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# Capacity of Storage of Participant Cargoes

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***Abstract---*** *Warehouses located at points of transshipment of goods from one type of transport to another perform important functions of converting cargo flows with the goal of further most efficient transportation. When designing a piece-and-piece cargo warehouse, it is necessary to choose the best way to store goods, while ensuring the most complete filling of the warehouse area with goods, as well as the minimum costs when moving goods inside the warehouse. Mathematical models are proposed that establish the relationship between the individual parameters of the unit-cargo warehouse. The models were used in the study of the mutual influence of the parameters on each other; the storage capacities of packaged goods were also determined.*

***Keywords---*** *Delivery, Packaged Cargo, Rack, Pallet, Storage Area, Storage Capacity, Warehouse.*

## I. INTRODUCTION

The need for their timely delivery makes demands both on the transportation process and on warehouse technologies. Warehouses located at points of transshipment of goods from one type of transport to another perform important functions of converting cargo flows with the goal of further most efficient transportation. Delivery efficiency depends on how well equipped and organized these warehouses are in transport.

When designing, reconstructing, or optimizing a containerized cargo warehouse, it is necessary to choose the best way to store goods, the type and parameters of racking equipment. At the same time, the most complete filling of the warehouse area with goods should be ensured, as well as the minimum costs when moving goods inside the warehouse. To date, the warehouse system has a bottleneck in the storage area. This phenomenon is associated with the greatest employment, low labor productivity, and in some cases the use of low-skilled labor.

As a rule, racks and walkways in the warehouses of piece cargo are located perpendicular to each other, as shown in Figure 1.

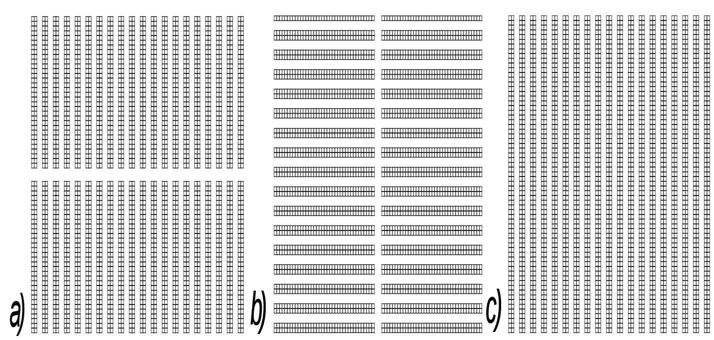


Fig. 1: Traditional Warehouses Equipped with Frame Racks

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The traditional arrangement of shelving has its advantages in terms of the number of places intended for storage of goods, but also has disadvantages in increasing operating costs associated with the distance of movement of loading and unloading machines from loading and unloading places to storage places. Existing methods for calculating the capacity of a unit-cargo warehouse are not quite perfect. There is a need to clarify and supplement the existing ones and develop more accurate method for the capacity of piece-cargo warehouses. Various literature sources talk about the rational arrangement of frame shelving, while many recommendations are not justified. In this regard, in this paper, questions arise:

- On the location of the racks across the width of the warehouse;
- About laying the pallet in the depth of the rack;
- About the capacity of the warehouse in height;
- About the rational ratio of width and length.

## II. METHODS OF RESEARCH

The problem of determining the area of the warehouse, which functions mainly in the storage area, is studied in [1].

The procedure for finding the optimal warehouse design solution in article [2] is considered in three stages of costs: costs associated with initial investments (construction and maintenance of facilities), inventory costs and costs associated with warehouse capacity. Also, in [2], a procedure was developed for finding the optimal design for a storage area, including methods of analytical optimization and modeling. The study [3] examined the elements that affect the required storage capacity in a stochastic environment. The required power is measured in terms of its deviation from the rated required power. The study also developed a simulation model for measuring the relationship between warehouse capacity and various relevant parameters. The study [4] is devoted to minimizing the total cost of stocks by optimizing the storage area of the warehouse. In [5], the problem under consideration consists in determining the optimal size of the warehouse used to store products for a limited time. The article [6] provides a detailed overview of studies on warehouse planning, and its effective assessment. Each section of the warehouse, including a cargo storage area, is also discussed. In [7], the authors developed a deterministic stock model. The model allows you to determine the rational operation of the warehouse for various periods of storage of goods in the warehouse. In [8], a stock model was developed with a demand coefficient depending on the warehouse capacity. It is assumed that the level of demand is a polynomial form of the current level of stocks in a warehouse.

An approximate approach was developed in [9], which helps determine the capacity of containers. Research [10] is aimed at finding rational values for the parameters of the container terminal, or rather, the terminal capacity at the storage site. The purpose of the article [11] is to show that the delivery of goods is influenced by various factors, such as loading, unloading and storage at the warehouse, which are described in the article.

The article [12] proposes an approach to the formation and composition of intelligent transport systems in industrial warehouses. This approach is based on an original combination of analytical and simulation models of a transport and technological system that implements a set of transport and logistics methods for the functioning of the organization of railway transport and technological systems. The article [13, 14] gives recommendations on increasing the power factor of electric forklifts in a warehouse. A wide overview of warehouse planning problems is given in article [15]. The goal is to provide a link between scientific researchers and warehouse practitioners, explaining which planning models and methods are currently available for warehouse operations. In article [16], the problem of determining the size of a warehouse is considered, the task of which is to minimize the total cost of the order, storage and warehouse storage of stocks. The article [17] presents a warehouse planning procedure that uses the principles of mass storage in order to increase the optimal use of warehouse space and reduce loading and unloading operations. The purpose of the article [18] is to assess the value of warehouse planning.

The above studies do not fully answer the question of the capacity of warehouses of piece cargo. There are no exact answers on how to place racks, how to place a pallet in a rack, the search for the optimal ratio of the width and length of the warehouse, and the question of finding the right height of the racks. The answers to all these questions can be found in this article.

Capacity of a unit-cargo warehouse is determined by the number of freight warehouse units located in its storage area. When designing a storage zone, it is necessary to choose the most rational way of storing unit-piece cargo, the type of storage units, rack and handling equipment.

In this case, it is necessary to completely fill the storage area with cargo units and maximize the use of warehouse volumes. The capacity of a unit-cargo warehouse is determined by the formula 1.

$$R = x \cdot y \cdot z, \quad (1)$$

where x-is the number of transport packages located across the width of the warehouse building;

y - is the number of transport packages along the length of the warehouse building;

z - is the number of tiers for the height of the warehouse building;

The number of transport packages located across the width of the warehouse building can be determined by the following formula:

$$x = 2 \cdot \varepsilon \left\{ \frac{B - B_e - B_0}{B_a + 2 \cdot (a + w)} \right\}, \qquad (2)$$

Where 2-is the number of racks in the section consisting of two racks and the passage between them;

B - the width of the covered warehouse, mm;

$B_0$ - part of the width of the covered warehouse, which cannot be occupied by shelving, mm;

$B_a$ - width between racks for the handling equipment, mm;

$B_e$ - width of the reception-dispatch expedition, mm;

a - is the length of the transport package mm;

w - is the gap between the pallet and the rack structure, mm;

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The number of transport packages along the length of the shelves is determined by the formula (3).

$$y = 3 \cdot \varepsilon \left\{ \frac{L - n_a \cdot L_a}{l_1} \right\}, \qquad (3)$$

where L is the length of the covered warehouse, mm;

$L_a$ - is the transverse width of the passage through the covered warehouse, mm;

$l_1$ - rack cell length (for pallets with dimensions of 1200 × 800 mm, the cell length is exactly 2800 mm, and for pallets with dimensions of 1200 × 1000 mm, the cell length is 3300 mm);

$n_a$ is the number of transverse passages along the length of the warehouse:

$$n_a = \varepsilon \left\{ \frac{L}{a} \right\};$$

3 - the number of pallets placed in a standard cell.

The number of tiers in height is determined by the formula 4.

$$z = \varepsilon \left\{ \frac{H - h - C}{C} \right\} + 1, \qquad (4)$$

where H - is the height of the covered warehouse, mm;

C - tier height, m, is determined by the formula: C = 150 + c + e (where 150 mm is the height of the pallet, s is the height of the load on the pallet, mm; e - height dimension equal to the thickness of the longitudinal beam of the frame rack and the gap between the load and the bottom of this beam of the next tier in height, take e = 200 - 300 mm);

*1* - additional upper tier; h - the gap between the upper load in the rack and the bottom of the floor trusses is 500 mm (used to install pipelines, lighting devices, etc.);

ε {...} - designations of the integer part of the number resulting from the performance of actions in brackets (rounding down the integer).

## III. CITATIONS

The question of the ratio of the width and length of the warehouse. When designing warehouse buildings, indicators such as column pitch, span and warehouse height are used. The column pitch is the distance between the main transverse load-bearing structures (usually the column pitch is 6 or 12 m). Span distance between the longitudinal bearing structures (12, 18 and 24 m). Warehouse height is the distance between the level of a clean floor and the bottom of the floor trusses. In order for the indoor warehouse to meet the requirements of rational technology, it must have a certain ratio of length and width. The most rational are 1: 2 ratios; 1: 2.5; 1: 3; 1: 5.

Indicators of the capacity of warehouses of piece-piece cargo, taking into account the use of width and length in

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1: 2 ratios; 1: 2.5; 1: 3; 1: 5 and the height of the warehouse building are shown in Figure 2.

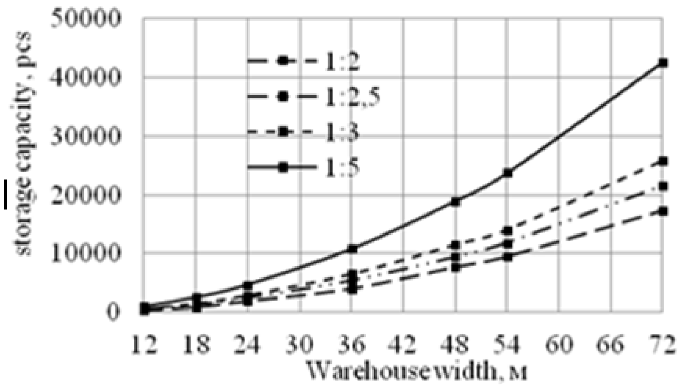


Fig. 2: Dependence of the Capacity of Cargo Units on the Width with Different Ratios to Length with a Warehouse Height of 7.2 m.

Figure 2 shows that the ratio of the width and length 1: 5 provides the largest storage capacity, this is understandable and does not require additional explanation.

The question of laying the pallet in the depth of the rack. It is recommended to install pallets with the long side in the depth of the rack to obtain the largest storage capacity. The correctness of such a solution can be reliably confirmed (or refuted) by calculations using the above mathematical formulas.

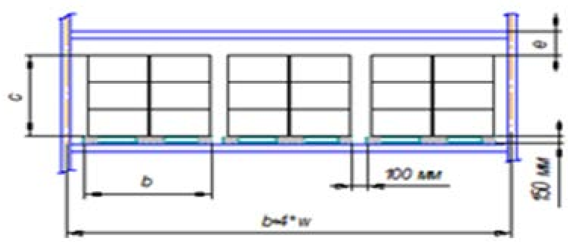


Fig. 3: Laying the Pallet with the Short Side b in the Depth

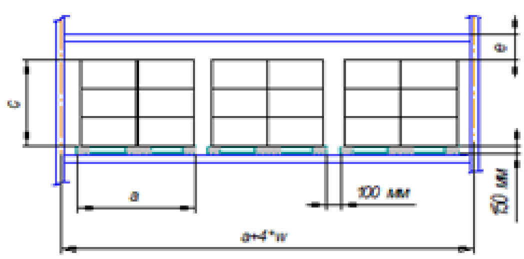


Fig. 4: Laying the Pallet with The Long Side a in the Depth of the Rack

The results of calculating pallet stacking for the options under consideration are shown in Figure 5.

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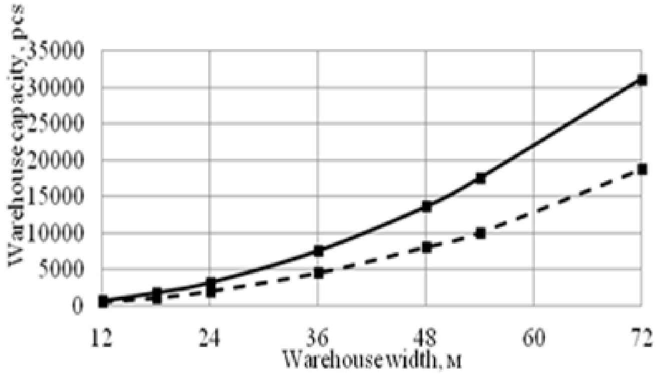


Fig. 5: Dependence of warehouse capacity with a ratio of length and width 1:3

The graphs in Figure 5 show that it is really recommended to install the pallet with the long side in the depth of the rack to obtain the greatest capacity.

When calculating the capacity of a unit-piece warehouse, equipped with frame racks are installed along the long side of the warehouse, however, a justified decision is extremely rare (see Figures 6 and 7).

Fig. 6: Long side of the racks, located across the width of the warehouse

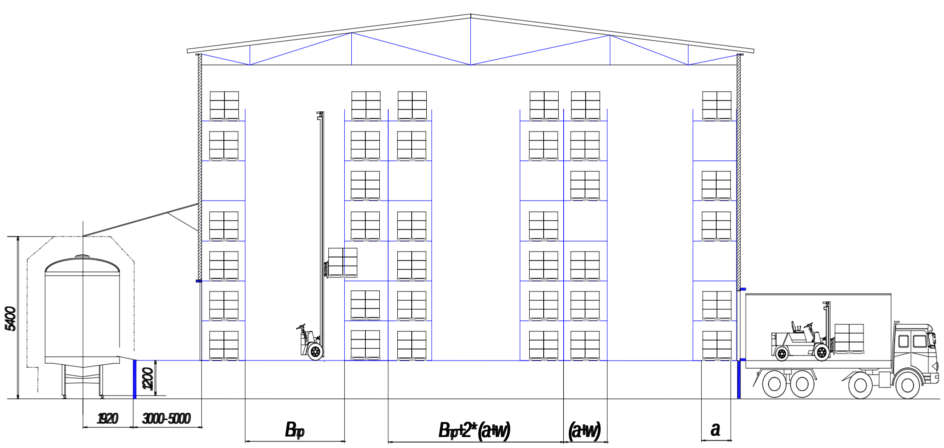


Fig. 7: Long Side of the Racks Located Along the Width of the Warehouse

Number of tiers for the height of the warehouse building is determined depending on the usable storage height and the height of the transport package (see Figure 9).

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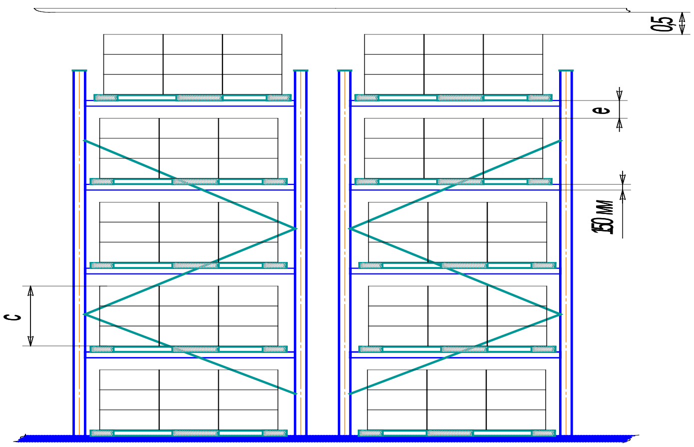


Fig. 8: Number of Tiers in Height

## IV. RESULTS

Discussion of the results. Based on the calculation of the parameters of the storage area, a parametric series of the unit-cargo warehouse was developed for various options (see table 1).

Table 1: (Fragment). Parametric Series of Mechanized Warehouses of Piece Cargo with a Warehouse Height of 7.2m

| **Designation** | ***x,*** | ***y,*** | ***z,*** | ***R*** |
|---|---|---|---|---|
| EP-STK -7,2-1-24 | 4 | 24 | 4 | 384 |
| EP-STK -7,2-1-36 | 6 | 36 | 4 | 864 |
| EP-STK -7,2-1-48 | 10 | 48 | 4 | 1920 |
| EP-STK 7,2-2-72 | 14 | 72 | 4 | 4032 |
| EP-STK 7,2-2-96 | 20 | 96 | 4 | 7680 |
| EP-STK 7,2-3-108 | 22 | 108 | 4 | 9504 |
| EP-STK -7,2-3-144 | 30 | 144 | 4 | 17280 |
| EP-STK -7,2-1-30 | 4 | 32 | 4 | 512 |
| EP-STK -7,2-1-45 | 7 | 45 | 4 | 1260 |
| EP-STK -7,2-1-60 | 10 | 61 | 4 | 2440 |
| EP-STK -7,2-2-90 | 15 | 90 | 4 | 5400 |
| EP-STK -7,2-2-120 | 20 | 118 | 4 | 9440 |
| EP-STK -7,2-3-135 | 22 | 135 | 4 | 11880 |

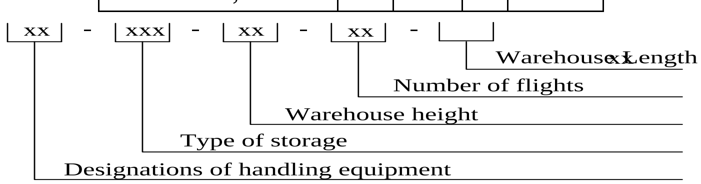


Fig. 9: Designation of Options

## V. CONCLUSION

Consequently, in this work, we studied the conditions for filling the warehouse along the length, width and height for different parameters of the cargo. Numerous variants of rack storage of cargo units on pallets with dimensions of 1200 × 800 mm were investigated, as a result of which the laws of changing the capacity of the

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warehouse storage area were derived. An analysis of these patterns leads to the following conclusions:

- with increasing warehouse height, the capacity increases for various cargo parameters;
- with an increase in spans, the efficiency of the warehouse width increases;
- parametric series has been developed to assess the capacity of a unit-cargo warehouse.

When designing, reconstructing, improving and optimizing the structure and functioning of a unit-cargo warehouse equipped with frame racks, it is recommended to use the mathematical models developed in this work.

## REFERENCES

[1] Lee, M. K., & Elsayed, E. A. (2005). Optimization of warehouse storage capacity under a dedicated storage policy. *International Journal of Production Research,* 43(9), 1785–1805.

[2] Rosenblatt, M. J., & Roll, Y. (1984). Warehouse design with storage policy considerations. *International Journal of Production Research*, 22(5), 809–821.

[3] Rosenblatt, M. J., & Roll, Y. (1988). Warehouse capacity in a stochastic environment. International *Journal of Production Research,* 26(12), 1847–1851.

[4] Cormier, G., & Gunn, E. A. (1996). Simple Models and Insights for Warehouse Sizing. *Journal of the Operational Research Society*, 47(5), 690–696.

[5] White, J. A., & Francis, R. L. (1971). Normative Models for Some Warehouse Sizing Problems. *A I I E Transactions*, 3(3), 185–190.

[6] Gu, J., Goetschalckx, M., & McGinnis, L. F. (2010). Research on warehouse design and performance evaluation: A comprehensive review. *European Journal of Operational Research*, 203(3), 539–549.

[7] Bhunia, A. K., & Maiti, M. (1998). A two warehouse inventory model for deteriorating items with a linear trend in demand and shortages. *Journal of the Operational Research Society*, 49(3), 287–292.

[8] Singh, C., & Singh, S. R. (2012). *Optimal ordering policy for deteriorating items with power-form stock dependent demand under two-warehouse storage facility. OPSEARCH,* 50(2), 182–196.

[9] Roll, Y., Rosenblatt, M. J., & Kadosh, D. (1989). Determining the size of a warehouse container. *International Journal of Production Research*, 27(10), 1693–1704.

[10] Daurenbek I. Ilesaliev, Shahboz R. Abduvakhitov,Azizbek F. Ismatullaev, Shakhobiddin G. Makhmatkulov (2019). Research of the main storage area of the container terminal. *International Journal of Engineering and Advanced Technology (IJEAT),* 9(1), 4625-4630.

[11] Ilesaliev Daurenbek, Merganov Avaz. Research package efficiency general cargo. *International Journal of Engineering and Advanced Technology (IJEAT),* 9(1), 6880-6884.

[12] Rakhmangulov, A.N., Sladkowski, A., Osintsev, N.A. (2016). Design of an ITS for industrial enterprises. In A. Sladkowski, T. Pamula (Eds.), *Intelligent transportation systems – problems and perspectives. Switzerland: Springer.* doi: 10.1007/978-3-319-19150-8_6

[13] Ziyoda G. Mukhamedova. (2019) Energy efficiency review and monitoring of special self - propelled railway rolling stock. *International Journal of Recent Technology and Engineering (IJRTE),* 7, 572-576

[14] Ziyoda G. Mukhamedova. (2016). Numerical model for calculation of fluctuations in the main-bearing frame of railcar with changing stiffness and physical parameters. *Journal of KONES Powertrain and Transport*, 23(2), 255-261.

[15] Gu, J., Goetschalckx, M., & McGinnis, L. F. (2007). Research on warehouse operation: A comprehensive review. *European Journal of Operational Research,* 177(1), 1–21. doi:10.1016/j.ejor.2006.02.025

[16] Goh, M., Jihong, O., & Chung-Piaw, T. (2001). Warehouse sizing to minimize inventory and storage costs. Naval Research Logistics, 48(4), 299–312.

[17] Larson, T. N., March, H., & Kusiak, A. (1997). A heuristic approach to warehouse layout with class-based storage. *IIE Transactions,* 29(4), 337–348. Strack, G., & Pochet, Y. (2010). An integrated model for warehouse and inventory planning. *European Journal of Operational Research*, 204(1), 35–50.

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