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METHODICAL MAIN REGULATIONS OF THE OPTIMIZATION OF THE LOGISTICS DELIVERY SYSTEMS PARAMETERS WITH CONSIDERATION OF ITS TRANSPORTATION MODE

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МЕТОДИЧНІ ОСНОВИ ОПТИМІЗАЦІЇ ПАРАМЕТРІВ ЛОГІСТИЧНИХ СИСТЕМ ДОСТАВКИ ВАНТАЖІВ З УРАХУВАННЯМ СПОСОБУ ТРАНСПОРТУВАННЯ

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As a result of the analysis of known models and methods of the cargo delivery systems optimization, it was established that the task of choosing the method of delivery (containers, packaging), as well as the choice of the carrier, was decided separately. This approach does not allow us to consider system constraints and criteria, which leads to the choice of an acceptable, but not always optimal, solution. A methodology and an economic-mathematical model that allows to solve the task of determining the route of delivery within the framework of one model, considering additional requirements when choosing transport, the carrier and the mode of transportation are described in this article

Key words: *method of the delivery system organization, economic-mathematic model.*

Introduction. Logistics is not only a factor in increasing the efficiency of the enterprise's economy, but it plays a decisive role in the development of countries. The main goal of logistics is to reduce logistics costs in the final cost of products, as well as to increase the transit potential. Today, the share of logistics costs in the final cost of products remains quite high and is on average 20-35%.

Currently, for an effective assessment of the development of logistics, there is a methodology that allows us to assess the current state of the country's logistics industry. As a basis for determining the logistics rating, experts identified 6 major criteria on the basis of which the LPI (Logistics Performance Index) is calculated.

These criteria include: 1) efficiency of customs and border clearance, 2) quality of trade and transport infrastructure, 3) ease of the international transport organization at competitive prices, 4) quality and competence of logistics services, 5) tracking of goods, 6) timeliness of cargo deliveries.

It is not difficult to notice that the improvement of criteria 3, 4 and 6 is possible while using mathematical methods and models. Thus, for the effectively implement the management functions of logistics systems, it is necessary to focus not only on known economic-mathematical methods and models, but also to create new ones that are capable of adapting in accordance with changes in the external and internal environment.

Statement of the problem. The study of models and methods of the cargo delivery systems optimization, as well as factors which determine the quality of delivery, has shown that for the solution of the task of determining their parameters, the classical transport task and its various complicated applications are successfully used, allowing to receive as a result a set of optimal routes, with consideration of transshipment points, transport modes and identify specific logistics intermediaries in the delivery system.

Need to mark, that the method of transportation in the spoken models is determined beforehand, that means its justification is carried out outside the single model of the logistic delivery parameters optimization. This approach does not allow us to take into consideration system constraints and criteria, which often leads to the choice of an acceptable but not optimal solution.

Analysis of the latest publications on the problem. The solutions of the problems of choosing logistic intermediaries and the optimal delivery system were reflected in the works of Anikin V.A.[1], Gadzhinsky A.M.[2], Lukinsky V.S.[3], Mirotin L.B.[4], Sergeev V.I.[5], Voevudstsky E.N.[6], Poddybnaya N. N.[7],[8], etc. However, despite on the achieved results, it is still urgent to develop new methodological approaches that allow solving complex problems of the design of cargo delivery systems.

Goal of the study. The purpose of the study is to develop a methodological approach and an economic-mathematical model for designing a homogeneous cargo delivery system with minimizing costs, increasing efficiency and competitiveness.

The realization of this goal is conditioned by the need to solve some interrelated tasks:

- Analysis of the transport development during the performance of export operations;
- Analysis, development trends and use of the logistics theory during delivery of goods;
- Design of the cargo delivery system and development of a generalized algorithm for selecting the delivery system with consideration of its limitations.

The object of the study is transport, forwarding companies and other operators on the market that participate in the delivery system.

The subject of the study is models and methods for managing the delivery of goods, as well as factors affecting the quality of logistics intermediaries.

During the research that existed before the solution of the tasks, there were used: theoretical analysis, generalization of scientific literature, as well as methods of operations research. The results are based on the conceptual apparatus and the theoretical basis of such directions as: general economic theory, system analysis, logistics.

Results of the study. On the basis of the studies during the development of the methodological basis for optimizing the logistics delivery systems parameters, considering the mode of transportation, we take into consideration that logistics is the science of planning, controlling and managing the transportation, storage and other material and intangible operations that are performed in the process of bringing raw materials and materials to production enterprise, in-plant processing of raw materials, materials and semi-finished products, bringing finished products to the consumer in accordance with the interests and requirements of the latter, as well as the transfer, storage and processing of relevant information.

As the delivery system, we mean a set of subsystems that ensure the delivery of goods from the consignor to the consignee. Such subsystems are: shipper, consignee, transport system, transshipment and storage points.

The logistics approach in the delivery system is determined by:

- in the integrity of the delivery system from producer to consumer;
- considering the criteria of minimum total costs for the performance of all logistics operations;
- in compliance with the requirements of the consumer in terms of time, place of delivery, quantity and quality (logistics principles: 7 rules of logistics: the right cargo, in the right place, at the right time, in the right quantity and quality, to the right consumer, with minimal total costs)
- in the mandatory presence of the control subsystem (coordinator-forwarder, who organizes the delivery "from door to door").

In this way, the logistics delivery system is a set of subsystems that generates, moves and absorbs a material flow, whose coordinated functioning on the basis of economic, technical and technological integration allows to optimize the receipt of material values with certain qualitative and quantitative characteristics at a certain time and place of a certain consumer with a certain level of costs.

From all being said, a method has been developed for the formation of a cargo delivery system, which consists of the following stages (Figure 1):

1. Information research, formation of initial data. At this stage determine the list of variables and objects of research. Important selection criteria for the information formation are the accuracy and consistency of the data. In this case, the characteristics should not differ in meaning and in the range of the study objects (in the territorial plan and in the period of time).

2. Analysis of the information source about the senders and recipients. It is necessary to find out the geographical location of the departure and destination points, the amount of cargo, whether there is available in each of the points of departure and the necessary amount of cargo for the recipients.

3. Analysis of information about the transshipment points. Possible points of transshipment and their carrying capacity are defined, which in our case is assumed to be unlimited.

4. Analysis and formation of possible transportation options. At this stage, the variants of the delivery system are formed and analyzed. To do this, it is necessary to form a multitude of available modes of transport, modes of transportation and possible carriers, after that to build the delivery chain and calculate the cost of shipping the goods.

4.1. Selection of the mode of transport. The basis for choosing the mode of transport which is optimal for a particular transportation is information on the characteristics of various modes of transport.

4.2. Selection of transportation modes. At this stage, it is necessary to choose among the possible modes of transportation the cheapest, the most safe and convenient to use, considering the advantages and disadvantages of each option.

4.3. Selection of the carrier. The choice of logistics intermediaries is based on system criteria. The main criteria for choosing carriers include: reliability of delivery time, transportation tariff, financial stability of the carrier, safety of cargo, tracking of items.

5. Formation of initial data. At this stage it is necessary to know the cost of transportation of the chosen cargo in different ways and by different carriers from the points of departure to the transshipment points and from the transshipment points to the points of consumption.

6. Formation of cargo delivery chains. At this stage, it forms all possible cargo delivery chains from senders to consumers.

7. Definition of restrictions at points of departure and consumption. At this stage it is necessary to find out how much cargo is at the disposal of the shippers and how much cargo needs to be delivered to the points of consumption.

8. Formation of the criteria for optimizing the construction of chains. In order to choose the best variant of cargo delivery it is necessary to determine the criteria of optimality. Cost criteria – the transportation plan is optimal, if the minimum costs for its realization are received. Time criteria – the transportation plan is optimal, if at least a minimum of time is spent on its implementation.

9. Construction of the model in general form.

10. Construction of a model with numerical data. At this stage, the model is generally described in detail for a specific case.

11. The solution of the problem with the help of a computer.

12. Receiving the optimal route of cargo delivery.

13. Functioning of the projected supply chain.

14. Analysis of the quality of functioning. At this stage, the quality of delivery is analyzed, which must comply with the norms.

Here is a model of the sequence and relationship of the steps in fig. 1.

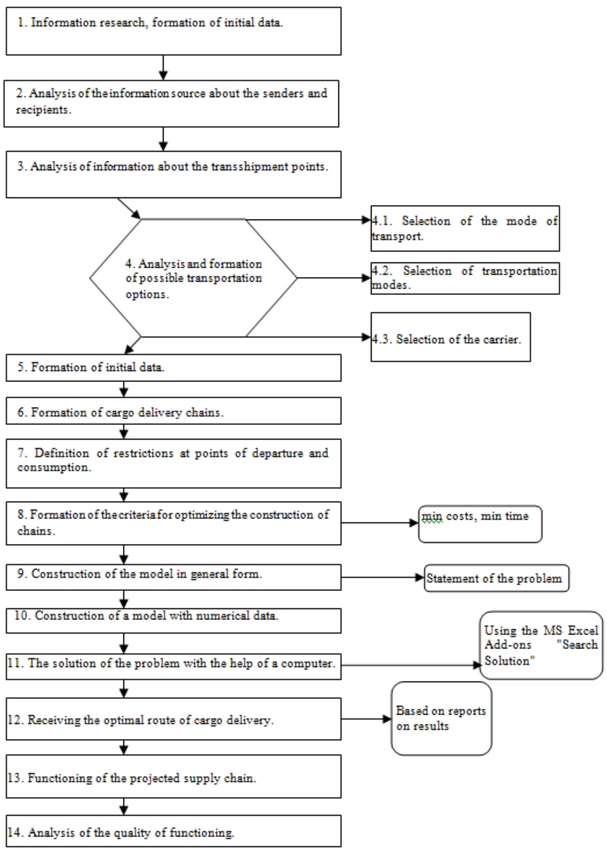

Fig. 1. The method of forming the delivery system

According to the developed method of forming the delivery system, an economic-mathematical model of the transport task was developed.

Conventional sign:

i – Port of departure,

γ – Port of transshipment,

j – Destination point,

p – Mode of transport,

k – Mode of transportation,

l – Carrier,

a_i – Quantity of cargo at the port of departure,

b_j – Needs at the destination point,

$C_{i\gamma}^{plk}$ – cost of transportation of 1 ton of cargo from the i-th supplier to the y-th transshipment port, p-th mode of transport, l-th carrier k-th mode of transportation.

$C_{\gamma j}^{lk}$– the cost of transporting 1 ton of cargo from the y-port of transshipment to the j-th recipient by the l-th carrier, k-th way of transportation.

$C_{i\gamma(\text{вт})}^{plk}$ – cost of 1t loss of cargo during transportation from the i-th supplier to the y-th transshipment port, l-th carrier, k-th mode of transportation.

$C_{\gamma j(\text{вт})}^{lk}$ – cost of 1t loss of cargo during transportation from the y-port of transshipment to the j-th recipient by the l-th carrier, k-th way of transportation.

$C_{i\gamma(\text{т})}^{plk}$ – cost of packaging for transportation of 1 ton of cargo from the i-th supplier to the y-th transshipment port, l-th carrier, k-th mode of transportation.

$C_{\gamma j(\text{т})}^{lk}$ – cost of the container for transporting 1 ton of cargo from the y-port of transshipment to the j-th recipient by the l-th carrier, k-th way of transportation.

The following variables are used in the model:

$x_{i\gamma}^{plk}$ – quantity of cargo that is transported from the i-th port of departure to the y-th port of transshipment, the p-th mode of transport, the l-th carrier, the k-th mode of transportation.

$x_{\gamma j}^{lk}$ – quantity of cargo that is transported from the y-port of transshipment to the j-th recipient by the l-th carrier, the k-th way of transportation.

Statement of the problem using the above notation:

A certain homogeneous product that is located at *m* departure points A_1, A_2 ..., A_m, in which there are respectively a_1, a_2, ..., a_m cargo units, it is necessary to deliver *n* destinations B_1, B_2, ..., B_n, in each of which it is necessary to deliver b_1, b_2, ..., b_n through the points of transshipment Г. The cargo is delivered in a mixed transportation (land, where there is a choice of the transport mode for delivery: rail, road, and sea-component of the route). In this case, the condition is met that the total available quantity of products at the points of departure is equal to the total requirements at all destinations. Transportation is the p-th mode of transport, k-th mode of transportation is the l-th carrier.

It is necessary to choose the route of cargo delivery from the sender to the recipients, which provides the minimum costs during the cargo transshipment route, while satisfying the basic needs of consumers in the necessary mode of transportation.

Target function. The criterion of optimality is the cost of transportation, packaging and costs for all ways of its delivery.

$$
\begin{aligned}
Z = &\sum_{i=1}^{m}\sum_{\gamma=1}^{\Gamma}\sum_{p=1}^{P}\sum_{l=1}^{L}\sum_{k=1}^{K} C_{i\gamma}^{plk} x_{i\gamma}^{plk} + \\
&+\sum_{\gamma=1}^{\Gamma}\sum_{j=1}^{n}\sum_{l=1}^{L}\sum_{k=1}^{K} C_{\gamma j}^{lk} x_{\gamma j}^{lk} + \\
&+\sum_{i=1}^{m}\sum_{\gamma=1}^{\Gamma}\sum_{p=1}^{P}\sum_{l=1}^{L}\sum_{k=1}^{K} C_{i\gamma(вт)}^{plk} x_{i\gamma}^{plk} + \\
&+\sum_{\gamma=1}^{\Gamma}\sum_{j=1}^{n}\sum_{l=1}^{L}\sum_{k=1}^{K} C_{\gamma j(вт)j}^{lk} x_{\gamma j}^{lk} + \\
&+\sum_{i=1}^{m}\sum_{\gamma=1}^{\Gamma}\sum_{p=1}^{P}\sum_{l=1}^{L}\sum_{k=1}^{K} C_{i\gamma(m)}^{plk} x_{i\gamma}^{plk} + \\
&+\sum_{\gamma=1}^{\Gamma}\sum_{j=1}^{n}\sum_{l=1}^{L}\sum_{k=1}^{K} C_{\gamma j(m)j}^{lk} x_{\gamma j}^{lk} \rightarrow \min
\end{aligned}
\qquad (1)
$$

Restriction (2) – restriction on the export of cargo from the ports of departure.

$$\sum_{\gamma=1}^{\Gamma}\sum_{p=1}^{P}\sum_{l=1}^{L}\sum_{k=1}^{K} x_{j\gamma}^{plk} = a_i \quad \left(i = \overline{1,m}\right) \qquad (2)$$

Restriction (3) – to meet the needs of recipients.

$$\sum_{\gamma=1}^{\Gamma}\sum_{l=1}^{L}\sum_{k=1}^{K} x_{\gamma j}^{lk} = b_j \quad \left(j = \overline{1,n}\right) \qquad (3)$$

Restriction (4) is a balance equation, the content of which is that the cargo that was delivered to the port of transfer (the left side) must be sent (right side).

$$\sum_{i=1}^{m}\sum_{p=1}^{P}\sum_{l=1}^{L}\sum_{k=1}^{K} x_{i\gamma}^{plk} - \sum_{j=1}^{n}\sum_{l=1}^{L}\sum_{k=1}^{K} x_{\gamma j}^{lk} = 0 \left(\gamma = \overline{1,\Gamma}\right) \qquad (4)$$

Restriction (5) – restriction of carrying capacity of the carrier on the first overland section.

$$\sum_{i=1}^{m}\sum_{\gamma=1}^{\Gamma}\sum_{k=1}^{K} x_{i\gamma}^{plk} \le r^{pl} \quad \left(p = \overline{1,P}; l = \overline{1,L}\right) \qquad (5)$$

where r^{pl} – carrying capacity of the l-th carrier by the k-th delivery mode.

Restriction (6) – restriction of carrying capacity of the carrier on the second land segment.

$$\sum_{\gamma=1}^{\Gamma}\sum_{j=1}^{n}\sum_{k=1}^{K} x_{\gamma j}^{lk} \le r^{l} \quad \left(l = \overline{1,L}\right) \qquad (6)$$

where r^{l} – carrying capacity of the l-th carrier.

Restriction (7) – the needs of the recipients in the transportation of cargo in a specific container (method).

$$\sum_{\gamma=1}^{\Gamma}\sum_{l=1}^{L} x_{\gamma j}^{lk} = b_j^k \quad \left(j = \overline{1,n};\ k = \overline{1,K}\right) \qquad (7)$$

Restriction (8) is the total requirement for a specific tare.

$$\sum_{j=1}^{n} x_j^k = b_j \quad \left(k = \overline{1,K}\right) \qquad (8)$$

Restriction (9) – restriction on the quantity of cargo, which will be delivered to the consumer in the necessary container.

$$\sum_{\gamma=1}^{\Gamma}\sum_{l=1}^{L} x_{\gamma j}^{lk} = \sum_{k=1}^{K} b_j^k \quad \left(j = \overline{1,n}\right) \qquad (9)$$

Restriction (10) is the restriction in the general need for cargo transportation in a specific tara (k-th method) from the y-port of transshipment to the j-th port of the recipient by the l-th carrier.

$$\sum_{\gamma=1}^{\Gamma}\sum_{j=1}^{n}\sum_{k=1}^{K} x_{\gamma j}^{lk} = \sum_{j=1}^{n} b_j^k \quad \left(k = \overline{1,K}\right) \qquad (10)$$

Restriction (11) - restriction in cargo transportation in a specific tara (k-th method) from the i-th port of production to the γ-th port of transshipment by the l-th carrier.

$$\sum_{i=1}^{m}\sum_{\gamma=1}^{\Gamma}\sum_{p=1}^{P}\sum_{l=1}^{L} x_{i\gamma}^{plk} = \sum_{i=1}^{m} a_i^k \quad \left(k = \overline{1,K}\right) \qquad (11)$$

Restriction (12-13) is a balance constraint that determines the equality of the used packaging in the transport process (k-th method).

$$\sum_{i=1}^{m}\sum_{\gamma=1}^{\Gamma}\sum_{p=1}^{P}\sum_{l=1}^{L} x_{i\gamma}^{plk} - \sum_{\gamma=1}^{\Gamma}\sum_{j=1}^{n}\sum_{l=1}^{L} x_{\gamma j}^{lk} = 0 \qquad (12)$$

$$\sum_{i=1}^{m} a_i^k - \sum_{j=1}^{n} b_j^k = 0 \quad \left(k = \overline{1,K}\right) \qquad (13)$$

The restrictions (14, 15) are the condition of non-negativity of the variables.

$$x_{i\gamma}^{plk} \ge 0 \ \ (i = \overline{1,m}; \gamma = \overline{1,\Gamma}; p = \overline{1,P}; l = \overline{1,L}; k = \overline{1,K}) \qquad (14)$$

$$x_{i\gamma}^{lk} \ge 0 \ \ (\gamma = \overline{1,\Gamma}; j = \overline{1,n}; l = \overline{1,L}; k = \overline{1,K}) \qquad (15)$$

Conclusions. Modeling and optimization of logistics systems in the forwarding companies' activity in the current conditions of the Ukrainian economy are becoming increasingly relevant in connection with the intensification and development of economic relations.

In today's world, where market relations prevail, the most important for forwarding companies is the competitiveness, which is possible while using a logistics approach to solving the problems of distribution of material flow.

The concept of logistics for the management of economic systems lies in an integrated approach to the management of material flow.

With high competition in most areas of the economy, the final price for the product, that is, the price that the consumer pays, considering all logistic operations that are necessary for the delivering the goods, plays a very important role.

Designing a cargo delivery system is a complex and multifaceted task. While solving such tasks, it is necessary to carry out a set of activities that are related to the design of the delivery system, choice of delivery options, analysis and choice of logistics intermediaries, quality control of their activities. At the same time, it is necessary to consider that the main criteria for the consumer at present are compliance with delivery dates (exactly at the time) and minimization of expenses.

As being said, the goal was defined: to develop a methodology and an economic-mathematical model for optimizing the delivery system, considering additional requirements for the selection of transport, the carrier and the mode of transportation.

As a result of the work, the following was received:

1. A methodology for the formation of a cargo delivery system has been developed, consisting of 14 stages;

2. A model of delivery design has been proposed, which shows the interaction and interrelation of the delivery stages;

3. An economic-mathematical model of cargo delivery has been developed, taking into account additional requirements for the selection of transport, the carrier and the mode of transportation (tare).

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Піддубна Н.М., Удовиця О.О. Методичні основи оптимізації параметрів логістичних систем доставки вантажів з урахуванням способу транспортування.

В результаті аналізу відомих моделей і методик оптимізації систем доставки вантажів було встановлено, що задача вибору способу доставки (тара, упаковка), а також вибір перевізника вирішувалася *відокремлено. Такий підхід не дозволяє врахувати системні обмеження та критерії, що призводить до вибору допустимого, але не завжди оптимального рішення. В роботі наведено методику та економіко-математична модель, що дозволяє системно, в рамках однієї моделі вирішити задачу визначення маршруту доставки з урахуванням додаткових вимог при виборі транспорту, перевізника і способу перевезення*

***Ключові слова**: методика формування системи доставки, економіко-математична модель*

Поддубная Н.Н., Удовица О.О. Методические основы оптимизации параметров логистических систем поставок грузов с учетом способа транспортировки

В результате анализа известных моделей и методик оптимизации систем доставки грузов было установлено, что задача выбора способа доставки (тара, упаковка), а также выбор перевозчика решалась обособленно. Такой подход не позволяет учесть системные ограничения и критерии, что приводит к выбору допустимого, но не всегда оптимального решения. В работе приведена методика и экономико-математическая модель, позволяющая системно, в рамках одной модели решить задачу определения маршрута доставки с учетом дополнительных требований при выборе транспорта, перевозчика и способа перевозки

***Ключевые слова:** методика формирования системы доставки, экономико-математическая модель*

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