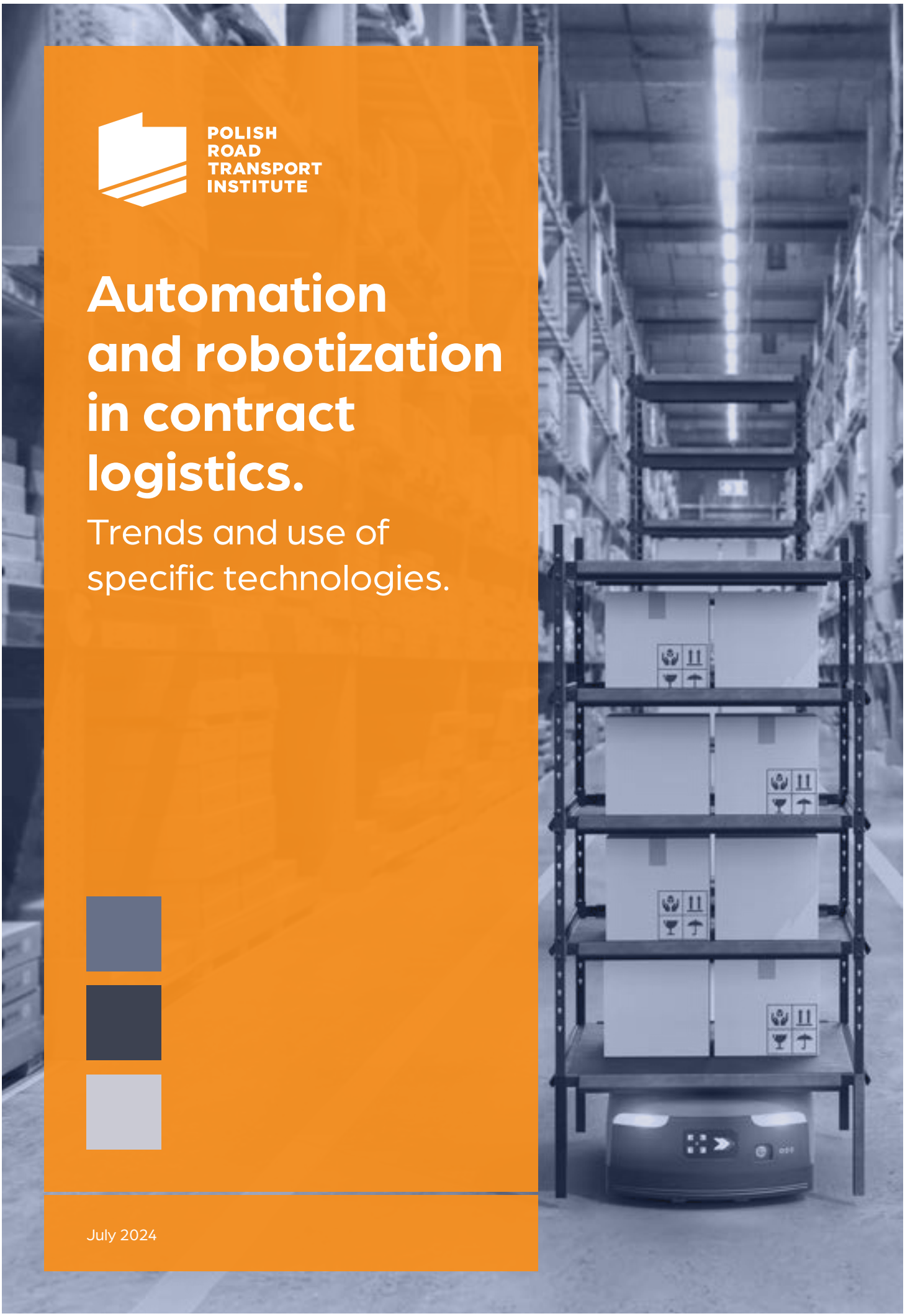
POLISH ROAD TRANSPORT INSTITUTE

Automation and robotization in contract logistics.

Trends and use of specific technologies.



July 2024

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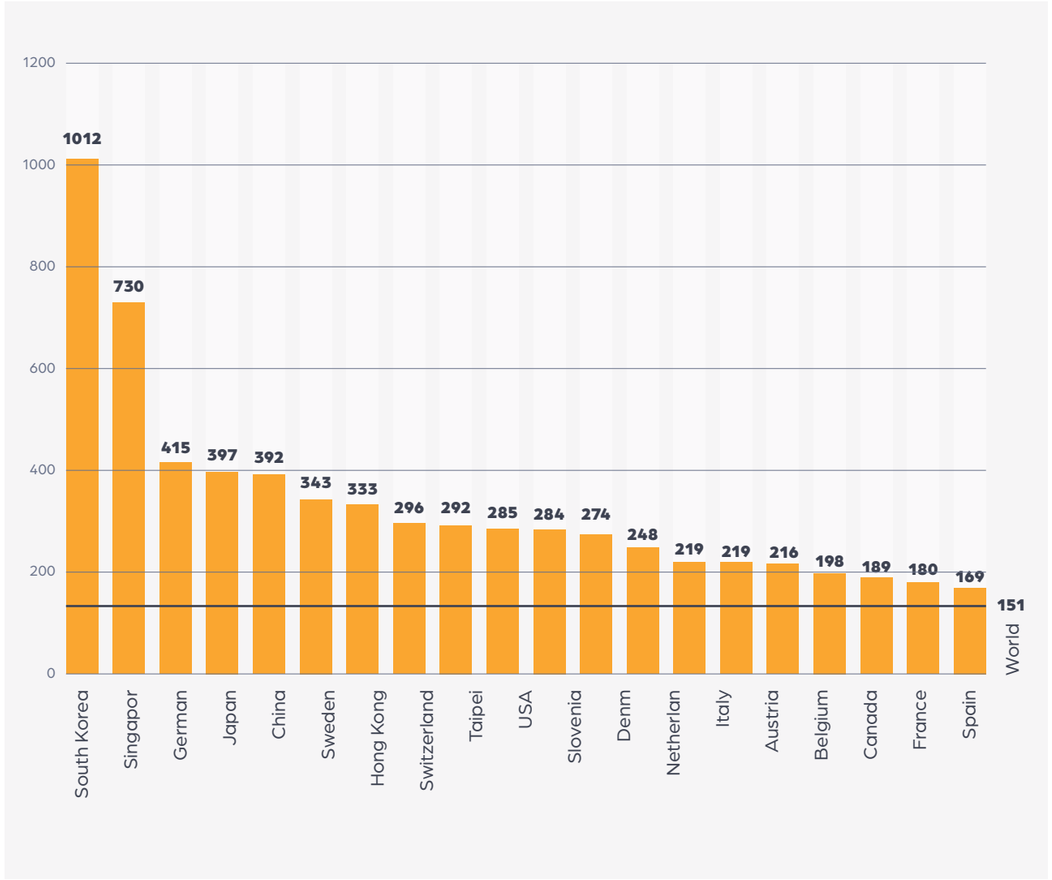
1 Introduction

The development of technology over the last dozen or so years has led to a significant increase in the level of production mechanization and automation of enterprises. The International Federation of Robotics (IFR) has identified five trends in 2024 that global robotization will follow. These include: the extensive use of artificial intelligence and machine learning, extension of the cobots' operating range, popularization of mobile manipulators, digital twins, as well as humanoid robots. [76]

Digitalization has increased the efficiency of the entire business sector mainly on three levels: in terms of creating value in the new business reality, in terms of creating value in processes that use the concept of customer experience management, and in building the fundamental capabilities of the company. [1]

Logistics, let alone warehousing, is not an exception here. New technologies can not only help the development of operations within an economic area or logistics structure, but also change the balance of power of the entire sector.

Rys. 1.1. Liczba stosowanych robotów w przemyśle na 10 tys. pracowników na świecie w 2022 roku.



Source: [77]

Unfortunately, Poland is far from the forefront in the race of global automation and robotization. According to IFR data from the World Robotics 2023 report, South Korea (1,012), Singapore (730) and Germany (415) had the most installed robots per 10,000 employees in 2022. Poland was not even in the top twenty of the list, which included the Czech Republic with 189 robots. According to the same list, 22,742 units worked in Poland, which translated into a density of 71 per 10,000 employees. This represented about half of the European average. [77; 79] Moreover, according to Statista, the share of companies using work automation in Poland in 2021–2023 increased from only 4.6% in 2021 to 6% in 2023. [78]

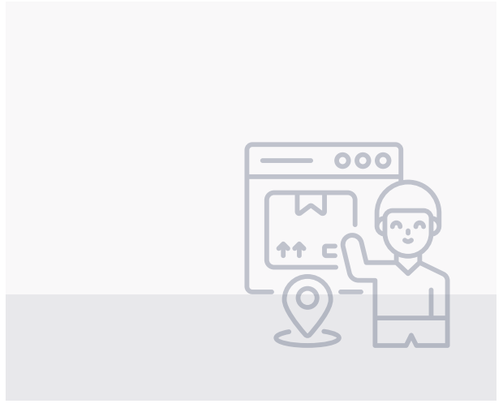
We present this report to you in order to describe in detail the technologies already used in practice in contract logistics, as a kind of roadmap for the T&L industry.

2 Level of digitalization of warehouses in

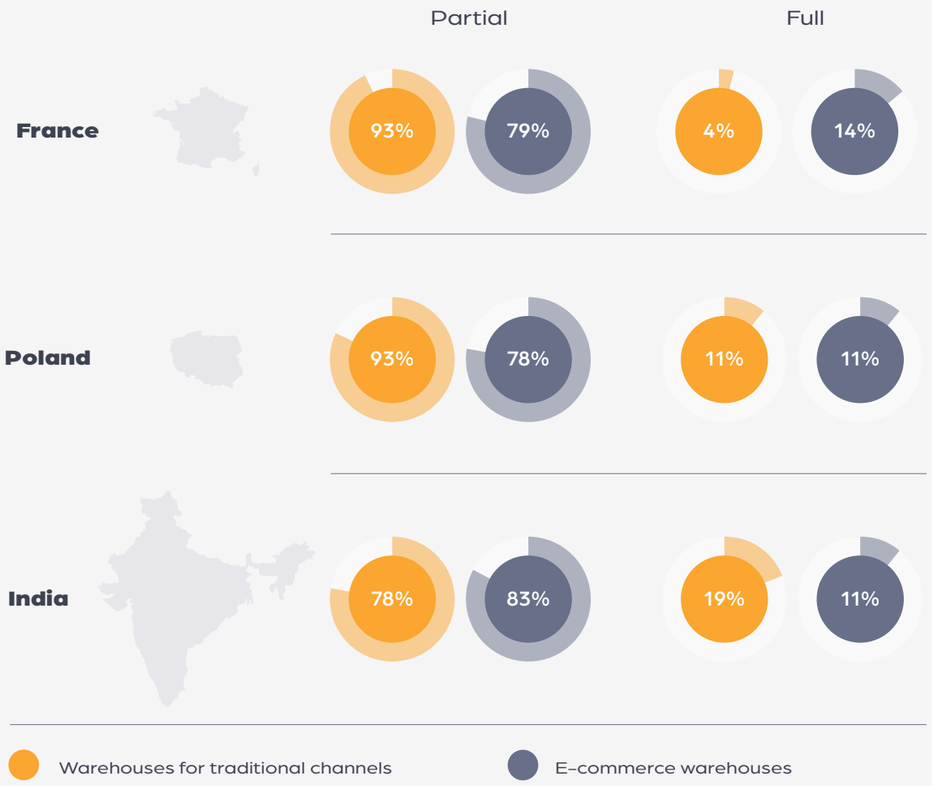
Digitalization and automation are not the same thing. Digitalization should be understood as the introduction or increase of the share of digitalized data in the process. Automation, on the other hand, is the replacement of human work by a machine. Although digitalization and automation are two separate phenomena, in most cases they occur at the same time. The vast majority of modern automatic systems operate on the basis of digital data. So when we talk about automating inventory processes, we also mean digitalizing them.

2.1. Description of the warehouse market in Poland

The report "Warehouse automation: a catalyst for business efficiency," published by FM Logistic in February 2023 and based on surveys of logistics professionals in three sectors – FMCG, Retail and Beauty & Luxury – in France, Poland and India, shows that up to 82% of companies consider at least partial automation to be the norm in all types of warehouses. What's more, 76% of companies that currently have partially automated warehouses for e-commerce and 45% of those who have partially automated warehouses for traditional channels intend to fully automate them in the future.



Rys. 2.1. **Stopień częściowej automatyzacji magazynów w trzech krajach: Francja, Polska, Indie**



Źródło: FM Logistic

Jean-Christophe,

Machet CEO, FM Logistic.

Warehouse operations are not only becoming more complex, but they are also becoming increasingly important for sustainable supply chains. The growth of e-commerce, supply chain disruptions, and rising labor costs are forcing companies to take steps to increase warehouse productivity and efficiency. One of these steps is undoubtedly automation

2.2. Key factors for warehouse automation

Question: What is the importance given to the different drivers of automation and innovation in traditional channel warehouses?

95% **Increase in operational efficiency / increase in the correctness of order fulfillment**

Key factors for automating e-commerce warehouses

- Improved operational efficiency/improved order fulfillment — 93 %
- Better customer service — 90%
- Error reduction — 88%
- Better data management — 85%
- Speed of order preparation and delivery — 85%
- Real-time visibility and tracking / better inventory control — 83%
- Increased security — 83%
- Improved performance/better order fulfillment efficiency — 80%
- Optimum space allocation — 78%
- Cost efficiency / reduction of handling and storage costs — 78%
- Enhanced supply chain sustainability — 76%
- Improved visibility into changes in cost structure — 73%
- Encouragement for standardization — 68%
- Lack of skilled labor — 61%

Key factors for automating warehouses for traditional channels

- Improved operational efficiency/improved order fulfillment — 93%
- Better customer service — 89%
- Increased security — 86%
- Speed of order preparation and delivery — 85%
- Error reduction — 85%
- Optimum space allocation — 84%
- Better data management — 83%
- Improved performance/better order fulfillment efficiency — 72%
- Enhanced supply chain sustainability — 77%
- Cost efficiency / reduction of handling and storage costs — 77%
- Enhanced supply chain sustainability — 76%
- Improved visibility into changes in cost structure — 73%
- Encouragement for standardization — 68%
- Lack of skilled labor — 61%

The entrepreneurs surveyed for the purposes of the report indicated that the main reason (94%) for automation in their organizations is the improvement of efficiency, accuracy of operations and customer service. Warehouse operators for e-commerce also clearly indicate (90%) that an important factor in favor of automation is the reduction of errors in processes. This is directly related to the development of e-commerce, which imposes ever higher expectations on logistics operators in terms of time and quality of service. For operators of traditional channel warehouses, increasing security appeared to be more important (84%).

While all warehouse operators see value in process automation, the majority (80%) report that the high cost of investment and long payback periods are a major barrier to automation. Respondents also raise the issue of the party responsible for conducting and financing the process. More than 50% believe that companies need to make initial investments. For 3PLs who have chosen to bear the investment costs, the preferred solution is to add capital expenditure to the project fee and charge it to the company for the duration of the contract. It is worth noting that most companies plan to make even small investments in automation or innovation, and about two-thirds of them have a separate budget for this purpose. In the vast majority of cases, it is in the range of up to 19% of their total investment outlays.

More than three-quarters of 3PLs believe that automation reduces operating costs. At the same time, the expected period of reaching the break-even point of the investment is from 2 to 4 years. Like payback time, it can be a critical factor in automation decisions.

The digitalization and automation of warehouses is an unstoppable trend, as the experience of the last few years shows. It is essential for optimizing processes, space allocation and the most efficient management of resources. Large companies have already discovered that once they reach a certain size, it is impossible to effectively manage operations without automation. This is confirmed by FM Logistic's research, according to which 43% of large e-commerce companies and 30% of large traditional channel companies currently have at least one or more fully automated warehouses.

2.3.Technologies used in FM Logistic

FM Logistic has also implemented technologies for its customers to optimize the most sensitive stage, i.e. order picking. One of them are Locus robots, which support order picking. The latest implementation is AutoStore technology for automated storage and order processing. It uses warehouse robots that move on rails across the surface of the warehouse area, pick up bins and deliver them to the operator's station, where the picking process takes place. Thanks to these technologies, the workload of employees has been relieved, and at the same time the accuracy and correctness of picking has increased. Innovative technologies have also been part of the packaging process. An automatic carton erector – perfectly tailored to the size of the contents and a machine for cutting the height of boxes increased the fill factor of vehicles by 30%. Finally, digital systems have been implemented to evaluate workstations in terms of ergonomics, in order to take ergonomic criteria into account when designing further automation systems.

Yannick Buisson,

Managing Director of FM Logistic for France, Spain and Central Europe

We innovate and automate to deliver measurable results. We strive to automate warehouses wherever it makes operational and cost sense, while taking steps to raise awareness of the growing importance of automation. Full automation of all warehouse processes – from receipt of product to shipment – is not yet our goal

The example of FM Logistic shows that even smaller, but wisely implemented changes have a huge impact on the quality of warehouse processes and give a huge competitive advantage. The trick is not to make a huge investment in automation, but to analyze and optimally implement systems that will actually contribute to improving the quality of work and efficiency of the warehouse.

3 Implementation of modern technologies in warehouse management

While international supply chains are still recovering from the COVID-19 pandemic, the most devastating in the history of the European Union (Brussels has allocated more than €2 trillion to the stimulus and recovery plan), the economic recession caused by the armed conflicts in Eastern Europe and the Middle East and the sustainability goals of logistics are bringing new challenges. [2] There is much evidence that disruption of logistics networks is the new normal in the warehouse economy. To avoid destabilizing supply chains and to be agile and responsive to business opportunities, the logistics industry is looking for solutions that support the transformation of the delivery industry.

3.1. Transformation of the logistics structure

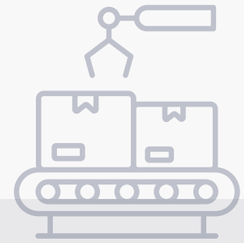
The phenomena that have the greatest impact on the transformation of the logistics structure are twofold: those related to economic development, i.e. the globalization and internationalization of operations, and those resulting from the technological revolution, i.e. the digitalization of the broadly understood levels of cooperation between companies and process control in the distribution network. The most important phenomena worth mentioning are:

- the use of information and telecommunications (ICT) technology, including satellite and radio identification systems, allowing for the coordination of product and information flows in time and space,
- standardization and automation of business processes; their individualization requires increased delivery discipline and continuity of inventory optimization processes,
- customization of products (departure from mass production in favor of personalized production), which requires an increase in their number in the market, increased choice, acceleration of quality, convenience of purchase for consumers, which implies flexibility of production, in accordance with market signals, as well as the search for and development of distribution channels
- a growing number of large-format stores maintaining smaller inventories and requiring better service from suppliers,
- transformation of distribution processes that require data collection and analysis, expansion of the information resource chain, integrating data from external cooperators, suppliers or customers in real time,
- expanding forms of cooperation between companies and the implementation of new business models, resulting in an increased tendency to outsource logistics services,
- the shortening of the market life cycle of products, which imposes time discipline in the process of production and distribution of the implementation of a new product, as consumers do not want to wait long for novelties or improvements.

This means that the challenges faced by the modern logistics sector do not only concern the delivery of goods or the storage of cargo, but also the processes of managing and coordinating the cooperation of companies in real time as a response to rapidly changing demand. In order to meet these expectations, logistics companies focus on improving process support through better use of the company's existing resources and the implementation of new solutions.

3.2. Evolution of technology

In an industry that relies on knowledge and data, information technology plays a key role in process management. The awareness of the breakthrough nature of these technologies, which build a competitive advantage and provide new opportunities for the development of the organization, gives an incentive to change the adopted way of conducting transport and logistics activities. The main objectives include international networks linking production plants, machines and logistics facility management systems, autonomous information exchange within unified systems that integrate devices and databases, or intelligent, traceable products that know the possibilities and paths to reach their destination. This approach provides benefits in terms of streamlining the production and distribution of goods. New technologies therefore affect logistics constantly, forcing the sector to evolve and implying new challenges (Table 3.1).



Tab. 3.1. Evolution and challenges in logistics

Reference area	Past	Present	Future
Communication system	Analog	Analog and digital, Internet & Intranet	Digital, Internet of Things, digital/technological cloud
Concept	Neo-Taylorism	Lean Management, Lean Production	Smart Factory, virtual organizations, digital supply chains
Solution	Mechanization and automation	Automation and computerization	Virtualization and system integration, robotization, artificial intelligence, cyber-physical system (CPS)

Źródło: [1]

It is important to be aware of the mechanisms at work in the market for new technologies. Revolution and trend are very different concepts, and by focusing only on the most popular technologies, it is easy to overlook the significant potential of solutions that can have a significant impact on industrial transformation. Companies seeking long-term growth should focus on investing in the technology trends that are most important to their business.

Every year, McKinsey Global Institute analysts distinguish several technologies that have the greatest potential to change business structures. Table 3.2 presents the results of McKinsey research from 2013 [4] compared to 2023. [5] It highlights how much the list of technologies that have the greatest potential to change the business and society has changed. The table also shows the results of Deloitte's research [6] on the most common technologies used in the logistics industry in 2024.

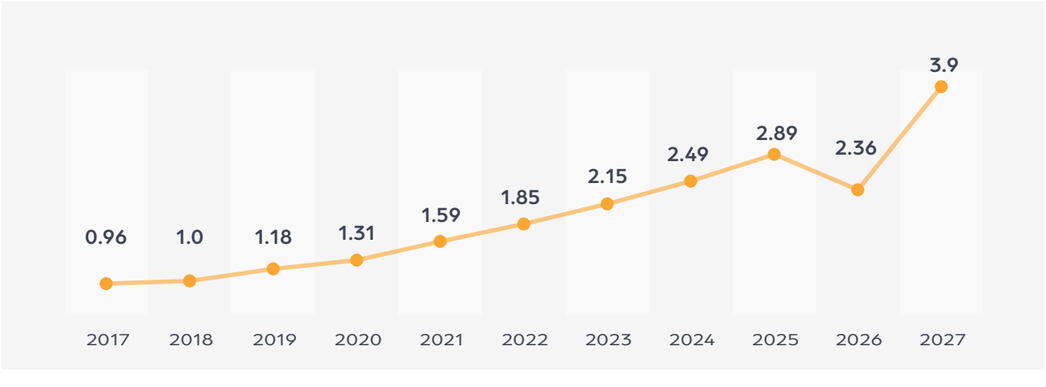
Tab. 3.2. List of technologies with the greatest potential in 2013 and 2023 and the greatest potential of technology in logistics in 2024

2013	2023	2024
Mobile Internet	Artificial intelligence	Artificial intelligence
Automation of knowledge -based work	Industrialization of machine learning	Blockchain
Internet of Things	Generative AI	Cloud computing and data storage
Tech cloud	Next-generation software development	Autonomous vehicles and drones
Advanced robotics	Trust architectures and digital identity	Internet of Things (IoT)
Autonomous technologies (means of transport)	Web3	Inventory and network optimization
Genomics	Advanced connectivity	Predictive analytics
Energy storage	Cloud and edge computing	Robotics and automation
3D printing	Electrification and renewables	Sensors and automatic identification
Advanced materials	Mobility technologies	Wearable and mobile technology
Renewable energy	Climate technologies beyond electrification and renewables	3D printing

Źródło: Opracowanie własne na podstawie danych McKinsey i Deloitte

The progress and development of new technologies is evidenced by spending on digital transformation services. By 2027, global spending on digital transformation is estimated to reach $3.9 trillion. (Fig. 3.1). The market for generative artificial intelligence, whose applicability is accelerating, could grow from $40 billion in 2022 to $1.3 trillion in 2032. [7] In turn, the robotics industry could grow from $62.7 billion in 2022 to $218 billion in 2030, [8] and cloud computing could grow from $676.2 billion in 2024 to $218 billion in 2030. [9]

Rys. 3.1. Global spending on digital transformation technologies and services 2017–2027 ($trillion)



Source: [33]

In the case of the logistics industry, the key solutions for many years have been integrated, comprehensive IT systems that cooperate with each other to perform the agreed tasks within the entire logistics complex and consolidate the communication process between individual departments in the company. An important role in the process of supply chain management is played by ERP (Enterprise Resource Planning) systems, based on the concept of integrated enterprise management as a unified structure for rational and efficient use of available potential.

In most manufacturing and logistics companies, widely used tools to support the warehouse management process are WMS (Warehouse Management System) systems, which can be a program independent of ERP, and programs in which individual modules are responsible for warehouse management. Warehouse management systems support RFID (Radio Frequency Identification), pick-to-light, pick-to-voice, or pick-to-belt technologies, which are primarily useful in the picking process (increasing productivity, improving picking accuracy and efficiency).

Warehouse Control Systems (WCS), on the other hand, are advanced software used to control and manage processes and automatic devices in the warehouse, such as conveyors, sorters, ASRS systems, warehouse robots and other automated transport systems. The WCS acts as an intermediary between the higher level of warehouse management (WMS) and the physical equipment operating at the warehouse level. The main functions of the system include: traffic and routing management, integration of automatic devices, monitoring and control of operations and broadly understood optimization of goods storage.

The future direction of investments in modernization of warehouses and modern solutions used in the process of storing goods remains automation, autonomization,

mechanization and robotics, including the support of artificial intelligence. Such solutions are increasingly becoming the basis for areas such as goods receipt, goods storage, order processing, sorting, cross-docking, picking, shipping or internal transport and are widely used in individual areas in warehouses. [10]

3.3. Warehouse operations and improvements

According to a study by the Material Handling Institute, the implementation of new technology in warehouses leads to a 50% increase in productivity and a 25% reduction in operating costs. [11] With the growing demand for fast and efficient supply chain operations, the role of technology in warehouses is expected to continue to gain further prominence. The most significant developments that have had both positive and negative impacts on the implementation of intelligent warehouse technologies in recent years include:

- global warming, which has caused extreme weather conditions that disrupt the supply of goods (floods, heat waves) and which has also led to an increase in energy prices,
- the COVID-19 pandemic, which forced companies to temporarily minimize human labor due to the need to maintain social distancing, but immediately afterwards drove the development of automated logistics systems,
- the progress of globalization, which, contrary to the assumption that it would soon change in favor of regionalization of production, has been accelerated by the development of e-commerce platforms and the need to automate related processes. [12]

Companies faced two challenges: first, to meet the growing consumer demand, and second, to maintain a competitive advantage. As a result, distribution center automation – improving the efficiency of every aspect of the warehouse flow from receiving to shipping – has become a priority for most companies.

Selecting and implementing technology in a warehouse is a process that requires key decisions. The following factors have been identified in the literature as having a direct impact on the success of implementing modern solutions. They are divided into the following groups:

- business factors, related to the definition of logistics processes in the company. If the company uses an ERP application, this section specifies how information is exchanged between the warehouse management system and the host application,
- technical factors, relating to hardware infrastructure (e.g., choice of application server, radio terminals, scanners and barcode printers). The design of the entire wireless network should be an important consideration in the absence of network infrastructure preparation,
- organizational factors, i.e. structured activities to implement the project based on established rules (e.g. training of employees, creation of working groups, implementation teams, appointment of leaders responsible for specific areas),
- operational factors, i.e. establishing the rules to be followed in the daily use of the systems. [10]

It is also important to determine achievable objectives, the degree of achievement of which will demonstrate the benefits obtained as a result of the use of new solutions. They are an important reference point for analyzing the subsequent impact of warehouse infrastructure implementation and modernization decisions. The literature identifies the following strategic and specific objectives that can be used in the evaluation of systems implemented in logistics: improving the quality of logistics services, improving the quality of customer service, reducing lead times, reducing the flow time of goods

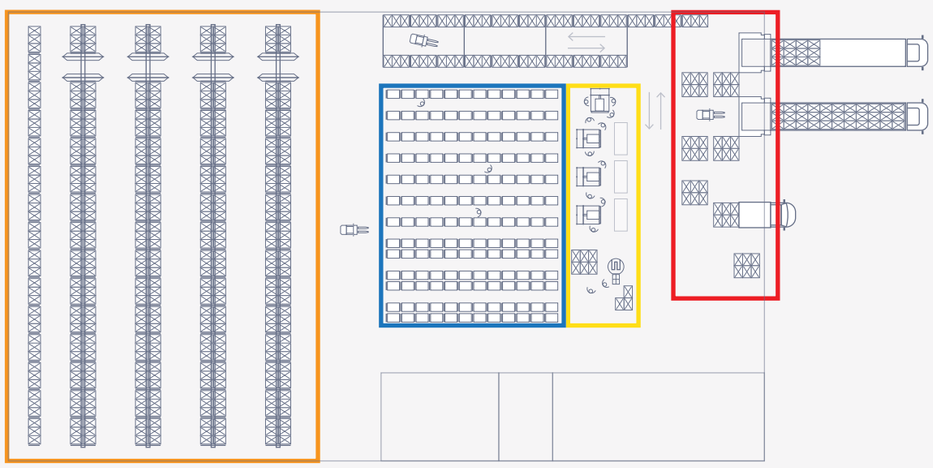
in the warehouse, and reducing costs. In the context of systems used in storage facilities, it is also necessary to consider better use of space, improved safety and reduced errors. [10]

Due to the course of operations and the need to create a consistent process, warehouses are divided into several main zones (Fig. 3.2). For the purposes of this study, the most common structure has been adopted, divided into the following zones:

- **unloading and loading zone,**
- **goods receipt zone,**
- **storage zone,**
- **picking and sorting zone,**
- **release and shipping zone.**

Zones are physically or logically separated areas in warehouses, defined by the type of goods stored in them, as well as the division of equipment and personnel involved in storage, handling or picking. Depending on their role and needs, warehouses can also have zones for returns, maintenance, repackaging, quarantine, or complaint handling.

Fig. 3.2. The most important zones in warehouses



Source: [33]

There are two types of automation of these types of facilities and the areas within them:

1. Physical automation. This type provides for the replacement of heavy, physical work of employees with fully or partially automated and autonomous devices.

2. Digital automation that focuses on replacing manual operations in inventory management. In this case, companies implement inventory tracking, reporting, and data collection software. [12]

The technological layout of the warehouse defines the connection of zones, the flow of goods and the use of the available space for the storage of units and the operation of personnel and equipment. Operating errors that result in the improper functioning of a particular area, person, or piece of equipment cause a process to be disrupted, which can lead to its stoppage. [14] An optimally designed and, above all, modernized facility is effective, efficient and safe.

Two types of technologies used in Polish and European warehouses – physical and digital automation solutions – will be presented later in the report. They have been divided according to the place of use in the warehouses and the operations carried out.

3.4. Loading and unloading zone

In the loading and unloading zone, which is usually located outside of the distribution center at the loading docks, the goods are received and shipped. Trucks or other means of transport used for the transport and distribution of goods have direct access to the zone.

In a well-organized warehouse, the areas dedicated to loading and unloading goods are located on the sides of the storage facility. This way, the stacking and collection of loading units can be carried out without the need to move to other areas. These are the so-called integrated zones in the warehouse. Their advantage is the speed of reloading – trucks can be positioned at docks that can be connected to the building. [15]

The loading dock area is an essential part of any warehouse. The more docks in a building, the more trucks the center can handle, increasing the flow of goods. Manual unloading of a means of transport takes – depending on the type and weight of the cargo – about 30 minutes, loading – from 40 minutes to 1.5 hours. Automating this process reduces the unloading time to about 10 minutes. The loading and unloading process is crucial for the operation of the warehouse due to the level of criticality of this area (means of transport must not block the warehouse).

3.4.1. Systems and applications

There are many innovative solutions on the market today that can improve the efficiency of the loading and unloading processes. In the case of digital solutions, this can be done using the Yard Management System (YMS). The software automates communication between the warehouse and carriers, coordinates the movement of vehicles within the DC (e.g., on the maneuvering area, docks, parking lots, or warehouse access control points), and ensures error-free loading and unloading of trucks. Digital solutions on loading docks offer the following benefits:

- they accelerate operations by dynamically picking and loading loads onto vehicles,

- they shorten the duration of logistics activities by reducing transportation time, streamlining the flow of goods to warehouse systems, and increasing the speed at which orders are shipped,

- they increase loading safety by eliminating the risk of errors and low process efficiency,

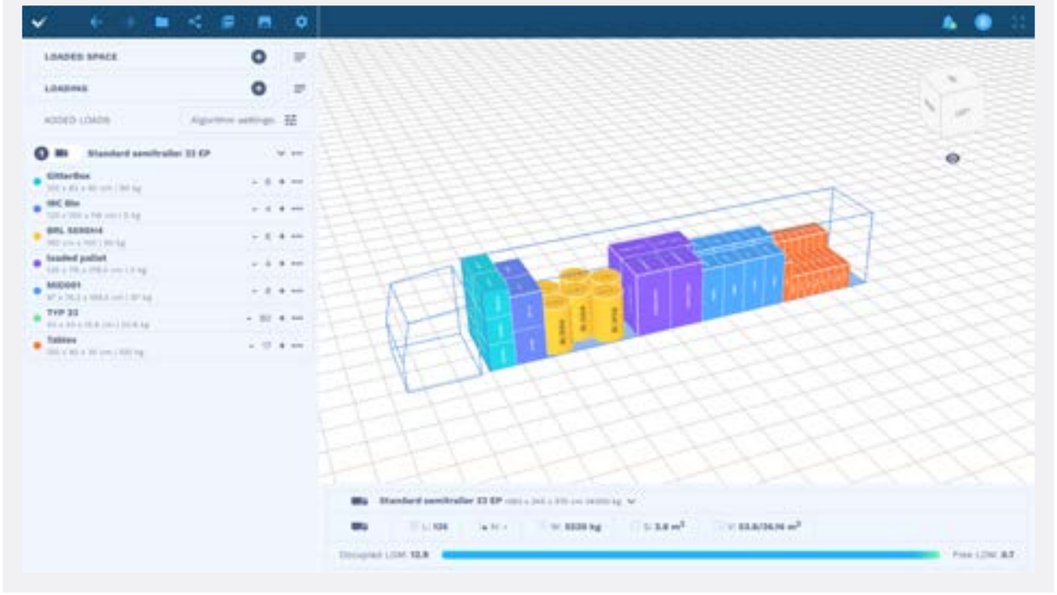
- they save space in the warehouse by efficiently executing processes and reducing the amount of space allocated to storage,
- they optimize the work of warehouse workers by limiting their involvement in the process and allowing their reassignment to other tasks,
- they improve the communication of the warehouse with other actors in the supply chain (manufacturers, suppliers and customers). [16]

The process of loading and unloading trucks in the zone can also be optimized with WMS software. The system increases the efficiency of inbound activities at the distribution center. This software:

- improves code reading and control of loading units by entering them into the system and assigning them a location,
- improves the planning of the flow of goods by analyzing the ASN (Advanced Shipping Notice) document,
- speeds up the verification and documentation of orders,
- thanks to the possibility of connection with forwarding programs, it facilitates combination of individual shipments. [16]

Mobile apps for load management also help improve efficiency at the docks. Goodloading is a platform that shows the optimal arrangement of pallets on a semi-trailer or container in a 3D visualization (Figure 3.3). After adding a list of loads and selecting the appropriate space, the program arranges the loads with maximum use of the available space.

Fig. 3.3. Goodloading app [17]



Source: [17]

The tire manufacturer Continental has also developed an AI-based solution for measuring available cargo space in trucks, semi-trailers, and trailers (Figure 3.4). After securing the cargo, the driver should use a smartphone to take a picture of the cargo area. The image is uploaded to the cloud, where artificial intelligence calculates the available space.

Fig. 3.4. Trailer Capacity Assessment software

Source: [18]

Waiting time for loading can be minimized with special time slot management software. Such systems increase warehouse throughput, advance resource planning, and support digital communication between the logistics department, warehouse, and transportation companies (Fig. 3.5). The system allows carriers to book slots and change booking statuses. Time slot management software can reduce loading wait times by 70% and increase warehouse efficiency by 25%.

Fig. 3.6. Dock Scheduler delivery booking software

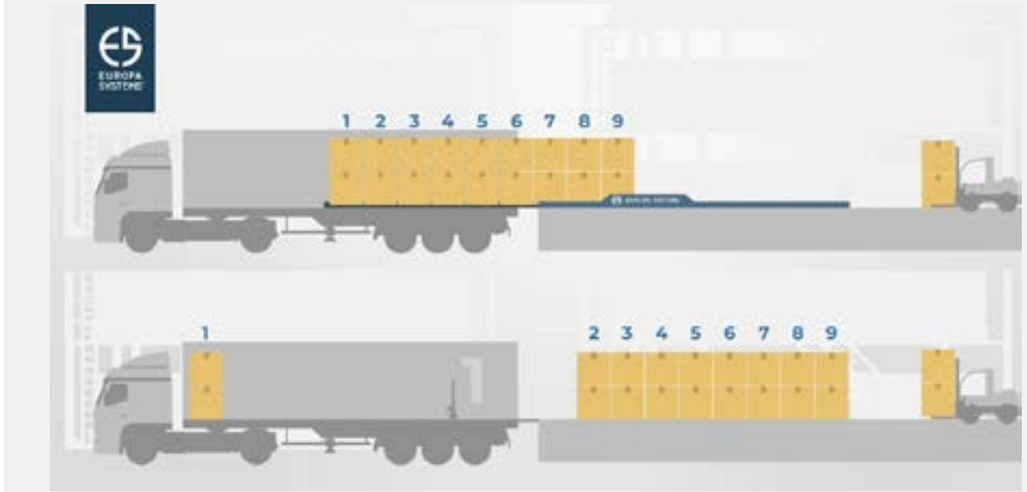
The study by the logistics platform Trans.eu shows that only 30% of users are familiar with solutions for managing time slots, and only 14% of them say that they actively use these tools. An analysis by Cargoon, the provider of the Dock Scheduler tool, showed that after implementing a time slot management tool in a company with about 60 loads per day, the percentage of deliveries made outside the platform was 8%. [20]

3.4.2. Loading and unloading systems

Na optymalizację procesów zachodzących przy dokach pozwala ATLS (Automatic Truck Loading System) – automatyczny system załadunku i rozładunku ładunków. System robotyzuje układanie i pobieranie palet oraz minimalizuje udział operatorów w tym procesie (Rys. 3.6). Automatyczne doki przeładunkowe oferują wiele korzyści:

- they increase efficiency: a full truck (33 pallets) can be loaded or unloaded in minutes,
- they allow efficient use of space: accelerating unloading reduces dock-to-store time (the time between the arrival of the cargo at the dock and its placement in the appropriate storage location),
- they secure the load: during handling, the system reduces sudden movements and thus damage,
- they optimize labor utilization: the system reduces the number of operators needed in one of the busiest areas of the DC,
- they protect operators: automatic loading docks eliminate possible accidents by restricting movement and increasing safety when working on the docks,
- they reduce operating costs: the system allows for an increase in the volume of goods issued and received, the use of fewer forklifts, a reduction in the physical workspace required for operations, etc.

Fig. 3.6. Loading with ATLS



Źródło: [18]

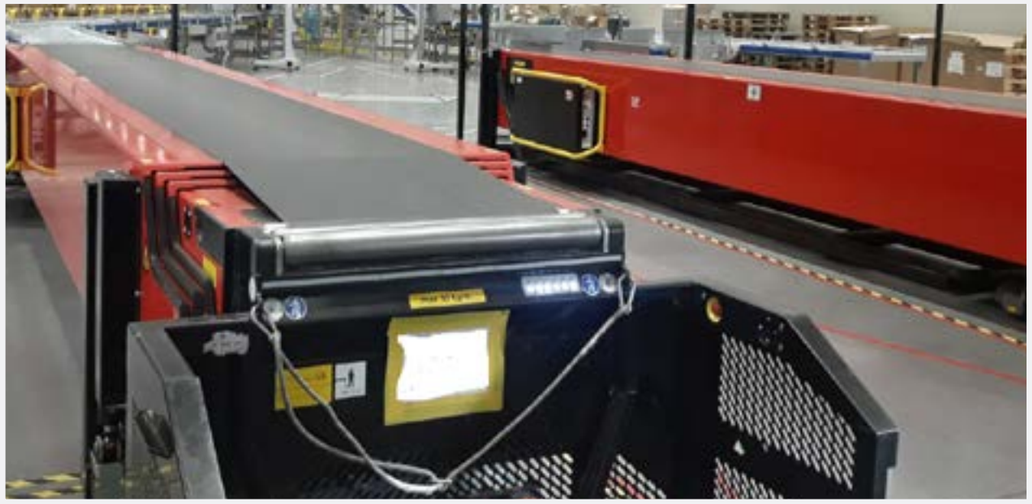
The ATLS market has experienced tremendous expansion and growth over the past decade due to the changing needs of the logistics and transportation industry. Global Industry Analysts estimates that the global market for automated truck loading systems will grow from more than $2 billion in 2022 to $3.8 billion in 2030. [22] This increase in demand can be attributed to a number of factors, including technological developments, the drive for operational efficiency, and the demand for safer working conditions.

The global market for ATLS is dominated by Europe and in particular by countries such as Germany, the United Kingdom, France, and Italy. Thanks to the extensive use of technology in the logistics industry, the Old Continent has a market share of 43.8% (2022 data). In terms of individual sectors, the FMCG industry has the largest share in the ATLS market (38.2%). The main reason for this is the growing popularity of e-commerce platforms in the fast-moving consumer goods sector, which requires rapid delivery. [13]

3.4.3. Telescopic conveyors

Telescopic conveyors (Fig. 3.7) help to increase safety, ergonomics and reduce the time it takes to unload and load trucks. In addition, they increase efficiency in line with the Lean Manufacturing philosophy (more efficiency with fewer resources) and reduce the number of forklift trips. Feeders (conveyors) are used, for example, for semi-trailers up to 13 m in length and are used to transport cartons, crates, bins and small pallets. The length of the telescopic conveyors can be adjusted to suit loading and unloading points.

Fig. 3.7. **Telescopic conveyors used in GXO Logistics warehouses**



Źródło: [3]

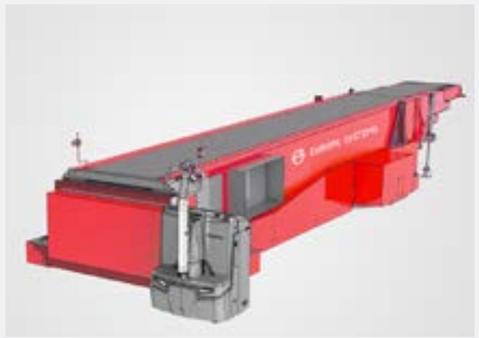
There are several types of conveyors. The telescopic conveyor belt (Fig. 3.8) is mainly used for loading and unloading packages, where the transport is carried out by a rubber belt. The conveyors can be extended two or three times. The roller conveyor also allows for the movement of the drop and collection points. It is possible to install the conveyor in a fixed position, dedicated to one dock, or in a powered version, which is flexible.

Fig. 3.8. **Telescopic conveyor belt from Europa Systems [23]**

Źródło: [24]

For flexible loading and unloading, there is a mobile conveyor version (Fig. 3.9.). The machine can be transported between docks or zones. The conveyor can be maneuvered with one hand in the mobile version. The conveyor can be prepared for unloading a new dock in a matter of minutes.

Fig. 3.9. **Mobile conveyor belt from Europa Systems [24]**



Źródło: [24]

Access to hard-to-reach loading and unloading points is facilitated by a telescopic conveyor with a basket (Fig. 3.10). The basket is adjusted to the required height to allow personnel to load and unload goods safely.

Fig. 3.10. **Telescopic conveyor with basket from Europa Systems [25]**

Źródło: [25]

3.4.4. Manipulators

Industrial manipulators help workers perform handling tasks in the manufacturing process. In production plants, they are controlled manually or automatically. Manipulators in warehouses (Fig. 3.11) are placed at the end of telescopic conveyors or can be placed independently. The solution is easy to implement and can be used by anyone.

Manipulators in warehouses can be used not only for loading and unloading vehicles, but also for order picking – optimizing the activities of storing, palletizing, depalletizing and moving loads, i.e. wherever a worker needs to move heavy objects.

The main benefits of the equipment are to increase safety, reduce the time taken to complete the above operations and minimize the need for workers to use additional equipment such as lifting straps or trolleys. The effectiveness of operations is increased by minimizing downtime due to the absence of employee injuries and the ability to engage people of different ages and genders in these tasks.

Fig. 3.11. **Manipulators used in GXO Logistics warehouses**

Źródło: [3]

Łukasz Lewicki,

Head of Sales Contract Logistics at Rohlig SUUS Logistics

In our warehouse in Tarnowo Podgórne, in order to improve the unloading of sea and rail containers, which often contain a wide variety of goods such as electronics, household appliances and clothing, we have installed a modern conveyor belt dedicated to this process. What does it mean in practice? The employee picks the goods from the pallet and places them on the conveyor belt that takes the products out of the container. The articles are then picked up by another person who is at the other end of the machine. What's more, the conveyor automatically extends and slides into the container during unloading. This improvement has made the process much more efficient, requires fewer people, and is less physically demanding

3.4.5. Robots

Until recently, it was not possible to fully automate vehicle loading and unloading operations. This changed in 2023 with the commercial launch of robotic arms. Multi-joint robots can be used to lift and place goods onto semi-trailers or unload vehicles. These robots are used for everything from order picking, packing, storing, and palletizing to loading and unloading a wide variety of goods, including pallets, cartons, and individual items.

The major shipping companies are already starting to use similar solutions. FedEx, a U.S.-based company that handles more than 15 million packages a day, has deployed the DexR robot (Fig. 3.12) in its warehouses, which is manufactured by Dexterity, a California-based startup that specializes in developing robotic systems for a variety of warehouse tasks. The goal of the new robot is to use artificial intelligence to, for example, stack rows of packages of different sizes in a truck. The machine uses cameras and lidar sensors to analyze packages, which come in all sizes, shapes and weights, and then plans the loading.

Just a few years ago, AI wasn't smart enough to handle this kind of complex process. Many tools are designed to perform repetitive tasks with extreme precision, but without self-learning and without the ability to make decisions based on situation analysis. Nonetheless, robotics is advancing rapidly. More and more machines are using artificial intelligence to recognize objects or determine how to pick them up, where to load them, how to load them so that the packaging is not damaged, and how to secure them in a semi-trailer.

Fig. 3.12. DexR robot used in FedEx warehouse

Źródło: [3]

Robots used for loading or unloading can be a solution to the problem of labor shortages. For example, Sagawa Express, a logistics and delivery service provider in Japan, uses Dexterity machines in its warehouses due to labor shortages. The company said at the beginning of this year that it would start this process by teaching the artificial intelligence platform about its logistics operations to match the two-arm DexR to the Japanese company's existing logistics infrastructure. By 2026, the operator plans to put 1,500 of these robots to work.

DHL Supply Chain also uses similar robots. The logistics provider began working with Boston Dynamics, an engineering and robotics design firm in Waltham, Massachusetts, several years ago and has invested $15 million in the technology to automate the process of loading and unloading trucks.

The result of this collaboration is the Stretch robot, which consists of an arm, a suction cup holder and a mobile base (Fig. 3.13). Using the suction cup holder, the robots retrieve packages from a trailer, grab them from the top or side, and place them on a conveyor for delivery to the building. The boxes are then scanned and placed in the warehouse in accordance with the facility's material handling processes. The battery-powered robots work a full shift on a single charge, unloading up to 500 cartons per hour. The robot is guided by artificial intelligence combined with sensors, cameras and other controls. DHL estimates that after two months of the project, the solution increased productivity at the Carhartt facility by approximately 40%, and unloading was significantly faster than manual operations.

Fig. 3.13. **Stretch robot manufactured by Boston Dynamics for DHL Supply Chain**

Źródło: [27]

This is not the only solution offered to logistics companies by the American manufacturer. By 2025, Boston Dynamics will deploy dozens of its warehouse robots in European distribution centers as part of an agreement with German e-commerce giant Otto Group, which sells $17 billion in e-commerce goods annually in more than 20 countries. Spot four-legged robots (Fig. 3.14) are used to unload vehicles at more than 20 of the German company's facilities.

Fig. 3.14. **Spot robot by Boston Dynamics**

Źródło: [28]

The TruckBot from Mujin, founded in Japan and now based in the Netherlands, is a bit different, but has the same purpose. TruckBot (Fig. 3.15) is an autonomous robot that can unload both trailers and shipping containers at a rate of up to 1,000 loading units per hour. The machine is designed to be connected to a standard conveyor belt system. The robot can reach up to 15 meters into a truck trailer or container. Unlike robots that use an arm, the TruckBot combines grippers, sensors, software, and a controller with something found in many loading docks: a telescopic feeder.

Fig. 3.15. **TruckBot by Mujin**

Źródło: [29]

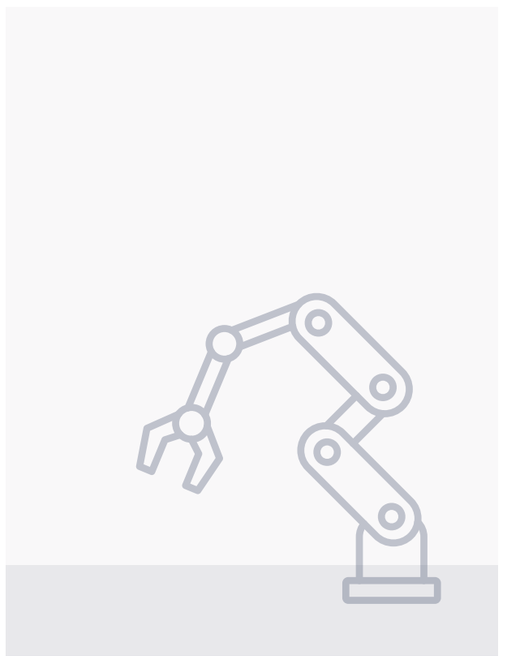
An international Tier 1 automotive manufacturer and supplier has deployed 9 autonomous SlipBots (Fig. 3.16) from Atlanta-based Slip Robotics to unload and load trucks in three shifts. The time for this process has been reduced from more than 40 minutes to 3 minutes. The company has seen a fourfold increase in driver productivity and dock throughput, a 90 percent reduction in truck downtime, and a 40 percent reduction in cargo damage. Damage to dock doors and trailers has also been eliminated. [31]

Fig. 3.16. **SlipBot by Slip Robotics [30]**

Źródło: [30]

Another solution for automated truck loading is the Ultra Blue robot (Fig. 3.17). The machine can drive autonomously into dock doors and vehicle trailers without any additional infrastructure (e.g. rails or guides). The robot transports, lifts and places loads directly into the trailer. It can be integrated with other devices such as telescopic conveyors, bar code scanners or sortation systems. Ultra Blue can handle multiple loading docks simultaneously.

Fig. 3.17. **Ultra Blue robot from Bastian Solutions**



Źródło: [32]

3.4.6. Forklifts

Autonomous equipment that helps load and unload trucks includes some forklifts (Fig. 3.18). They can save up to 80% of employee time, while increasing throughput and process efficiency. They are independent and can work in groups.

Fig. 3.18. Trey autonomous forklift truck from Gideon Brothers start-up [34]

Źródło: [34]

3.5. Goods receipt zone

The basis for the effective operation of a logistics facility such as a warehouse is the proper adaptation of the warehouse space to the operations and procedures to be carried out. The goods receiving area plays a key role in the organization of the goods receiving process – in this area activities such as quantitative and qualitative verification of orders, sorting of received goods, labeling of products and designation of locations in the storage area of the warehouse are carried out. Typically, this zone is located away from storage areas and loading or unloading areas.

In a properly organized warehouse, there is an established system for efficiently removing packaging and other waste from the receiving area, and if goods need to be de-stacked, there is space for staging goods from

pallets or containers. A key element in preventing a bottleneck in the receiving area is correctly determining the quantity of goods to be received at the facility and planning the process accordingly.

The planning process in the receiving area is closely coordinated with the operation of the entire supply chain. A smooth process ensures good communication between all participants in the logistics network (carriers, suppliers, distributors, and warehouses), reduces the risk of unforeseen situations, and allows the operators responsible for receiving the goods to have all the necessary information before the trucks arrive.

Goods are unloaded at the loading docks, from where they are transported to the receiving area and then to the consolidation area or directly to the warehouse area of the facility. Before that, however, the cargo must be subjected to control procedures, which require verification of booking lists with waybills and the actual status of deliveries. Some goods require additional inspection.

When goods arrive at the warehouse, employees ensure that each load is properly marked and registered. Traceability of stored products is a fundamental element of an optimally functioning warehouse, which is why their labeling should be carried out both in traditional warehouses and in those managed by the WMS system.

3.5.1. Systems and applications

The level of standardization in the receiving process affects the likelihood of unexpected situations occurring. The Warehouse Management System (WMS) minimizes this likelihood and eliminates the need for paper documentation. For inbound processes, the WMS software optimizes activities such as forecasting inbound goods, registering inbound loads, labeling, or determining the location of goods. WMS functions that are useful when performing receiving activities:

- goods receiving management: receiving processes designed to receive loads from a variety of sources, such as vendor purchases, inter-warehouse transfers, production orders, and customer returns. Part of this process is the control of the variety of goods, their quantity, characteristics and condition or quality. The product introduced into the warehouse becomes part of the inventory. This information is compared to the order received from the ERP (Enterprise Resource Planning) system,
- location management: location-related processes. These processes are used to manage orders for placing goods in the warehouse and determine the best location based on the type, characteristics, dimensions of the goods, etc. This is done according to predefined rules and strategies,
- shipping process management: processes involved in preparing orders for shipment to customers, transfer to other warehouses, or return to suppliers. This function is concerned with issuing goods and reducing inventory through activities such as picking, issuing full containers, consolidating orders, and preparing delivery vehicles for shipment. [35]

Direct automation of receiving operations depends on the functionality of the specific ERP system and how it is integrated with other warehouse management systems (WMS) or yard management systems (YMS). ERP systems can facilitate the work of the receiving department by:

- automation of the process of registering receipts in the system, which allows for quick verification of deliveries and facilitates accounting processes,
- real-time tracking of the status of orders and deliveries, which facilitates warehouse planning and coordination with purchasing and sales departments,

- integration with product identification systems such as bar code scanners or RFID (Radio-Frequency Identification) systems, which can speed up sorting and verification processes,
- managing supplier, order, and product information, facilitating decision-making processes and internal communication,
- optimizing inventory management by accurately monitoring stock levels and automatically generating purchase orders when stock falls below a set minimum.

YMS systems can also help optimize work in the receiving area, although their main area of activity is focused on managing the docks and external operations of the warehouse. A YMS can optimize the operation of the receiving area by, for example, reducing wait time for unloading, making better use of loading docks, or increasing warehouse throughput.

In addition, scanning and identification applications (e.g., for bar code reading) and RFID systems help streamline the receiving process (Fig. 3.19). They enable fast and accurate verification of incoming goods, as well as their identification and tracking in the warehouse.

Fig. 3.19. Zebra Technologies scanners used by Raja Group

Źródło: [36]

3.5.2. Automated guided vehicles

Automated guided vehicles (AGVs) can transport various types of loads without human intervention. They move along clearly defined routes that are marked in the warehouse (Figure 3.20).

Fig. 3.20. Jungheinrich AGVs designed for very narrow aisles

Źródło: [37]

The machines monitor the environment in real time with an extensive sensor system. If they detect an obstacle – another machine or a pedestrian – they automatically slow down or stop, ensuring safety (Fig. 3.21). Some models scan the area around them and automatically adjust the scanning range to match the speed of the vehicle. This means that as the vehicle accelerates, the scanning area also increases, ensuring a quick response when an obstacle is encountered.

Fig. 3.21. AGVs move around the warehouse unattended

Źródło: [37]

The advantage of AGVs lies in their ability to perform a variety of transport tasks without human intervention, which results in numerous benefits, such as increased operational efficiency (AGVs allow for the automation of transport tasks, resulting in increased efficiency and speed of operations), improved safety, which is possible thanks to advanced sensor systems, optimization of warehouse space (AGVs can be programmed to work in different warehouse layouts), and reduction of operational costs, e.g. by reducing labor costs, minimizing human error, and optimizing energy consumption.

Also noteworthy is integration with management systems. It allows for automatic assignment of tasks to trucks based on various criteria such as priority, location or availability of resources; real-time monitoring of trucks to track task status, truck location and technical condition; and analysis and use of data to optimize various aspects of logistics operations such as task lead time analysis, energy consumption or route efficiency.

The disadvantages of AGVs include relatively high investment costs related to the costs of purchase, infrastructure adaptation, integration with existing systems, and staff training. These factors can delay the achievement of a return on investment. Additionally, the technical complexity of these machines can extend the implementation time and generate additional costs associated with employing qualified technical personnel. Finally, there are limitations in applications. AGVs are most effective in routine operations, but their effectiveness may be limited in more complex environments.

AGVs can be classified into various categories based on the method used to guide the vehicle.

- electromagnetic guidance: the vehicles follow the routes set by the cables placed under the warehouse floor. This solution is effective for fixed transport routes, but it should be noted that each change requires time-consuming construction work,
- image recognition: artificial intelligence algorithms are responsible for route selection, utilizing the surrounding environment as observed by panoramic cameras,
- optical guidance: provided via a reflective tape that marks the route along which the vehicles are to move. The system's primary component is a sensor that detects reflected light. This solution does not require any architectural changes to the warehouse, in contrast to electromagnetic guidance,
- laser guidance: the vehicles are equipped with laser scanners that accurately determine their location in the warehouse based on a map of the facility stored in memory. One of the key benefits of this system is that it does not require the installation of wires or tapes,
- 2D-3D mapping: the vehicles guided by this method do not require any additional equipment. The virtual map, created from information gathered by cameras and sensors, allows them to safely navigate around the object.

AGVs are available in a variety of configurations. The most common ones on the market are single load vehicles (designed to move individual load units during each trip, e.g. pallets, rolls, cartons), forklifts, similar to traditional ones, designed to move one or more pallets at a time, and tractors, which are used to move vehicles without their own drive, e.g. platforms of a logistics train.

The global market for automated guided vehicles is valued at $4.79 billion in 2023 and is expected to grow at a CAGR of 9.7% between 2023 and 2030. [39] Market analysis has shown that rapid technological advancement, particularly in the areas of artificial intelligence, robotics, and automation, is one of the key drivers of the AGV sector. The increasing demand for automated solutions in areas such as logistics, manufacturing, warehousing and distribution is also accelerating the development of this type of equipment.

3.5.3. Autonomous mobile robots

Autonomous mobile robots (AMRs) are used to partially or fully automate the transport of goods, significantly increasing the efficiency of warehouses and key logistics points (Fig. 3.22). Their low height allows them to move freely under the racks, lift pallets from the racks, and then independently transport them to a specific location. AMRs utilize QR codes strategically placed on the floor or laser geonavigation technology. They are equipped with advanced obstacle avoidance detection and avoidance systems along the route. The vehicles are programmed to select the most efficient route and to execute tasks in the most optimal sequence, which significantly enhances the overall efficiency of the logistics operation.

Fig. 3.22. WDX and VersaBox platform robot

Źródło: [40]

The most important functional areas of AMRs include:

- mapping of the environment: robots scan the entire production or warehouse hall and operate on the basis of the current workspace of internal processes,
- data-driven process design: tools enable visual process design and evaluation of different process options,
- process control: the system collects real-time data such as transport orders, location data and the status of robot work,
- process resource management: robot fleet managers oversee the configuration of the intralogistics system and provide support in maintenance and resource management.

The capacity of autonomous mobile robots varies by model, with some capable of transporting loads weighing up to 1,500 kg per transport route. The incorporation of contemporary safety technology allows for the utilization of conveyors in high-traffic warehouse environments and heavily utilized loading bays. Various types of sensors constantly monitor the vehicle's surroundings, preventing collisions and ensuring traffic safety. This allows robots to work safely with both humans and other vehicles, even in confined spaces (Fig. 3.23).

Fig. 3.23. Mobile robots from Linde

Źródło: [41]

As an illustration, Jungheinrich's Arculee S mobile robot facilitates secure human-machine operation through the integration of 360-degree safety sensor technology. (Fig. 3.24). The 360-degree safety concept provides continuous monitoring of the entire vehicle, enabling the machine to stop safely in front of people or obstacles.

Fig. 3.24. **Mobile robot from Jungheinrich**

Źródło: [37]

Case study

In 2021, GXO Logistics initiated a partnership with a food and beverage manufacturer to streamline the distribution of goods at its high-tech hub in Nieuwegein, the Netherlands. This temperature-controlled, 24/7 logistics center needed a solution that would allow orders to be placed in the correct order for loading onto specific trucks and placed in the optimal layout for unloading at their destination. The pilot project lasted until 2023. The implementation of autonomous Lowpad robots (Fig. 3.25) at 16 distribution sites has improved the safety, efficiency, quality, and profitability of the customer's operations. The robots have increased operational efficiency by 60%.

Fig. 3.25. **Autonomous mobile robots Lowpad by GXO and Lowpad**

Źródło: [42]

3.5.4. Stacker cranes and conveyors

In warehouses, there are two types of material handling: horizontal and vertical. The former is done manually by employees using forklifts or other machines. Vertical handling, on the other hand, is a bit more complicated. It is used primarily during the unloading and loading of individual goods. In this case, goods need to be lifted or lowered to great heights, which can be challenging, especially with heavy loads.

Material handling equipment can be divided into three main categories: manual (e.g., pallet trucks), powered (e.g., forklifts), and automated (e.g., pallet or box conveyors). Automated equipment operates under the control of the WCS, which plays a key role in controlling and managing all automated equipment in the warehouse. But the WCS alone will not improve warehouse performance. It needs additional software that provides it with the right data and tools to analyze and optimize logistics processes, such as WMS.

The most popular devices of this type are pallet and box stacker cranes, which are characterized by high speed loading and unloading of racks. The basic types of stacker cranes include single-column, double-column, and automatic trilateral stacker cranes (Fig. 3.26). Trilateral stacker cranes are well suited for automating facilities with trilateral manned vehicles.

Fig. 3.26. **Trilateral stacker cranes from Mecalux**

Źródło: [43]

Roller and chain conveyors are another popular group of equipment used in warehouses. Their task is to move pallets and bins internally between different areas of the warehouse or production hall, as well as between the warehouse and the factory. In facilities where there are fixed routes for the flow of goods, AGVs or AMRs can perform a similar function.

Next, there are pallet lifters, which are ideal for vertical transport of pallets in multi-story warehouses. In facilities with limited goods flow, manual equipment is often used. On the other hand, warehouses that handle large volumes of orders need automated systems to speed up the movement of goods. Solutions such as hydraulic tables (Fig. 3.27) or vertical conveyors (Fig. 3.28) are integrated into pallet conveyor lines to increase the speed of lifting and lowering palletized goods and improve the flow of goods.

Fig. 3.27. Hydraulic table from Mecalux

Źródło: [44]

Hydraulic tables can also be used as part of conveyor lines. Roller or chain conveyors are assembled on top of the lines and tasked with overcoming slight differences in height within the line. The elevation levels of hydraulic tables vary between 100 mm and 2,000 mm. This solution is also implemented to optimize the performance of pick stations when picking from pallets: it raises the unit load to the height of the operator so that they can work in an ergonomic position with improved safety and throughput.

Fig. 3.28. Vertical conveyors, also known as automatic pallet lifts, from Mecalux

Źródło: [44]

Vertical conveyors are an integral part of the conveyor line and are used to move pallets to considerable heights, often to other floors of the warehouse. This solution allows the loading of one or two pallets at a time. Vertical conveyors are coordinated with the movement of the conveyors via warehouse control software (WCS). This, in turn, is supervised by the warehouse management system (WMS), which decides where each product should be placed and, thus, which path it should take to reach that location.

Two more advanced technologies should also be noted: shuttles, which move goods along a specific route, and the automated Pallet Shuttle system, which integrates automated systems into warehouse storage processes (Fig. 3.29). As part of this solution, forklifts are replaced by specialized stacker cranes or transfer cars that perform a transport function for the Pallet Shuttle equipment and the load. The car enters the storage channels and places each pallet in the deepest available space.

All movement operations are performed in full compliance with WMS instructions.

Fig. 3.29. Automated Pallet Shuttle from Mecalux

Źródło: [45]

3.5.5. Sortation systems

Automated sortation systems (Fig. 3.30) are a key element in optimizing the processes for managing large quantities of goods in logistics warehouses. These advanced systems use robots or automated conveyors to identify, sort, and route products to their precise locations. This way, the sorting process is much faster. Sorters direct accepted goods to the appropriate locations in the racks.

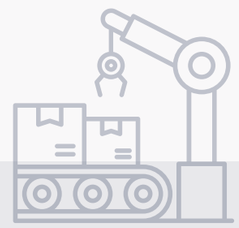


Fig. 3.30. Zautomatyzowany system sortowania firmy Dematic

Źródło: [46]

Automated sortation systems can process thousands of units per hour, far exceeding the capabilities of manual sorting. The systems can be adapted to sort different types and sizes of goods without the need for manual intervention. Automated sortation systems can handle the increase in shipping volumes during periods of increased consumer activity and logistics peaks.

3.5.6. Scanning technologies

Managing the flow of products in the warehouse requires the use of an appropriate system that enables effective inventory control and efficient picking, receiving, and shipping of goods. Bar codes are one of the most effective and relatively inexpensive ways to provide information about a product. The use of wireless bar code readers enables real-time inventory control and efficient organization of logistics operations (Fig. 3.31).

Fig. 3.31. **Czytnik kodów kreskowych firmy Jungheinrich**

Źródło: [47]

Wireless bar code readers use a variety of technologies to read codes. The most common type of bar code reader is the LED model, which uses a beam of light to illuminate the code and capture a digital image of the bar code. The main benefit of these readers is their competitive price point and durability. However, they do have slower processing speeds and less precision than other types of readers. Another popular type of bar code reader is the laser reader, which uses a laser beam to read bar codes. While these products offer a longer read distance and higher scan quality, they are more susceptible to damage. Additionally, 2D vision scanners are available for use in scanning a variety of code types, including QR codes.

In warehouses, bar code readers are used primarily for inventory, receiving, picking and shipping. Thanks to the use of appropriate software, the information read by the readers is transmitted and processed in warehouse management systems, allowing effective integration of logistics processes.

Case study

Automation of scanning of quality certificates with the use of an RPA robot

One DHL customer encountered difficulties with the quality certificate scanning process, which was entirely manual. An employee scanned certificates on a scanner that was not connected to the network and manually entered the file name, obtaining the number from SAP. Following the completion of the scanning process, the files were saved to a USB drive. At the conclusion of each shift, the disk was transferred to an employee for manual data transfer to the server.

DHL Supply Chain has implemented RPA (Robotic Process Automation), which has streamlined the quality certificate (CofC) scanning process. The fundamental components of this solution were as follows:

- Batch scanning: Rather than requiring manual scanning by an employee, all CofCs were scanned in bulk once a day, thereby increasing the efficiency of the process.
- RPA: To streamline the scanning process, an RPA bot has been implemented. The bot divided all the CofC pages, assigned them a name, and saved them to the correct location on a shared drive. This process eliminated the need for manual data entry, saving time.
- Network access: RPA facilitated seamless data transfer and sharing on the company network.

Advantages of the solution

The workforce is more productive. The implementation of RPA has resulted in the release of one full-time equivalent (FTE) position, which can now be redeployed to address tasks that have contributed to the observed volume increase. The enhanced efficiency enabled the client to optimize the utilization of their workforce.

The latest versions of the CofCs are available. An automated process ensured that quality certificates were current and readily available for final inspection and release of finished products. This enhances overall operational efficiency and accuracy.

Disadvantages of the solution

Initial investment. The implementation of RPA technology requires an initial financial investment, which can present a challenge for some companies. However, the long-term efficiency gains often offset the initial costs.

Training. The introduction of new technology into an existing operation may necessitate additional training for employees to ensure optimal utilization of the solution.

3.6. Storage zone

The storage area differs from the other zones in terms of its unique features. This is the largest space in the warehouse. The objective of this zone is to provide a secure storage facility for goods awaiting further processing or shipment. It is essential to develop an effective capacity plan for this area, as it has a direct impact on the efficiency of the entire warehouse economy.

The warehousing process commences with the delivery of goods to a designated area, where the products are prepared and secured in advance to form loading units. Subsequently, the units are stored at the specified locations. The storage process requires the appropriate arrangement of goods and systematic monitoring of inventory, as well as the preparation of goods for further logistics steps.

The storage area is equipped with a range of machinery and technology, including internal transport solutions such as forklifts and cranes, as well as other specialized equipment and tools. Many of them have already been described in the previous parts of the report. Integrating the goods storage area with the picking area allows for more efficient logistics processes.

3.6.1. Systems and applications

The location of goods storage is a critical piece of information in distribution centers. Knowing the precise location of goods enables the optimization of goods release processes, the acceleration of order fulfillment, and the reduction of operating costs. Large warehouse facilities utilize location-based recording systems to streamline inventory management and provide precise location information for goods. The division of warehouse space into zones, with detailed marking of locations (e.g., racks), facilitates more efficient management and faster access to products.w.

Some WMS functions permit the configuration of an unlimited number of storage zones and locations within the warehouse. This enables the efficient allocation of goods to designated zones and locations, streamlining the organization of the packing process and the preparation of packing lists, thereby optimizing the planning of goods release from the warehouse. The implementation of location functions in warehouses facilitates optimal space management, minimizes the time required for searching and retrieving goods, and accelerates the order fulfillment process.

In the storage area, RFID technology is also in use, playing a vital role in the quick identification and tracking of goods, automation of inventory processes, increased accuracy of inventory management, and improved efficiency of product tracking. This technology makes it easier and faster for workers to locate items in the warehouse. This speeds up the picking process and minimizes errors.

The use of RFID tags, bar codes, or QR codes to mark packages also allows for the complete restoration of control over individual units. The ability to register releases and returns, along with the date and code of the contractor or driver, provides precise information about available returnable containers and those that need to be recovered, ensuring optimal resource management. RFID systems provide the ability to track the full logistics of returnable packaging, monitor its circulation, control the time spent at the contractor's, and plan the dates of return to the warehouse (Fig. 3.32). These systems also provide precise data that can be used as a basis for invoicing for packaging rental, storage, or disposal.

Fig. 3.32. Workflow diagram of the system for recording returnable packaging

Źródło: [47]

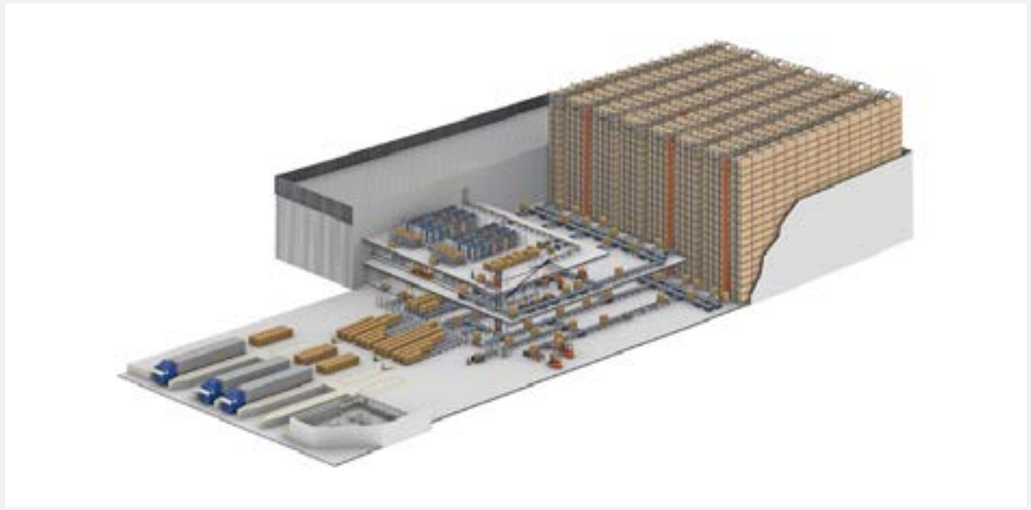
warehousing area include integrated inventory management, optimization of logistics processes, and streamlining of order and delivery management. The advantages include, among others, enhanced visibility of inventory levels and more effective resource planning. Furthermore, ERP facilitates more effective data analysis.

Mobile applications are also utilized in the storage area to facilitate the optimization of storage processes and ensure efficient handling and inventory management. These applications include inventory management, bar code scanning, goods location tracking, and warehouse management support. They also include route optimization for warehouse personnel and order picking assistance.

3.6.2. Storage systems

One of the key advantages of Automated Storage and Retrieval Systems (ASRS) is their ability to maximize space efficiency by intelligently managing available vertical and horizontal space.

Fig. 3.33. Automated Storage and Retrieval System (ASRS)



Źródło: [48]

ASRS systems work with warehouse control systems (WCS). Labor costs represent a significant portion of warehouse operating expenses. However, automation has the potential to significantly reduce this cost. Furthermore, optimized order flow and enhanced ergonomics enhance safety and comfort for manual workers. Making the appropriate adjustments to the right ASRS system can result in an immediate improvement in operational efficiency.

The rapid growth of the e-commerce industry has resulted in the introduction of numerous automated storage and de-warehouse technologies to the market. These technologies vary in operational dynamics and their ability to handle a range of goods, including varying sizes and types.

ASRS technologies can be grouped according to the method of delivering goods to the operator, which allows for the classification of three main categories. Each of these methods offers distinct advantages and can be more closely aligned with the specific operational requirements of the warehouse.

ASRS technologies

- **picking from shelves (the operator receives the entire shelf or tray with products),**
- **picking from bins (the operator receives individual bins containing a certain number of products),**
- **robot picking (robots pick up products and deliver them directly to the operator).**

The warehousing process is complex and requires the implementation of the appropriate infrastructure and equipment to guarantee the safe and efficient storage of goods. One of the most frequently utilized solutions is the storage rack, which enables optimal utilization of available space and facilitates convenient access to stored materials. For the purposes of this study, several types of storage racks are presented.

Static racking systems

These structures are designed to accommodate the storage of loads in an organized and efficient manner. There are a variety of storage solutions available, including pallet racks, which allow for dense racking, shelving racks (lower than pallet racks, allowing easy access to smaller cargo units), cantilever racks (designed for storing longer and unusually shaped loads), and drive-in racks, which provide high-density storage.

Dynamic racking systems

These systems are designed to relocate in order to reduce the time required to access cargo and streamline the logistics process. Dynamic storage systems include mobile racks for convenient access to units, flow-through racks that utilize gravity for efficient load transportation, ideal for applications where the FIFO principle is paramount, and satellite (shuttle) racks for optimal density, designed to accommodate fast-moving goods.

Carousel racking systems

Available in horizontal or vertical variants, the carousel racks use a system of movable shelves to deliver bins with goods directly to the operator (Fig. 3.33). Thanks to automatic rotation at the request of the employee, they allow the selection of a specific product without the need to move. They are a proven and cost-effective solution, although the efficiency of these units is contingent upon the number of products stored on a single shelf, and they are not designed to accommodate a large volume of items. To expand functionality, additional equipment must be acquired.

Fig. 3.33. Carousel racking system from Jungheinrich

Źródło: [49]

Other notable advantages include high picking efficiency and rapid handling processes, while offering immediate access to all items. The use of carousel racks is particularly justified in locations where traditional, static storage methods are constrained by a lack of available space.

The implementation of carousel racks has the potential to reduce picking time by 40–70%. Based on a standard access time of 15 seconds and the lower time reduction value of 40%, carousel racks can streamline the picking process, reducing the time per item to 9 seconds.

These systems are available in both standalone and fully integrated formats. Their functionality can be enhanced with additional expansion and modernization packages, allowing customers to respond flexibly to changes in warehouse processes.

The primary benefit of ASRS is the space savings it enables by optimizing vertical space, reducing the need for storage space. These systems are designed to seamlessly integrate into existing warehouse processes, offering a direct connection to WMS systems.

Horizontal carousel modules (Fig. 3.34) represent a cutting-edge solution that employs oval guides with high-density storage bins mounted on them. The design allows for horizontal rotation, providing operators with convenient access to slow- to medium-moving products.

Fig. 3.34. Horizontal carousel modules from Kardex

Źródło: [50]

To enhance the efficiency of the picking process and maximize throughput, these modules are frequently grouped into bins. This mechanism allows operators to select orders from one carousel while simultaneously queuing up others. This approach enables the achievement of throughputs of up to 600 lines picked per hour, facilitated by the integration of pick-to-light technology and the implementation of batching stations that allow for the concurrent processing of multiple orders.

Vertical lift modules

Vertical lift modules (VLM) are an efficient space-saving solution that vertically stacks trays, delivering them to the operator in a manner similar to an elevator (Fig. 3.35). These units are perfectly suited for the storage of goods of unusual dimensions. The system is designed to adaptively adjust tray return in order to facilitate effective inventory management. Similar to carousels, VLMs are less efficient and capacious. However, this can be partially compensated for by increasing their number and consolidating orders.

Fig. 3.35. Vertical lift modules from Jungheinrich

Źródło: [51]

VLM is a solution designed to meet the specific needs of warehouses with a frequently changing assortment. As a closed system, the unit comprises shelves on either side, an extractor and a controller that enables the selected product to be delivered directly to the user via the user-friendly handling opening situated at an optimal height.

By enabling the extractor to prepare the next shelf for access during picking from the current one, significant reductions in waiting times can be achieved.

Miniload system

This automated storage solution is designed for the secure and efficient storage of small-sized goods. A distinctive feature of the miniload system is the gripper on the stacker crane, which is designed to move on rails and handle full bins or cartons (Fig. 3.36). While the technology is proven and reliable, the system is older and slower than more modern alternatives. The failure of a single stacker crane can result in the complete shutdown of access to the entire aisle.

Fig. 3.36. Miniload system from LoopStore

Źródło: [52]

The stacker crane is the central component of the automated system. It uses vertical space, allowing installation on multiple levels. This approach not only enhances picking and stocking efficiency but also, with the use of management software, facilitates real-time inventory management.

The rack design offers a substantial storage capacity, despite its compact dimensions. A key feature is its multi-level nature, which allows for simultaneous operation of the stacker cranes at different levels, thereby further increasing the efficiency of the system.

The rack, which also serves as a track for the stacker crane, does not necessitate the implementation of specific floor modifications, such as the establishment of a central aisle. This simplifies the integration process with the existing warehouse infrastructure.

Mobile racking systems

Mobile racking is an effective solution that provides high density of loads, allowing for a notable expansion in storage capacity while maintaining direct access to individual pallets (Fig. 3.37). These racks, placed on electrically driven platforms that run on rails, offer flexibility and efficiency in managing warehouse space.

Fig. 3.37. Movirack system from Mecalux

Źródło: [53]

Mobile racking solutions offer a number of advantages that contribute to increased efficiency in warehouse operations. By increasing the capacity of the facility by 80% to 120% compared to standard pallet racks, these units offer a valuable solution for optimizing space. Mobile racks provide convenient access to each pallet, enabling more efficient management of capacity and streamlined logistics processes. The use of these products in cold stores and freezers results in energy savings due to more efficient use of storage space and a reduction in the volume of cooled air. The system allows for the simultaneous opening of up to three work aisles, thereby streamlining the order picking process. Mobile racks are a highly versatile solution that can be adapted to suit a variety of load types. Furthermore, they are fitted with sophisticated security systems that safeguard both personnel and stored assets. The racks are load-bearing, with a load capacity of up to 600 tons per moving platform, allowing for the storage of substantial cargo.

Łukasz Lewicki,

Head of Sales Contract
Logistics at Rohlig SUUS
Logistics

Sprinkler system for storage of flammable goods

At the SUUS branch in Tarnowo Podgórne, located near Poznań, we have taken the initiative to install racks equipped with a sprinkler system in our storage facility for flammable goods. The system is automatically activated when ignition of products is detected, effectively extinguishing the fire or limiting its spread until the fire brigade arrives on the scene.

A comparable system has been installed in a designated warehouse area in Urzut, near Warsaw, for furniture products containing highly combustible structural and infill components.

VNA storage system

The VNA (Very Narrow Aisle) configuration (Fig. 3.38) is an efficient use of space (Fig. 3.39) in a warehouse setting. A central element of this system is a semi-automatic forklift with a lifting cab, which offers both pallet storage and goods picking. The VNA's efficiency and safety are further enhanced by the use of an induction loop, which eliminates the need for traditional guide rails.

Fig. 3.38. VNA storage system from Still

Źródło: [54]

High storage racks, separated by narrow aisles, represent an effective solution for maximizing storage space utilization. In comparison to traditional warehouses, these facilities enable a reduction in the width of aisles by up to 65%.

Fig. 3.39. **VNA warehouse with Crown forklift truck from WDX**

Źródło: [55]

The most significant challenges associated with forklift systems in high racks pertain to mast vibrations at elevated heights, which can be further compounded by uneven floor surfaces, and the necessity to navigate confined spaces. Modern driving assistance systems address these issues by compensating for uneven ground, thereby ensuring mast stability and work safety. Furthermore, trucks can be fitted with automatic guidance systems, enabling precise navigation in confined spaces without the risk of collision. This enhances the safety and efficiency of the operators.

Paweł Michalak,

Contract Logistics CEE Director at Rohlig SUUS Logistics

At our Szczecin branch, we utilise high-bay vertical lift modules for the storage of automotive products, including car spare parts. The implementation of this solution enables a more efficient and accelerated order picking process. Here's how it works. Once the order has been scanned, the shelf with the required items is lowered, allowing for swift retrieval of the necessary goods. The algorithm is designed to learn which products are most often released together, on one order, and then suggests moving them to the same shelf in order to speed up the process. In contrast, with traditional racking, although the WMS system indicates the product location on the scanner, we must still access each shelf and retrieve the goods.

3.6.3. Robots

Warehouse robots represent a crucial component in the full automation of storage processes. The automated storage and retrieval of loads in designated locations, made possible by these solutions, greatly enhances the efficiency and speed of warehouse operations while reducing costs..

Stacker cranes

Warehouse stacker cranes (Fig. 3.40) are specialized devices that automate the placement and retrieval of goods from racks. These devices are equipped with a microprocessor that enables them to receive and process commands from the warehouse management system (WMS).

They operate in three modes: automatic, semi-automatic, and manual, allowing for flexibility to meet the diverse needs of the warehouse. In automatic mode, the stacker crane operates independently, receiving commands via a microprocessor. In semi-automatic mode, the operator can send commands to the stacker crane. In manual mode, the stacker crane is controlled manually, primarily for maintenance purposes.

Fig. 3.40. **Stacker cranes from Mecalux**

Źródło: [56]

The assembly of a warehouse stacker crane is an excellent solution for companies looking to improve efficiency, enhance service levels, and ensure the safety of goods and operators. Stacker cranes are an optimal solution for warehouses with a high variety of goods and high turnover, as well as in cold stores or freezers, where they enable a reduction in the space needed for cooling (Fig. 3.41).

Fig. 3.41. Układnice w chłodniach firmy Mecalux

Źródło: [56]

Warehouse stacker cranes offer a number of advantages that make them an invaluable asset in the automation of warehouse processes. Thanks to the ability to work at heights of up to 45 meters and a narrowing of the aisles to 1.5 meters, stacker cranes facilitate a more dense storage configuration, increasing the utilization of both the area and the volume of the warehouse. Additionally, they facilitate convenient access to the collected goods, streamlining the processes of receiving and releasing pallets. Furthermore, stacker cranes are fitted with energy regenerators, which help to reduce costs and promote environmentally-friendly logistics solutions.

It should be noted that the solution also has some drawbacks. This solution requires an initial financial investment, but it will generate savings and a quick return on investment over time. Furthermore, to ensure optimal operation, only one stacker crane is permitted in each aisle, which may result in additional costs. To achieve optimal performance, stacker cranes must be integrated with transport systems such as conveyors, which can introduce additional complexity into the system. [57]

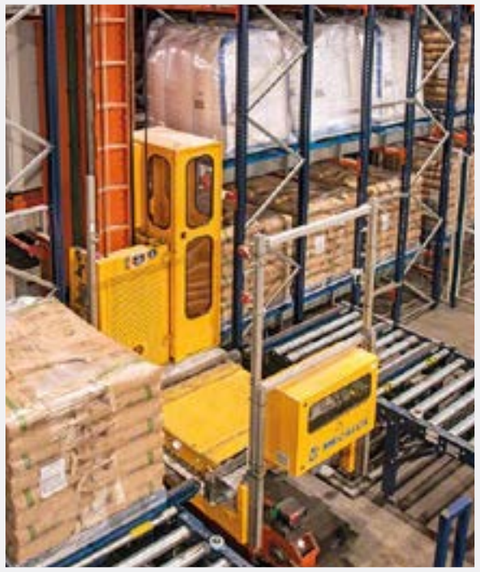
Shuttle system

A cutting-edge solution utilizing robotic shuttles that operate independently on different levels, ensuring swift and efficient delivery of goods to the operator. These systems can be adapted to operate on multiple levels, thereby increasing throughput. The main disadvantage of these systems is their mechanical complexity. However, their speed and ability to deliver products quickly make them a valuable solution for high-throughput warehouses.

The primary distinction between the semi-automatic and automatic versions of the Pallet Shuttle is the method by which the electric shuttle is positioned on the rack. In the case of the semi-automatic version, it is the responsibility of the forklift operator to place the Pallet Shuttle at the beginning of the storage channel. In the automatic version, the truck is conveyed between the

loading and unloading area, through different levels and storage channels by the stacker crane, thereby eliminating the need for manual intervention. Furthermore, the advanced APS system allows stacker cranes to operate in narrower aisles, with a width of less than 1,600 mm, and to reach greater heights, exceeding 40 m (Fig. 3.42).

Fig. 3.42. ASRS with Pallet Shuttle system from Mecalux in a warehouse over 40 m high



Źródło: [56]

The Pallet Shuttle system is designed to accommodate two types of handling equipment: shuttles or stacker cranes. The optimal choice depends on factors such as the frequency of loading and unloading operations, the number of SKUs stored, and the availability of pallets. A comparison of the two solutions reveals that shuttles are more capable of handling multiple pallets than stacker cranes. This distinction can be a key factor in selecting the optimal system for your warehouse application. [59]

This system is especially suited to companies that manage a significant volume of pallets per SKU. This solution is ideal for the storage of fast-moving products, such as perishable goods, where automatic devices facilitate continuous and independent pallet loading and unloading operations. The system can also be used as a temporary storage facility for cargo awaiting use in the production or logistics process or for direct shipment to customers.

Cube-based system

The structure is characterized by a high density of bins forming a cube on which robots are deployed to perform a range of tasks, including sorting and delivering goods to the workstation (Fig. 3.43). This solution represents the pinnacle of advanced technology, offering unparalleled storage density and an optimal solution for limited-space environments. The system's modular design allows for flexibility and scalability..

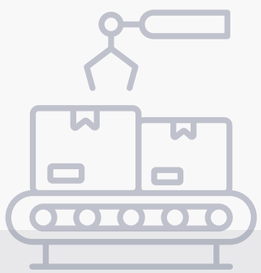
Fig. 3.43. Robotic cube-based ASRS system from Kardex

Źródło: [50]

This solution is a warehouse system that leverages cutting-edge technology to streamline the storage and picking processes for optimal efficiency. The system's functionality is based on a number of core components that, when combined, result in an extremely efficient storage solution.

The system is comprised of an aluminum frame that forms a net-like structure, which encompasses the bins and robots. This solution is designed to align precisely with the unique spatial needs of the warehouse. The system's modular design allows for flexibility in adapting to different storage space configurations and sizes. The robots are designed to operate continuously, 24/7.

The most optimal routes in the network are used to pick and deliver goods, based on calculations made by the controller. The system utilizes durable bins for the storage of goods, with the contents monitored by the system database for optimal inventory control. The bins can also be divided into compartments of varying sizes, facilitating the organization and segregation of goods.



Case study

ROI after two years

Bergfreunde is a European online retailer of outdoor equipment. In August 2016, the company inaugurated a new 10,000 m² logistics center, which placed particular emphasis on the deployment of the AutoStore system. At the Rottenburg-Ergenzingen logistics center, 80 robots are responsible for the management of 94,000 bins distributed across 16 levels. Consequently, a workforce of over 100 employees, operating in two shifts, is capable of processing up to 200,000 items per week.

The implementation of the AutoStore system has resulted in a significant increase in picking efficiency, with the company's productivity rising by over 400%. Prior to the introduction of AutoStore, the company could perform 45 picks per hour. Following the integration of AutoStore, this figure has increased to 175, demonstrating a notable enhancement in operational efficiency. This resulted in a reduction of the lead time to less than three h O k d th i bl f

Fig. 3.44. AutoStore system

AGVs and AMRs

An efficient intralogistics system in the storage area is not only about sophisticated mobile robots; it is also about integrated and well-designed internal transport solutions that are adapted to the plant infrastructure. It is essential to plan the system in a way that allows for seamless integration with automatic supplementary devices, such as pallet lifts, roller conveyors, or loading stations. This ensures an efficient and safe flow of materials, enhancing overall operational efficiency and safety.

The automation of logistics processes is contingent upon the establishment of a well-organized warehouse space and an efficient internal transport system that accounts for current conditions and potential expansion. The deployment of AGVs and AMRs across the zone enables not only the automation of transport operations but also the optimization of available space, while maintaining the highest standards of work safety.

Further information on AGVs and AMRs can be found in other sections of the report.

Case study

Reducing high costs and increasing productivity with AGVs

A DHL client encountered a number of difficulties:

- the client's objective was to achieve a sustainable reduction in costs,
- the ongoing labor shortage introduced greater complexity to logistics operations,
- one of the primary objectives was to enhance productivity,
- work in a complex and highly variable warehouse environment required adaptability,
- the transportation of pallets in the warehouse resulted in a significant loss of time, with an estimated 25 km being transported each day.

DHL introduced a flexible robot designed to autonomously pick and transport pallets in the warehouse. This solution exhibited several distinctive characteristics:

it could seamlessly integrate into the existing warehouse setup without the need for significant modifications,

- it did not require WMS integration, which simplified the implementation process,
- the robot was developed with the specific purpose of working safely alongside human operators.

The solution yielded several advantages. The introduction of the robot resulted in a notable reduction in labor costs, i.e. elimination of approximately two full-time equivalent (FTE) positions, representing a savings of over EUR 40,000 on an annual basis. In addition to savings in labor costs, the company saw a reduction in expenses related to the management of material handling equipment (MHE), contributing to overall cost savings. The solution had a direct impact on employee satisfaction, as it reduced the physical strain associated with manual pallet transport. Furthermore, the robots eliminated the need for manual pallet transportation.

It should be noted that the solution also had some drawbacks. The deployment of autonomous robots still necessitates a considerable initial investment, including the cost of acquiring and deploying a fleet of robots. Furthermore, the use of technology for critical operations may introduce security vulnerabilities. Technical issues or failures have the potential to disrupt operations and require ongoing maintenance and support.

Case study

Autonomous transport within the warehouse

DHL introduced at one of its customer's warehouses a versatile robot that autonomously picks and moves trucks. To minimize safety concerns and create a collaborative and harmonious work environment, the robot is designed to work safely with humans. This resulted in enhanced safety and quality standards, which were of paramount importance to the customer.

\+ The introduction of autonomous robots has resulted in a notable increase in productivity, estimated at approximately 40%. This improvement can be attributed to the robot's capacity to work continuously and efficiently, making it a valuable addition to the workforce.

One of the most notable benefits of the solution was the substantial time savings it offered. The average robot saved 2.5 hours of transport time per 8-hour shift. This enabled employees to focus their time and energy on more value-added tasks, thereby enhancing overall operational efficiency.

Another significant advantage was the reduction of employee fatigue. In a fast-paced logistics environment, it is crucial to reduce the physical strain on employees to maintain a consistent level of productivity. The autonomous robot's ability to handle repetitive, labor-intensive tasks helped to reduce worker fatigue.

The introduction of robots enabled employees to concentrate on tasks with greater added value. The reallocation of resources enabled employees to participate in tasks that demanded critical thinking, problem-solving, and decision-making abilities.

\− The implementation of the solution required an initial investment. The expense associated with developing, implementing, and maintaining a solution of this nature may prove prohibitive for some companies. The reliance of operations on technology makes them vulnerable to the risk of technical failures or disruptions, which could potentially lead to significant disruptions in warehouse operations. It is essential to maintain and troubleshoot the robot fleet in order to prevent unexpected downtime. The advent of robotics may necessitate a shift in the skill set required of employees. Some employees must adapt to new roles or acquire the necessary skills to manage and maintain a fleet of robots, which can present a challenge.

3.7. Picking and sorting zone

The picking zone is a dedicated operational area within the warehouse that facilitates the preparation of goods for shipment. Its size and functionality should be tailored to align with the inventory volume and operational specifics of the warehouse in question. It is crucial to segregate this zone from the rest of the warehouse when implementing automated solutions, such as conveyors or automatic pallet lifts, to ensure optimal functionality and safety. The picking zone can be integrated with the storage zone or function as a separate area, depending on the specific requirements and scale of the operation.

The effective management of the picking area in warehouses offers considerable advantages. These include increased employee productivity and the capacity to process more orders in less time, as well as enhanced order accuracy through the use of sophisticated warehouse management systems. Furthermore, the digitalization and automation of the zone facilitate more efficient planning and utilization of warehouse space, while also reducing the time needed to prepare and ship orders. Effective management of the picking zone also contributes to improved work safety by reducing the risk of accidents and injuries.

3.7.1. Systems and applications

The distribution warehouse picking process represents a significant challenge in terms of labor and costs. This is largely due to the necessity of providing retail service, which encompasses the handling of full transport units and individual products. To reduce costs and enhance efficiency, innovative solutions such as multi-picking and batch-picking have been introduced. Multi-picking is a process that allows several orders to be handled simultaneously using special trolleys. Each order is allocated a space on the trolley, which reduces unnecessary movement and the need for numerous repetitions of operations. Batch picking enables the consolidation of multiple orders onto a single carrier, reducing the time and effort required for picking. However, this method necessitates additional sorting to separate the orders. The objective of both approaches is to enhance the efficiency of the picking process by minimizing the number of required operations and optimizing employee movements.

The application of contemporary picking techniques undoubtedly enhances operational efficiency in warehouses. However, there are opportunities to leverage human capabilities even more effectively. In the process of picking, humans typically rely on two of their five basic senses: sight and touch. Advanced visual and voice systems can significantly improve this process.

The use of visual and voice systems engages multiple senses, which not only enhances efficiency but also mitigates the potential for errors and optimizes workflows. By leveraging the full spectrum of sensory capabilities of employees, these systems unlock new avenues for optimizing warehouse operations while allowing for the invaluable human element of intuition and problem-solving flexibility. Below are some of the most popular systems of this type:

Pick by Light i Put to Light. These are contemporary solutions employed in the goods-picking and sorting process within warehouses. The Pick by Light employs LED indicators on each shelf of the rack to direct employees to the appropriate location for picking goods. The display then provides the necessary quantity information. The Put to Light system is designed for efficient sorting of products. Once a product has been identified, a signal is generated indicating the appropriate placement location.

Pick by Point. This tool provides employees with precise location information for products stored in larger warehouse outlets, including details on where goods are stored on pallets. Further details, such as the quantity of items to be picked, can be displayed on a centrally located screen in the picking area. This system is especially beneficial in large warehouses, where the precision and speed of product localization are essential for the efficient operation of logistics processes.

Pick by Frame. This is an advanced version of the picking aid that builds on the Put to Light concept and introduces an element of multi-picking. This mechanism is based on a mobile frame that is placed on a picking trolley. A crucial feature is the incorporation of LEDs into the frame, which illuminate the designated area on the trolley for picked goods, promptly assigning them to a specific order. This solution significantly streamlines the picking process by minimizing the time needed to sort and assign products to individual orders.

Pick by Vision. This cutting-edge system is designed to streamline the picking process, leveraging the latest visual technologies. This system employs smart glasses, which are synchronized with the WMS. When a warehouse worker scans a product's bar code, the smart glasses automatically display pertinent information about the item, such as the quantity required for picking. The picking operation can be confirmed by a camera integrated into the spectacle frame.

Pick by Voice. The method provides support for the picking process, utilizing voice signals to convey instructions to warehouse personnel. Employees are provided with headphones and receive voice commands regarding the location and quantity of products to be retrieved. Furthermore, confirmation of task completion is accomplished via voice command, a predefined set of words.

The primary benefit of warehouse picking support systems is the enhanced speed and accuracy of goods identification, which enables a notable reduction in the time required to locate items and prepare orders. It should be noted, however, that there are also some limitations. The primary challenge may be integrating with the WMS system, particularly if it is an older or less sophisticated version of the software. To fully leverage the potential of these systems, it is essential to integrate them with advanced picking techniques, such as multi-picking or batch-picking. This integration requires the deployment of suitable software solutions. In the case of frequent reorganization of warehouse processes, the functionality of some of these systems may also be compromised. One drawback of Pick-by-Light technology is that it often requires significant installation costs and extensive wiring. It is also possible that working with systems such as Pick by Voice or Pick by Vision may become monotonous for some employees, which could have an adverse effect on their job satisfaction. [61]

WMS systems are compatible with all picking methods. The automation of the picking process with the use of this software enables a number of benefits, including the ability to perform tasks with greater speed and accuracy, while also enhancing the safety of employees through the integration of modern technologies such as pallet stacker cranes, industrial conveyors, and anthropomorphic robots. These devices, when used in conjunction with the system, guarantee that the picking process is completed with precision, from selecting items from the racks to preparing them for shipping.

The WMS system employs sophisticated algorithms to optimize picking paths, directing employees along the most efficient route to individual order items, thereby reducing the time needed to prepare orders. Furthermore, integration with mobile terminals allows employees to verify the correctness of goods in real time. Additionally, the system enables users to split orders based on priority. The WMS is a game-changing solution that streamlines the transmission and processing of crucial warehouse data. The implementation of such a system allows for a significant reduction in the number of errors in the picking process, with a potential reduction of up to 99% compared to traditional management methods. [62]

In contrast, the WCS software manages the movement and routing of goods within the warehouse, directing them to the designated picking or sorting zone. Fur-

thermore, the WCS coordinates with equipment such as conveyors, sorters, warehouse robots, and carousel systems to facilitate seamless goods movement in alignment with the designated picking and sorting procedures. The system is also capable of prioritizing warehouse tasks based on specific criteria, such as delivery times, thereby enabling the faster delivery of critical orders.

ERP systems, on the other hand, are designed to automatically plan the demand for materials and goods based on sales data and forecasts. This functionality helps to minimize the risk of production downtime and optimize picking processes. They enable automatic order processing and can be integrated with other warehouse management systems.

Bar code and QR code scanning applications in the picking and sorting area facilitate rapid product scanning and automated inventory updates. e-Kanban systems facilitate remote monitoring and inventory management, as well as automatic generation of replenishment orders, which ensures the continuity of production and storage processes.

3.7.2. Sortation systems

These cutting-edge technologies utilize robots and automated conveyors to efficiently identify, sort, and route products to designated locations (Fig. 3.45). The implementation of these systems results in a more efficient, precise, and effective sorting process. This automation mitigates the risk of errors caused by human factors and significantly reduces the time needed to fulfill orders, thereby enhancing efficiency and customer satisfaction.

Fig. 3.45. Sorter from Conveyco

Źródło: [63]

The classification of sorting systems is based on a variety of sorter types, which are adapted to the specific needs and characteristics of the shipments. Below are some of the most popular types of sorters:

- Line sorters are distinguished by their straightforward design, which employs belts or rollers to facilitate the movement of products along a fixed route. These units are ideal for the efficient sorting of items of similar sizes and shapes, directing each product to a designated unloading point.

- Cross-belt sorters comprise multiple transport loops, enabling the efficient sorting of products of various sizes and shapes while offering significant flexibility in shipment management.

- Bombay (split-tray) sorters are designed for the efficient handling of large and heavy objects. The use of mechanisms such as a mechanical arm enables the movement of objects to the correct pathways.

- Disc sorters employ rotating discs to sort items according to their size and shape, directing them to the unloading point.

- Cross sorters are sophisticated systems that utilize cross conveyors to facilitate precise shipment sorting by changing the direction of the conveyor belt.

- Slide sorters employ a smooth surface to transport products to designated unloading points, making them an optimal choice for sorting delicate items and minimizing the risk of damage.

In addition to traditional sorting systems, advanced technologies such as robotics and artificial intelligence (AI) and machine learning are emerging as viable alternatives. Robots offer greater flexibility and adaptability, enabling a more diverse approach to sorting processes. On the other hand, technologies based on artificial intelligence and machine learning have the ability to learn independently and improve sorting processes, thereby enhancing accuracy.

The latest developments in sorter and warehouse automation technology indicate several key trends that will influence the future direction of these products. It is anticipated that these systems will become more integrated with advanced technologies, including artificial intelligence and machine learning. This will facilitate more extensive automation of sorting processes.

Another key area of focus is the introduction of more flexible and adaptable systems. These solutions are designed to support a wide range of products and adapt to dynamic market requirements, enabling a faster and more effective response to customer needs.

Another emerging trend is the personalization of sorting systems and warehouse automation. Adapting these technologies to align with the specific needs of industries and the requirements of individual companies will enable enhanced operational performance and increased competitiveness. [64]

In sorting systems, specific parameters are used to evaluate efficiency. The most important of these is the number of products sorted per hour. It is important to note that the efficiency of the sorting process is dependent on a number of factors, including the size of the items being sorted. Another crucial factor is the speed of parcel movement, often expressed in meters per second, which impacts the sorting process. It is also crucial to ensure that sorting accuracy is maintained to the highest standard. This involves correctly identifying each item and directing it to the appropriate location, which depends on the effectiveness of the scanning equipment. [65]

3.7.3. Stacker cranes and conveyors

Pallet and bin stacker cranes in the picking area provide automation of the flow of goods at the stage of receipt and release, thereby markedly enhancing the efficiency of logistics processes. The benefits of implementing stacker cranes include full automation of load management, accurate control of current inventory levels, minimization of operator errors, ability to adapt to specific storage conditions (e.g., controlled temperature or humidity), and improved worker safety by limiting access to aisles.

Industrial conveyors can also significantly increase the efficiency of picking and storage processes, while minimizing the risk of damage to the stored goods (Fig. 3.46).

Fig. 3.38. Conveyor belt from Mecalux in an order picking area

Źródło: Mecalux, https://www.mecalux.pl/blog/przenosniki-przemyslowe-rodzaje, [dostęp: 31.03.2024]

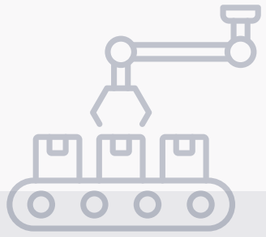
Belt conveyors are flexible and durable, and are ideal for transporting loads of varying characteristics. They are widely used in the agri-food, pharmaceutical and construction industries.

Chain conveyors are suitable for handling pallets with containers and are known for their long service life. They are popular in the agri-food, automotive and recycling industries.

Roller conveyors for pallet handling are indispensable in automated warehouses where pallets are the main load carrier. They are suitable for transporting heavy goods and work with stacker cranes.

On the other hand, container roller conveyors are ideal for electronics and logistics companies handling smaller loads. These products are highly configurable and have low maintenance costs.

Further details on the use of stacker cranes and conveyors for automation in discrete warehouse management zones can be found in other sections of this study.



3.7.4. Robots

Automated guided vehicles

AGVs are gaining traction as a preferred solution for internal transport automation, offering unmanned navigation on designated routes. Automated guided vehicles are instrumental in the movement of goods in picking and sorting areas.

AGVs are an optimal solution for companies utilizing lean manufacturing or just-in-time production methods, ensuring a continuous supply of materials to production lines. While they are not advised for locations with a high volume of goods, these vehicles can markedly enhance operations in automated warehouses and production plants, particularly in the transportation of heavy loads and materials between diverse plant areas.

Investing in AGVs is therefore an especially cost-effective solution in production and warehouse environments, where high-efficiency internal transport is required while reducing operating costs and human error.

Łukasz Dziadczyk,

Head of Logistics VAS at Rohlig SUUS Logistics

To enhance the speed and efficiency of co-packing operations at Rohlig SUUS Logistics, we utilize goods conveyors equipped with automatic belts to facilitate the transportation of products on production lines.

These devices utilize modular belts to facilitate the automated movement of products on the belts, thereby eliminating the need for manual intervention by employees, which would otherwise be required in the absence of this technology.

This solution is particularly effective in situations where product sets are being created, with items moving along the belt while employees focus on adding more items. It is important to note that at the end of the conveyor system, there are buffer rollers where the goods are stopped, allowing the carton to be sealed and transferred to the pallet.

Łukasz Lewicki,

Head of Sales Contract Logistics at Rohlig SUUS Logistics

VNA (Very Narrow Aisle) trucks

The majority of our warehouses are equipped with VNA (Very Narrow Aisle) trucks, which have been designed to enable goods to be picked from any location on the rack.

This solution not only accelerates the said process but also enables optimal utilization of storage space. The VNA eliminates the need to store goods on lower racks accessible from the floor, enhancing operational efficiency.

It should be noted that in order to utilize this solution, employees were required to obtain the necessary qualifications to work at height.

Autonomous mobile robots

These smart machines are equipped with advanced sensor systems and rely on artificial intelligence algorithms and accurate warehouse digital maps to efficiently navigate the picking area and adapt to the changing environment. While they are most commonly used to move lighter loads, such as packages or boxes, there are also models on the market that are capable of transporting heavier loads, including pallets.

The integration of AMRs with warehouse management systems, such as WCS or WMS, markedly enhances logistics processes. These robots are capable of automatically planning the most efficient routes between warehouse locations, as well as avoiding obstacles and responding dynamically to changes in the work environment.

The classification of mobile robots in the context of warehouse operations is driven by the functions they are tasked with, leading to a diverse and specialized field of automation. In the operator-to-product configuration, the robots serve as a dynamic picking truck, tracking the operator through the warehouse. The operator retrieves the products directly from the racks and deposits them into the robot. Upon completion of the picking process, the robot transports the order to the consolidation and packing area. This feature enables the operator to remain in the picking area, thereby increasing work efficiency. In the product-to-operator category, robots are used to transport product racks directly to the picking station.

The parcel sorting process in the warehouse is automated by mobile sorting robots (Fig. 3.47). The labels on the packages are scanned to identify their final shipping locations, after which the packages are moved to the appropriate zone. The versatility of these systems allows them to handle a range of sorting tasks, from straightforward package routing to specific shipping lines to more sophisticated operations requiring precise product sorting based on intricate criteria.

Fig. 3.47. Mobile parcel sorting robots from Mecalux

Źródło: [67]

Some sorting robots are mounted on specially designed platforms. The packages are placed on the robots by employees, which then sort and direct them to the appropriate exit channels leading to the dispatch area. This system allows for the effective management of the flow of goods from different levels of the warehouse to the loading area.

Further information on autonomous AGVs and mobile robots can be found in other sections of this study.

Case study

Trucks with double Pick by Weight scales

Raben implemented the RAVAS solution at the client's site with the objective of reducing picking errors and optimizing inventory control, which in turn reduces inventory time. The company decided to modernize seven electric trucks and equip them with RAVAS double scales in order to improve efficiency and meet customer demands. This integration allows for the combination of two distinct scales into a single order picking truck with 2,400 mm forks, while also incorporating the weighing data into the WMS.

The primary benefit of the double scale is the capacity to manage the selection of two orders in one run. The correct placement of products on pallets can be determined by weighing each item. The order picker is equipped with a mobile weighing system built into the forks, enabling operators to verify each picked order line in real time. Picking errors are immediately detected and corrected. RAVAS' patented FLEXBOLT technology offers a mobile weighing solution with an error tolerance of 0.1% The installation of shock absorbers in the strain gauge sensors serves to prevent overstressing, thereby ensuring optimal weighing accuracy and repeatability. The load weight can be read with an accuracy of 100 grams.

The combination of wireless WLAN data communication and a full API protocol ensures immediate data availability in the WMS in real time. The RAVAS Data Manager (RDM) is a tool designed to streamline the use of Ravas scales integrated into order picking trucks.

The primary advantage that companies have realized through the use of Pick by Weight is the optimization of processes over time. Pickers are no longer required to perform manual counting of goods. This saves time and improves picking efficiency. In addition, the final process check was omitted.

Picking robots

Picking robots are designed to enhance the efficiency and reliability of the order preparation process in warehouses. The most popular anthropomorphic robots (Fig. 3.48) that perform pick-and-place operations are particularly valued for their versatility. Anthropomorphic robots are warehouse robots that can mimic human movements and functions, making them an ideal solution for warehouse tasks that require a more human approach, such as picking and placing small parts.

The design of these robots is inspired by the human body, which enables them to handle objects, tools and perform operations with similar dexterity and adaptability as a human. These devices are equipped with a dexterous set of manipulators, enabling a wide range of motion and functionality. Additionally, they are outfitted with cutting-edge sensors, cameras, and machine learning algorithms. [69]

In light of mounting production demands, automating the pick-and-place process has become a crucial objective for many companies. It allows them to streamline operations and mitigate potential errors. The advent of sophisticated robotic technology has enabled numerous businesses to automate packaging processes, boosting operational efficiency and creating avenues for employees to engage in more imaginative and creative work.

Fig. 3.48. Anthropomorphic picking robot from Mecalux [68]

Źródło: [67]

Case study

Picking zone

DHL's Assisted Picking solution is designed to optimize picking routes, minimizing the time spent picking orders while reducing operator fatigue and increasing overall satisfaction. The system divides the warehouse into designated picking zones, in which humans and robots operate concurrently.

At the core of the solution are autonomous robots from Locus, which are instrumental in enhancing productivity. They move to designated picking zones, each of which is dedicated to a specific category of goods. In the picking area, the robot displays detailed information about the products to be picked. This allows employees to focus on their tasks with due precision and efficiency.

Once the picker has placed the selected item in the robot bin, the machine takes over, autonomously navigating to the next picking location. This process runs smoothly, increasing the overall efficiency of warehouse operations.

The DHL solution offers several benefits. By automating the time-consuming task of transporting picked items, employees can focus on the picking process itself, reducing physical strain and fatigue. This provides a more comfortable working environment and contributes to the well-being and satisfaction of employees. Furthermore, automation facilitates a notable decrease in errors during the picking process. Robots are designed to maintain focus, which enhances accuracy. The modernization has resulted in a notable increase in the number of units picked per hour, which is a crucial performance metric in warehouse operations. In this instance, there was a 30% increase. Furthermore, the introduction of the Assisted Picking system with Locus robots led to a significant reduction in training time, with a 80% decrease observed. This allows new hires to become productive team members rapidly, which is particularly advantageous during periods of high staff turnover.

Case study

Digit humanoid robot

A pilot project involving Agility Robotics' Digit humanoid robot, designed to work on goods picking, is currently underway at the logistics center of the global women's apparel brand Spanx near Atlanta in the United States. The project is being managed by GXO. (Fig. 3.49)

Digit, which stands at 1.80 meters tall and weighs 63.5 kilograms, is capable of lifting loads up to 23 kilograms. It has been designed to work alongside humans in a variety of work environments, with the ability to be easily adapted to a range of warehouse tasks through software updates.

The robot's developers collaborate with GXO to provide training in routine tasks, such as moving containers from autonomous mobile robots to conveyors. Digit enhances the security of warehouse operations, allowing employees to dedicate their attention to more strategic logistics activities.

Fig. 3.49. Agility Robotics' Digit robot used by GXO

Źródło: [70]

Collaborative robots

Collaborative mobile robots (CMRs) (Fig. 3.50) are robotic devices designed to work in direct collaboration with humans in a variety of environments, including warehouses, manufacturing facilities, and logistics centers.

The primary objective of CMRs is to enhance the efficiency, safety, and flexibility of work processes by automating transportation and handling tasks. CMRs can automatically move materials between different locations in the warehouse or on the production site, deliver components and raw materials directly to workstations, and enable a continuous flow of production. This minimizes downtime due to material shortages. Thanks to navigation and obstacle detection systems, they can safely cooperate with people and other vehicles in a dynamic working environment, reducing the risk of accidents and injuries. In e-commerce warehouses and distribution centers, CMR robots streamline order picking and packing operations, boosting productivity and reducing employee turnover. In fact, the robots deployed in GXO's warehouses have doubled productivity and cut turnover by 30%.

Fig. 3.50. Collaborative robot used in GXO warehouses from 6 River Systems

Źródło: [71]

Operator Eye system

Operator Eye is an AI-powered solution (Fig. 3.51). The objective of this system is to identify and eliminate error patterns, thereby reducing downtime and the need for employee involvement in the picking process. This approach has proven to reduce picking errors by approximately 75%. Operator Eye employs a camera system to record errors in real time during picking, enabling the creation of algorithms that learn from the operator's performance. The system is designed to detect errors, adjust operations, and make decisions regarding the continuation or cessation of work, in a manner analogous to autonomous vehicles.

One of the most significant advantages of the Operator Eye system is its ability to enhance machine efficiency without requiring any modifications to the operator's workflow. Once the requisite information has been acquired, the system will automatically reset the machine, thereby enhancing its efficiency. Furthermore, Operator Eye can be utilized in other machinery where operator restart is necessary, such as pallet stackers.

In addition to enhancing the safety, efficiency, and productivity of warehouse teams, this solution enables employees to prioritize value-added tasks such as identifying and resolving quality and equipment issues. Furthermore, the data retrieval module enables operators to oversee and enhance operations and the customer experience. This may entail identifying problematic packaging types and assisting suppliers in implementing changes to streamline processes.

Fig. 3.51. **Operator Eye from Körber and GXO Logistics**

Źródło: [72]

GRS robots

GRS (Global Robotics Services) robots are part of a modular and scalable robotic solution designed to streamline operations, enhance throughput, and ensure accuracy in sorting processes in warehouses and logistics centers (Fig. 3.52). They operate on the principle of robotics as a service (RaaS), which allows for rapid and straightforward implementation.

Fig. 3.52. **GRS robots used in GXO warehouses [73]**

Źródło: [73]

The robots can achieve throughput three times greater than that of other sorting methods, while also enhancing accuracy and reducing errors. They can be quickly adapted to changing requirements.

Case study

GRS in GXO Logistics warehouses

GRS robots were utilized in a 3D sortation system at a GXO Logistics installation (Fig. 3.52), situated at a logistics center in Stradella, Italy.

During the 30-day pilot project, more than a dozen 3D sorting robots were programmed to handle 30 trucks with more than 450 target bins, achieving a throughput of 1,200 units per hour. This represents a throughput capacity that is more than three times greater than that of previous solutions.

The project has resulted in enhanced operational efficiency and throughput, as well as optimized working hours associated with the sorting process. It has also led to a reduction in errors and an improvement in order traceability.

Palletizing and depalletizing

Palletizing is typically conducted in the order preparation area or in a dedicated packing and picking area within the warehouse. This is the process by which goods are stacked and secured on pallets into load units, ready for transport.

Depending on the size of the warehouse and the nature of the activities being carried out, palletizing can be carried out manually by employees or automated with specialized palletizing machines (Fig. 3.53).

Fig. 3.53. **Palletizing robot from Kuka AG**

Źródło: [71]

Palletizing robots are sophisticated automated devices designed to streamline and optimize production processes. The market offers a wide range of palletizing robots, distinguished by their design, functionality, and application. Examples include robots with articulated arms, Cartesian arms, vacuum systems, and mechanical grips. Palletizing robots with a depalletizing function are designed to automatically unload products from pallets.

Palletizers and depalletizers are available in a variety of models and configurations to meet the specific needs of manufacturing and logistics processes. These include low-level devices (the process of stacking products onto pallets takes place at a low level), high-level devices (products are transported to a high level where they are then placed onto pallets below), robotic devices that use one or more robotic arms to manipulate products and stack them onto pallets, or layered devices that stack multiple products onto pallets at once.

Case study

30,000 cartons per day while maintaining quality

At the end of March 2021, the second stage of investment related to the implementation of robotic palletizing stations was completed in the largest co-packing center of Raben Logistics Poland in Gądki near Poznań.

In cooperation with PiDT, the operator implemented two palletizing stations. They are based on KUKA's fastest robotic manipulators in their class. Four different product shapes can be palletized simultaneously with the technology used. Specially designed grippers with an integrated stabilizing plane eliminate the limitations associated with the variety of package shapes. In addition, they are equipped with suction cups that allow them to pick up and place cardboard dividers without operator intervention. Using the intuitive FlexPal software, the company is able to adapt the unit to a new production in a matter of minutes, without the need for advanced engineering skills.

The specificity of services provided in a multi-client operation is characterized by high dynamics and the need to quickly adapt to changes. The goal of the project was to create a solution that was as universal as possible and that could be easily adapted to the new product range in a non-invasive and simple way, while at the same time improving work ergonomics. Today, by automating this part of the process, the company can palletize up to 30,000 cartons per day while maintaining repeatable quality.

3.8. Packing and shipping zone

The release and shipping area in the warehouses plays an important role in the final stage of the logistics process. In this area, employees are involved in preparing, organizing, and efficiently shipping orders. It starts with picking, where workers pull products from different parts of the warehouse to fulfill specific orders. This process is often supported by a variety of technologies, such as WMS systems, bar code scanners or warehouse robots.

The packing area in warehouses is often located within or in the immediate vicinity of the release and shipping area. This arrangement is essential to ensure efficient and seamless operations, enabling a smooth transition of products from the packaging process to the final stage of preparation for shipment. This system allows for rapid and streamlined order management, minimizes downtime between packing and shipping, and mitigates the risk of errors and product damage. The integration of these zones enables more efficient utilization of warehouse space and human resources, which is particularly crucial in warehouses with high capacity and those handling a substantial volume of e-commerce orders.

3.9. Systems and applications

WMS systems are an invaluable asset in the realm of releases and shipments, as they markedly enhance the efficiency, precision, and velocity of warehouse operations. Furthermore, WMS enables the management of shipment priorities based on a range of criteria, including delivery times and specific customer requirements. Updating inventory data on an ongoing basis ensures the availability of accurate product information, which enables more efficient shipment planning and reduces the likelihood of delays.

Automatic generation of shipping documents, such as waybills or address labels, streamlines the packing and shipping process, ensuring compliance with all applicable regulations. Integration with courier systems and transport platforms automates the exchange of shipment information, streamlining the monitoring of shipments and communication with customers.

Transport management systems (TMS) facilitate the optimization of shipment planning and monitoring processes. They can be utilized to streamline the selection of carriers, optimization of rates, planning of routes, and real-time monitoring of shipments. Some ERP system modules can also be leveraged to streamline packaging and shipping operations. These tools streamline order and invoicing management.

Łukasz Lewicki,

Head of Sales Contract Logistics at Rohlig SUUS Logistics

We have implemented a dedicated packaging zone and a quality and quantity control zone for goods for one of our e-commerce clients. This integrated infrastructure includes automated conveyor belts and packing stations, which are connected to monitoring, WMS, and EDI. This solution allows for the exchange of commercial and financial documents, including orders, shipment bookings, and invoices.

These tools enable pickers to rapidly retrieve goods from the racks by displaying their location on a scanner provided by the WMS. The goods are then conveyed automatically to the packing staff. Furthermore, the zone is equipped with packaging and fillings of varying sizes to accommodate the dimensions of the shipment. The algorithm recommends a selection to employees.

Furthermore, integration of monitoring, WMS, and EDI systems assures that all products adhere to the requisite quality standards and are consistent in terms of quantity with the customer's order.

Virtual shipping gateways are sophisticated IT systems designed to automate and optimize shipping processes. This solution is based on virtual monitoring and management of the goods leaving the warehouse, integration of shipping data from WMS or ERP, and automatic processing of orders on their way to the customer.

They automate the process of identifying, weighing, scanning, and sorting shipments in real time Additionally, they facilitate the automated generation of shipping documents, address labels, and other requisite materials, thereby markedly accelerating the preparation of shipments for transport. Furthermore, integration with courier systems enables direct transmission of shipment data and real-time status updates.

On the other hand, the integration of warehouse systems with courier systems and e-commerce platforms represents a crucial step in the automation of processes in the release area. This enables seamless and effective management of shipments, from the initial order preparation stage through to shipment and delivery to the customer. This enables the automation of processes that traditionally required manual data entry and supervision.

The following is an overview of the integration process:

1. 1Once the order has been prepared and confirmed in the warehouse system, the shipment information is automatically transferred to the courier system. In response, the system generates a shipping label with a unique tracking number, which is automatically printed in the warehouse and applied to the shipment.

2. The integration facilitates electronic data exchange between warehouse systems and e-commerce platforms, including order, shipment, delivery status, and return information. This feature allows for seamless order status updates and product availability in real time.

3. The system is designed to automatically select the most optimal shipping options for each order based on contracts with individual couriers and analysis of costs, delivery times, and customer preferences.

3.10. Packaging automation

Cartoning machines

Automation is frequently employed in the packaging of products that require strict sanitary standards, including food, pharmaceuticals, and cosmetics. In this case, solutions such as cartoners and automatic carton fillers are highly effective.

One automatic solution in this area is the I-Pack system. This on-demand packaging system automates the forming, filling, and sealing of cartons for a wide range of products. The system automatically forms the carton to the exact dimensions of the packaged product. It precisely fills the space around the product in the carton with the appropriate filling material. Once the carton is filled, it is automatically closed and secured, and then labeled.

Case study

700 cartons per hour at GXO Logistics warehouse in the Czech Republic

The I-Pack system automates repetitive packaging operations, thereby enhancing the comfort, safety, and operational efficiency of the work process.

One of the key advantages of I-Pack is its ability to optimally adjust the height of packages, which allows for an average reduction in package size of 30%. The reduction in packaging size has a direct impact on lowering transportation costs and reducing the environmental impact by minimizing the amount of air transported in trailers.

The I-Pack system offers a range of benefits, including high efficiency (up to 700 cartons per hour), automation of the process (replacing the work of 11 people dealing with manual closing of packages), and reduction of transport costs (optimization of package size to reduce the space occupied by shipments).

Automatic sealing machines

An automatic sealing tunnel (Fig. 3.54) is a packaging device that automates the process of packing products in shrink film. By integrating sealing and shrinking functions into a single continuous process, these machines enhance operational efficiency while elevating the quality and visual appeal of packaging.

The integration of the machine with automatic loading systems allows for automatic product feeding, reducing the necessity for manual operation. From a technical standpoint, the machine's programmable operating parameters, including the temperature in the sealing tunnel and the speed of the conveyor belt, facilitate rapid adaptation to a diverse range of products and films. These machines can be integrated with ERP and WMS systems.

Rys. 3.54. Automatic sealing machine from Master-Pack

Źródło: [75]

Łukasz Dziadczyk

Head of Logistics VAS at Rohlig SUUS Logistics

In 2023, our company prepared 5.4 million cans of an alcoholic beverage for sale for one of our FMCG clients as part of our banding and co-packing services. The repackaging process was undoubtedly made more efficient by the use of an automatic sealing tunnel machine designed specifically for this cooperation.

The products were delivered to us in multi-packs. Due to the necessity of affixing the excise stamp, they had to be unpacked. Our objective was to return the packaging to its original condition, as it was when the goods were delivered to us. The machine enabled us to repack up to 21,000 cans per day. The entire process was conducted at our SUUS branch in Sokołów, located near Warsaw.

Film sealers

A film sealer operates by applying a high temperature to the sealing point, which results in a permanent connection between the film edges after pressure is released and cooling occurs. The process can be automated or semi-automatic, depending on the type of sealer and production requirements.

In the automated version, the sealer can be integrated into a production line where the sealing process is fully synchronized with other production steps, such as package filling, labeling, and packaging. Operators set the sealing parameters, including temperature, time, and pressure, and then the machine performs the sealing process without the need for continuous human intervention.

Case study

50% reduction in time and 30% decrease in film usage

A DHL customer faced particular difficulties in the area of container acceptance.

- Due to the variable heights of the pallets, which ranged from 0.5 to 3.1 meters, a versatile solution was required to ensure efficient wrapping.
- Manual wrapping was the preferred method, but it led to different wrapping quality and caused efficiency issues.
- The manual wrapping process yielded inconsistent results, which could potentially compromise the integrity of the goods during transit and storage.
- The client's objective was to enhance operational efficiency and reduce labor costs, thereby optimizing the utilization of human resources.

DHL implemented a solution that introduced a mobile load wrapping machine from PKG. It has brought the following benefits:

- better wrapping quality: wrapping quality has notably improved,
- task reassignment: employees saved about 50% of their time,
- savings on film: film consumption has been reduced by 30-40%.

This solution presents two main disadvantages: a high initial investment and the necessity for additional operator training.

Packaging robots

Packaging robots are sophisticated automated systems designed to streamline product packaging operations. The primary objective is to automate a range of activities, including packaging, closing, labeling, palletizing, and depalletizing (Fig. 3.53). Their operations are based on programmed instructions that define the movement of products and packaging.

These devices can be equipped with a variety of tools, including grippers, vacuum suction cups, and special label applicators, enabling them to handle a diverse range of tasks. Advanced vision systems enable robots to recognize the position and orientation of objects, allowing for precise grasping, placement in packages or on pallets, and other packaging tasks.

Further information on packaging robots can be found in other sections of this study.

Wrappers

Wrapping machines, also known as pallet wrappers, are devices used to automatically wrap loads on pallets with stretch film, which protects the goods from damage, contamination, and movement during transport and storage. The automation of the wrapping process has the potential to bring about significant improvements to logistics operations, enhancing both the safety and efficiency of packaging processes.

The wrapper automatically applies the stretch film around the load on the pallet, creating a compact and stable loading unit. The process typically commences with the placement of a pallet of goods on the machine's platform. Subsequently, the pallet can be rotated around its axis, while the film is dispensed from the roll and stretched evenly around the load, depending on the type of machine in use. In other types of machinery, the head with the film moves around while the pallet remains stationary. Once the process is complete, the film is automatically cut and secured.

Labeling and marking systems

A labeling and marking system is an integrated solution for the automatic application of labels, stickers, or direct marking of products, packaging, or pallets. These systems comprise a variety of components, including label printers, applicators, bar code scanners, machine vision systems for verification, and label data management software.

The first step in automating the labeling process is to select the appropriate label and determine the information to be included on it. The information is then printed on a label that is automatically applied to the product, packaging, or pallet by the applicator. In the case of direct marking, the information is printed directly on the surface of the product or packaging using techniques such as inkjet, laser, or thermal transfer.

Scanners

Scanners in the release and shipping area are instrumental in streamlining logistics processes, particularly in the areas of product identification, order verification, and shipment data management. There are a number of different types of scanners that are used in various stages of the shipping process. These include manual, desktop, and mobile computers with scanning capabilities, as well as vision systems.

Scanners facilitate the swift verification of product picking and packaging accuracy for all items in an order. Furthermore, data from scanners can be leveraged to optimize order picking routes. Additionally, the system is equipped with the capability to automatically generate waybills, invoices, and other shipping documents.

Łukasz Dziadczyk

Head of Logistics VAS at Rohlig SUUS Logistics

Automatic labeler for cylindrical products

One of the most frequently requested services in contract logistics is product labeling, which includes information about the goods in the language of the country to which they are exported. From one perspective, the process is repetitive. From another, it is one in which the margin of error during application is minimal. At SUUS, we utilize an automatic labeler for cylindrical products for one of our customer projects in the alcohol industry. The machine is capable of labeling beverage bottles with a variety of labels, including both standard white labels and transparent labels. Efficiency is a critical objective of this project. We are well-positioned to meet this challenge effectively by leveraging partial automation of the process.

Equipment supporting the banding process

To enhance the efficiency of the banding process, we are implementing the use of machines equipped with a label feeder, which enables the automatic application of glue. The employee's role is limited to affixing the label to the product, rather than preparing it by applying an adhesive. The implementation of this solution results in increased efficiency and enhanced comfort at work.

Case study

Saving 5 seconds per pack

DHL encountered a challenge in the process of packing outbound shipments. It was common practice for operators to place the RF scanner down and pick it up again when handling cartons, as the use of both hands was required for the task. This recurring process not only resulted in inefficiencies but also caused delays in the packaging operation.

DHL provided a solution that leveraged the capabilities of a wearable scanner. A glove scanner with a trigger located under the thumb allowed operators to access the scan function hands-free. The solution also included a Bluetooth access point to seamlessly connect the wearable scanners to the packing station computer, ensuring reliable and efficient data transfer.

The solution resulted in significant time savings of approximately 5 seconds per packaging operation. While this may seem modest for individual operations, it adds up to significant time savings for high-speed logistics operations.

Disadvantages include significant up-front costs and the need for additional operator training.

4 Barriers and opportunities in the implementation of new technologies in warehouses

In today's fast-paced business world, warehouses play a key role in ensuring smooth deliveries, optimizing logistics processes, and increasing operational efficiency. As technology advances, businesses have access to increasingly sophisticated tools that have the potential to revolutionize the way they manage their inventory and warehouse operations.

While modern technologies promise to improve efficiency and profitability, their implementation is not always straightforward. They face a variety of challenges, both technical and organizational, which can be barriers to their successful implementation. Concurrently, the implementation of innovative technological solutions presents a multitude of prospects and advantages, with the potential to radically transform the operational landscape of warehouses.

This chapter will examine the challenges and opportunities presented by the introduction of new technologies in warehouses. With the input of industry experts, we will examine these challenges and the opportunities they present in the context of optimizing warehouse operations and enhancing company competitiveness.

Opportunities	Bariery
sortation systems	high implementation costs
warehouse robots and cobots	depreciation
RFID technologies	appropriate personnel qualifications
automation of warehouse processes	resistance from staff
inventory tracking and monitoring	incorporation of new technologies into existing systems

4.1. Barriers to the implementation of new technologies in warehouses

The decision to automate processes is a strategic one that will have an impact on the entire business and the company's future capabilities. In Poland, modern technologies supporting processes in warehouses are already widely utilized. An increasing number of warehouses are equipped with popular automation solutions for specific processes, including packaging, internal transport, and sorting shipments. Nevertheless, numerous obstacles remain, and the implementation of technology in Poland is not yet as pervasive as in Western Europe.

High cost of introducing new technologies to the warehouse

One of the main barriers is the high cost of introducing new technologies into the warehouse. The costs associated with implementing advanced warehouse management systems, process automation, or IoT (Internet of Things) technologies can be considerable, particularly for smaller companies or those in the early stages of development. Furthermore, it frequently necessitates the provision of training to existing personnel or the recruitment of external specialists, which in turn gives rise to additional expenditure.

"The cost of investment in relation to labor costs remains high, and despite initial plans to streamline processes in warehouses, customers often prefer to defer financial decisions until the final calculation of the return on investment," states Anna Galas, Business Development Director Poland, DHL Supply Chain.

"From our experience of managing e-commerce projects, we believe that it is already beneficial to consider flexible automation methods that can alleviate the pressure on warehouses during peak periods or in locations where it is challenging to source labor, particularly skilled warehouse workers," she adds.

Depreciation

In addition to investment costs, a further challenge in implementing technology solutions in multicustomer warehouses is their depreciation. Why?

– "Given the diverse customer base served by these facilities, the products stored therein exhibit a range of characteristics, including varying dimensions and weights, as well as differing service conditions. To ensure effective depreciation of the technology, it is essential to identify projects with comparable characteristics during the planning stage of warehouse filling. Similarly, implementing solutions for customers from an industry that has not been previously served in a given facility presents its own set of challenges. The use of certain tools is subject to health and safety, fire protection, and warehouse infrastructure regulations, particularly with regard to the storage of goods from ADR groups. Therefore, certain technological elements should be implemented already at the stage of building or equipping the warehouse," explains Łukasz Lewicki, Head of Sales Contract Logistics at Rohlig SUUS Logistics.

Appropriate personnel qualifications

The Rohlig SUUS Logistics expert notes that certain tools require employees to possess the necessary qualifications.

"In the case of VNA system trucks, these are additional qualifications that must be met in order for an individual to be permitted to work at height. It is notable that a limited number of professionals possess these qualifications. Similarly, in the event of a machine failure, we require a technician on our team who will be able to efficiently restore the machine to proper working order. Therefore, in order to implement these new tools, we must either provide training for our current employees or hire new personnel who will be adequately qualified," he states.

Resistance from staff

We now turn our attention to the next challenge, namely resistance from the staff. The introduction of new technologies often necessitates changes to existing work processes, which can create uncertainty among employees. Fears of job loss, difficulty learning new systems, or a lack of trust in new solutions can impede effective change management and hinder the implementation of new solutions. But it doesn't have to be that way.

"Despite the common perception that employees are reluctant to embrace automation in the workplace, our findings indicate a positive attitude towards automated warehouses. Employees are keen to learn how to use the equipment and view such a workplace as a valuable opportunity to advance their careers and develop new skills. „Our goal is to enhance the quality of work for our employees, and these changes are a result of our commitment to digitization and automation in warehouses, as well as the introduction of new robotic solutions," says Anna Galas, Business Development Director, Poland, DHL Supply Chain.

Automated warehouses are garnering interest from employees

Dawid Kwiatkowski, Digitalization Manager Operations Excellence, DHL Supply Chain, adds that thanks to robots taking care of the time-consuming task of transporting picked items, employees can focus on the picking process itself, reducing physical strain and fatigue. "Freeing employees from monotonous and physically demanding tasks increases their satisfaction. Happy employees are more motivated and stay with the company," he assures.

Incorporation of new technologies into existing systems. It is also important to consider how new technologies can be integrated into existing systems. It is not uncommon for warehouses to have their own management systems or software, which can present challenges when integrating with new solutions. Incompatibility between different systems can result in significant operational challenges and impede the effective functioning of the warehouse.

"In the context of value-added services in contract logistics, the integration of new technologies should be considered when the project entails a substantial volume of goods and repetitive activities. Why? For instance, in the labeling process, where there are numerous items with varying dimensions, the implementation of an automatic labeler may not always be a cost-effective solution. This is because it would require adaptation to each product type, which would not necessarily result in increased productivity. It is also important to be aware that the installation process for a given solution is often time-consuming, which requires careful planning and advance preparation for implementation well in advance of the project start date," says Łukasz Dziadczyk, Head of Logistics VAS at Rohlig SUUS Logistics.

4.2. Opportunities for the implementation of new technologies in warehouses

The implementation of new technologies in warehouses presents numerous opportunities and benefits that can significantly enhance operational efficiency and competitiveness. Despite the challenges, the potential gains are significant.

"The implementation of technological solutions in contract logistics offers numerous advantages, including process optimization, accelerated order fulfillment, and enhanced efficiency – which is especially crucial when servicing companies from the e-commerce sector. Furthermore, the incorporation of technological advancements enables us to establish a competitive edge," claims Łukasz Lewicki, Head of Sales Contract Logistics at Rohlig SUUS Logistics.

One of the main opportunities is the automation of warehouse processes. The use of advanced sortation systems, warehouse robots, and RFID technologies enables the automation of numerous routine tasks, thereby enhancing efficiency and reducing the potential for human error. Automation can also reduce lead times and

optimize warehouse space, which translates into time and cost savings.

"The use of technology in the area of co-packing offers a number of advantages, including increased efficiency, faster processing times, and the ability to maintain quality standards (e.g., the label on the bottle must often be applied with a margin of error of up to 1 mm). Furthermore, the implementation of automated solutions frees up employees to perform less repetitive and physically demanding tasks, allowing them to focus on more complex and value-added activities with greater efficiency. It can therefore be concluded that the use of technology has a positive impact on other manual warehouse processes," says Łukasz Dziadczyk, Head of Logistics VAS at Rohlig SUUS Logistics.

Another significant opportunity is to enhance inventory tracking and monitoring. The combination of IoT technologies and advanced warehouse management systems provides businesses with enhanced visibility over their inventory. Real-time monitoring enables more rapid response to shifts in demand, prevents stock-outs, and minimizes excess inventory.

Furthermore, modern technologies can assist warehouses in achieving sustainable development goals. Optimizing routes, reducing energy consumption, and utilizing environmentally friendly materials can help minimize the environmental impact of warehouse operations.

It is also worth noting that the implementation of new technologies can provide a competitive advantage for the company. The latest solutions in warehouse equipment offer enhanced flexibility, speed, and efficiency, enabling businesses to better serve their customers and strengthen their business relationships.

In conclusion, while there are some obstacles to overcome, the introduction of new technologies in warehouses presents a significant opportunity to enhance logistics operations, boost efficiency, and gain a competitive edge in the market.

5 Warehouse automation applied by leading developers

The industrial real estate market is characterized by intense competition. Developers outdo each other not only in delivering space on time and at an attractive price, but also in offering solutions that facilitate cost management and optimization. As in the housing industry, marketing brochures are no longer sufficient for sales. They are being replaced by 3D tours, and the industrial sector is raising standards. This is happening in several ways. For example, there are Big Data systems that provide constant access to documentation and allow for ongoing cost tracking. There are also sensors, remote lighting control, and devices with access to augmented reality.

ESG marketing activities are now a standard and integral part of every investment, having evolved from being a fashionable and desirable way to achieve a green image. In order to minimize the environmental impact of their projects, investors are turning to modern technologies that improve energy efficiency and reduce operational carbon footprints.

What are the practical implications of applying modern technologies and innovations to the industrial market?

5.1. Actions taken by developers in the field of utility consumption

PANATTONI

Solutions such as the selection of appropriate materials, improvement of the insulation of walls and roofs, ventilation with recuperation, LED lighting, external dusk sensors, internal motion sensors, heat recovery from refrigeration equipment and air recuperators are becoming standard features in Panattoni's modern warehouses. On the other hand, water conservation is made possible by leak detection systems, the use of aerators, the use of grey water, and other means. Energy and water consumption are optimized by sophisticated building management systems, such as BMS.

Furthermore, as part of the standard procedure, Panattoni prepares the roof structures of all new investments for the installation of photovoltaic panels. Energy suppliers are selected with the objective of supplying the majority of the energy from renewable energy sources (RES). The Danfoss factory in Grodzisk Mazowiecki is an excellent example of a low-emission facility. Its success is due to a combination of energy efficiency, heat recovery, and the use of only renewable energy sources. At Panattoni Park Konin, which received the second BREEAM Outstanding rating in Poland, there was a notable reduction in primary energy consumption, with nearly a quarter of the energy required for the building's operation (22.8%) coming from a photovoltaic installation.

From the outset, the facilities undergo energy modeling in accordance with BREEAM standards at the "Excellent" level, which represents the pinnacle of the industry in Poland. The company's strategy is focused on reducing heat loss, which is achieved through the use of solutions such as improved thermotechnical properties of the enclosure structure, energy-efficient windows, an LED lighting system inside the building and in the adjacent area, and destratificators that redirect heat from the upper parts of the building to the lower parts.

To meet the specific requirements of tenants, Panattoni provides a range of supplementary solutions, including docks with locking mechanisms and pneumatic aprons, air curtains, heat recovery systems from refrigeration equipment, and air recuperators. Another key aspect is the incorporation of additional skylights in the hallways and the deployment of contemporary glazing in the office facade. This not only enhances the daylight penetration within the buildings but also optimizes thermal insulation, thereby fostering a more comfortable work environment.

Furthermore, heat pumps are becoming an increasingly popular solution in the context of energy savings. The shortened payback period on investment in this technology allows heat pumps to generate substantial savings, reaching hundreds of thousands of zlotys per year.

PROLOGIS

In order to meet the needs of customers and their employees, Prologis is creating parks that operate as vibrant, highly functional office and warehouse facilities. The implementation of LED lighting, increased insulation in the walls and roof, and the installation of additional skylights in the roof and walls has resulted in a notable reduction in heating and electricity costs. In addition, solar panels are being installed to heat water in office buildings, and photovoltaic panels are also helping to save energy. Predicting and managing usage costs is supported by facility management systems and electronic fault reporting systems.

HILLWOOD

In addition to installing indoor motion sensors and photovoltaic panels on the roofs of its facilities, Hillwood has taken further steps to reduce the negative impact of warehouse lighting on the environment by replacing traditional lighting fixtures with modern and efficient ones. Moreover, the angle of their tilt and the focus of their light have been adjusted to illuminate only their own property while minimizing the illumination of neighboring areas. Through these measures, Hillwood has reduced light spill and provided greater control over the illuminated area.

The developer is installing motion sensors and lighting management systems inside the buildings, as well as an outdoor lighting control system. Thanks to it, such lighting operates at only 25% of its full power at night. This solution minimizes light pollution, reduces indirect glare, and minimizes interference from adjacent lighting. In addition, luminaries and fixtures have been installed that are expected to last for the next 25 years. This minimizes the need for frequent replacement and waste.

GLP

GLP projects in Poland are characterized by a practical approach to technology. Taking into account the needs of the users, the developer has developed a number of solutions that it is introducing in each new hall, including intelligent weather or lighting control using the DALI system, and the roofs of all new facilities are prepared for the installation of photovoltaic panels.

During the construction phase, GLP uses advanced thermal imaging systems to inspect insulation, which eliminates uncontrolled heat loss during the building's operational phase. The company is open to implementing additional technologies suggested by customers.

7R

7R is making its first investment in the spirit of the recently adopted new decarbonization strategy. Environmentally friendly solutions are expected to save energy, lower operating costs and reduce the carbon footprint of the facility under construction in Lower Silesia: operational CO2 emissions will be more than 50% lower compared to buildings constructed in accordance with the technical requirements of the building code.

In the future, the building will also require much less electricity to operate. According to 7R's calculations, the reduction in primary energy demand per square meter per year will be almost 70% compared to current regulations.

During the design phase of the facility, the developer carried out extensive thermal modeling, which, among other things, led to the development of solutions that allow such a large reduction in emissions. The technical solutions used include: high-efficiency LED lighting, increased air-tightness of the building, improved specification of heating and ventilation systems equipped with heat recovery systems, as well as high-efficiency heat pumps and a system of photovoltaic panels.

LCUBE

LCUBE uses advanced technologies to create assets that are attractive for investment. The smart systems installed in each park are selected on a case-by-case basis and may include roof deflection monitoring or smart metering to monitor and report utility consumption, including ESG parameters. Energy-efficient LED lighting is activated by motion sensors in common areas and on the facade, and the developer also uses destratificators to manage heating in the rooms. Rainwater retention is implemented in the parks.

WHITE STAR

White Star facilities provide a variety of technological solutions that enhance comfort, safety, and work efficiency. The investor has facilities in its portfolio that had been certified for energy efficiency and environmental friendliness long before such certification became a standard practice among companies. The developer's complexes utilize low-flow, water-saving fixtures, and supporting systems allow for the monitoring of key systems, including:

- Cooling node – monitoring a number of key pa-

rameters, including temperatures, the status of pumps and actuators, the operational status of the cooling unit, and any failures that may occur. Possibility of adding operating time schedules.

- Heating node – monitoring a number of key parameters, including temperatures, the status of pumps and actuators, and any failures that may occur. Possibility of adding operating time schedules.
- Monitoring of key parameters from LV and MV switchgear network analyzers, including voltage, current, and power consumption.
- Monitoring of heating cables.
- Monitoring of failure of transformer core temperature sensors and ventilation of the transformer room.
- Monitoring of antifreeze sensors of air handling units.
- Monitoring of the water supply in the facility.

Furthermore, notifications of critical technical and fire emergencies (in addition to on-screen displays) are sent via SMS, enabling immediate responses. The fire alarm system also monitors the operation of the booster pump on the sprinkler system. Additionally, a remote reading system is available for selected heat meters. The presence of concentrators on the premises allows for comprehensive monitoring of both heat and cold meters.

SEGRO

SEGRO is a market leader in the application of systems and technical equipment in industrial facilities. The developer is increasingly utilizing the BMS platform in warehouses, which streamlines management, saves resources, and provides optimal user experience.

The BMS platform allows for the real-time control of heating, cooling, ventilation, and lighting systems in SEGRO warehouses, enabling the optimization of energy consumption and the overall efficiency of the building. The platform is equipped with devices that communicate their current technical status, enabling the swift identification of any failures or defects.

The DALI (Digital Addressable Lighting Interface) lighting control system used by the developer enables precise control of individual lighting fixtures and groups of lights, which results in energy savings, an extended lifespan for light sources, and an enhanced user experience. The use of LED lighting in warehouse buildings offers a dual benefit of reducing energy consumption and enhancing safety, both inside and outside the premises.

Furthermore, solar energy is utilized to reduce energy consumption from the power grid and to facilitate the return of surplus energy produced to the system. This increases the share of renewable energy sources in the overall energy balance of the economy and contributes to the reduction of CO_2 emissions. SEGRO systematically implements photovoltaic solutions in its portfolio.j. Additionally, the developer installs heat pumps, an environmentally friendly device that transfers heat energy from external sources (e.g., air, water, ground) to a location with a higher temperature (heating system), where it is utilized to heat buildings or tap water.

MDC2

As the developer notes, modern companies require modern support, convenient access, full technological facilities, and 24/7 monitoring of the facility to facilitate business growth. MDC2 buildings are managed by intelligent systems that support cost optimization and offer the possibility of installing motion detectors or a DALI lighting system. The roofs have been prepared for the installation of photovoltaic panels, and the insulation of walls and roofs has been increased. The developer is also collaborating with renewable energy suppliers to facilitate the purchase of green, reliable energy by tenants as part of their overall purchasing needs.

5.2. Technical solutions with the use of technology in industrial buildings

PANATTONI

The developer has implemented a series of enhancements to facilitate tenant usage of logistics parks, including the installation of automatic entrances with license plate recognition and electric vehicle charging stations. The facilities are managed by intelligent management systems, which facilitate the management of utility consumption and building operating costs. Furthermore, the improvement of increased load-bearing parameters of roofs and facades reduces the costs of possible adaptation of the warehouse to the needs of production or installation of additional equipment.

Panattoni prepares the floors of the new facilities in a way that allows tenants to implement projects to automate logistics and manufacturing operations, with the majority of them not requiring additional profiling. Another tool that streamlines the development of tenants and the integration of modern technologies is the strategic placement of main switchgears in close proximity to potential power supply points. This approach eliminates the need to relocate the transformer system. The fire protection system utilized in Panattoni's warehouses also permits seamless expansion and potential integration with the latest automatic systems.

In order to ensure the well-being of tenants' employees, the developer has provided additional sanitary facilities in the halls, which shorten the routes during breaks. Furthermore, the developer has used waste wind turbines to build lounge furniture in the common areas. That said, Panattoni underscores the importance of a well-managed technical team and the value of good management, even in the context of cutting-edge technology.

PROLOGIS

Prologis parks utilize automatic plate-reading systems to facilitate entrance, and have installed electric car chargers, bike sheds, and bike repair points.

The enhanced load-bearing capacity of the floor, augmented insulation of walls and roof, and augmented fire resistance enable tenants to utilize contemporary solutions without necessitating significant structural modifications to the building.

Furthermore, the developer provides a variety of amenities for employees as part of the PARKLife™ program, including rest areas for tenants, barbecue shelters, and even outdoor BookBox libraries. Furthermore, there are plans to introduce unmanned toilets for drivers. The smooth operation of the park is overseen by a dedicated team of Prologis property managers.

SEGRO

The automatic number plate reading system is also successfully deployed at SEGRO's logistics parks. The solution offers enhanced security and communication efficiency for employees and regular suppliers, which is a crucial benefit for customers in the logistics and courier sectors. It also saves time and provides comprehensive registration of traffic in the area of the logistics park.

Tenants can also report defects through a dedicated system. This enables more rapid identification of issues and more effective warehouse management. The system allows for remote monitoring of the technical condition of equipment and adjustment of their operation to tenant needs, greatly streamlining and facilitating the work of service employees.

All Polish SEGRO logistics parks offer electric car charging facilities. The implementation of modern infrastructure facilitates the use of low-emission transportation options for both customers and employees, thereby reducing the negative environmental impact.

7R

The developer offers the option of charging electric cars and using automatic entrances with license plate recognition. New parks will include a relaxation zone for employees, which will be equipped with furniture selected as part of the 7R initiative. This initiative supports the community of young artists and the wellbeing of warehouse employees. Furthermore, bicycle shelters will be installed in front of the buildings.

GLP

GLP is also among the organizations that are responding to trends related to the automation and robotization of logistics processes. The developer sees great potential in the use of data analytics and artificial intelligence.

The company offers a dedicated global GRS platform for customers who wish to utilize robots in a flexible Robotics-as-a-Service model. This means they can subscribe to ready-made, complete robotic solutions and avoid significant upfront investment. Furthermore, RaaS allows for swift scalability, adapting to evolving market conditions, such as seasonal demand fluctuations. The European GRS team engages in multiple talks with prospective clients, including those in Poland. To date, over 30 implementations have been recorded around the world. These have resulted in significant improvements in operational efficiency, with increases in shipment preparation speed of over 60% and improvements in product sorting precision of almost 100%.

GLP has extensive experience in the creation of digital twins for buildings. This involves the design, construction and management of buildings using BIM modeling technology. This system provides all designers, project managers, industry specialists, and subcontractors with consistent, up-to-date information about the building, stored securely in the cloud. This solution enables faster decision-making, reduces operating costs, minimizes troubleshooting time, and streamlines warranty management. Furthermore, entry barriers with automatic license plate recognition are also a standard feature.

HILLWOOD

Hillwood is committed to enhancing the tenant experience through the introduction of automated entrances, electric car chargers, and innovative solutions that minimize light pollution. The developer's actions demonstrate that business success and environmental protection, as well as consideration of the needs of local communities, can coexist. This is the primary objective of the investor.

WHITE STAR

The investor benefits from the Singu Smart Security Desk platform, which automates the management of logistics complexes by handling vehicle traffic using RFID tags. Once attached to the car window, the tags are recognized upon entry and exit, automatically opening the barrier. Furthermore, the system employs complementary LPR (license plate recognition) technology, which facilitates barrier opening based on license plates. Singu FM helpdesk platform offers additional support for contacting tenants and responding efficiently in case of failures of facility installations and streamlining the process of servicing monitored equipment.

LCUBE

The developer provides access management to the premises, including the use of automatic barriers and the availability of parking spaces. To ensure effective communication with tenants, the facility maintenance reporting system is utilized. LCube is currently outsourcing its property management services to external companies that utilize their own software and hardware for building management. The company performs a consistent analysis of the solutions proposed by external property managers, ensuring alignment with the established standards.

LCUBE investments are concentrated in urbanized areas, predominantly industrial, situated in proximity to major communication routes. Furthermore, LCUBE prioritizes the preservation of green spaces and the creation of a pleasant living environment for its tenants.

MDC2

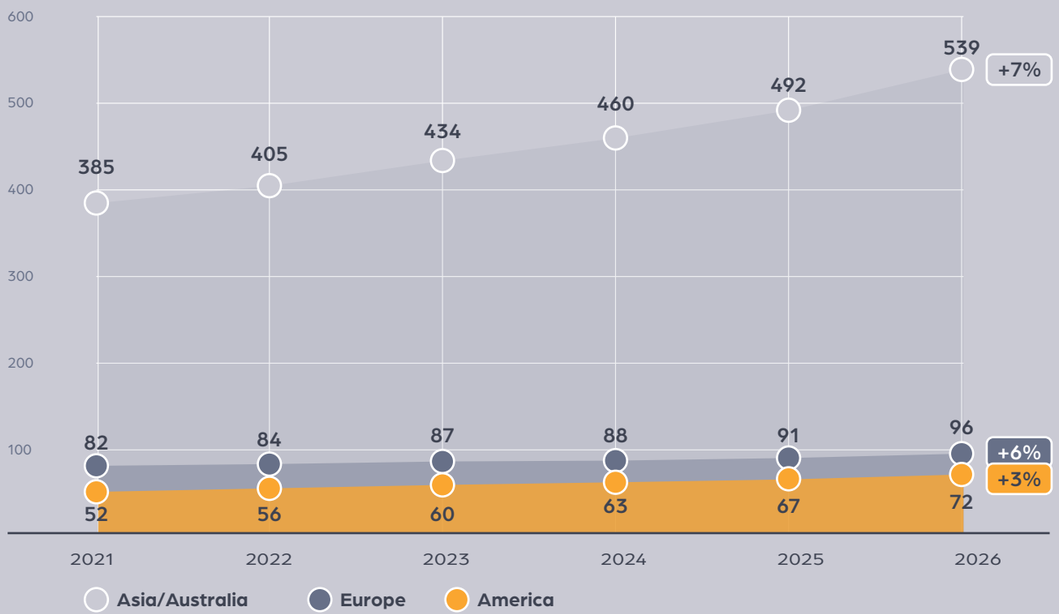
MDC2 provides electric car charging facilities at its parks, offers automatic entry with plate recognition, and provides automated booking services.

The developer is committed to sustainable construction practices, including energy efficiency and minimizing carbon dioxide emissions. From its perspective, green buildings offer owners and tenants significantly reduced maintenance costs, which is why it prioritizes environmentally conscious projects from the outset of the development process. It establishes retention reservoirs and organizes outdoor relaxation zones.

6 Summary

There is no turning back from automation and robotization. In the era of unfavorable demographic trends and a shortage of employees in contract logistics, further robotization will ensure the development of the industry. The International Federation of Robotics (IFR) projects that the average annual rate of increase in the share of robotization will remain at 7% from 2024 to 2026.[80]

Forecast of annual growth in the level of robotization for 2023–2026



With the implementation of new technology in warehouses, based on automation and

productivity should increase 50%

operating costs will fall 25%

Opportunities offered by robotization and automation:

- More efficient sortation systems
- Advanced warehouse robots or RFID technologies
- Automation of warehouse processes
- Real-time inventory tracking and monitoring

Why automate logistics?

- improved quality of logistics services
- improved customer service
- shorter lead time
- reduced flow time of goods in the warehouse
- cost reduction
- improved competitiveness

Barriers to the use of modern technologies:

- High cost of introducing new technologies to the warehouse
- Depreciation
- Appropriate personnel qualifications
- Resistance from staff
- Incorporation of new echnologies into existing systems

5 global trends in robotization

- use of artificial intelligence and machine learning
- extended range of cobot operation
- popularization of mobile manipulators “MoMas”
- Digital Twins
- humanoid robots

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