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USE OF MODERN TECHNOLOGIES IN THE OPTIMALIZATION OF WAREHOUSE PROCESSES

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This article, incorporating a case study, analyses the evolution of warehouse processes toward modernization, focusing on the practical aspects of implementing innovation within a demanding industrial environment. The primary objective and research problem of this study is to assess the potential of modern IT and automated technologies to optimize processes and enhance warehouse operational efficiency. The study examines an enterprise's adaptability, defined as the speed at which solutions improving warehouse structure are implemented. The modernization of existing systems plays a critical role in the implementation of advanced warehouse management methods. The study explores the application of technologies ranging from RFID (Radio Frequency Identification) units to complex WMS (Warehouse Management System) class systems. A major challenge for today's industrial sector is the ability to integrate AI and machine learning with the still-essential element of human labour. Such digital transformation is becoming a tangible form of competitive advantage, while unpredictable times force management to take a decisive stance, which translates into increased organizational endurance. Modern warehousing is the key to achieving both operational and optimization excellence. This study also highlights the opportunity to integrate AI with personnel through "pick-by" systems, while identifying the lack of rapid adaptability as a primary implementation barrier. Executing modern solutions is difficult and costly from an organizational perspective, as it requires full commitment from management and the continuous improvement of infrastructure and resources. Furthermore, the necessity of tailoring technology to the business profile, product range, and contractors is emphasized. In conclusion, achieving the operational optimum through AI is feasible, provided it proceeds gradually and prudently.

Keywords: storage, RFID, automation, WMS, smart warehouse

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1. INTRODUCTION

The continuous development of modern technologies compels both entrepreneurs and consumers to monitor ongoing market shifts. However, these changes exert a more profound impact on enterprises than on end-users, necessitating a series of adjustments, including the alignment of internal policies and restructuring management frameworks. Currently, organizations operate in a preparatory phase, acclimatising to a new reality. Nevertheless, adapting to emerging solutions is imperative. The warehousing process, along with its peripheral operations, is increasingly supported by various information systems. Implementing modern technology into warehouse management allows for the optimization of specific processes. Consequently, an increasing number of enterprises are opting to implement artificial intelligence (AI) to enhance process efficiency. This translates into improved space utilization and more effective achievement of operational objectives. The challenges a manager must address in optimally coordinating various activities include fleet management (e.g., forklift fleets) and workforce management. The introduction of artificial intelligence may serve as a remedy for the aforementioned concerns. Furthermore, AI supports the optimization of order-picking routes, which significantly boosts labour productivity within the warehouse (Domagała, 2025). Will modern technologies contribute to the enhancement of warehousing processes? Will the role of the human element in the warehouse remain as significant as it has been to date? These questions are being posed by many organizations whose objective is the conscious management of warehouses and, more broadly, logistics. This study aims to examine an enterprise's capacity to adapt to the emerging horizon of artificial intelligence. Its fulfilment of the expected role in the functioning of a contemporary warehouse will be crucial for achieving maximum productivity. Adaptation involves decision-making related to the implementation of new technologies, which will translate into increased market attractiveness and serve as a strong competitive differentiator. Consequently, warehouses will operate more efficiently and adapt more effectively to dynamic market fluctuations.

2. THEORETICAL ASPECTS OF WAREHOUSE OPERATIONS

A warehouse, together with its surroundings (users and environment), constitutes a dynamic, controllable system. By defining its distinct structure, comprising various elements (subsystems) and interconnections, it is possible to describe those factors essential to its functioning (Szymonik, 2019). Crucial to its operation is the capacity for stable integration with the environment, which involves the timely supply of production lines and operational resilience during crisis situations. Furthermore, it performs a prognostic function, actively influencing the market through demand research and risk analysis. Warehouses continuously optimize efficiency by measuring and analysing the relationships between logistical processes and the external environment. In so doing, warehouses provide noteworthy advantageousness such as achieving economies of scale in transportation and production, improving customer service by shortening delivery times, managing changes in demand that enable on-time production, and smoothing the flow of material by sorting sufficient semi-finished items (Momeni, Jain, 2024).

A warehouse is understood as a unit where numerous processes occur, in line with an established technology. It is managed by a team of competent professionals who coordinate its operations and the surrounding processes. The essence of a warehouse is also captured by the statement that it is a planned space for the effective storage and manipulation of inventory (Niemczyk, 2010). As a facility, a warehouse utilizes not only its floor area but also its height to maximize its potential capacity.

Warehousing is a process encompassing key activities related to the receiving, storage, order picking, movement, maintenance, inspection, inventory counting, and dispatching of stock (Miszewski, 2019).

The functions of warehouses are divided into supporting processes related to marketing, production, and the reduction of transportation costs. Consequently, maintaining a steady flow of resources necessary for production is facilitated, and the execution of promotional campaigns is made possible by accumulating larger quantities of inventory. In manufacturing enterprises, three types of warehouses most commonly occur (Niemczyk, 2010):
- materials, raw materials, and packaging;
- finished goods (and occasionally prefabricated components and semi-finished products);
- spare parts and consumables (utilized by maintenance services).

Warehouses can be classified according to: their purpose, the physical state of materials, construction categories from a civil engineering perspective, and their specific type (tab. 1).

Table 1. Types of warehouses – classification

TYPES OF WAREHOUSES – CLASSIFICATION			
PURPOSE	INDUSTRIAL	DISTRIBUTION	RESERVE
PHYSICAL STATE OF MATERIALS	UNITIZED LOADS	LOOSE MATERIALS	LIQUIDS AND GASES
CONSTRUCTIONS CATEGORIES	OPEN-STORAGE	SEMI-OPEN	ENCLOSED
OPERATIONAL TYPE	UNDERGROUND	GROUND-LEVEL	SINGLE-STORY

Source: own work prepared on the basis Niemczyk, 2010, pp. 14-15.

2.1. Unit loads

Transport and warehouse packaging is formed into unit loads. A unit load is defined as a specific quantity of cargo consolidated into a single entity using auxiliary binding materials or transport equipment in a manner that ensures the stability of its shape, dimensions, and content from the point of consolidation throughout the entire transport chain until its disassembly (Bomba, 2018).

Materials stored in the warehouse are kept on appropriate pallets, in containers, bins, bundles, or packages. Additionally, unit loads influence the economics of transport and warehousing, as they contribute to reducing the space occupied by a given product and provide greater manoeuvrability, thereby mitigating the risk of damage (Bril, Łukasik, 2012). The most prevalent unit load utilized in enterprises is the wooden flat pallet, known as the Euro-pallet. Certain pallets are marked to facilitate identification within the storage yard. The species most resistant to mechanical damage include pine, spruce, and fir. Wood exhibits hygroscopic properties, meaning it readily absorbs water from the environment. The moisture content of the wood used for pallet production should not exceed 30% (Szeląg, 2018).

The open-pool pallet system involves the shared use of the same unit loads by multiple stakeholders to minimize procurement costs. This system consists of a deposit and a rental fee, allowing organizations to focus their strategies on more critical operations rather than on purchasing new pallets. One of the most prominent operators of open-pool systems is CHEP, which, due to its extensive experience, is frequently recognized as an industry leader (Sowa, 2021) (fig. 1).

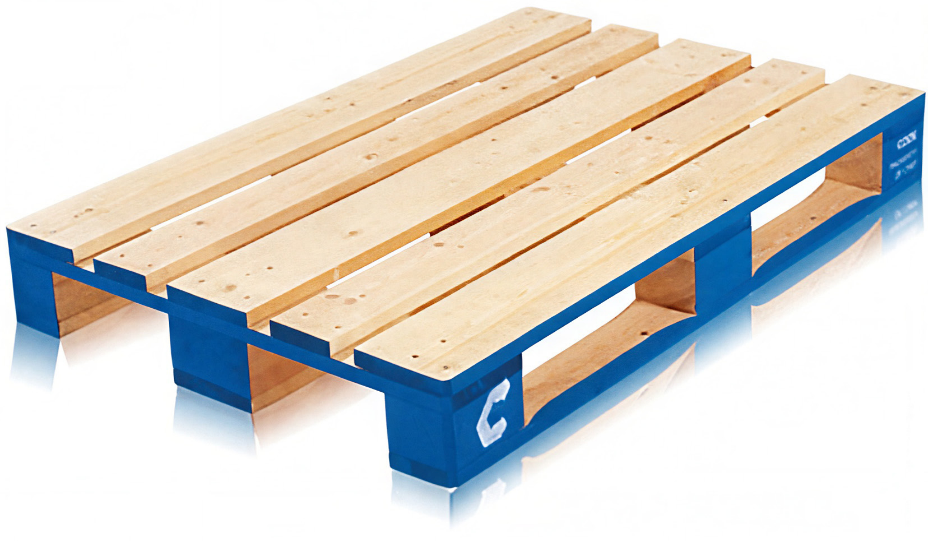


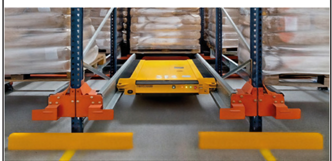
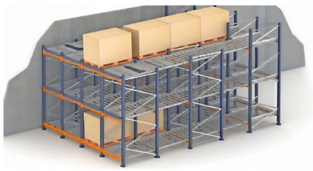
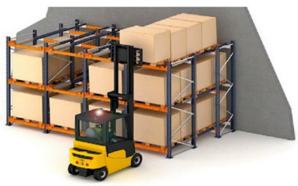
Fig. 1. CHEP Pallet 1200 × 800 mm (Chep.com.pl 2025)

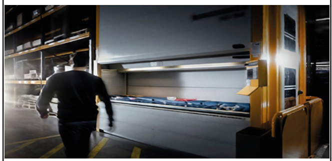
For the purposes of this study, four warehousing processes were identified:

1) Receiving: two types are distinguished: external and internal. External receiving involves unloading goods, typically with prior advanced shipping notice. This prevents operational chaos and allows for adequate warehouse preparation. Internal receiving, on the other hand, occurs when materials are transported between facilities (e.g., from hall A to hall B) within the same enterprise. Quality and quantity control consists of ad-hoc inspections to verify whether the goods meet basic standards. Fundamental quantity data is contained in the supplier's external note. Visual inspection involves checking for damage or crushing. If the incoming goods are raw materials required for production, laboratory testing or examination is mandatory. Upon successful testing, the raw material may be officially entered into the warehouse inventory.
2) Storage: this encompasses activities related to the placement of stock within the warehouse space in an appropriate and ergonomic manner. However, its primary objective is the safekeeping of inventory. Warehouses employ one of two slotting methods: fixed locations or random (free) locations. In the fixed location method, goods are assigned a strictly defined column and rack cell. This allows one specific product to be stored, thereby mitigating the risk of errors or difficulties in retrieval. Conversely, the random location method is the opposite to fixed locations: goods may be placed in any available opening. This method optimizes the warehouse's storage potential more effectively. It is estimated that transitioning from fixed to random location management can free up approximately 30% of warehouse capacity (Niemczyk, 2010). ABC Analysis allows stored goods to be categorized into groups based on their frequency of dispatch. Group A items are the most frequently picked and are therefore located closest to the dispatch zone. Groups B and C are positioned accordingly. This approach minimizes the order-picking route.

The application of ABC analysis in the warehousing process enables selective inventory management. From hundreds of stock units, it identifies those items that require special attention due to carrying costs and, in particular, the value of frozen working capital (Galińska, 2016). The most common storage configuration is the pallet racking system, understood as the infrastructure and the processes occurring within it. Introducing a unit load that is uniform in terms of dimensions and weight yields measurable benefits by reducing the operating costs for all participants in the supply chain (Marcjaniak, 2018). Meanwhile, racks – the carriers of unit loads – are defined as spatial, multi-level structures used for storing assortments on structural components (Papadopoulos-Woźniak, 2021) (tab. 2).

Table 2. Types of warehouse racks

RACK TYPES	FIGURE	APPLICATION
STATIONARY (FIXED)		A support structure, permanently anchored to the ground. Designed for bulk storage
MOBILE		A bolt-framed construction, anchored into the floor, which allows for movement within the warehouse space
DRIVE-IN WITH PLATFORM		Maximum space utilization. LIFO (Last-In, First-Out) operation
FLOW, GRAVITY-DRIVEN		Manufacturing enterprises; homogeneous products utilizing the FIFO (First-In, First-Out) method
PUSH-BACK		A pallet accumulation system for deep storage. Pallets are placed on rollers and pushed backward. Storage and retrieval are performed from the front.
SHELVING		Storage of goods with low weight and small dimensions

RACK TYPES	FIGURE	APPLICATION
CANTILEVER		Maximum utilization of warehouse floor space, designed for the storage of long items
SPECIALIZED		Designed for storing goods without direct support, e.g., rotary and vertical carousel systems

Source: own work, prepared on the basis of Szymonik, Chudzik, 2018, pp. 64-71.

The transport equipment most frequently utilized in warehouses and logistics centres includes manual pallet jacks, order pickers, electric/gas/internal combustion forklifts, reach trucks, systemic trucks, pallet stackers, and palletizers. Internal transport should not be treated as a separate activity, but rather as an integral element of the overall process. It is a process inherently linked to the execution of specific tasks within a system: establishing tight linkages within integrated chains allows for the rationalization and optimization of this process (Głodowska, Świderski, 2019). Unit loads can be positioned on the floor and within the storage space in various ways relative to the traffic aisles (Niemczyk, 2010). Row storage involves placing unit loads in rows separated by aisles, ensuring unobstructed access to the cargo. This method is most suitable for warehouses with high assortment diversity; however, its primary disadvantage is the underutilization of available floor space. Block storage involves stacking unit loads (e.g., pallets) directly on the warehouse floor, side by side and on top of each other, in blocks or stacks with minimal spacing. The main advantage is the highly efficient utilization of warehouse space. Implementing the FIFO (First-In, First-Out) or FEFO (First-Expired, First-Out) principles in this type of storage is challenging. This issue does not arise if a single row within the block contains units of the same assortment and batch. Stacking refers to placing unit loads one above another on several levels (Niemczyk, 2010). To ensure the stability of the stored unit, a vertical clearance of at least 0.4 m must be maintained between the top of the highest unit and the lowest point of, for example, the rack structure. The choice of stacking method (within racks or without) depends on the load's compressive strength.

3) Picking: order picking is the costliest activity in contemporary warehouses. It not only requires significant labour intensity but is also difficult to automate, can be complex to plan, and is prone to errors; most importantly, it has a direct impact

on customer service. The most frequent errors include omitting items from an order, shipping items other than those ordered, or dispatching incorrect quantities (Richards, 2016). To maximize efficiency, the placement of goods within the zone should minimize the travel distance. The methods most commonly applied are FIFO, FEFO, and LIFO (Last-In, First-Out). Picking is typically executed according to a specific picking list or via radio frequency terminals. Regardless of the method utilized, it is essential that the instruction contains precise data regarding the item, such as its location, quantity, packaging type, etc.

4) Issuing: although this is the final stage of the warehousing process, its role remains as crucial as the preceding operations. It involves the physical handover of goods to the recipient and the formal confirmation of this transaction. Two main types are distinguished: external and internal dispatch. In the former, the goods leave the company and are delivered to the recipient, which requires loading onto an external means of transport. In contrast, in the case of internal dispatch, goods are moved within the premises of a given enterprise, for example, to another department or warehouse. This type of dispatch is not subject to rigorous formalization (Galińska, 2016).

3. ROBOTIZATION, TRANSFORMATION AND AUTOMATION

Advancing automation and robotization continuously replace human labour across increasingly diverse fields. Automation refers to the reduction or substitution of human labour, in both physical and mental spheres, through the utilization of machinery. Humans still play an essential role in performing tasks in warehouses, despite advancing automation and digitalisation. Moreover, many warehouses rely on human operations, whether or not supported by some form of robotisation (Cretskens et al., 2026). Robotization, meanwhile, is a similar process, in which human tasks are replaced by the work of robots. The automation of service mechanisms through the application of software – referred to as robots – is known as Robotic Process Automation (RPA). Automation and robotization are irreversible processes (Kardasz, 2017). WMS (Warehouse Management System) is specialized software whose primary objective is to support and optimize procedures executed within a warehouse; it monitors, supervises, and manages the flow of materials. It may function as a standalone system or as an integrated component of MRP II (Manufacturing Resource Planning) or ERP (Enterprise Resource Planning) frameworks. Polish enterprises are demonstrating increasing confidence in WMS-class tools, which translates into steadily growing interest in such systems (Jurczak, 2019). The growing availability of panel data from WMS exports and structured survey data enables dynamic, longitudinal performance analyses. These data sets capture operational metrics along side qualitative indicators such as automation levels, flexibility, and service reliability (Rismanchian et al., 2026).

3.1. Warehouse Intelligence Software – a modern optimization solution

The objective of Warehouse Intelligence (WI) software is to optimize business processes within the field of intralogistics by modifying the parameters of the logistics management system (such as WMS or its derivatives). This allows for resource utilization planning at a high level of granularity that was previously unavailable without this type of software. It represents a fundamental shift compared to the traditional approach to digitalizing intralogistics processes.

Until now, WMS-class systems have treated the warehouse in a static manner, focusing on recording receipts, movements, and the dispatch of goods. In contrast, the goal of WI is to model warehouse processes and map the warehouse reality in the most detailed way possible. This makes it possible to identify which warehouse operational parameters should be changed and to what extent (Jurczak, Danisz, 2022).

3.2. Automatic Identification Systems EPC/RFID

The GS1 Automatic Identification System serves as the foundation of warehouse management (Niemczyk, 2010).

1) GTIN (Global Trade Item Number).
2) SSCC (Serial Shipping Container Code).
3) GLN (Global Location Number).

This system enables the seamless tracking and identification of goods throughout the supply chain. The EPC/RFID system combines the Electronic Product Code with radio-frequency identification to track individual products throughout supply chains. The Electronic Product Code (EPC), also referred to as a "radio barcode" or "next-generation barcode", is a modern system that offers numerous possibilities. It is based on a 96-bit packaging identifier capable of identifying individual items, bulk packaging, or logistics units. Furthermore, the EPC is equipped with a chip and an antenna, enabling the easy electronic recording of information as an encoded identifier, replacing traditional paper-based versions (Szczepanik, 2018). Radio Frequency Identification (RFID) provides a method for the efficient, rapid, and automated identification of various objects, including pallets and entire means of transport. Current standard barcode technology relies on placing labels with a Universal Product Code (UPC) on each product, which must then be read by specialized scanners (Ulatowski, Łukasik, 2017). RFID benefits every participant in the supply chain by enabling the automatic replenishment of stock with minimal human intervention, as well as the placement of tags containing product information within the packaging, for instance, to monitor the appropriate temperature during transport. RFID can be read from a distance depending on its technology and frequency, but it is important to note that especially when reading several tags at the same time, successful reading of all tags is not guaranteed. This is due to interference or absorption of radio waves (Nagy, Tamas, 2024).

3.3. Pick-by systems

Currently, "pick-by" systems are increasingly utilized in warehouses to enhance the efficiency of implemented processes, particularly order picking (Galińska, 2016). The Pick-by-Point system employs a mobile light source to precisely indicate storage locations; upon order activation, the light beam illuminates the specific shelf, while the required quantity is typically communicated via wireless headphones. Similarly, Pick-by-Light relies on visual signalling through LED displays mounted directly on the racks, providing precise data on location and quantity while enabling paperless, automatic inventory updates. Another solution is Pick-by-Voice, which utilizes voice communication through headsets, allowing operators to confirm tasks verbally and maintain "hands-free" productivity. Finally, the Pick-by-Scan system involves the direct transmission of order data from a central system, such as a WMS, to mobile scanners.

4. THE WAREHOUSE OF THE FUTURE

Automated Guided Vehicles (AGV) navigate along predetermined paths. When they detect obstacles, they must stop and wait until the obstruction is removed. These vehicles utilize various spatial orientation methods, including inductive, laser (LGV), visual, and gyroscopic systems. AGVs are able to perform order-picking tasks in collaboration with humans by following predetermined paths to autonomously navigate through the warehouse and aid human pickers by carrying the crates for collected orders (Hosseini et al., 2026). In contrast, Autonomous Mobile Robots (AMR) are fully independent. Unlike AGVs, they can not only detect obstacles but also decide to bypass them and calculate a new, optimal route. In addition, the precise navigation and task execution provided by AMRs help minimize human errors, improving accuracy and overall productivity (Zhen et al., 2025). It is estimated that AMRs will constitute 80% of industrial robots by 2027, with their number in factories reaching 15 million by 2030 (Domagała, 2025). The automation of warehouse processes also allows for the elimination of costs associated with heating or lighting. Furthermore, it enhances occupational safety and promotes error-free task execution. Machine learning algorithms can analyse historical data, seasonality, demand fluctuations, and inventory levels to recommend optimal replenishment and slotting scenarios. Intelligent warehouses are a key element of the digital transformation in logistics. Looking ahead, the further development of smart warehouses is expected to trend toward hyper-automation (the total elimination of manual processes), 24/7 autonomous operations, and cloud-based logistics management known as Warehouse as a Service (Domagała, 2025).

The Lean philosophy will be increasingly applied alongside cross-docking, supported by automated racking systems reaching heights of 30-45 m. These facilities will incorporate photovoltaic panels and wind turbines aimed at harnessing energy. Several companies are experimenting with drones to move small, lightweight products from delivery vans to customer locations – the "last mile" challenge. Drones are already being used by some firms within warehouses for cycle counting and other inventory monitoring tasks. To date, it is humans, rather than software, that have maintained control over these drones (Friedman, 2021).

4.1. Intelligent forklifts

The forklift remains the most frequently utilized means of transport in the warehouse. The selection of an appropriate vehicle is dictated by such factors as the type of cargo transported and the intensity of the operator's workload. Beyond their primary tasks, forklifts are also used for auxiliary production activities, such as supplying individual production departments with pallets, or facility maintenance tasks, including machinery repair and snow removal. The choice of equipment must result from a thorough analysis of working conditions – surface type, temperature, dust levels, transport distances, and the frequency of duty cycles. Only such an approach allows issues related to the durability and efficiency of the device to be avoided (Zając, 2025). The short distances to be covered by forklifts and their use in relation to the loads moved must be taken into account because the less loaded a forklift is, the less efficient it becomes. Moreover, these vehicles are regularly measured by their costs in relation to their operators – forklift drivers – who are an important part of a storage system, as well as maintenance costs and their use (hours worked), based on the reading of the hour meters inserted in the forklifts (Nunes et al., 2026). Continuously evolving technology enables the implementation of appropriate practices, thereby increasing operator safety. An example would be that equipment can help fight fatigue and discomfort, empowering operators to remain focused and efficient throughout their shift. Product characteristics that promote comfort, such as power-assisted steering, extra cushioning for shock absorption, and pedal-free operator presence systems are also advantageous (Yale, 2026).

For instance, the Raymond intelligent forklift (fig. 2) prioritizes the operator, who is equipped with a safety harness and a lanyard. If the operator is not correctly tethered, the load-lifting capability is disabled, and the vehicle's speed is restricted to 1 mile per hour (approximately 1.6 km/h). Intelligent forklifts enhance warehouse productivity through the use of real-time monitoring, data analytics integration, and operator-assist technologies, leading to improved efficiency and optimized labour allocation (Curtis, 2024).

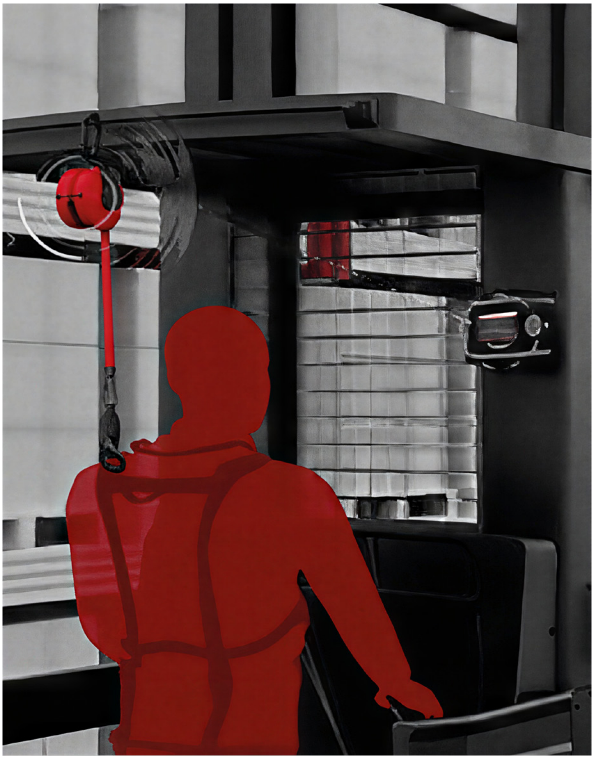


Fig. 2. iWAREHOUSE Integrated Tether System (Raymondcorp.com 2025)

5. METHODOLOGY

In the era of the evolution of modern technologies, the warehouse has ceased to be merely a place for storing goods and has become an integral link in production systems. The role of modern technologies is increasingly critical for maintaining operational continuity through such aspects as synchronization with production lines or the optimization of buffer stocks. The research was qualitative and based on the single-case-study method. The choice of this method was dictated by the need for a detailed analysis of the implementation of specific technologies, including AMR and RFID. The case study enables the researchers to identify barriers and processes that could be overlooked in quantitative research.

The study used an interview with the deputy warehouse manager of Rosinski Packaging, a producer of packaging, caps and plastic bottles based in Bielsko-Biała. The interview was conducted on 18 November 2025, via MS Teams remote communication tools, and was a disclosed, individual and categorized study. The conversation was preceded by sending out a questionnaire of relevant issues, which enabled the deputy manager to prepare detailed data regarding warehouse processes. The research sample was selected purposively, with the key criteria being the function performed in the organizational structure and knowledge of the specifics of the assortment. The deputy manager's data remained anonymous. The interview consisted of open-ended questions related to the company's development perspective in the field of modern technologies, as well as the individual opinion of the deputy manager regarding the applied warehouse management methods. Moreover, the interview was based on the coding and categorization of the respondent's statements, which allowed the degree of technological maturity of this enterprise to be assessed and identification of key technical, financial, and human barriers. In the first step, statements were transcribed and meaning units extracted. Following this, appropriate codes were assigned to individual phenomena, such as automation obstacles, system implementation costs, or improvements resulting from the implementation of modern tools.

This study provided an in-depth analysis of the implementation of technologies that will change the paradigm of industrial warehouse work in terms of replacing traditional methods of internal transport and goods records with autonomous mobile systems (AMR) and digital identification systems (RFID), while minimizing direct human involvement. Although the study concerns one entity, the highly detailed data obtained from Rosinski's deputy warehouse manager allows for a reliable presentation of adaptive mechanisms that can serve as a reference point for other enterprises with a similar production profile.

6. RESEARCH RESULTS

Based on the research, it can be concluded that implementing technologies supporting the picking process through "pick-by" systems is unfeasible due to the specific warehouse environment. Regarding Pick-by Light: "At Rosinski Packaging, we face challenges that this technology cannot solve; for instance, we produce high-volume packaging (bottles, canisters) stored only on pallets rather than in small racking bins" – Deputy Warehouse Manager at Rosinski Packaging. There is potential difficulty in verifying the consistency of information provided by the system with the actual inventory on the rack due to the cubic volume of individual products. On the other hand, Pick-by Voice also presents a challenge due to the high noise levels originating from the production halls adjacent to the warehouse. Additionally, the workforce is multinational, which would extend the time required for potential tool calibration. Regarding product labelling technology, the enterprise utilizes GS1 system standards, such as barcodes, because "every single one of our customers has barcode readers" – Deputy Warehouse Manager at Rosinski Packaging. It is also important to note that the cost of printing a barcode is minimal, whereas implementing RFID tags would impose an additional financial burden on the company. The storage process itself is also unconventional, as the first batch of newly produced packaging is assigned a location by a warehouse worker rather than a system. When asked about the reasoning behind this decision, the Deputy Warehouse Manager stated: “With large and light packaging, a visual assessment of whether a given pallet will fit into a specific rack opening – taking into account, for example, a slight lean of the goods beyond the pallet outline – is still more effective when performed by a human”. The implementation of modern forklift components equipped with sensors, cameras, or lifting assistance systems is unfeasible due to the outdated warehouse infrastructure, specifically the flooring and the racking system. “In the old hall, where the floor has *settled* and shifted over the years, forklift sensors would constantly report errors or force a reduction in operating speed for safety reasons” – Deputy Warehouse Manager at Rosinski Packaging. Current monitoring of rack occupancy also fails to meet predefined assumptions, as the enterprise has not implemented any solution allowing for a real-time, automatic overview of rack availability. “Planning space for an incoming batch of goods is primarily done through a physical inspection of the warehouse by a worker or the warehouse manager” – Deputy Warehouse Manager at Rosinski Packaging. This leads to a lack of efficiency in the bottleneck process, where “goods are placed wherever there is free space, rather than where it would be optimal from a dispatch logistics perspective” – Deputy Warehouse Manager at Rosinski Packaging. The lack of rack occupancy control generates a domino effect, overloading other stages of the supply chain, increasing operating costs, and causing delays in deliveries to end customers.

7. CONCLUSIONS

Investing in modern technologies undeniably translates into future profits for companies. However, it requires significant adaptation in both economic and technical terms. The dynamic changes occurring in the field of AI essentially force companies to gradually implement these solutions. Traditional storage and picking methods based on manual labour and static databases are giving way to ecosystems that are autonomous, predictive, and fully integrated. Success in this field is measured not by the number of devices deployed, but by the extent to which the order-to-shipment cycle is shortened while minimizing the unit cost of operations. In the coming years, warehouse process optimization will involve not only purchasing robots but, above all, data integration. Even the most advanced systems, such as Very Narrow Aisle (VNA) trucks or Autonomous Mobile Robots (AMR), lose their effectiveness when confronted with architectural barriers, such as the uneven flooring found in the company analysed in this study. Unlike forklifts, AMRs do not require a driver; they are safe for pedestrians, and are unaffected by noise, allowing “empty runs” by staff to be eliminated. This article demonstrates that the future of the industry lies in Vision Picking (AR) and AI Vision Gates, which eradicate human error without being affected by the acoustic conditions of the hall. The worker wears Augmented Reality (AR) glasses, seeing arrows that lead to the rack and a photo of the product to be picked on the lens. At the loading dock, a camera system with an AI processor is installed; as a forklift passes with a pallet, the system reads all barcodes in a fraction of a second (even multiple codes simultaneously) and verifies them against the order in the system. Virtual reality (VR) can improve the spatial orientation of mobile robots by developing sophisticated navigation solutions that reduce time and financial costs (Zimmer et al., 2025). Implementing these solutions in Rosinski Packaging could significantly contribute to increased warehouse efficiency and improved process quality. The pioneering Warehouse Intelligence software would seem to be an equally beneficial solution, as it allows for an accurate mapping of warehouse reality; in the case of the analysed entity, this represents one of the primary challenges. A more thorough analysis of warehouse dysfunctions would allow for the accurate identification of remedies, enabling the enterprise to embark on a path of implementing ever-newer technologies. These process-enhancing technologies and next-generation systems dynamically change storage zone priorities based on demand, thereby shortening picking paths. Warehouses and distribution centres are considered an important element in supply chains, and there is a need to address perspectives and features including next-generation agility and adaptability to market demands, modular and connected systems, learning and intelligent agents, treating data as an asset, virtual system models, and digital supply chain visibility (Dusadeerungsikul et al., 2022). Modern warehouse optimization is a process involving continuous improvement supported by digital tools capable of adapting to changing market requirements, product types, and customer expectations. Warehouse management is a strategic area, and its effective execution provides businesses with a competitive advantage (Biçer et al., 2025). Thus, the winners will be those companies capable of combining infrastructural stability with appropriate, intuitive software.

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WYKORZYSTANIE NOWOCZESNYCH TECHNOLOGII W OPTYMALIZACJI PROCESÓW MAGAZYNOWYCH

Streszczenie

Artykuł wraz z elementem studium przypadku analizuje ewolucję procesów magazynowych w kierunku ich unowocześniania, koncentrując się na praktycznych aspektach wdrażania innowacji w wymagającym środowisku przemysłowym. Głównym celem i problemem badawczym opracowania jest ocena możliwości wykorzystania nowoczesnych technologii informatycznych i automatycznych w celu optymalizacji procesów oraz zwiększenia efektywności funkcjonowania magazynu. Analizie poddano zdolność adaptacyjną przedsiębiorstwa rozumianą jako szybkość wdrażania rozwiązań usprawniających strukturę magazynu. Aspekt modernizacji dotychczasowych systemów pełni kluczową funkcję w procesie implementacji nowoczesnych metod zarządzania magazynem. W opracowaniu przybliżono wykorzystanie technologii od poziomu jednostek RFID (Radio Frequency Identification) po złożone systemy klasy WMS (Warehouse Management System). Wyzwaniem dzisiejszego sektora przemysłowego jest umiejętność zintegrowania AI czy uczenia maszynowego z wciąż istotną pracą człowieka. Cyfrowa transformacja staje się realną przewagą konkurencyjną, a nieprzewidywalne czasy wymuszają podjęcie konkretnego stanowiska ze strony kierownictwa, co przekłada się na zwiększenie wytrzymałości przedsiębiorstwa. Nowoczesne magazynowanie stanowi klucz do osiągnięcia doskonałości operacyjnej i optymalizacyjnej. W opracowaniu wskazano też na szansę integracji AI z personelem poprzez systemy typu pick-by, jednocześnie identyfikując brak możliwości szybkiej adaptacji jako główną barierę wdrożeniową. Realizacja nowoczesnych rozwiązań jest trudna i kosztowna z punktu widzenia organizacji, ponieważ wymaga pełnego zaangażowania kadry zarządzającej oraz ciągłego udoskonalania infrastruktury i zasobów, a także odpowiedniego doboru technologii do profilu działalności, asortymentu i kontrahentów. Konkludując, osiągnięcie optimum operacyjnego z wykorzystaniem AI jest możliwe, o ile przebiega stopniowo i rozważnie.

Słowa kluczowe: magazynowanie, RFID, WMS, automatyzacja, inteligentny magazyn