

WAREHOUSING ACTIVITIES AS A COMPONENT OF RESILIENT SUPPLY CHAINS. MANAGEMENT PROCESSES AND DIGITAL TRANSFORMATION

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Abstract

The research examines warehousing activities as a critical component of modern logistics systems and a key factor in ensuring the resilience of supply chains under conditions of economic instability, global disruptions, and digital transformation. The main objective of the research is to analyse the theoretical foundations and management processes of warehousing activities at the enterprise level, as well as to determine their role in enhancing operational efficiency and adaptability within supply chains.

The scope of the research covers the essence, functions, and classification of warehousing activities, as well as the process of their organisation and management. Special attention is paid to the analysis of warehouse operations, including receiving, storage, order picking, and distribution processes, as well as the role of warehouse systems in transforming material flows. The study also considers strategic decisions related to warehouse ownership, location, size, and system configuration.

The research further explores the role of warehousing in building resilient and sustainable supply chains, particularly in the context of crisis conditions and increasing uncertainty. The importance of integrating modern logistics technologies, such as warehouse management systems (WMS), barcoding, radio frequency identification (RFID), and cross-docking, is emphasised as a means of improving efficiency, reducing costs, and enhancing flexibility.

The methodological basis of the study includes a combination of general scientific and special research methods. These include analysis and synthesis for the generalisation of theoretical approaches, comparative analysis for evaluating different definitions and classifications of warehousing activities, and a

systems approach for examining warehousing as an integral element of the logistics system. In addition, elements of process analysis are used to study the structure and sequence of warehouse operations.

The results of the research demonstrate that effective management of warehousing activities contributes significantly to improving enterprise performance, optimising logistics costs, and increasing the overall resilience of supply chains. The findings highlight the need for enterprises to adopt modern technologies and integrated management approaches in order to remain competitive in a rapidly changing environment.

Keywords: *Warehousing activities; supply chain resilience; warehouse management; logistics systems; digital transformation*

One of the most important elements of the logistics infrastructure is warehousing, which allows us to manage stocks in accordance with the requirements of various logistics systems and transform the material flow almost on a par with production.

In recent years, warehousing activities have become increasingly important as they are aimed at preserving products and reducing transport costs. Therefore, it is necessary to rationally organise warehousing activities at the enterprise, use warehouses efficiently and minimise the costs of warehousing operations. In today's environment, the competitiveness of an enterprise largely depends on the efficiency of its warehouse operations. Effective warehouse management is one of the key logistics tasks and a tool for providing high-level service [11].

It is known that more than 95% of the turnover time of goods is accounted for by logistics operations [9]. In addition, in the overall cost structure, the cost of maintaining stocks is more than 50% and most of the working capital of enterprises is usually allocated to stocks (from 10 to 50% of all enterprise assets). Thus, the reserves for improving economic performance lie in the rational management of stocks and reducing the time of goods passing through the logistics chain [13].

Warehousing activities are an important element of the technological processes of industrial enterprises, and for wholesale and retail trade, it is the basis, so warehouses of enterprises and organisations that aim to stay ahead of competitors need modern organisation, modern technologies and qualified personnel. Today, the goods movement system has taken on a completely new form for consumers, producers, suppliers and other participants. An integrated approach to logistics involves managing end-to-end flows that pass through all parts of the logistics system. Warehousing activities are not only an integrated component but also a backbone of the logistics system, which includes the accumulation, processing and distribution of material flows. This approach helps ensure that the entire system achieves a high level of profitability.

The warehouse activity refers to the operations and tasks that take place within a warehouse facility. These activities include receiving and inspecting incoming shipments, storing and organizing inventory, picking and packing orders, and shipping products to customers or other locations.

Some common warehouse activities include [2]:

receiving: This involves checking the quantity and quality of incoming shipments, verifying product information against purchase orders, and recording the received items in the inventory management system;

storage: Warehouse employees organize and store the received items in designated locations using different storage systems such as racks or shelves. They ensure that the inventory is properly labeled and easily accessible;

order picking: This activity involves locating and collecting the required items from their storage locations based on customer orders or restocking needs. Order pickers may use manual picking methods or employ various warehouse equipment like forklifts or order pickers;

packing: After picking the items, warehouse workers pack them securely using appropriate packaging materials. This step may involve labeling, bundling, or adding protective materials to ensure safe transportation;

shipping: The warehouse activity also includes preparing the packed orders for shipment by generating shipping labels, arranging transportation, and loading the products onto trucks or carriers. This step may involve coordinating with shipping providers or third-party logistics companies;

inventory management: Throughout these activities, warehouse staff regularly update the inventory system, ensuring accurate stock levels and tracking movements of items. They may conduct periodic stock counts or cycle counts to maintain inventory accuracy;

returns and restocking: The warehouse activity also involves accepting returns from customers, inspecting the returned products for damage or defects, and redistributing them back into the inventory if feasible.

Efficient management of these warehouse activities significantly contributes to the overall supply chain operations of an enterprise, ensuring timely delivery, efficient inventory management, and customer satisfaction.

Warehousing activities are understood as a set of the following components [15]

- warehouse (storage facilities and storage areas)

- loading and unloading systems;

- internal transport systems;

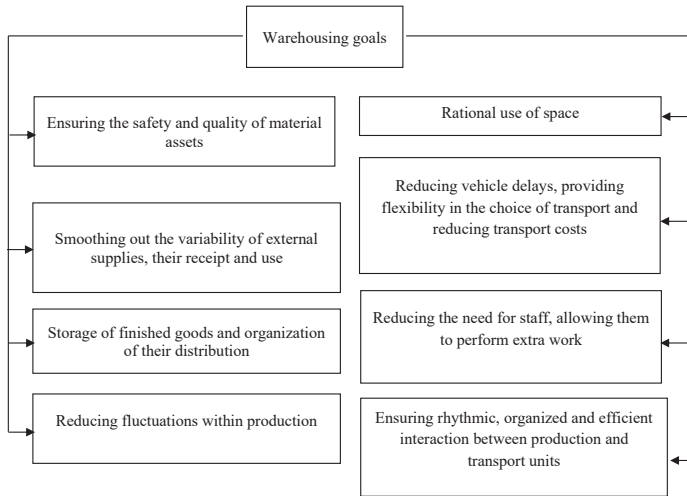
- cargo processing systems (barcoding systems, packaging and packing lines, sorting, ordering);

- cargo storage systems (racks, containers, pallets, special equipment for maintaining the quality of goods);

The creation of an effective warehousing system based on a logistics approach is aimed at achieving the following

goals (Fig. 1.).

Figure 1. Structure and Classification of Warehousing Goals



Note. The diagram illustrates the main objectives of warehousing, including ensuring the safety and quality of material assets, rational use of space, reducing transport delays and costs, smoothing variability of external supplies, optimizing staff workload and improving coordination between production and transport units.

The achievement of the described goals set for warehousing activities makes it possible to harmonise and dampen production cycles.

The main purpose of organising warehousing activities at enterprises is to

- accumulation of stocks of raw materials, fuel, products, etc. in the required quantities;
- rational organisation of loading, unloading and internal warehouse operations, taking into account minimisation of labour costs and cash flows;
- ensuring full safety of material assets;

- proper use of warehouse space and volumes and rational operation of internal warehouse equipment;
- organising the delivery of resources to the places of consumption;
- organisation of the process of promoting rational consumption of materials, maximum use of waste, as well as containers, etc. [18].
- Today, the main tasks in the process of warehouse management are:
- analysing the efficiency of existing warehouses;
- determining the number of warehouses for an efficient logistics system;
- selection of the warehouse location;
- development of the logistics process in the warehouse;
- selection of ways to store resources in the warehouse [7].

The main concept of warehousing activity is the concept of “warehouse”, therefore, in turn, this definition requires careful analysis.

The movement of material flows in the logistics chain requires the concentration of the necessary stocks in certain places, for which the relevant warehouses are intended. Movement through a warehouse involves the expenditure of live and materialised labour, which increases the cost of goods. In this regard, the problems associated with the functioning of warehouses have a significant impact on the rationalisation of material flows in the logistics chain, the use of vehicles and turnover costs [13].

Today, a warehouse is a well-regulated multi-level organisation integrated into a single technological process with automated systems for accounting for stored stocks, from their acceptance to delivery to the end user. Thus, a modern warehouse is a complex structure, both from the

technical and managerial sides [15].

The main reasons for the use of warehouses in modern economic activity are the following [16]:

- coordination and levelling of supply and demand in supply and distribution (through the creation of insurance and seasonal stocks of products);
- reduction of logistics costs during transportation (through the formation of optimal delivery batches);
- maximum satisfaction of consumer demand;
- creating conditions for an active sales strategy;
- uninterrupted supply of end users and organisation of their inventory;
- flexible service policy, in particular, in systems with independent demand.

Experts use several different terms for warehouses, most commonly referred to as distribution and logistics centres. Distribution centres are sometimes thought to be places where finished goods are stored on their way to end users, while logistics centres store a wider range of products and can be located at different points in the supply chain. There are also other names (transit centre), which indicate that the facility not only stores materials but also performs a certain set of other activities [16].

There is a widespread belief that warehouses are created exclusively for the storage of material assets. However, warehouses do not create new material values or additional use value, so storage as an end in itself is of no use. As a rule, the quality of goods can only deteriorate from storage in a warehouse, and in financial terms, the purposeful storage of goods in a warehouse can only lead to losses, since, firstly, the material assets stored in a warehouse are temporarily excluded from financial circulation, although some resources were spent on their acquisition and production,

and secondly, the storage of goods itself requires certain costs [20].

In fact, no type of material resources is produced to be stored in warehouses. And yet warehouses exist and are widespread in all sectors of the economy, in industry, transport, wholesale and retail trade, construction, agricultural production, etc. This is due to the fact that in modern conditions warehouses perform a number of essential functions [4, 20]:

1. Transformation of the production assortment into the consumer assortment in accordance with the demand and in order to fulfil customer orders.
2. Warehousing and storage of products in order to equalise the time, quantity and assortment gaps between production and consumption of products, which allows for continuous production and supply on the basis of created inventories, as well as in connection with the seasonal consumption of certain types of products.
3. Consolidation and disaggregation of goods - the warehouse can perform the function of combining (consolidating) small consignments of goods for several customers, until the vehicle is fully loaded, which helps to reduce transport costs. At the same time, the warehouse can receive goods from manufacturers destined for several customers, which are then divided into smaller batches according to orders and sent to each customer.
4. Provision of services. An obvious aspect of this function is the provision of various services to customers that ensure a high level of customer service to the enterprise.

The purpose of creating warehouses in logistics systems is not to save material resources, but to transform the parameters of material flows for their most efficient use.

Parameters include the size and composition of transport consignments, type and method of packaging, number of items in transport consignments, time of arrival and departure of transport consignments, etc. In other words, the main task of a warehouse is to transform the material flow, accumulate, process and distribute goods among consumers [20].

The notion of a harmoniously organised logistics system as a system without warehouses is erroneous. Harmony in logistics is achieved by the right combination of warehousing and transit methods of moving tangible products from the primary source of raw materials to the end consumer. A warehouse in logistics is used only when it improves the performance of the end-to-end process. Thus, the role of the warehouse is to create conditions for optimising the material flow [13].

A modern warehouse as a management object has a complex internal structure and performs a number of functions for the transformation of material flows, as well as the accumulation, processing and distribution of goods among consumers. At the same time, a warehouse is a subsystem of a higher-level structure, which is a logistics chain that forms the technical and economic requirements for the warehouse system and sets the goals and criteria for its optimal functioning. A modern large warehouse is a complex technical structure consisting of many different subsystems: real estate, technical means for storing and handling goods, an information system, etc.

The warehouse information system functionally connects all areas and services of the warehouse and ensures the management of flows. It includes processing incoming documents, placing orders with suppliers, managing the receipt and dispatch of goods, controlling the availability of goods in the warehouse, accepting customer orders, processing shipping documents, selecting shipping batches, developing rational schedules and routes for the delivery

of goods, processing customer invoices, exchanging internal information within the enterprise, and generating, processing and storing statistical information.

There is an objective need for warehouses as specially equipped places used to hold stocks at all stages of the material flow, from the primary source of raw materials to the end consumer. This fact explains the large number of warehouses of various types and forms.

Warehouse classification refers to the categorization of warehouses based on various factors such as size, function, location, and ownership. This classification helps in understanding the different types of warehouses and their specific characteristics. Some common classifications of warehouses include [11] :

1. Public Warehouse. These are owned and operated by third-party logistics providers (3PLs) who offer warehousing and distribution services on a rental basis to multiple companies;
2. Private Warehouse. These warehouses are owned and managed by individual companies for their own storage and distribution needs. Private warehouses offer more control and customization options as they are dedicated to a specific enterprise;
3. Distribution Center. These warehouses are strategically located near major transportation routes and serve as hubs for receiving, storing, and distributing goods. They often handle large volumes of inventory and have efficient transportation connections;
4. Fulfillment Center. These large-scale warehouses are specifically designed for e-commerce and order fulfillment operations. They use advanced technology and automation to process and ship online orders efficiently;

5. Bonded Warehouse. These warehouses are authorized by customs authorities and are used for storing imported goods before they are cleared by customs. This allows companies to delay paying import duties until the goods leave the warehouse for domestic consumption;
6. Cold Storage Warehouse. These warehouses are equipped with refrigeration or freezing facilities to store perishable goods such as food and pharmaceuticals that require controlled temperatures;
7. Automated Warehouse. These high-tech warehouses utilize automation and robotics to perform various tasks such as loading/unloading, picking, and sorting of inventory. They optimize efficiency and reduce labor-intensive operations;
8. Small Warehouse. These are smaller-scale warehouses often used by small businesses or startups with limited storage requirements. They offer more affordable storage solutions with lower rental costs;
9. Cross-Docking Warehouse. These warehouses facilitate the direct transfer of goods from inbound to outbound transportation without the need for long-term storage. They help in reducing inventory holding costs and speeding up order fulfillment;
10. Mega Warehouse: These are large-scale warehouses that cover vast areas and handle significant volumes of products. They are typically used by multinational corporations and major retailers for centralized storage and distribution.

Warehouse classification may vary depending on industry and regional factors, and warehouses often combine different features to cater to specific needs.

Currently, the classification of warehouses by class

according to the international consulting enterprise Knight Frank has become widely known. This classification allows to evaluate the warehouse from the logistical point of view: how it will be possible to organise technological processes in the warehouse in the future, as well as the logistics of incoming and outgoing flows.

A warehouse is an integral part of almost any enterprise engaged in production. In order to organise a warehouse, it is necessary to make the most efficient use of the warehouse volume, i.e. the usable area of the warehouse.

The main functions of warehousing are loading and unloading operations on road transport; acceptance of goods; placement of goods and materials for storage (stacking of goods in racks, stacks); picking and packing of goods; intra-warehouse movement of goods; preparation, conclusion and maintenance of warehouse storage agreements (preparation of invoices, acts, invoices, payment control); control and organisation of picking of consignments [17]. All warehouses operate according to the warehouse process flowchart.

The efficiency of warehousing activities is determined by the level of their specialisation, the use of modern forms of organisation and technologies, as well as various means of mechanisation and automation, and the rational use of warehouse facilities and space.

Therefore, in turn, the creation of a rational warehousing system is a means of achieving efficient warehouse operation, optimising the enterprise's turnover and increasing its competitiveness.

Own warehouse or public warehouse. One of the main problems faced by a enterprise in the process of securing warehouse space is the issue of warehouse ownership. There are two main alternatives: acquiring warehouses in ownership (including on a lease basis) or using public warehouses.

The process of organising warehousing activities consists

of three main parts. At the first stage, it is necessary to define the goals of the warehouse organisation, analyse the parameters of cargo flow and warehouse operations, and determine the criteria for effective operation. The final stage is the selection of the optimal variant of the system as a whole, which is carried out taking into account the technical and economic assessment of the warehouse system. The organisation of new or reorganisation of existing warehousing activities should be based on certain principles (Tab. 2).

Table 2. *The process of organizing an enterprise's warehousing activities*

No.	Principles and their content
1.	The principle of a systematic approach
	This principle is to consider all elements of the warehouse system as interconnected and interacting to achieve a single goal. This principle implies logistics coordination and integration, which consists in considering warehousing activities as an integral part of a higher-level system.
2.	The principle of economic efficiency
	The principle involves assessing the economic efficiency of warehousing activities in terms of their contribution to the overall economic efficiency of the logistics system.
3.	Technology priority principle
	Consideration of warehouse technology as a starting point for building an effective system for the operation of all warehouse activities. Technology largely determines the structure and list of participants in warehouse processes. Changes in technology can significantly alter the structure of processes, the duration of their implementation, the structure of interconnections, and the sequence of operations and procedures. At the same time, it should not be forgotten that technology is determined by the customer.
	Process approach principle

4	Building a warehouse system based on the crucial role of the business processes that take place in it. Each business process is aimed at achieving a local goal set by the warehouse system as a whole, and their aggregate is aimed at achieving the strategic goals of its owner. Processes determine the document flow and decision-making procedures, the organizational structure of the warehouse system and affect the level of costs.
5.	The principle of optimal construction
	Achieving optimal levels of technical equipment, information support, organizational structure and staff qualifications. When optimizing warehousing activities, the main criterion should be the ratio of total costs and efficiency.
6.	The principle of a single information space
	This principle implies the integration of information flows arising in the course of warehousing activities with other information flows within the system and with the external environment. The creation of a single information space will significantly reduce the time required to support warehouse technological processes and the availability of information to service consumers.
7.	The principle of total quality management
	Provision of services to optimize customer risks by ensuring the quality of services, optimizing time and cost of warehouse processing

Note. This table summarizes the main principles for organizing warehousing activities, emphasizing systematic, process-oriented, technological, and efficiency-driven approaches, as well as the importance of information integration and quality management.

The process of organising the warehousing activities of an enterprise includes several issues that need to be addressed, the successful resolution of which can guarantee the effective functioning of the warehousing activities of an enterprise [13]:

- choice between own warehouse or public warehouse;
- number of warehouses and location of the warehouse network;

- size and location of the warehouse;
- choice of warehousing system.

The solution to these issues is still not fully formalised, but some provisions leading to one or the other choice can be cited.

There are factors that act both in favour of the decision to create or acquire your own warehouse and factors that act in the opposite direction [18].

The main advantages of own warehouse are related to [20]:

- high degree of control over operations;
- ensuring the integration of warehouse operations with other elements of the of the internal logistics process of the enterprise;
- facilitating communications;
- intangible benefits associated with the image of the enterprise;
- the possibility of greater control over products.

A critical factor in the cost-effectiveness of an enterprise's own warehouse is a consistently high turnover. Therefore, in conditions of consistently high turnover in a well-known market with constant sales, it is more expedient to have your own warehouse.

The advantages of public warehouses include [20]

- flexibility, which allows to take into account changing demand, for example, seasonal demand;
- access to qualifications and experience that the enterprise itself does not have;
- use of the most modern equipment and the latest methods
- warehousing operations;

- no need for large investments in the development of warehousing facilities;
- easier access to a wider geographical region;
- use of economies of scale to reduce warehousing costs;
- Reduction of transport costs by combining cargo with cargo of other companies;
- guarantee of high quality and efficient service.

The choice between a public warehouse and an in-house warehouse is one aspect of the «make or buy» decision, and therefore requires a break-even analysis. This is, of course, a simplistic approach, as there are many other factors to consider when choosing warehousing options. However, the main issue is whether a public warehouse can provide the same (or better) service at the same (or lower) cost. If it can provide better service or lower costs, then these are obvious arguments in favour of choosing such a warehouse [13].

Number of warehouses and location of the warehouse network. Small and medium-sized firms that limit their sales to one or more neighbouring regions usually have one warehouse. For large firms with a large national or international market, this issue is very complex, and they have to overcome significant difficulties in solving it. In solving this problem, a compromise method and analysis of the need for warehouse space in different sales regions should be applied. In this case, the most common two options for the location of the warehouse network are centralised (mainly one large warehouse) and decentralised (dispersion of a number of warehouses in different sales regions). Of course, the issue of increasing the number of warehouses is associated with a change in costs [15].

The territorial location of warehouses and their number are determined by the capacity of material flows and their rational organisation, demand in the sales market, the size

of the sales region and the concentration of consumers in it, the relative location of suppliers and buyers, the specifics of communication links, etc. However, first and foremost, the issue of increasing the number of warehouses is related to changes in costs and their behaviour [20].

Size and location of the warehouse. This problem is very close in nature to the previous one and is solved quite simply in the case of a public warehouse, since the location of the warehouse and the required warehouse space can be easily changed with the change in the enterprise's interests. This problem becomes more complicated in relation to the enterprise's own warehouse.

Determining the size and number of warehouses are interrelated decisions, as they are usually inversely related; in other words, as the number of warehouses increases, the average size of each warehouse decreases. The general trend nowadays in an organisation's distribution system is to have fewer warehouses, but these warehouses will be larger [3].

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The most important factors affecting the size of a warehouse include [18]:

1. The level of customer service.
2. The size of the market(s) served.
3. Number of products offered on the market.
4. Size of the product(s).
5. Cargo handling systems used.
6. Throughput (inventory turnover).
7. Production time for order fulfilment.

8. Requirements for central and inter-rack aisles.
9. Types of shelves and racks used.
10. Level and types of demand.

Selection of a warehousing system. The warehousing system involves the optimal placement of cargo in the warehouse and its rational management. The development of a warehousing system is based on the selection of the most efficient system out of all technically feasible systems for solving the task by means of quantitative and qualitative assessment.

This process of selection and optimisation involves identifying interrelated factors systematised into several main subsystems [13]:

- ↻ warehoused cargo unit;
- ↻ type of storage;
- ↻ warehouse maintenance equipment;
- ↻ picking system;
- ↻ cargo movement management;
- ↻ information processing;
- ↻ structural features of buildings and structures.

The description of the logistics process in the warehouse allows for a more detailed description of the organisation of the warehouse activities of the enterprise, since knowledge of each stage of the material flow through the warehouse allows for further identification of the problem area of the warehouse when forming the warehousing system of the enterprise.

The logistics process in a warehouse should be considered as an integral system, because all warehouse operations are interconnected, which forms the emergence of the entire warehouse logistics system.

Logistics processes in a warehouse are complex and involve a lot of labour and money. They require complete

coordination of all processes at the enterprise: from the supply of production resources to the fulfilment of customer orders.

Supply of stocks of products to the warehouse and control over deliveries. The essence of these operations is to maintain the volume of stocks at the required level to meet customer demands. At the same time, the amount of stocks must be aligned with the warehouse capacity. Control over the supply of products allows for rational and efficient use of the warehouse space, thereby ensuring the symmetry of stock processing while meeting the necessary conditions for shelf life, which generally ensures the rhythmic operation of the entire logistics system at the enterprise.

Unloading and acceptance of goods. At this stage, depending on the terms of the contract, special equipment is used to accept cargo units into the warehouse. The rational use of unloading equipment allows this operation to be carried out in a short time, reducing cargo losses and overall costs [5].

Intra-warehouse transportation. This operation involves moving cargo between different warehouse areas using different lifting equipment. The routes of equipment movement should be “through”, which will reduce the time of cargo transportation, and the number of transshipment (transfer from one type of equipment to another) of cargo should be minimised.

Warehousing and storage of goods involves placing goods in the appropriate places in the warehouse. Goods should be stacked in such a way as to maximise the use of the height and area of the storage area. To do this, the individual properties of the goods must be taken into account.

Customer order picking involves preparing goods for shipment in accordance with customer orders. The use of information and addressing systems in the warehouse significantly reduces the time required to place an order

and helps ensure its reliable fulfilment. Information systems help to choose the best route for transporting goods and to form an economical consignment, i.e. to maximise the efficiency of vehicle use.

Transportation and forwarding of orders. This operation can be carried out using the customer's vehicles or the warehouse. The most cost-effective way of transporting orders is through a centralised warehouse delivery. Thanks to a well-established transport system, you can achieve a significant reduction in transport costs.

The collection and delivery of empty containers is an important element in the warehouse logistics process, as containers are usually reusable equipment and account for a large part of the total costs. Therefore, it is necessary to organise an efficient exchange of them between the warehouse and consumers [16].

Order fulfilment control and customer service are coordinated with the sales department. Order fulfilment control involves monitoring, according to the appropriate schedule, the proper execution of the order.

Customer service involves the provision of pre-sales, sales and after-sales services to customers. Pre-sales services are provided by the sales department, while sales and after-sales services are provided by the warehouse.

All stages of the logistics process are closely linked to information services. Information provides each stage of the logistics process in a warehouse with the necessary data for the optimal functioning of warehouse services.

The key factors affecting the efficiency of warehousing activities include: quality of warehouse service and customer satisfaction, use of investments, level of logistics costs, duration of logistics cycles, and productivity of warehouse operations [11].

Thus, any enterprise that has a warehouse, let alone

a warehouse network, faces many problems of various levels, both strategic and operational. The organisation of warehousing activities begins with the solution of strategic tasks related to the structure of the warehouse network, which is necessary to achieve the company's goals and provide greater flexibility to the customer service system. In fact, the formation of effective warehousing activities should help the company to cover the maximum sales market, adapt to environmental changes with minimal losses from lost sales

Good warehousing operations have a positive impact on reducing logistics costs. Therefore, the issue of improving warehousing activities becomes relevant, and it should not be forgotten that domestic enterprises are not ready to make significant investments in this area today, as they do not have such opportunities, but they are aware of the need to improve it. They prefer maximum results with minimum costs [14].

Two directions of development of warehousing activities can be distinguished in terms of its organisation [2, 14, 16]:

- the first direction is related to the development of logistics technologies aimed at optimising specific operations in warehousing activities (e.g. product identification, product placement, shipment of goods);
 - the second is related to the development of logistics technologies that optimise warehouse operations in general.
1. The introduction of bar coding in the warehouse simplifies and speeds up the process of product identification. This technology can significantly speed up the process of product acceptance (if the cargo units already have a barcode), significantly reduce the risk of “human errors” in the process of performing technological operations and taking

inventory, and simplify the search for the right product on the shelf. The introduction of bar coding is also justified by the fact that more and more often large customers of manufacturing enterprises make it a prerequisite for the purchase of products to have a bar code [15];

2. One of the promising areas in warehousing is radio frequency identification (RFID). This system has appeared relatively recently abroad. The main elements of the system are tags, an antenna and a computer. Information is applied to the tag using a computer. The tag is placed inside the pallet. After that, all the tag data is transferred to the computer using an antenna. The use of radio frequency identification allows you to control the movement of cargo, reduce the time for processing information and thereby reduce costs [11];
3. The next area of warehouse optimisation is cross-docking. Cross-docking is a technology and the process of accepting and shipping goods and cargo through the warehouse directly, without placing them in a long-term storage area. The classic cross-docking model involves direct transshipment from one vehicle to another (sometimes accompanied by simultaneous re-stocking and some other possible operations with goods and cargo). Thus, cross-docking allows for a significant reduction in the cost of warehouse storage of goods and cargo, idle and empty transport runs, etc.)

The reasons and needs that necessitate the use of cross-docking can be very different, but are always determined by the situation when it is necessary to promptly speed up the process of receiving goods of the ordered volume and completing them by end users:

- ⊖ picking of goods in a set from different shipping sources (locations);

- direct transshipment of goods from one transport, the destination of which is a cross-docking site, to another transporter, the unloading point of which will be the end user, or another warehouse, or the midpoint of cross-docking [11].
- 4. Goods should be placed for storage in such a way that the number of movements of warehouse workers during subsequent technological operations is minimal. For this purpose, all commodity items are divided into 3 groups, after which “hot” and “cold” warehouse areas are allocated for their storage.

In order to make the optimal distribution of the entire nomenclature, the warehouses use the ABC-XYZ analysis method. In this case, in relation to the technological process, the main criterion for dividing commodity items into groups will be the number of approaches/movements of warehouse personnel during technological operations, in particular, during the procedure of picking orders for production or customers [14].

After the ABC-XYZ analysis, the stock rate is calculated for each item that is in the warehouse at one time, then the number of storage locations for each item is determined and allocation is made based on the analysis. The “hot” zone is usually located closer to the shipment area, on the shelves located in the central aisle, in the lower tiers of the shelves. This arrangement can significantly reduce the time for performing technological operations (placement for storage, picking, etc.) [16].

- 5. Warehouse automation with the use of a WMS (Warehouse Management System) can significantly reduce the time of operations, reduce their cost, reduce the number of errors, improve the quality of customer service, increase staff productivity, reduce the cost of storing goods, i.e. to carry out the most efficient warehouse management [2].

The principle of WMS operation is as follows. The warehouse area is divided into zones by the type of technological operations in order to automate procedures: receiving, placing, storing, processing and shipping goods, which allows to streamline the work of personnel in different areas and effectively distribute areas of responsibility [15].

At the implementation stage, the system enters a description of the physical characteristics of the warehouse, loading equipment, parameters of all equipment used, and rules for working with them. All goods are marked with barcodes. Technological warehouse operations under the control of the system are carried out on the basis of barcode data, storage locations and loading equipment. Loading and unloading operations and warehouse workers are equipped with radio data input/output terminals, which are a portable computer that communicates with the main system server via a radio channel.

The system can use any of the existing types of codes or print labels with an internal barcode. The system takes into account all the requirements for storage conditions when allocating storage space for goods. For example, humidity, temperature, expiry dates, manufacturers, sell-by dates, suppliers, compatibility rules and any other parameters can be taken into account. The WMS system automatically selects storage locations for received goods and generates tasks for warehouse workers. Tasks are displayed on the screen of radio terminals in the form of elementary step-by-step commands individually for each employee [17].

6. Modelling the movement of flows allows to determine their quantitative characteristics. With regard to warehouse logistics, simulation modelling as an effective tool that ensures high calculation accuracy due to the possibility of detailed “playback” of the behaviour of the modelled system provides solutions to the following tasks: determining the optimal location of the warehouse complex based on data on

possible suppliers, consumers and intermediaries; selection of a space-planning solution for optimal warehouse capacity and compatibility, selection of equipment; determination of the number of selected types of lifting and handling equipment.

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