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Research paper

Ensuring Competitiveness of Logistics Service by Selecting the Type of Storing Single-Piece Cargoes

Iryna Trunina[1], Volodymyr Zahorianskyi[1*], Olena Zahorianska[1], Dmytro Moloshtan[1]

[1]Kremenchuk Mykhailo Ostrohradskyi National University
**Corresponding author E-mail: zagor_vlad@ukr.net*

Abstract

Efficient transportation of cargoes from the point of the cargo traffic start to the final consumers can significantly influence competitiveness of logistics service that leads to the necessity of analysing the known approaches to substantiating the selection of the storing type (pile storage or rack storage) when warehousing single-piece cargoes. To formalize the problem of selection based on the analysis, the authors develop the model, which is suggested to use the quantity of the stored pallets with single item cargoes. The calculations according to the suggested mathematical model envisage intensive computations with repeated calculations; therefore the corresponding recursive algorithms are developed for this mathematical model. The corresponding recursive algorithms for the model are easily realized in the software product. The developed algorithms can be easily realized in the software product with graphic interface on the enterprises delivering logistics services to enhance their competitiveness.

Key words: *Algorithm; pallet; Single-piece cargo; Rack storing; Pile storing.*

1. Introduction

The main task of business logistics is the most effective cargo transportation from the point of the traffic start to the final consumers that can significantly influence competitiveness of logistics services since about 50% in the structure of the product prime cost are costs of storing, transporting, packing and other operations relating to the transportation of inventory holdings [1]. Cargoes are the main material component of logistics that is meant for designing the whole system of the rational traffic organization [2].
Mechanical and automated storages of various types, function and organization of handling are the objects adapted and equipped for the most effective transformation of traffics where the appropriately organized transportation process should start and finish.
According to the kind of the processed cargoes, there are storages of single-piece cargoes, container storages, bulk cargo storages, liquid consignment storages, metal-roll storages, timber cargo storages, etc. [2]. Single-piece cargoes are on the special place since they are meant for transforming parameters of the finished product, i.e. the most valuable cargo.
Single-piece cargoes are conventionally divided into piece-bulk (for example, bricks, non-ferrous metal ingots, punchings, forgings, etc.) and tare-piece (sometimes called tare-packed) which are transported in rigid, rigiflex packings and envelopes (for example, in wooden, plywood, plastic cases, plywood tares, sacks, barrels, bales, etc.) [3].
Depending on the volume-bulk parameters single-piece cargoes are subdivided into the following groups (according to "The Integrated Norms of Output and Time on Carriages, Motor Car and Store Handling Work" [4]: cargoes in sacks, mat bags, packets which comprise different cargoes (in jute, linen, (one- and three-layer) paper, plastic sacks or packets, etc.), cargoes in packs, cargoes in cases (in wooden, metal, plywood, plastic, carton ones), in boxes (chests), gratings, nets, bunches, as well as cargoes without packing (including such single-piece cargoes as roofing paper, ruberoid, slate, bitumen, bricks, parquet, riveting, tablets, strips in packs and bunches) with the mass of one place up to 250 kg except metals and timber materials, as well as barrel cargoes (in metal, wooden and plywood barrels, drums, coils, rolls (paper), on bobbins) with the mass of one place up to 500 kg.
The range of tare-piece cargoes numbers over 15,000 items [3].
The specific mass of tare-piece cargoes is about 20% of the total transportation volumes done by all kinds of transport. In addition, the costs of their handling, sorting and storing operations reach about 40% of the total expenses on handling that reflects on the ending price of logistics services and respectively can decrease their competitiveness.

2. Analysis of the Reference Data and Problem Statement.

Selection of the most rational way and technology of warehousing causing the selection of equipment, arrangements and constructions is the most important aspect of the task of designing or reconstructing the storage [2, 7–9].
The notion "way of storing" includes storing type and its characteristics, kinds and parameters of tares for warehousing of cargoes, kinds and parameters of racks and piling equipment [2].
The accepted way of storing significantly determines the rational placement and stowage in the store [10–12].
The storing types (ways of stowage) of single-piece cargoes comprise [10, 13]:
– pile storing when cargoes (goods) are stored mainly in tares, without unpacking, with the use of flat, stand and case pallets;
– rack storing when cargoes (goods) on the racks can be stored both packed and unpacked; this type relates to the wide subsorting of goods inside the storage. In his later works, O. B. Malikov adds also a conveyor type of storing to these two types of storing [2] (Fig. 1).

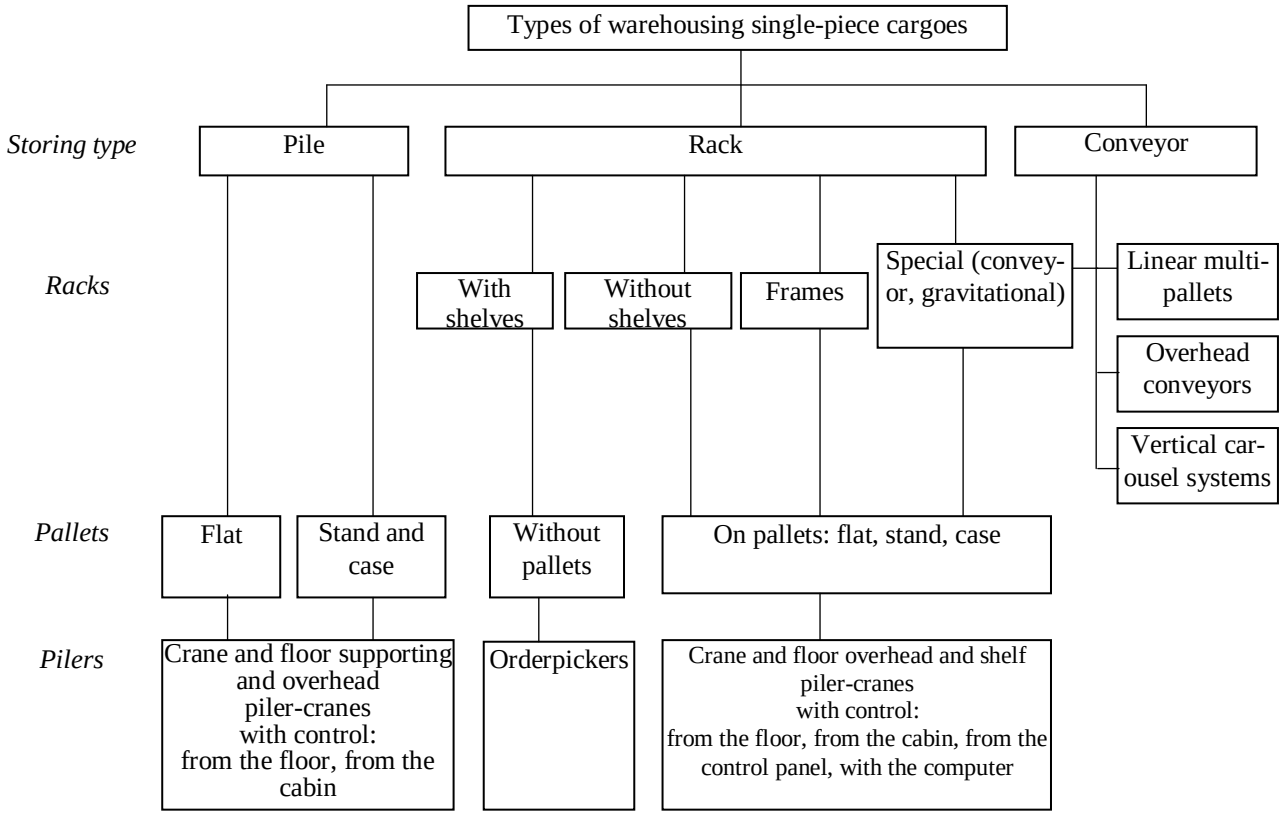

Fig. 1: Classification of the types of warehousing single-piece cargoes [1, 11].

Pile stability and, as a result, minimization of loses relating to damaging due to the wrong warehousing, relating to the stowage cargoes directly one on another one in layers (tiers) or with the use of pallets. In this case, there is a task of the cargo stowage onto the pallet with the maximum filling of its area and the height and the stability of the cargo on the pallet that is determined by the ratio of the sizes of tare-piece cargo and the pallet and the stowage requirements.

Tare-piece cargoes are transported and stored in the standard or unified tares with the parameters regulated by the state standards, particularly by the international standard State Standard 21140-88. Tare. The size system determining the unified size system of the transportation tares on the basis of nominal pallet sizes 800*1,200 and 1,000*1,200 mm, as well as the outer size of the consumer tares that should fit into the internal sizes of the transportation tare.

According to the recommendations of the International Organization for Standardization, the decisions of the European Federation of Packing and other organizations, the pallet of the sizes 1,200*800 mm is accepted as a module for unifying the tare. The unified number sequence for outer sizes of the transportation tare is done in accordance with this module. The possible combinations of the rectangular cross-section tare overall sizes (including the height) are received based on the unified sequence. There are 114 types and sizes of rectangular cross-section tares on the area and 52 on the height included into the State Standard 21140-88. It should be noted that there are 32 combinations that allow using 100% of the pallet area.

The pile cargoes include objects that are uniform on the geometric form and the sizes, are laid in several height tiers and one or several length piles [5].

In this case, the packed load places on one horizontal layer of pile are called a tier.

The feature (or rather disadvantages) of the cargo pile storage is the necessity to envisage measures of ensuring stability of the pile and the safety of people working on the pile or near it [14].

These measures include:

– cargo removing from the pile is done only from the top to the bottom;

– strapping the large-size cargoes must be done by certain cargo parts considering its mass and centring;

– pile stowage of the packets with cargoes requires a special attention concerning the ensuring of their stability. Deformed packets must not be piles; they are placed in separate piles of the lowered height;

– insufficiently stable piles must be removed using fenders installed on the storage floor and assuring the vertical lines of piles neighbouring with the place of removal from the fall of the packets; it is allowed to use pilers with the vertical pressing plates performing the same functions.

In accordance with GOST 18338-73 Industrial packing and racks. Terms and definitions, rack is multi-stage device for storing piece cargoes.

The applied racks are without shelves and frame-grating, dead-ended, pass-through, gravitational, mobile, console, E-type racks [2]. The definition of terms are given in the State Standard 18338-73.

The selection of the warehousing type is influenced by a complex of factors including the kind and volume of the stores cargoes, sizes of the new cargo lots, features of processing them, etc.

Thereby, the selection of the warehousing cargo type requires the selection of the storing type (if this cargo is stored in piles or in racks). The accepted types and parameters of the storage tare, piling or racking equipment will depend on this selection.

In addition, the technology of work and the type of the mechanization means determine the storage height. When using the pile storing and the floor mechanization means, the storage height is 4.5–6 m, while the rack storing requires more height, up to the high-rise rack storages [15].

It should be noted that there are various recommendations on the selection of the storing type [10, 13, 14, 16] but there is no accurate algorithm of such selection that would allow formalizing the procedure of selecting the storing type by using the array of pa-

rameters of the cargoes directed to the storages and the traffic characteristics as initial data.
Thus, formalization of the problem of selecting the type of storing single-piece cargoes while designing a new storage or reconstructing the existing one, representation of the problem of selection in the form of sequential logic and mathematical actions is a highly relevant task.

3. Research Aim and Tasks.

The conducted research aims at developing the algorithm of selecting the type of single-piece warehousing (starting from the selection of the pile or rack storing type) based on the known recommendations and mathematical dependencies.
The established aim is achieved due to the fulfilment of the following tasks:
– formalization of the problem of selecting the warehousing type (pile or rack type of storing, types and parameters of the tare for storing the cargoes) when warehousing single-piece cargoes on the basis of the known recommendations and corresponding dependencies by developing the mathematical model of the task;
– representation of the mathematical model of the task in the form of algorithms visually representing the process of taking decision and being the basis for creating a software product.

4. Methods of Solving the Task of Single-Piece Cargo Storing Type.

4.1. Known Methodical Approaches to the Selection of Single-Piece Cargo Storing Type.

There is a variety of the types of cargo stowage applied on the modern mechanized and automated storages and they lead to various significantly differing technical-economic indicators (for example, the possible combinations of types, sizes of pallets on their cargo storage height and the possible variants of the pile cargo stowage considering combinations of various types and sizes of pallets and the piling equipment [13]).
As a rule, the pile storage is applied for seasonal, large-size goods having a large storing volume [10]. Stowage of goods into the pile must ensure access to any item. The goods with the storing volume over 3 m^3 that are released without unpacking with the whole cargo packets (excluding high-rise storages) can be also stored in piles.
The rack storing is reasonable to be used for the major part of nonfoods and some kinds of provisions of the broad assortment having a small storing volume [10]. The condition for applying this storing type is a wide subsorting of goods inside the storage.
According to another approach [13], the warehousing types for multi-nomenclature and single-type cargoes differ significantly.
Multi-nomenclature cargoes are characterized by a big variety of physical characteristics and bigger quantity of items (up to several tens of thousands). In case of storages on industrial enterprises these are materials, tools, electric goods, spare parts, etc. As a rule, these cargoes are reasonable to be warehoused in grating racks.
Single-type cargoes include those, which are similar in physical characteristics, have a small quantity of items, are accepted and released by big lots (cargoes in sacks, add-in products, and finished products). These cargoes are characterized by the lack of ensuring direct access to any stored cargo item and they can be stored in blocks – piles or special racks (dead-ended, pass-through, gravitational, etc.).
Storing cargoes in racks are known to be reasonable if the arrival is bulk or the cargo nomenclature is small. In other cases, the usage of the rack cargo storages is the most efficient.
From the point of view of the approach considering the pallet sizes [13],it is more reasonable to apply a high-rise rack cargo storage with the use of piler-cranes when using flat wooden pallets of the size 1,200*800 mm and the quantity of the stored pallets with one cargo item less than four for the cargo warehousing.
The pile storage is recommended when the quantity of the same stored pallets with one cargo item is more than three if the allowed quantity of tiers in the pile equals four.
The rack storage is reasonable when using the flat wooden pallets of the sizes 1,600*1,200 mm and the quantity of the stored pallets with single cargo item up to two.
The pile storage is more economical when the quantity of the same stored pallets with single cargo item if more than two [13].
It is noted [13] that the given expenses can be decreased by 2.5 times if there is one stored pallet, by 28% if there are two stored pallets with the same cargo when comparing the rack storage in the pallets 1,600*1,200 mm to the pile storage. The given expenses can be decreased by about 8% for every tonne of the cargo if there are three stored pallets when the pile storage is applied.

4.2. Procedure of Selecting the Type of Single-Piece Cargo Storing Based on the Developed Mathematical Model.

The type of storing is suggested being selected as a pile storing or rack storing on the parameter R_1 (the quantity of the stored pallets with single item cargo).
The parameter R_1 for storages of multi-nomenclature cargoes is 2...5, this parameter is 10...15 and more for storages of bulk cargoes with a small number of items [14].
When the quantity of the cargo items is small (tens of items), the parameter R_1 can be calculated for every cargo item or for a similar cargo group.
In this case, the quantity of pallets with the cargo for each i^{th} item or a group of cargoes (i = 1, 2, …, n where n – quantity of items or groups of cargo) is defined from the expression

$$R_{1i} = \frac{I_i}{\bar{G}}, \quad (1)$$

where I_i – storing stock for each i^{th} item or a group of cargoes; $\bar{G}$ – average pallet load.
Storing stock for each i^{th} item or a group of cargoes is defined from the expression [13]

$$I_i = \frac{k_z \cdot Q_i \cdot \left[\tau_{xp}\right]_i}{360}, \quad (2)$$

where k_z – coefficient of the stock nonuniformity considering accidental fluctuations of the twenty-four-hour arrival and departure cargo traffic to the storage, k_z = 1,05…1,3 [14]; Q_i –yearly traffics of the cargo (group of cargoes) arrival; $[\tau_{xp}]_i$ – normative term of storing the i^{th} cargo (the i^{th} group of cargoes) on the storage, days.
Storing terms depend on the storage function, regularity of cargo arrivals and departures, kinds of transport, etc. In the non-market economy the storing terms (stock norms) are established by normative documents (for example, [14]). Nowadays they are determined by enterprises considering the economic appropriateness. As a rule, the customer sets the developer the storing terms (stock norm). The average storing terms for storages of tare-piece cargoes is considered to equal 3...4 days [17].
If the possibility P_i of the i^{th} cargo group in the general nomenclature is known, the average pallet load is defined from the expression

$$\bar{G} = \sum_{i=1}^{n} G_i \cdot P_i , \quad (3)$$

where G_i – cargo mass of the i^{th} group on the pallet (pallet load).
When calculating approximately with unknown sizes of separate cargoes especially for the small cargoes of the size by 10–12 times less than the pallet size, the pallet load, tonnes, (capacity, cargo mass on the pallet) is determined by the expression [14]

$$G_i = a \cdot b \cdot c \cdot f_3 \cdot \gamma_i , \quad (4)$$

where a, b, c – length (size along the pass), width (size in the depth of the pile or rack) of the cargo storage item and the high of cargo stowage on it, m; м; $f_з$ – coefficient of the tare fulfilment considered as 0.6...0.9, and more accurately when the cargo sizes are known – in relation to the sizes of pallets and cargoes [14]; γ_i – volume mass of the i^{th} cargo, tonnes/m^3; values γ are specified, for example, in [2, 13].
In this case, the cargo storage item is understood as some quantity of cargoes placed on the flat, stand or case pallet.
If the sizes of the cargo α, β, δ and its mass m, kg, are known, the pallet load, tonnes, is defined by the expression [13]

$$G = \frac{a \cdot b \cdot c \cdot f_3 \cdot m}{1000 \cdot \alpha \cdot \beta \cdot \delta} \quad (5)$$

For larger cargoes the pallet load is recommended [2, 13] to be determined by more accurate method of theoretical cargo stowage on pallets which is conveniently to do with the help of simple models – formulas based on the reciprocal correlations between the cargo and the pallet sizes (the models of placing cargoes onto the pallets according to 15 most used types of cargo stowage given in [2, 13] are applied here).

5. Results Of Studying the Problem of Selecting the Storing Type Based on the Algorithm.

As stated above, in case when the quantity of cargo items is small (up to several tens), the calculation is done for each separate item (sort, type and size) of the cargoes. If the quantity of cargo items is more, all cargoes are divided into single-type groups on their physical characteristics and the calculations are done according to the typical representatives of these groups [2, 13, 18–20].

It is noted, that the value $\bar{G}$ equals 0.6 tonnes [24] for the most spread wooden flat pallet of the sizes 1.2×0.8 m [21–23].
If the majority of values R_{1i} received according to the dependency (1) is not more than 5, the rack cargo storing is recommended, in the opposite case – the pile storing.
When the quantity of the cargo items is big (hundreds of items), the parameter R_1 is suggested being calculated in average. In this case, the total cargo stock stored on the storage at the same time, tonnes, is [14]:

$$I = \frac{k_z}{360} \sum_{i=1}^{k} Q_i \cdot \left[\tau_{xp} \right]_i , \quad (6)$$

and the quantity of pallets with the single item cargo is defined by the expression

$$R_i = \frac{I}{n \cdot \bar{G}} , \quad (7)$$

in this case, n – the total quantity of the cargo items.
If the value R_1 is less than 5, the rack cargo storing is used, in the opposite case – the pile storing.
The developed algorithm of selecting the type of storing is given in Fig. 2.

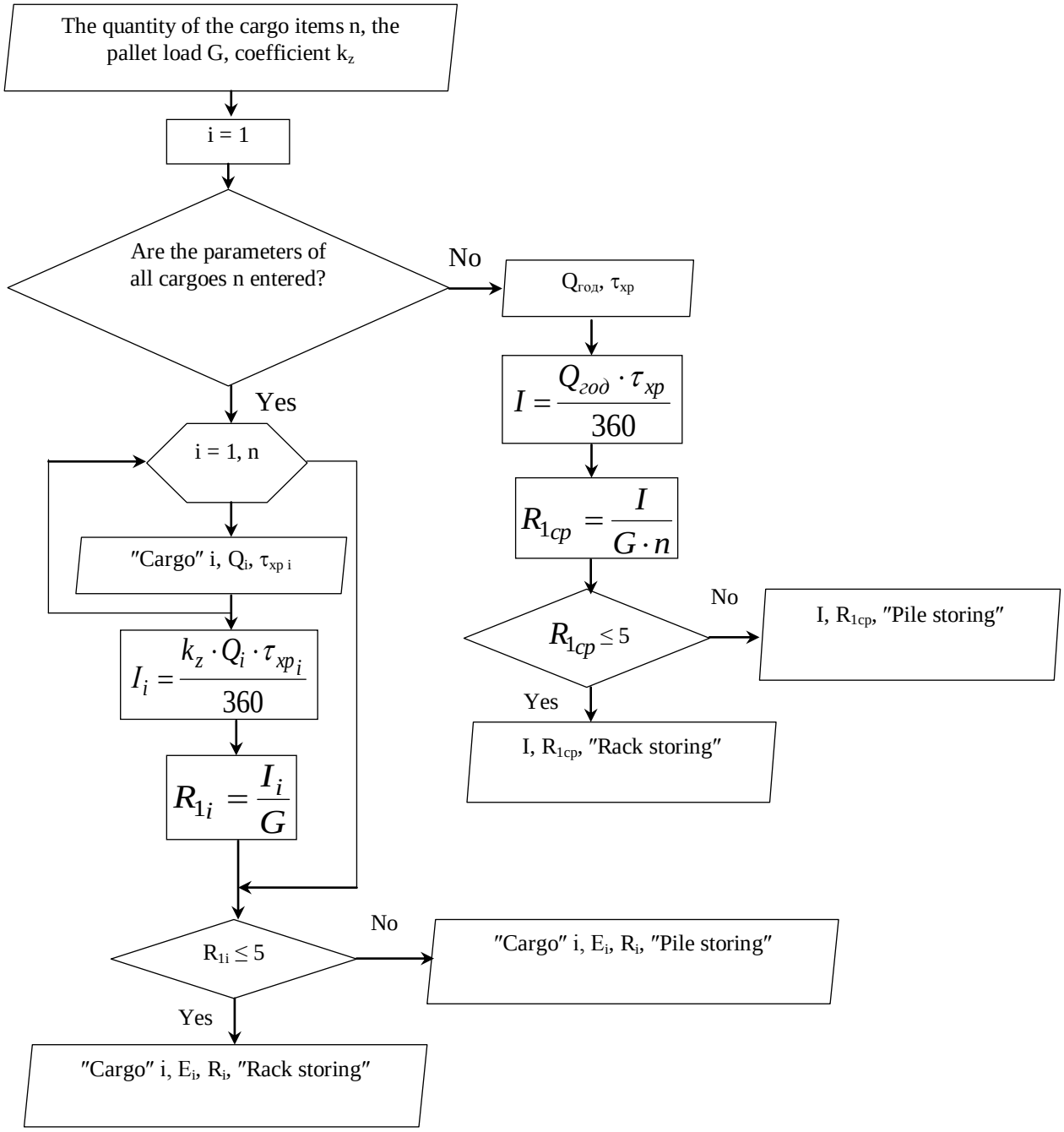

Fig. 2: Algorithm of the storing type selection.

The developed algorithm determining the capacity of the transportation-storage tare is given in Fig. 3.

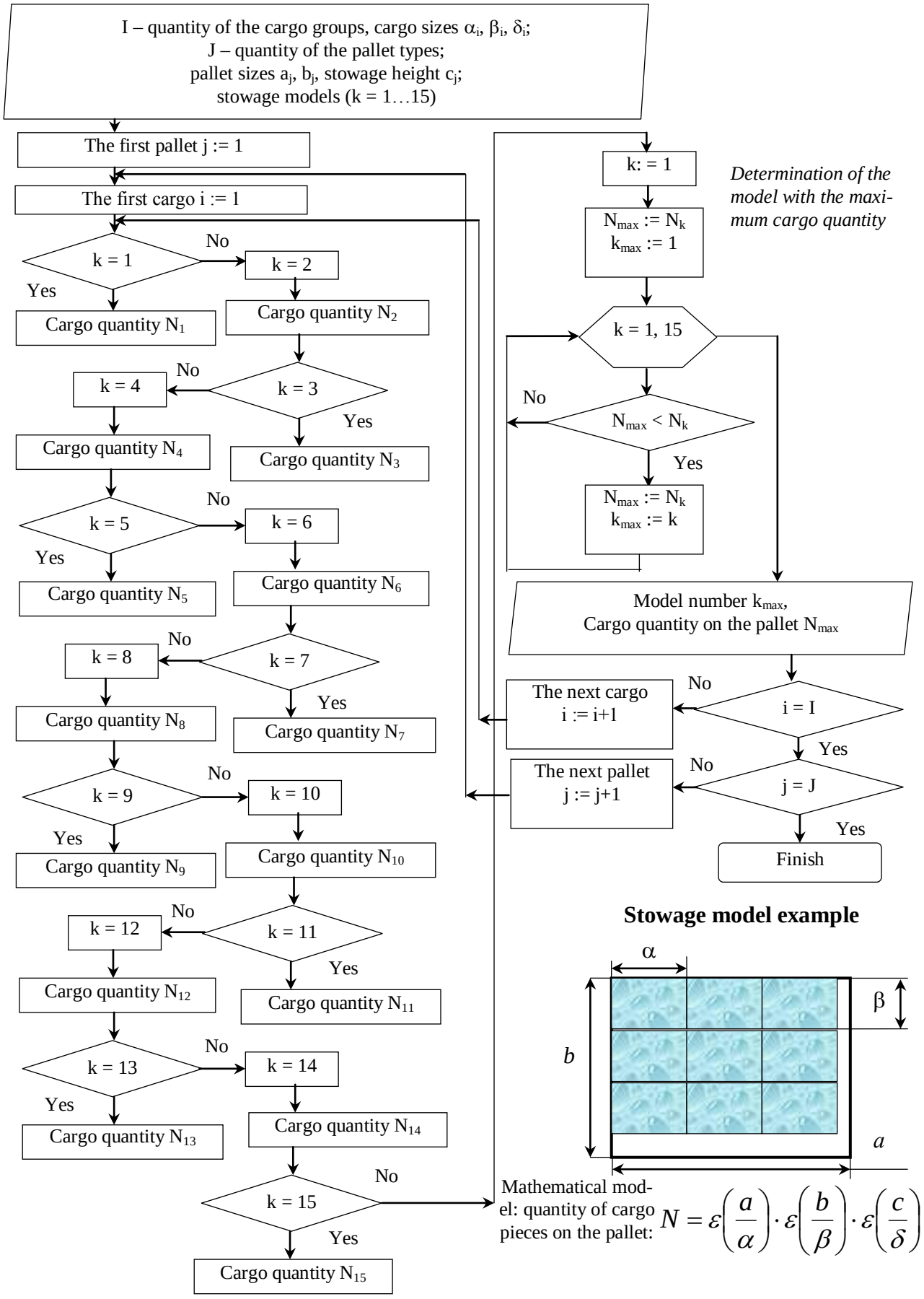

Fig. 3: Algorithm of determining the capacity of the transportation-storage tare by the method of theoretical stowage.

The developed algorithm determining the types, parameters and quantity of the transportation-storage tare (based on [20]) is given in Fig. 4.

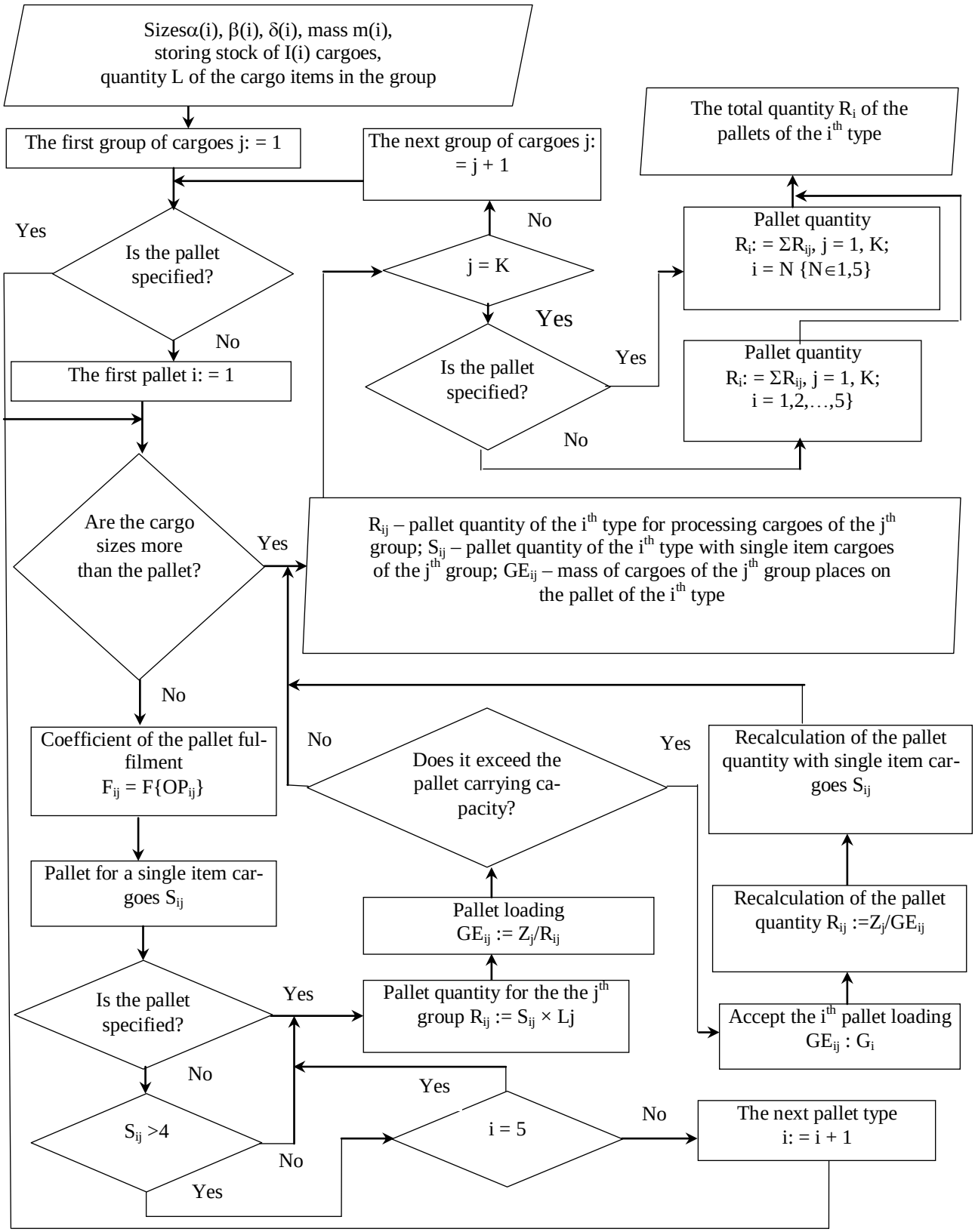

Fig. 4: The developed algorithm determining the types, parameters and quantity of the transportation-storage tare (based on [20]).

6. Discussion of the Results of Studying the Problem of Selecting the Storing Type Based on the Algorithm

As followed from the mentioned above, the calculations of the suggested mathematical model envisage a big volume of the repeated computations that is the cause of this mathematical model being suggested to use the appropriate algorithms including the structural ones (Fig. 2 and 3) which are a combination of the three basic algorithmic structures – sequence, fork and iteration [25].

The developed algorithms can be easily realized in the form of the program software with graphic interface.

Earlier, in our country the usage of computers for designing storages was supposed to be directed to the development of the integrated system of the automated design of the transport-storage complexes. The prerequisites for it were in the fact that separate tasks appearing when designing the technological part of single-piece cargo storages were solved with the help of computers of those days for a range of years. They included, for example, determination of the transportation-storage tare capacity, technical-economic indicators of the cargo-storing zone, parameters of the participants of the outer transport handling, etc. The task of developing a complex system of the automated design of the transportation-storage complexes was not realized due to objective reasons. It should be supposed that there is no need in such systems both for the storage complex and for other industries considering the current conditions and forms of property. Although, the frequent tasks relating to the selection of the best decisions similar to the tasks studied in this article can be successfully represented in the form of computer programs and solved with the maximum effectiveness.

7. Conclusions.

The mathematical model designed based on the logistics experience and the known recommendations, the combining parameters characterizing the single-piece cargo warehousing selection process allows developing and improving the following algorithms:

– selection of the single-piece cargo storing type using the data array of the parameters of the cargoes arriving to the storage and the traffic characteristics as initial data that allows formalizing the procedure of selecting the storing type (pile storing or rack storing);

– determination of the transportation-storage capacity by the method of theoretical stowage based on the mathematical models of cargo stowage onto the pallets according to the most used ways of cargo stowage (the example of such model is given in Fig. 3) which uses the data array of the cargo and pallet sizes as initial data and the model number when a maximum quantity of this cargo and its quantity can be placed on this pallet as the results;

– determination of the types, parameters and quantity of the transportation-storage tare using the data array of the pallet and cargo characteristics as initial data and the pallet types and parameters that are optimal for storing these cargoes as the results, as well as the pallet quantity for each type needed for warehousing the whole existing cargo stock for each of the groups.

It is not difficult to create a software product with intuitive graphic interface using the spread environment for visual programming (for example, Delphi or Visual Basic) based on the developed algorithms.

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