

DIGITIZATION OF WAREHOUSING PROCESSES: AN OPERATIONAL EFFICIENCY PERSPECTIVE

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Abstract

In the domain of logistics system, the role of warehousing is frequently underestimated in comparison to transportation and distribution. Historically, warehouses were regarded exclusively as storage facilities, with operational efficiency being accorded negligible priority. However, with the rapid growth of e-commerce and the increasing need for fast deliveries, the situation has changed. In the context of intense competition, businesses are compelled to expedite order processing while maintaining precision, thereby exerting increased pressure on warehouse operations. Consequently, the adoption of digitization is becoming more common in warehouses, helping improve inventory visibility, task coordination, and access to information. The aim of this study is to present how digitization influences warehouse operational efficiency and to examine the main difficulties that may appear during its implementation. This research is based on the analysis of recent scientific publications, with focus on Warehouse Management Systems and barcode technologies. Results confirm in general that digitization can mainly improve operation accuracy in inventory tracking and make processes transparent and more controlled in everyday tasks. However, it was also observed that to achieve the goals, it is not enough to simply integrate technological solutions, companies also need to focus on organizational aspects such as employee training, changing management and overcoming the hesitance to adopt new technologies which present significant obstacles.

Keywords: warehousing, digitization, warehouse management systems, operational efficiency, logistics

Introduction

The warehousing process is the supported method used for logistics and supply chain management. Warehousing is a key point in the logistics and supply chain process linking the production/distribution process with the end customers. In the past warehouses were only used to store goods without any real strategic value; however, due to the pressures associated with e-commerce growth, the increased speed at which companies must ship their products, the increased service levels that are being demanded of companies, and the need to have orders delivered more quickly and accurately, the warehousing process continues to evolve and develop into highly complex operating centers that directly impact an organization's performance and competitive position. As a result, warehouse efficiency has become increasingly important for ensuring the overall success of supply chain operations.

The company's reliance on manual processes has resulted in operational inefficiencies, inaccurate inventory records, delays in shipments, higher operational costs, and multiple logistics issues. These problems demonstrate that new, better, and more productive ways to perform warehouses must be found. One way to overcome these obstacles is Digitalisation (Orelma & Seppä, 2024). This process utilizes digital technology to automate data capture, provide real-time data processing, and improve coordination amongst warehouse operations. The use of digital technologies in warehouses also provides tools for real-time monitoring, improves operational transparency, and helps facilitate decisions when managing a Warehouse (Tubis & Rohman 2023).

Digital Automation has progressed from merely being about simple tracking devices to now being more advanced with the implementation of artificial intelligence (AI) and machine learning (ML). As explained by Hasan et al. (2025), these innovations allow for predictive analytics, therefore, systems can calculate anticipated future inventory and consumer requirements prior to an event occurring. This gives extremely accurate forecasts and reduces the chances of excess stock in the supply chain and improves supply chains ability to react quickly to unforeseen changes that occur in the marketplace (Hasan et al., 2025).

Even though warehouses have implemented more digital technology than ever before, they still experience challenges with integrating systems, having employees trained or adapting to the new technology, and being ready for digital transformation. In addition, although much of the research on digitisation in SCM has been published, there exists a gap in the theoretical literature regarding the specific impacts of digital technology on the efficiency of warehouse operations. Consequently, there is a need to better understand the relationship between digitisation and improvements in warehouse operations and overall operational efficiency.

The aim of this article is to examine digitization solutions for improving the operational efficiency of warehouse processes from theoretical perspective.

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

1. To identify key digitization solutions applied in warehouse operations.
2. To analyze how these technologies affect key operational performance aspects.
3. To examine the role of digitization in improving operational control and decision-making in warehouse management.
4. To identify organizational factors.

Research Object is digitization solutions for warehousing processes.

Research Methods: Scientific literature analyses.

A qualitative approach was chosen for this research, mostly because it allows to step back and look at trends rather than chase isolated data points. The article search was carried out on Google Scholar, ResearchGate and ScienceDirect databases. The following keywords were used to search for articles warehouse digitization, logistics operational efficiency and digital transformation engagement. In total, 50 articles were found, but 10 articles were analyzed based on the established criteria. The analysis is based on peer-reviewed journal articles and conference papers, publicly available and published between 2020 and 2025. The decision to rely only on full-text PDF sources was practical as much as methodological. It made it possible to check arguments in detail and to avoid relying on summaries or second-hand interpretations. The material itself is quite mixed, which is useful. It includes systematic literature reviews, practical studies based on real warehouse environments and more theoretical papers addressing ideas such as smart warehouses and information system integration from a wide perspective.

The chosen approach allows the identification of common points and challenges reported across different studies and logistics contexts.

Research findings on warehousing digitization

Warehousing is one of the fundamental processes implemented in supply chain management. According to (Hamdy W., Al-Awamry A., Mostafa N., 2022), it is an essential part of the integration of all operations in supply chains, and it defines also as a node where the objective is to manage and improve the flow of good not just keep them stationary. Efficient warehousing ensures continuous material flow, reduces storage costs, and improves customer service performance. It is considered an essential part of product flow due to its involvement in achieving optimum and continuous operation of the production and distribution processes (Tubis & Rohman, 2023). Logistics is the functional aspect of the storage and delivery of goods stored in a warehouse. Logistics is the planning and control of how goods, information, and services move from the producer to the customer. It includes transport, inventory, and warehousing to guarantee products reach destinations on time and in good condition (Eric Boafo Dadzie & Amponsah Richard, 2025).

Digitization of logistics processes enables companies to monitor real-time material flows and handle units better (Tubis & Rohman, 2023). Digitization means the use of digital tools instead of paper-based or manual work. It ensures real-time visibility, the speed of information sharing and make faster and smarter decisions (Orelma & Seppä, 2024).

In the context of Industry 4.0, digitized warehouses integrate technologies such as IoT sensors, data analytics, and automation to optimize performance. A warehouse management system (WMS) is an IT software solution for handling and optimising warehouse logistics activities and supporting warehouse process automation. They track inventory, organize storage, and plan tasks to make warehouse work faster and more accurate. (Minashkina & Happonen, 2023). WMS does not just monitor the stock in a warehouse, it also allows to generate reports about what is happening in the warehouse, to prioritize tasks and to measure performance all of which support operational control.

Warehouse operations are a critical part of logistics. According to Hamdy et al. (2022), that effective warehouse management will increase the flow of materials through the warehouse and reduce overall operating expenses. The use of digital technologies is helping to modernise warehousing, therefore enhancing and increasing the operational capabilities of warehouses.

Digitalisation is a term which means that companies create different types of technology such as computers and software to develop and automate their warehouse systems through data collection and tracking the movement of stock within their warehouses online (Orelma, Seppä, 2024). By being able to see how the warehouse works, companies can make better decisions (Tubis & Rohman, 2023). As warehouses become digitised, companies will be able to see exactly how much inventory they have, coordinate their operations (such as loading/unloading trucks), and overall enhance their warehouses. An important technology for warehouse digitization is the WMS. This information system optimises warehouse operations such as tracking inventory, order processing and storage management (Minashkina et al., 2023). WMS's enhance inventory accuracy, reduce operational errors and optimises warehouse activities on a daily basis.

Identification technology is a major part of warehouse digitization. Barcode & RFID systems help to automate the identification and tracking of products through their automated process. It decreases the opportunity for human error, including manually entering products into inventory databases. Deepali & colleagues (2024) conclude that using barcode technology during logistics operations will improve both inventory accuracy and operational efficiencies in warehouses.

According to the below Table 1, warehouse performance is being improved through the use of identification technologies, connectivity systems, automation technologies, and advanced analytical systems - these technologies allow for both automated data capture, monitoring in real time and optimization of processes, which significantly increase operational efficiency.

By implementing digital technologies, companies will receive a number of operational advantages. The greatest advantage is increased inventory accuracy; real-time tracking and automated data capture lead to a decrease in discrepancies between the amount of physical inventory on hand and what is recorded (computerised) in the warehouse, noticeably improving inventory control thereby lessening operational risk. Moreover, digitisation ultimately will provide a more efficient method for processing orders by optimisations in the picking process as well as decreasing human error. Ultimately, digitisation is now improving process transparency through the provision of real-time monitoring of performance and/or operational visibility.

Table 1. Classification of digital technologies in warehousing

Category	Examples	Description
Identification technologies	Barcode, RFID	Automated data capture and item identification. Improves accuracy and reduces manual entry.
Location and positioning	UWB (Ultra-Wideband), GPS	High-precision tracking within warehouses for better asset visibility.
Connectivity and IoT	Sensors, IoT gateways	Real-time data exchange and device communication.
Automation and Robotics	AGVs, AMRs	Automated movement of goods, supports picking and transport.
Data and Analytics	Big Data, Ai, Machine Learning	Predictive analytics and optimization (e.g., demand forecasting, routing).
Advanced Systems	Digital Twins, Blockchain	Strategic planning and secure traceability.

Source: Based on Tubis & Rohman's systematic review framework

As shown in Table 2, digitized warehouses provide real-time inventory monitoring, improved accuracy, and enhanced operational transparency compared to traditional warehouses. These improvements demonstrate the significant impact of digitization on warehouse efficiency.

Table 2. Comparison of traditional and digitized warehouse operations

Aspect	Traditional warehouse	Digitised warehouse
Inventory control	Periodic manual checks	Real-time system monitoring
Order picking	Paper-based instructions	Barcode-supported picking
Error frequency	High	Low
Process transparency	Limited	High

Source: adapted from Deepali et al. (2024, Section 4); Tubis & Rohman (2023, Section 3).

Table 3 presents a comparison of different inventory tracking technologies. Barcode systems provide reliable and cost-effective identification, while RFID and UWB technologies offer more advanced tracking capabilities and higher accuracy. These technologies improve warehouse visibility and operational control, supporting efficient warehouse management.

Table 3. Comparison of Inventory Tracking Technologies in Warehousing

Technology	Line of Sight Required	Scan Speed	Typical Accuracy	Location Accuracy	Main Use Case	Reference
Barcode	Yes, scanner must see the label directly	Slow, scans one item at a time	95–98% accuracy in normal warehouse operations	No real-time location tracking	Basic inventory control, picking, shipping	Lowry Solutions (2025)
RFID (UHF)	No line of sight required	Very fast – can scan hundreds of items per second	95–99%+ inventory accuracy	Location accuracy: about 1–5 meters	Automated inventory tracking, high-volume warehouses	
UWB (Ultra-Wideband)	No line of sight required	Real-time tracking	Very high accuracy	Extremely precise: 10–30 cm location accuracy	Real-time asset tracking, forklift smart warehouse positioning	Bahareh Masoudi, Nazila Razi & Javad Rezazadeh, (2025)

Digitization plays an important role in enhancing operational efficiency within a warehouse, according to a review of scientific literature. Various digital technologies including Warehouse Management Systems (WMS), barcodes, RFID, and

IoT devices provide companies with the ability to collect data, monitor processes, and optimize their performance in real-time, while also increasing operational accuracy and reducing the number of manual errors made within the warehouse.

As stated by Minashkina and Happonen (2023), WMS improves warehouse coordination by providing real-time visibility of inventory levels and enabling automated decisions to be made within the warehouse. This has a direct influence on operational control and resource management for the warehouse. In a similar vein, Deepali et al. (2024) found that barcode technology significantly enhances inventory accuracy due to an associated reduction in the amount of manual entry error made when entering inventory into an organization's database, leading to greater reliability for inventory tracking throughout the supply chain.

IoT technology has improved current warehouse processes by providing the ability to monitor in real-time warehousing operations and equipment (Tubis and Rohman, 2023). They show that IoT technology can enhance the visibility of the warehouse and allow the use of predictive and data-based management leading to the optimal operation of the facilities and ultimately improving performance.

Automation technology, such as automated guided vehicles (AGVs) and robotics, have increased the work performed in a warehouse through the elimination of manual labor and the enhancement of speed throughout the warehouse operations. These forms of technology have improved the productivity of work performed, reduced operational delays and increased safety for workers.

Nevertheless, while there has been a lot of discussion on how technology will be used in distribution centres, the research literature points out that simply using new technology does not guarantee successful implementation of the digitisation effort. There are many organisational issues, e.g. employee training, management support, and an effective approach to managing change, that must be considered when implementing digitisation. If there is no effective organisational adaptation, then some of the potential benefits of digital technologies will not be realised.

The human factor plays a vital role in determining the overall success of new digitized warehouse technologies. Technology provides the means for automating warehouse activities and employees must adapt those technologies for their day-to-day operations. Recent evidence shows that the degree to which employees are engaged in the digital transformation process is a significant contributor to their levels of performance after the deployment of a new warehouse management system (Nguyen, 2025). When employees are actively engaged with digital transformation initiatives, their ability to manage the complexity of warehouse operations improves significantly and therefore their level of job performance increases. Therefore, digitization is not solely a technological challenge, it is also an organizational challenge that will require management to emphasize employee motivation and engagement.

Training is one of the most important contributors to successful operations in logistics, and as indicated by Subhadhanuraja and Thiyagarajan (2025), effective training and development programs are closely related to increased employee job performance and satisfaction. The authors' research indicated that almost all of the logistics employees surveyed reported higher levels of accuracy completing their tasks after receiving focused training on using digital technologies (Subhadhanuraja and Thiyagarajan, 2025). However, a major obstacle to the use of digital tools in logistics is that many employees feel their employers do not provide them with enough time to learn and practice these new skills during their work hours. Therefore, to successfully implement digital solutions (e.g., WMS) within the logistics industry, employers need to treat training as a continuous operational function, rather than as a one-time function (Subhadhanuraja and Thiyagarajan, 2025).

Overall, the theoretical analysis confirms that digitization significantly enhances warehouse operational efficiency by improving inventory accuracy, process efficiency, and operational transparency. These findings highlight the importance of digital transformation in modern warehouse management.

Conclusions

1. According to this study, WMS and barcode technologies are at the base of current warehouses. These tools replace the slower process of working on paper with digital tracking, which has become a "scientific necessity" for logistics (Orelma, Seppä, 2024).

2. Inventory accuracy has improved dramatically through digitization and order processing time has also been greatly reduced due to warehouse use of real time monitoring through their systems compared to manual checks. Error rates have been reduced from high levels to low levels.

3. Real-time visibility and analytical reports are provided by digital systems, allowing the manager to make faster and better-informed decisions because he has accurate data regarding each task performed within the warehouse.

4. The main takeaway is that technology itself cannot achieve successful outcomes without employee training and is supported by management as well. Scientific studies show that when the employees are trained, they perceive technology as being easy to use. This perception is very important in terms of whether or not an employee will accept digital transformation.

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