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INNOVATIONS IN WAREHOUSE LOGISTICS: ANALYSIS AND PROSPECTS

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ABSTRACT

The article analyzes the progressive development of warehouse logistics and the ways to achieve it, in particular with the help of robotics, Big Data, electronic data interchange technology and additive technologies. The importance of warehouse logistics for companies and its impact on costs is emphasized. The main global trends and their impact on the financial result and quality of services are analyzed. An overview of various types of innovative development is provided, including their advantages, disadvantages, and prospects for use in warehouse infrastructure.

Keywords: warehouse logistics; innovative developments; automation; digital technologies.

1. INTRODUCTION

The global business ecosystem has been experiencing a period of rapid development in recent years, with leading global corporations actively considering the use of innovative technologies to maintain their competitive position, improve business processes and increase profitability. Warehouse logistics is one of the areas of focus. Modern warehouses, as an integral part of logistics systems, consist of a number of interacting elements that provide storage, processing and distribution functions. They are an important component for achieving a high level of profitability from the logistics activities of various enterprises. Warehousing logistics is becoming increasingly important in the online commerce sector as e-commerce continues to grow, especially in the light of the COVID-19 pandemic and the growing demand for warehouse space.

However, the development of e-commerce and online trading has led to problems with the organization of warehouse operations, such as inefficient logistics processes and slow order processing. For the further development of online sales, it is necessary to review the technological approach to warehouse management and distribution of goods, focusing on the implementation of modern innovations and global trends in this area. This approach is aimed at automating internal warehousing, integrating logistics processes and optimizing the interaction of all participants in the supply chain.

2. METHODOLOGY

The latest advances in artificial intelligence and automation, as well as the capabilities of smart devices, have created completely new conditions for revolutionary changes in the development and application of promising global trends in warehouse logistics based on innovation.

Robots.

The use of robots plays an important role in increasing the level of warehouse automation, which is becoming a global trend today. According to FNC experts, robotization will become the main driver of business development in the coming years, along with trends such as global distribution platforms and digital identifiers. All of this will help reduce the average time for logistics business processes, especially in large warehouse complexes, where the limit of human capabilities has, in principle, already been reached. In addition, robotic systems eliminate most of the mistakes made in the process of warehouse inventory management, reduce the number of accidents and the level of occupational injuries, and make most logistics operations in the warehouse easier. The integration of software and hardware solutions is aimed at realizing the task of accelerating warehouse operations by reducing the amount of routine work and increasing the efficiency of labor resources [1].

According to their functional purpose, warehouse robots are classified into the following types

- Self-propelled carts: they are designed to quickly move and stack goods, as well as to transport goods between different locations. Most models are equipped with a lifting mechanism for lifting goods;
- tow trucks: used to transport heavy robotic carts;
- palletizers: these devices are designed to automatically stack goods on pallets;
- sorters: they are used to identify and pack goods;
- drones: this equipment is used in the process of inventory and other tasks.

One of the key challenges of a robotic warehouse (Fig. 1) is to ensure efficient navigation of autonomous equipment indoors. There are different approaches to solving this problem. Some devices require special markings on the floor for navigation, while more advanced models can recognize objects in real time using artificial intelligence systems and built-in sensors.

Figure 1. Robotic warehouse

In recent years, warehouse management systems (WMS) have become increasingly popular. With their help, you can combine all data in one platform. The software makes it possible to analyze information about all warehouse processes. Connecting robots to such a product allows you to fully automate the operation of equipment. Constant updating of information makes it possible to determine exactly where and in what quantity certain goods are located, what products are currently being shipped, etc.

At the same time, data protection is ensured by integrating blockchain into warehouse systems. Modern cybersecurity technologies guarantee the safety of confidential information, as well as the stable and uninterrupted operation of software and robots performing physical tasks.

The warehouse robotization market in the world began to develop only 10 years ago, when Amazon began to introduce Kiva robots for human picking in its warehouses. There have been various prototypes of warehouse robots in the past. And yet, let's assume that the first significant impetus for the warehouse robot market was the creation of Amazon Robotics through the acquisition of Kiva Systems. At the same time, the warehouse robot market has seen significant growth only in the last 2 years. This is largely due to the coronavirus pandemic, when the need for high-speed delivery of goods with a shortage of staff in warehouses increased.

Among the leading companies in the field of warehouse robotization are the following:

1. Amazon: The company owns about 45 thousand robots at various enterprises and is constantly expanding their number. Since 2012, Amazon has been actively investing in automation, starting with the acquisition of Kiva Systems. Although there are more than 4 real employees for each robot, the company has significantly automated the processes related to the movement and search for goods in warehouses.
2. IKEA: The Swedish giant is actively using modern technologies to optimize the processes of storing and searching for goods. Large-scale robotic cranes greatly facilitate the tasks of employees related to the assembly, packaging and shipment of products.
3. Tesla: Elon Musk's company uses robots from Adept Technology, Inc. that can move freely around the factory, avoiding collisions with people and other objects, and independently connect to docking stations for recharging. Such devices perform various tasks, from greeting guests to transporting materials.

In addition, other well-known corporations, such as DHL, Meijer, LEGO, Coca-Cola, and others, are also actively using robotics for warehouse processes. This shows that automation of warehouse operations is an important direction for the future. The sooner companies realize this, the more chances they have to strengthen their competitive position.

According to a survey by Peerless Research Group, about 37% of respondents responded positively to the presence of robotics in their business (Fig. 2).

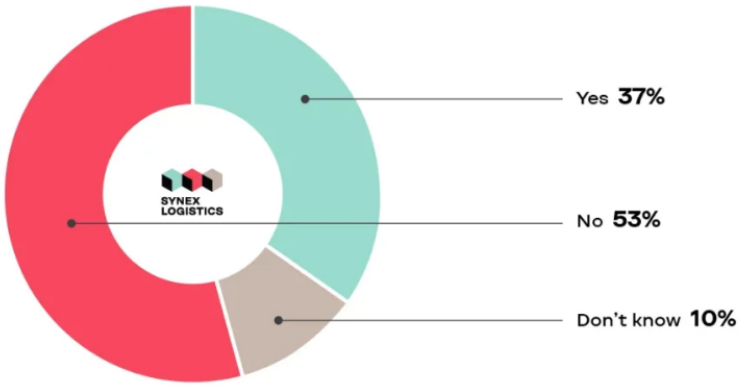

Figure 2. Results of the Peerless Research Group survey

The Boston Consulting Group predicts that the share of tasks performed by robots will increase from 8% today to 26% by 2025. China, Germany, Japan, South Korea, and the United States will become the leaders in robotic production (Fig. 3). Together, they account for 80% of all robot purchases. Unlike humans, who can double their productivity in 10 years, robots can double their productivity every four years, according to BCG analyst Sirkin [2].

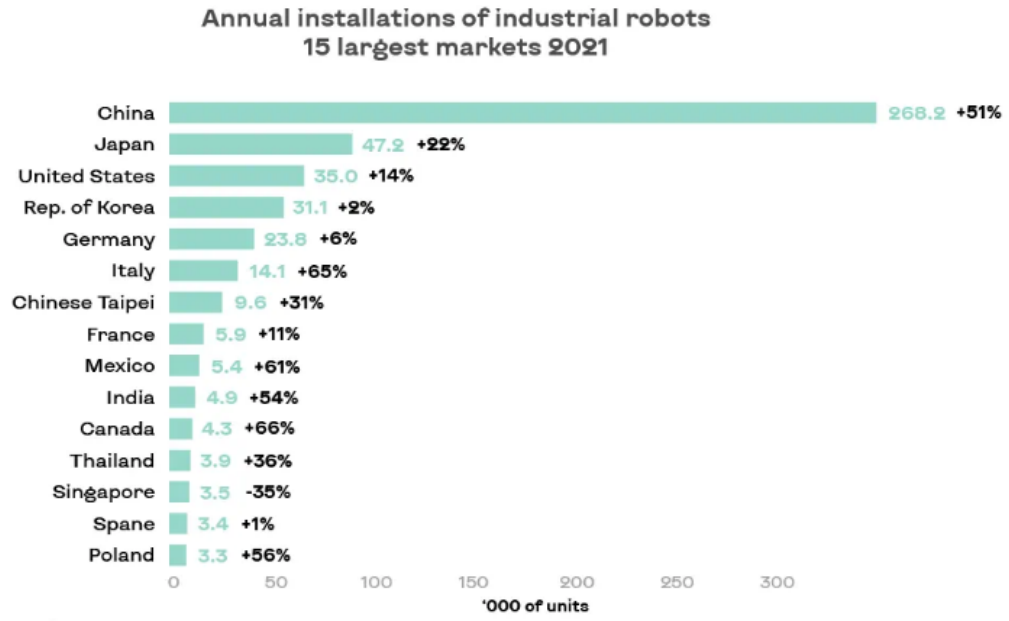

Figure 3. Statistics on the use of robotics in logistics in different countries

Big Data.

Big Data can be defined as a socio-economic phenomenon that results from the development of technological capabilities for analyzing vast amounts of data in complex sectors, with the aim of using them effectively. According to analysts, more than 2.5 exabytes of information are generated daily. In 2020, every inhabitant of the planet produced an average of about 1.7 megabytes of data every second, while the total amount of data generated by humanity reached 4,044 zettabytes. IBS forecasts indicate that by 2025, the global volume of data will grow tenfold compared to 2020. As a result, data will become a critical resource, and its protection will become a key aspect of modern life. Given these changes, the economic landscape will be transformed, and the average user will interact with connected devices approximately 4,800 times a day.

In the near future, Big Data will be actively used in warehouse logistics (Fig. 4). Big data analytics will allow forecasting demand fluctuations, identifying seasonality, adjusting warehouse processes (forecasting the load of receiving and labeling, smoothing peak hours), etc. Big Data can be used to build the results of a multivariate model. In addition, it stores information not only about all goods, their location, and movement, but also a huge amount of additional data: all clicks in the interface, delivery schedule, weather, customer information, and the distance of suppliers from the warehouse. At the same time, there is a continuous process of self-learning, i.e. the machine learns itself (the principle of machine learning) in real time and creates algorithms to optimize business processes.

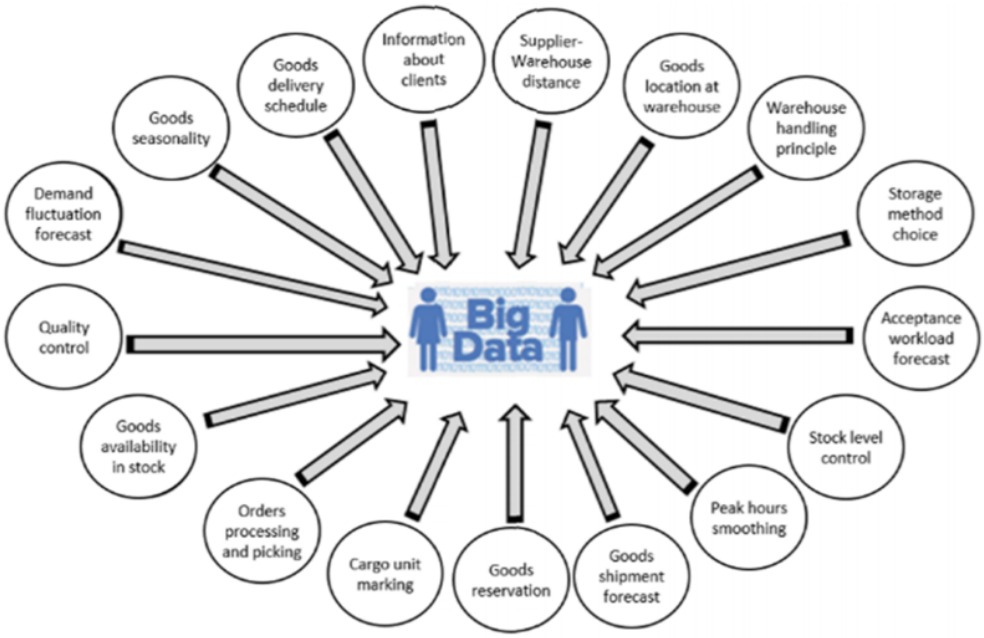

Figure 4. Big Data in warehouse logistics

The concept of Big Data is based on providing users with as much information as possible about an object or process in order to facilitate a careful analysis of the advantages and disadvantages before making decisions. In the context of intelligent systems, future scenarios are developed on the basis of large amounts of data, which allows simulating various options and analyzing their results. In a conventional warehouse, this approach makes it possible to identify the most popular products and optimize their placement near conveyors, as well as group similar or popular products in the so-called "hot zone". This helps to maximize the speed of order processing. At the same time, the system allows sorting goods by delivery region, transport operator, and cargo size, reducing the time for order processing and shipment by about 30%.

Traditional centralized data storage models, which typically use structured data, differ from modern approaches to working with big data. Accordingly, new methodologies and technologies have been developed to work effectively with such volumes of information. The effective use of Big Data technologies in warehouse logistics requires an integrated logistics management system that can serve as a source of data, the availability of formalized business processes, as well as awareness of the need for additional data and motivation to use it to make informed decisions [3].

Electronic Data Interchange.

Another trend observed in the global warehouse logistics system is the technology of electronic data interchange (EDI - Electronic Data Interchange). It is designed to automate document flow in the warehouse, from the creation of electronic documents to their processing, as well as its integration with existing/used business applications. EDI systems facilitate the exchange of data between the customer's and contractor's digital systems in a structured manner. When sending electronic documents, EDI systems provide information in a standard format, always preserving the content.

EDI automates the document exchange process by integrating electronic data with corporate applications. The data is automatically extracted from the sender's system, converted to a standardized format, and transferred to counterparties. Thanks to EDI, documents arrive at the end user in a familiar format, such as 1C or Microsoft Axapta.

EDI technology was developed to solve the problems of traditional document exchange. Such problems include long order processing times, high cost of exchange due to the need for phone calls and order confirmations, and lack of efficiency in invoicing.

The benefits of EDI include:

- delivery guarantee: the system notifies the sender of successful delivery;
- processing speed: about 170 types of messages can be processed and transmitted in 10 minutes;
- accuracy: the system controls the content of transmitted documents and immediately notifies of errors;
- cost-effectiveness: reduced personnel and material costs;
- confidentiality: secure storage and transmission of information;
- reliability: the use of MDNs for checksums guarantees the integrity of documents.

EDI requires companies to have international identification numbers, such as GLNs for companies and GTINs for goods, and is based on international standards that allow the secure use of the Internet for data transfer. The choice of platform for EDI depends on the volume of transactions and the number of participants in the document flow.

RFID.

Radio Frequency Identification (RFID) technology, which has become an integral element of modern warehouse logistics, significantly improves information transparency in every segment of the value chain - from the primary supplier to the end user.

The RFID system works as follows: a radio frequency tag is attached to an object that needs to be identified. All unique data about the object is stored directly on the tag. When the object approaches the reader, the tag sends the stored data through the reader's antenna. After receiving the data, the reader transmits it to a computer program via communication channels, usually a network or serial connection. The program then uses this data to identify the object and can update the information in the database, send alarms, or simply ignore the received data. An RFID system consists of an integrated set of components: a tag, a reader, an antenna, a host computer, and software, which together form a complete radio frequency identification solution. This system provides two-way data exchange between readers and an automated information system.

It should be noted that RFID technologies continue to improve. Among the significant advantages of RFID are increased control and transparency of inventory processes, simplification of inventory procedures and reduction of the risk of theft [4]. Figure 5 shows a block diagram of warehouse logistics using RFID technology.

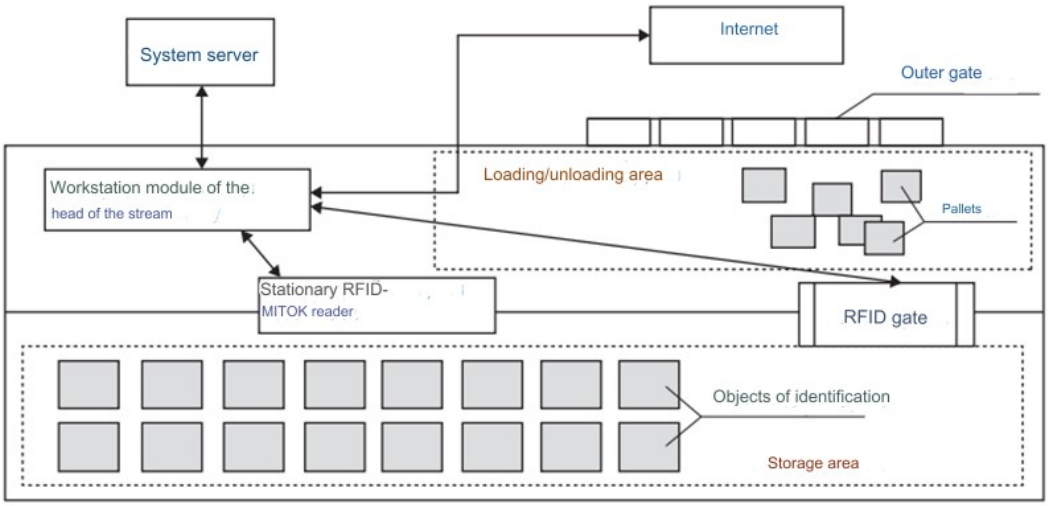

Figure 5. Block diagram of warehouse logistics using RFID

Today, research is underway to integrate RFID with drones to further automate inventory, which reduces inventory control time, avoids the need for manual counting of goods, reduces the need for additional labor resources, and minimizes human error.

The use of drones in warehouse complexes has such advantages as mobility, low cost, and quick payback period. However, there are also certain limitations, such as insufficient power and autonomy, limited spatial orientation capabilities due to internal use, and the lack of regulations to regulate the use of drones in warehouses. Currently, local positioning systems are being actively developed to replace GPS modules for internal use, as well as open SDKs that provide developers with the ability to control drone flights, collect data from RFID scanners, and integrate them with existing WMS systems.

Internet of Things.

Drones and robots are integral parts of the Internet of Things (IoT), which are planned to be implemented in modern warehouses. According to DHL and Cisco, the IoT market is expected to be worth approximately USD 10 trillion over the next ten years, of which USD 2 trillion will be in the logistics and supply chain management sector.

The impact of IoT on logistics processes is significant, especially in the context of warehousing and transportation operations. IoT-based solutions in warehouse logistics provide an opportunity to optimize the use of warehouse space, monitor the integrity of goods and other material assets, improve customer service, increase the efficiency of warehouse equipment, evaluate and improve the quality and safety of warehouse workers, and perform smart inventory.

WMS.

Modern warehouse complexes are complex technical systems that are managed by warehouse management systems (WMS and WCS). WMS is a software that is operationally based on the processing of data obtained from barcodes and RFID tags located on the product packaging. In turn, WCS is considered more advanced because it receives information not only from barcodes and RFID tags, but also from controllers and sensors located on the equipment. This additional information allows solving a variety of tasks, including determining the optimal warehouse capacity, its load, the speed of warehouse equipment, and maximizing its utilization.

In addition, WCS uses cameras located in different areas of the warehouse, which allows, among other things, to detect violations of the integrity of packaging and ensure the preservation of the consumer value of goods.

Additive technologies.
These technologies, which belong to the sixth technological mode, have a high potential for use in warehouse logistics. As "growth" technologies, they allow creating products or their components from metals, plastics and composite materials in layers based on a 3D computer model using 3D printing technology.
The introduction of 3D printing into the activities of logistics companies has significant prospects. Suppliers can supply raw materials instead of finished products and provide 3D printing services at delivery points, which will become an additional source of income. An electronic library of projects available on a local computer can be used for this purpose. Worn-out parts can be scanned in 3D and replicated.
MIT.
Recently, cross-docking, also known as Merge-in-Transit (MIT) technology, has become increasingly popular in the warehouse logistics industry. The main reason for this is a 20-30% reduction in the cost of organizing warehouse operations. This means that the process of receiving and shipping goods through the warehouse is carried out without their long-term storage.
Unlike a traditional warehouse complex, where goods are stored for further shipment to customers, the functions of a cross-docking center are end-to-end warehousing, i.e., receiving, sorting and shipping goods without their long-term storage [5]. This feature leads to a low level of land utilization, as free space is required for the movement and maneuvering of trucks and vans. In other words, cross-docking is an operational production system specially adapted for warehouse operations, in which storage costs are reduced in the process of moving cargo. The main advantage of cross-docking is the acceleration of the delivery of goods to the end user, which is crucial for perishable products.

3. CONCLUSIONS

Digital technologies and their widespread use in business practice have a significant impact on innovative solutions in logistics, which are transforming the technical and economic structure of many world-class economies. Warehousing logistics is one of the first areas to respond to systemic changes in technology and introduce elements of robotics and artificial intelligence. Given the current global trends such as robotics, big data, electronic data interchange (EDI), drones, Internet of Things (IoT), additive technologies, etc., the efficiency of warehouse and supply chain management is increasing, especially for non-standard solutions, which significantly stimulates the market. This leads to accelerated efficiency of warehouse operations, optimized inventory in the supply chain, increased productivity and quality, and reduced costs.

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