Yakushev, 2024; Acuna, Disalao, Emano, Listahan, Payla, Pogoy, & Teh, 2025).

Table 1 illustrates the distinction between digitalization in logistics as a whole and within warehouse management.

Table 1. Comparison of Digitalization in Supply Chain Logistics and Warehouse Operations

Aspect	Digitalization in Logistics	Digitalization in Warehouse Management
Focus	Integration of digital tools across the entire supply chain to optimize, automate, and increase efficiency (Smerichevska, Prodanova, & Yakushev, 2024)	Use of digital systems (WMS, barcoding, tracking) to automate warehouse operations and improve accuracy (Acuna, Disalao, Emano, Listahan, Payla, Pogoy, & Teh, 2025; Smerichevska, Prodanova, & Yakushev, 2024)
Purpose	Streamline material and information flows; improve coordination across all supply chain stages (Christopher, 2016)	Reduce manual errors, optimize storage and picking, and enhance inventory visibility (Acuna, Disalao, Emano, Listahan, Payla, Pogoy, & Teh, 2025)
Key Technologies	AI, IoT, Big Data for forecasting, route optimization, and tracking (Smerichevska, Prodanova, & Yakushev, 2024)	WMS, barcode/RFID systems, digital tracking tools for automated processing (Acuna, Disalao, Emano, Listahan, Payla, Pogoy, & Teh, 2025)
Operational Benefits	Real-time information exchange; better decision-making across the supply chain (Smerichevska, Prodanova, & Yakushev, 2024)	Faster documentation processing; improved monitoring and evaluation of warehouse performance (Smerichevska, Prodanova, & Yakushev, 2024)
Strategic Benefits	Increased efficiency, coordination, and competitiveness of the overall supply chain (Smerichevska, Prodanova, & Yakushev, 2024)	Enhanced responsiveness, operational performance, and accuracy in warehouse operations (Acuna, Disalao, Emano, Listahan, Payla, Pogoy, & Teh, 2025)

At the broader logistics level, digitalization focuses on **optimizing and integrating supply chain activities**, improving coordination, real-time decision-making, and overall efficiency (Smerichevska, Prodanova, & Yakushev, 2024; Christopher, 2016). In contrast, within warehouse management, digitalization targets **operational processes**, such as inventory tracking, order picking, and documentation, to reduce errors, increase accuracy, and enhance responsiveness to demand changes (Acuna et al., 2025; Smerichevska, Prodanova, & Yakushev, 2024). By separating these levels, the table highlights how digitalization operates both as a **strategic enabler across the supply chain** and as an **operational tool within warehouses**, reinforcing its overall importance in modern logistics systems.

Key Digital Technologies and Their Impacts

Warehouse Management Systems (WMS) are software platforms designed to support and optimize warehouse workflows, including inventory tracking, storage organization, picking, and shipping. Implementing a WMS allows companies to monitor inventory levels in real time, reduce manual errors, and accelerate order processing (Winkelhaus & Grosse, 2020). WMS contributes to improved coordination between warehouse operations and external supply chain activities, leading to smoother overall performance (Ivanov, Dolgui & Sokolov, 2019).

Radio-frequency identification (RFID) technology automatically identifies and tracks products using radio waves. Compared to traditional barcode scanning, which requires line-of-sight and manual scanning, RFID can read multiple tags quickly and without direct visual contact. This enhances inventory visibility and reduces human errors (Ivanov, Dolgui & Sokolov, 2019). However, higher infrastructure costs and integration requirements can be a barrier for some companies (Winkelhaus & Grosse, 2020).

Barcode scanning systems remain one of the most common digital tools in warehouses due to their relatively low implementation cost and ease of use. Empirical evidence further supports the effectiveness of barcode-enabled Warehouse Management Systems (WMS) in improving warehouse performance. A study by (Tarudin, Latif, and Adlan, 2025) shows that traditional warehouse operations based on manual recording and physical counting are prone to errors, delays, and inefficiencies. The implementation of a WMS barcode system enables automated data capture and real-time inventory updates, significantly improving operational accuracy and visibility. The findings indicate that inventory accuracy increased by approximately 80%, while operating costs decreased by around 20%. In addition, employees reported faster task completion, with nearly 70% perceiving improvements in operational speed, and warehouse space utilization improved by about 50%. The study also identifies processing time as a critical factor influencing warehouse performance, emphasizing that faster operations are a key benefit of digitalization.

Table 2. Impact of Barcode-Enabled WMS on Warehouse Performance

Performance Indicator	Before Implementation	After Implementation	Improvement
Inventory Accuracy	Manual, error-prone	Real-time accurate tracking	+80%
Task Completion Speed	Slow processes	Faster execution	+70%
Operating Costs	High	Reduced	-20%
Space Utilization	Inefficient	Optimized	+50%

Source: Compiled by the author based on (Tarudin, Latif & Adlan, 2025).

The table 2 demonstrates the operational improvements achieved through the implementation of barcode-enabled WMS. It highlights how digitalization enhances accuracy, reduces costs, improves speed, and optimizes warehouse space utilization. These results confirm the significant role of digital technologies in improving warehouse efficiency and performance.

Warehouse automation refers to robotics, automated storage and retrieval systems (AS/RS), autonomous guided vehicles (AGVs), and conveyor systems that reduce reliance on manual labour. Automation enhances speed, consistency, and scalability of warehouse operations (Winkelhaus & Grosse, 2020). Companies like DHL and Amazon employ advanced automation to handle high-volume operations efficiently (Ivanov, Dolgui & Sokolov, 2019). Research also shows that robotic technologies and automated warehouse systems significantly improve operational efficiency and order fulfillment speed while reducing operational errors (Boysen, de Koster & Weidinger, 2019). Nevertheless, automation requires substantial investments, technical expertise, and advanced maintenance, which can pose challenges to smaller organizations (Winkelhaus & Grosse, 2020).

The table 3 summarizes the key digital warehouse technologies discussed, outlining their functions, benefits, and limitations.

Table 3. Comparison of Digital Technologies

Technology	Primary Function	Main Benefits	Common Challenges
WMS	Software used to manage warehouse operations such as inventory tracking, storage, picking, and shipping	Real-time inventory visibility, increased accuracy, better workflow coordination	Integration with legacy systems and training requirements
RFID	Uses radio waves to automatically identify and track products with RFID tags	Enhanced visibility and tracking speed, reduced human errors	High cost and infrastructure requirements
Barcode Scanning	Uses optical scanners to read printed codes on products for identification and tracking	Low implementation cost, easy to use, improved data accuracy compared to manual recording	Requires line-of-sight scanning and manual handling, slower for large volumes
Automation	Automated systems that move, store, and retrieve goods with minimal human intervention	High efficiency, faster order processing, reduced labour dependency, scalable operation	High investment, technical complexity and the need for skilled staff

Source: Compiled by the author based on a synthesis of (Winkelhaus & Grosse, 2020; Ivanov, Dolgui & Sokolov, 2019; Tarudin, Latif & Adlan, 2025).

Efficiency Improvements in Digital Warehouse Operations

Academic research consistently shows that digital technologies help warehouses run more efficiently and perform better. That said, most studies in this area rely on qualitative evidence rather than offering precise numerical measurements of these gains. For instance, a systematic review by Winkelhaus and Grosse found that digital tools linked to Logistics 4.0 such as the Internet of Things (IoT), cyber-physical systems, and cloud-based monitoring tend to improve information transparency and coordination across logistics processes. These improvements, in turn, support greater operational efficiency and responsiveness (Winkelhaus & Grosse, 2020).

Research on smart warehouses supports this view, showing that combining automation, connectivity, and digital data flows enables warehouses to do more than just store goods. According to Tikwayo and Mathaba (2023), these technologies boost productivity and service quality, while also reducing failures and the costs associated with manual tasks. A related review by Tubis and Rohman (2023) highlights that technologies like IoT sensors, augmented reality, RFID, autonomous vehicles, and robotics are now central to Industry 4.0 warehouse solutions. These tools help speed up core operations and make them more reliable by enabling real-time monitoring and data exchange.

In e-commerce, where getting orders right and getting them out fast is everything, warehouses are relying more on automation. (Boysen, de Koster & Weidinger, 2019) point out that technologies like robotic picking stations, automated guided vehicles (AGVs), and other smart systems are now being used to handle tight deadlines and complicated orders. Compared to the old way of doing things where workers had to walk through the aisles to pick items one by one these automated tools help get more work done in less time and cut down on wasted effort. Looking across these studies, one thing is clear: even if researchers don't always put a specific number on how much more efficient things get, the overall evidence is strong. Digital technologies in warehouses are making a real difference by improving how data is captured, making processes smoother, reducing manual work, and helping systems respond faster. All of these are essential ingredients for strong performance in today's logistics world.

The study (Smart Warehouse Management Using IoT Sensors and RFID for Mid-Scale Manufacturing Enterprises, 2023) shows that combining IoT sensors with RFID creates a fully connected environment. Suddenly, you have real-time visibility over your goods, automatic alerts when something's off with inventory, and picking routes that optimize themselves. All of this means warehouses can react faster when challenges come up, get more out of their resources, and spend less time on labor-intensive tasks. The study also mentioned the difference in inventory accuracy, order fulfillment performance and labor productivity before and after the technologies implementation as shown in the table below.

Table 4. Comparison of Digital Technologies impact before and after implementation

Category	Metric	Before Implementation	After Implementation
Inventory accuracy	Inventory Accuracy (%)	86.4	94.8
	Stock Discrepancies (per month)	112	76
Order fulfillment Performance	Average Order Processing Time (hrs)	6.2	4.6
	Picking Errors (%)	3.8	1.9
Labor productivity	Orders per Worker per Shift	42	54
	Manual Data Entry Tasks	High	Minimal

The numbers in Table 4 clearly demonstrate what digital technologies can do for warehouse performance. Inventory accuracy jumped from 86.4% to 94.8%, a significant improvement. At the same time, stock discrepancies dropped from 112 to 76 per month, which shows that data reliability and control have gotten much better. Order processing time fell from 6.2 hours down to 4.6 hours and picking errors were cut in half. These results indicate significant improvements in per person, while manual data entry tasks were scaled way back. All of this confirms what the research has been suggesting: digital technologies like RFID and IoT directly improve efficiency, accuracy, and productivity in warehouse operations.

Integration with the Supply Chain

Digital technologies in warehouses do more than speed up internal processes, they also enhance integration across the wider supply chain (Salwa, 2023). When systems like Warehouse Management Systems (WMS) and RFID are connected with other supply chain functions, information flows more smoothly between suppliers, warehouses, and customers, which reduces confusion and supports faster decision-making (Zaid, Farooqi & Azmi, 2024). Technologies that enable real-time data exchange and analytics give companies a continuous view of inventory levels and order status, allowing managers to respond quickly to changes in demand and avoid costly stockouts or delays (Salwa, 2023). Research on supply chain digitalization shows that real-time tracking and analytics significantly improve supply chain responsiveness and operational visibility, enabling firms to adapt their logistics plans based on current conditions rather than on delayed reports (Zaid, Farooqi & Azmi, 2024).

Another critical aspect of supply chain integration is improved information exchange between entities (Holloway, 2024). Studies indicate that digital transformation increases the exchange of supply chain data, which enhances responsiveness and the ability of a system to adapt to market fluctuations or disruptions more quickly and effectively (Zaid, Farooqi & Azmi, 2024). When partners share data such as demand forecasts, inventory levels, and shipment updates in real time, planning becomes more accurate, and coordination across the network improves (Holloway, 2024).

Digital systems also support more advanced supply chain models like omnichannel logistics, where businesses handle orders from physical stores, online platforms, and marketplaces simultaneously (Salwa, 2023). Literature on

supply chain digitalization identifies digital technologies such as IoT, big data analytics, and AI as key enablers of these integrated operations because they harmonize data from multiple sources, reduce information silos, and facilitate synchronized order fulfilment across channels (Holloway, 2024).

Taken together, the evidence points to something broader: warehouse digital technologies don't just make things run more smoothly behind the scenes. They also help build a supply chain that's more connected, quicker to respond, and driven by real-time data. That means partners across the network suppliers, distributors, and retailers can make faster and smarter decisions because they're working with up-to-the-minute information (Salwa, 2023; Zaid, Farooqi & Azmi, 2024; Holloway, 2024).

Real-World Applications

To see how technology is changing the way warehouses work we just need to check out what big names like DHL and Amazon are doing.

DHL, for instance, has been rolling all sorts of robots and automated gear into its warehouses. Things like Autonomous Mobile Robots basically robots that move around on their own and automated picking machines are helping them get work done faster and with fewer mistakes (DHL, 2026, DHL AMRs case, 2025). These systems take over a lot of the heavy lifting literally so orders get processed quicker and inventory counts stay accurate. And it's not just a small experiment; DHL recently hit one billion robotic picks across its sites which really shows how effective these technologies are in real-world settings (DHL AMRs case, 2025).

Then there's Amazon, Walk into one of their fulfillment centers, and you'll see robots pretty much everywhere, working side by side with people to pick, move, and sort stuff (Amazon, 2025). All that automation means workers spend less time walking around and more time getting orders out the door. It also helps keep track of inventory with way more precision. That's how Amazon manage to ship out massive numbers of orders every single day without things falling through the cracks.

So these aren't just futuristic concepts anymore. Companies like DHL and Amazon are using robots and digital tools to run tighter, faster, and smarter operations and in the process, they're building the kind of supply chains that can actually keep up with today's world.

Challenges in Implementing Digital Warehouse Technologies

While digital technologies greatly improve warehouse efficiency and supply chain integration, they also bring several challenges that companies must address. These challenges include high costs, technical complexity, workforce adaptation, dependency on technology, scalability limits, and cybersecurity risks. The table below summarizes the main challenges and their implications.

The challenges presented in Table 5 demonstrate that although digital warehouse technologies significantly improve operational efficiency, their implementation is associated with several limitations.

Table 5 Challenges in Implementing Digital Warehouse Technologies

Challenge	Description
High implementation cost	Advanced technologies such as robotics and RFID require large financial investments in equipment and infrastructure (Winkelhaus & Grosse, 2020; Ivanov, Dolgui & Sokolov, 2019).
Technical Complexity & Integration Issues	Linking WMS, RFID, and robotics can be complicated. Poor integration can disrupt operations instead of improving them (Holloway, 2024; Salwa, 2023).
Dependence on technology & risk of downtime	Automated warehouses rely on systems that can fail. Power outages, software bugs, or hardware malfunctions can halt operations (Winkelhaus & Grosse, 2020).
Scalability and flexibility issues	Some systems are designed for specific workflows and may not easily adapt to new products, order volumes, or warehouse layouts (Holloway, 2024).
Cybersecurity and data privacy	Warehouses generate and share large volumes of data. Cyberattacks or data breaches can disrupt operations and expose sensitive information (Salwa, 2023).
Staff Training & Workforce Adaptation	Employees need training to operate, monitor, and troubleshoot digital systems. Resistance or insufficient training can reduce efficiency (Ivanov, Dolgui & Sokolov, 2019).

High investment costs and technical integration issues remain the most significant barriers, particularly for smaller organizations. In addition, the increasing reliance on digital systems introduces risks related to system failures and cybersecurity. Therefore, successful implementation of digital warehouse technologies requires careful planning, adequate financial resources, and continuous workforce training.

Conclusions

1. Digitalisation has become an important part of modern logistics systems. Digital technologies allow companies to collect and use operational data in real time, which improves visibility and coordination across supply chain activities.

2. The analysis shows that technologies such as Warehouse Management Systems (WMS), radio-frequency identification (RFID), barcode scanning, and automation systems play a key role in digital warehouses by improving inventory control, enabling accurate tracking of goods, and supporting more efficient warehouse operations.

3. Research findings indicate that the implementation of digital warehouse technologies increases logistics efficiency by improving inventory accuracy, reducing operational errors, and accelerating order processing.

4. The successful adoption of digital solutions in warehouses depends on several important factors, including sufficient financial investment, effective system integration, and the availability of employees with the necessary digital and technical skills.

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