M. Ya. Zabiyaka, Ya. A. Kuksa
3 st year students of School of Business BSU
Scientific supervisor:
senior Lecturer
E. M. Yelovaya

DETERMINATION OF THE OPTIMAL NUMBER OF WAREHOUSES AND THEIR LOCATION IN THE WAREHOUSE NETWORK OF THE ENTERPRISE

The concept of a warehouse and its functions at the enterprise. Types of warehouses and their classification

The relevance of the selected topic is due to the fact that the decision on the location of the site for the construction of warehouses and their number is the most important task and is taken taking into account many factors. That's why optimizing the warehouse network, selecting their optimal number and location are key aspects of logistics planning for companies. These decisions have a direct impact on the efficiency and competitiveness of the warehouse system, and therefore on the overall efficiency of the entire logistics chain. Studying the role and impact of these decisions on a company's warehouse network is becoming an integral part of logistics management. The study of methods for determining the optimal number and location of warehouses becomes an urgent task to improve the efficiency of logistics processes.

The purpose of this study is to analyze the impact of decisions about the optimal location of warehouses on the efficiency of the warehouse network of the enterprise. To achieve this goal, the existing warehouse systems of enterprises will be considered; the factors affecting the choice of the optimal number and location of warehouses will be analyzed; the logistics aspects of warehouse network development will be studied.

Warehouses are various structures consisting of interconnected elements, which have a certain structure and fulfill a number of functions for transformation of material flows, accumulation and redistribution of goods. A modern warehouse can be a fully regulated multi-level system united in a large technological process with automated systems for accounting of stored goods, starting from their receipt and ending with their release to the final customer. The modern warehouse is a complex structure consisting of technical and managerial sides, and various innovations and scientific progress are changing the structure of the modern warehouse, turning it into a complex of automated warehouse management systems [1].

Speaking about main functions of warehouse at the enterprise, we can point the main ones:

• Storage:

Warehouses offer storage space for goods, preventing wastage and ensuring protection. Planned storage meets steady demand, while extended storage caters to promotions, seasonal demands, or bulk purchases due to price expectations.

• Safety of Goods:

Warehouses protect goods from theft, damage, and adverse weather conditions through security measures, storage facilities, and pest control, reducing losses from wastage and spoilage.

• Movement of Goods:

Goods move through inbound receipt, storage transfer, order selection, and outbound shipping, requiring efficient warehouse infrastructure and software upgrades for uninterrupted orders.

• Financing:

Warehouses support inventory financing by providing collateral for loans secured by deposited goods. Certificates like "Warehouse-keeper's-warrant" can be used as collateral for loans, enabling depositors to secure short-term advances.

• Price Stabilization:

Warehouses aid in price stabilization by balancing supply and demand, storing excess goods during surplus periods and releasing them when demand rises, ensuring a steady supply in the market for price consistency.

• Information management:

Warehouse track and record information about materials and goods being sent into the warehouse and when they are stored and shipped out. The data maintained by the warehouse's information system must be timely, precise and error-free. This enables warehouse managers and staff to generate accurate insights to ensure stock availability, stock replenishment, and stock processing requirements [2].

All warehouses are divided into the following classes:

Class A+ warehouses are the top tier, meeting premium storage standards with modern facilities. These single-story buildings are spacious, column-free, with high ceilings for multi-level racking and advanced storage systems. They feature temperature control, fire safety systems, ventilation, security measures, and essential amenities like office areas and restrooms. The premises are well-illuminated, landscaped, equipped with dock shelters for efficient loading, and ideally located near major highways.

Class A warehouses also fulfill high logistics standards with slightly lower ceiling heights compared to A+ class. They are versatile facilities designed for various cargo storage, featuring sturdy structures, flat concrete floors, fire safety measures, and adequate loading platforms. These warehouses offer essential amenities, office spaces, and efficient loading facilities, ensuring optimal storage conditions for diverse cargo types.

Class A- warehouses are functionally similar to Class A facilities but offer lower-quality equipment and less favorable locations. They may not provide a full range of services or fully meet the standards of Class A facilities.

Class B+ warehouses are designed for storing various goods and offer a balance of affordability and essential warehousing conditions. These single-story rectangular buildings have concrete floors with anti-dust coating, regulated temperature, fire safety systems, and adequate ventilation. They feature height-adjustable loading platforms, landscaped surroundings, 24-hour security, and convenient access near highways. Mandatory amenities include office spaces, rest areas, showers, and fiber optic connectivity.

Class B warehouses are cost-effective solutions that meet modern standards. These one or two-story rectangular buildings can be new or renovated, with concrete or asphalt floors and ceilings of at least 6 meters high. They may include freight elevators for efficient transportation, heating systems, and auxiliary facilities. Office spaces, security guards, telecommunication networks, surveillance systems, and designated areas for unloading and maneuvering of large trucks are essential features for Class B warehouses.

Class C warehouses are typically insulated hangars or industrial facilities with a minimum ceiling height of 4 meters. They may have multiple floors with freight elevators and ground-level gates for cargo access. Temperature is maintained between +8 to +14°C with heating and ventilation systems. These warehouses may include office space, telecommunication networks, and perimeter security. They are conveniently located near highways with parking and maneuvering space for trucks.

Class D warehouses are simple facilities for short-term storage, often located in basements or non-residential areas. They may have basic amenities like heating, ventilation, and security systems. Office space and maneuvering areas for heavy vehicles may be available. These warehouses can be found in urban or industrial areas near highways [2][4].

Factors influencing the choice of the number and location of warehouses

One of the most important strategic decisions a company makes is the choice of geographic location and number of warehouses in order to maximize economic efficiency. For example, proximity to the highway network and consumers is an important location criterion for full-fill centers because of their delivery mode. Food retailers that accept online orders also tend to locate their warehouses much closer to consumers because of the need to maintain different temperature ranges for the products they deliver.

To choose a location for a warehouse, it is needed to evaluate many criteria, both quantitative and qualitative. Many companies focus primarily on where their customers are located and how many of them there are in a particular location, which, while noteworthy, is not as important as when choosing a retail store location. Other factors include land cost, labor availability, tax criteria, minimizing displacement and overall costs. Environmental considerations will also play a role in the decision. The following are specific factors to consider when determining where a warehouse will be located:

- Land costs and rental rates,
- Access to transportation networks,
- Availability of affordable skilled labor,
- Transportation links for staff,
- Free economic zones or free trade zones,
- Availability of existing buildings,
- Availability of utilities and communications networks, and the cost of connecting to and utilizing them,
- Commodity flows.

It is worth mentioning that warehouses are often located in "industrial areas" where there is already a "warehouse culture" to work with.

Fortunately, nowadays, when deciding where to locate a warehouse, it is not necessary to rely entirely on human intelligence, as there are a number of computer programs that take into account most of these criteria and offer some realistic options. Many of these systems work on a center of gravity approach, locating the warehouse at the center of supply and demand, based on the criterion of minimizing distances to customers and suppliers. In the advanced variant of this method, the warehouse is located in the center of mass demand and supply, based on the criterion of minimizing transportation costs when delivering goods to consumers and picking them up from suppliers.

Under the center of gravity approach, warehouses are located with the objective of minimizing transportation costs. The center of gravity approach allows a warehouse or distribution center to be located at a point that minimizes transportation costs for the types of products moving between the manufacturing plant and the market. This method is completely analogous to the physical method of determining the center of gravity of a body [5].

The method of determining the center of gravity of cargo flows is widely used to find the approximate location of the warehouse of an enterprise or distribution center of a trade organization that supplies consumers in a given region with goods. The essence of the method is to find an equidistant point from all consumers, taking into account their cargo turnover.

The problem of determining the coordinates of the point corresponding to the center of gravity of cargo flows can be solved using known mathematical formulas:

$X = \Sigma (Ai * Qi) / \Sigma Qi$, $Y = \Sigma (Bi * Qi) / \Sigma Qi$,

where Ai and Bi are coordinates of the i-th consumer; Qi - cargo turnover of the i-th consumer;

X and Y - coordinates of the center of gravity of cargo flows [6].

It should be noted that these formulas can be used when transportation tariffs for delivery of goods to the respective consumers are equal to each other. Otherwise, the dependencies for determining the coordinates of the distribution warehouse have the following form:

$$X = \Sigma (Ai * Qi) / \Sigma (Qi * Ti),\ Y = \Sigma (Bi * Qi) / \Sigma (Qi * Ti),$$

where Ti is transportation tariff for delivery of goods to the i-th consumer [6].

The application of the described method has one limitation. In the model, the distance from the point of consumption of the material flow to the location of the distribution center is considered in a straight line. In this regard, the modeled area must have a developed road network, because otherwise the main principle of modeling - the principle of similarity between the model and the modeled area - will be violated. otherwise the main principle of modeling will be violated - the principle of similarity between the model and the modeled object. By the method of determining the center of gravity can be optimized, for example, the location of the warehouse of the wholesale trade enterprise, supplying the district's stores with food products. In this case it is necessary to balance the cargo turnover of the stores served. If the service area of a wholesale warehouse includes several settlements supplied with a certain group of goods only from this warehouse, then on the model of the distribution system cargoes can be proportional to the population of the corresponding settlements.

Factors to consider when selecting a site for a distribution center after the decision on the geographical location of the center has been made.

1. Size and configuration of the site. A large number of vehicles serving the input and output material flows requires sufficient size and configuration of the site. The large number of vehicles serving inbound and outbound material flows requires sufficient space for parking, maneuvering, and travel. The lack of such space will result in congestion, loss of customers' time (possibly customers themselves). It is necessary to take into account the requirements of fire protection services: in case of fire there should be free passage of fire-fighting equipment to the warehouses. Any distribution center, being an element of some logistic system, in its turn, itself unfolds into a complex system. The storage facilities of the distribution center are only one of the elements of this system. For effective functioning of the distribution center on the allotted area for it it is necessary to organize the functioning of all other elements, as underestimation of any of them can negatively affect the operation of the entire center. In particular, on the allotted territory it is necessary to place:

- administrative and living quarters, including including a central office, a canteen, sanitary and domestic facilities for workers;
- security post;
- devices for waste collection and treatment.

2. Transportation accessibility of the area. A significant transportation costs are a significant component of the cost of operation of any distribution center. Therefore, when selecting a site, it is necessary to assess the roads leading to it, familiarize with the plans of the local administration to expand the road network. Preference should be given to the sites located on the main (trunk) highways. In addition, it is necessary to study the equipment of the territory with other means of transport, including public transport, which significantly affects the accessibility of the distribution center for both its own staff and customers.

3. Plans of local authorities. When selecting a site, it is necessary to get acquainted with the plans of the local administration on the use of adjacent territories and to make sure that there are no factors that could later have a restraining effect on the development of the distribution center [5, 3]. There are also some methods such as: method of complete enumeration, heuristic methods.

The method of complete enumeration.

The problem of choosing the optimal location is solved by a complete enumeration and evaluation of all possible variants of distribution centers location and is performed on the computer by methods of mathematical programming. However, in practice in the conditions of branched transportation networks the method may not be applicable, as the number of possible options as the network scale increases, and with them the labor intensity of the decision grow exponentially.

Heuristic methods.

Much less labor-intensive are suboptimal, or so-called heuristic methods of determining the location of distribution centers. These methods are effective for solving large practical problems; they give good, close to optimal results with low computational complexity, but do not provide finding the optimal solution. The name "heuristic" means that the methods are based on human experience and intuition. are based on human experience and intuition (as opposed to the formal procedure underlying the brute-force method). Essentially, the method is based on the "Pareto rule", i.e. the prior rejection of a large number of obviously unacceptable options. An experienced expert specialist, working in a dialog mode with a computer, analyzes the transportation network of the area and excludes unsuitable, in his opinion, options from the machine's task. Thus, the problem is reduced to a manageable size in terms of the number of alternatives to be evaluated. Only controversial options remain, for which the expert does not have an unambiguous opinion. For these alternatives, the computer performs the calculations according to the full program [5, 6].

The strategic selection of warehouse locations remains a pivotal decision for companies seeking to optimize economic efficiency. Various factors, both quantitative and qualitative, shape this decision-making process, including proximity to transportation networks and consumers, land costs, labor availability, and environmental considerations. When determining warehouse locations, the center of gravity approach plays a crucial role, focusing on minimizing transportation costs. This method calculates an equidistant point from consumers based on their cargo turnover, ensuring efficient distribution. However, its application requires a well- developed road network within the modeled area to maintain modeling accuracy. Moreover, considerations extend beyond just location. Warehouse sites must accommodate the size and configuration needed for efficient vehicular flow, ensuring adequate space for maneuvering and parking. Transportation accessibility and future development plans from local authorities also significantly impact the site's suitability. Various methods, such as complete enumeration and heuristic methods, aid in selecting optimal warehouse locations. While complete enumeration evaluates all possible options, its applicability diminishes with expansive transportation networks due to computational complexity. Heuristic methods, on the other hand, provide close-to-optimal solutions with less computational intensity, relying on human experience and intuition to streamline the decision-making process. Ultimately, the process of selecting warehouse locations is multifaceted, requiring a meticulous evaluation of multiple criteria, considering not only geographical factors but also transportation logistics, space requirements, and future developmental aspects guided by both mathematical methods and human expertise.

References

1. Ermolova, Y. A. Choosing the location of the warehouse complex / Y. A. Ermolova // Bulletin of the Magistracy. – 2020. – № 3–2 (102). – P. 27–28.

2. Grigoriev, M. N. Logistics : a short course of lectures / M. N. Grigoriev, S. A. Uvarov. – M. : Yurayt Publishing House, 2014. – 207 p.

3. Modern logistics / J. Johnson [et al.]; edited by N. A. Korzh. – 7th ed.: Translated from English. – M. : Publishing house «Williams», 2002. – 624 p.

4. Warehousing logistics : studies. The method. complex for students of specialty 1-26 02 05 «Logistics» / M. J. Banzekulivakho, O. S. Gulyagina. – Novopolotsk : PSU, 2015. – 268 p.

5. Gadzhinsky, A. M. Logistics: studies. The manual / A. M. Gadzhinsky. – 15th ed., reprint. and additional. – M.: Publishing and trading Corporation «Dashkov and Co.», 2007. – 472 p.

6. Drozdov, P. A. Fundamentals of logistics: a textbook / P. A. Drozdov. – Minsk, 2008. – 211 p.