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Model of the optimal composition of the main technical facilities of a container transport and technological system

To solve the problem of determining the rational type and parameters of containers, as well as the structure of their fleet for the delivery of cargo (cargo), taking into account whether the accepted type and structure of the container fleet corresponds to the values of the required (custom) batches for the delivery of products and the possibility of making appropriate adjustments to the container payload values, an economic and mathematical model of the optimal composition of the technical complex of a container transport and technological system has been developed.
transport and technological system, container, model, optimization, costs, transportations, technical facility

Formulation of the problem. The largest consumers of Ukrainian grain and legumes delivered by containers to the seaports of Ukraine are the countries of South and Southeast Asia, with Vietnam and India accounting for over 60% of the supply [1]. In addition to cereal grain cargo (wheat, millet), legumes (peas, etc.) and oilseeds (rapeseed, etc.) are packed into containers. Over 4/5 of all grain cargoes of Ukrainian export delivered by containers is wheat, slightly more than 10% is rapeseed, millet – more than 1%, other crops – up to 1%. The size of shipments of grain cargoes for export is on average 10–15 thousand tons, which leads to an increasing use of the transportation of these cargoes by containers.

In Ukraine, the company Elit Black Sea (Odessa) specializes in the transportation of grain cargo in containers. Such transportation is also carried out by such world's largest container lines (carriers) as MSC (Mediterranean Shipping Company), A.P. Moller-Maersk Group, CMA CGM, Zim Integrated Shipping Services, and CSAV Norasia. The rapid increase in the volume of container traffic in Ukraine began in 2000 [2]. On the territory of Ukraine, transportation of goods in containers is carried out by road and rail.

Analysis of the resent of the research and publications. Rail transportation of containers is about three times faster and cheaper than road transportation, road transportation depends on many factors – weather, traffic jams and drivers, weight control functions on roads. Despite all this, rail transport of containers is still poorly developed, the vast majority of containers are transported by road. In addition, for door-to-door transportation, road transport is the main and only means [3, 4].

The entire variety of technical means of the container transport system is combined into six main types (elements) that form the technical complex [5]: 1) a fleet of containers (universal and specialized), works inside containers), 3) technical means of transport (cars and road trains as part of truck tractors and container semi-trailers, railway rolling stock, etc.), 4) container terminals, points and bases (warehouses, access roads, etc.), 5) means of control, information and long-distance communication, 6) means of packaging and packaging of goods for shipment in containers.

Two elements of the technical complex - containers and mechanization for loading and unloading are closely related to the method of preparing cargo for transportation. Therefore, the type of packaging, the type of package, etc. are important. Means of packing cargo (for example, enlarged and lightweight), means of packaging designed to send goods in containers are the sixth type (element) of the technical complex of the container transport system.

Depending on the content and changes in the technical characteristics of the types (elements) that make up the complex of technical means of container transportation, the technology and efficiency of these transportations change. Therefore, in order to achieve the same goal - the delivery of a given amount of cargo of a certain nature at the required rate of transportation - it is possible to use several variants of the complex, which differ from each other in the composition of the elements and the parameters characterizing them.

The functioning of each variant of the technical complex is associated with certain costs. The variant of the technical complex, which gives a minimum of costs (in monetary and in-kind terms), will be optimal. The most important element of the complex of technical means of transporting containers are the containers themselves. They must meet the requirements of consignors and consignees: comply with the conditions for the transportation of these goods, their physical and transport characteristics, the size of the batch shipments of goods (by volume and weight), etc. [6, 7]. Containers, being transport equipment, must be adapted for through traffic on all modes of transport, their fast and safe reloading [8, 9].

In the case when the type and structure of the container fleet do not correspond to the ordered batches of cargo delivery in terms of mass or volume, losses occur and the efficiency of container transportation decreases.

If the carrying capacity and/or volume of the container is greater (all the more significantly) than the required shipment of cargo, then the payload of the container will be lower than the nominal value for this cargo, which will lead to an increase in transportation costs. In the opposite case, unjustified costs may arise due to an increase in stocks in the warehouses of the recipient of the products. Therefore, in specific calculations to determine the rational type and parameters of containers, as well as the structure of their fleet for the delivery of cargo (cargo), it should be taken into account whether the accepted type and structure of the container fleet corresponds to the values of the required (custom) batches of product delivery and make an appropriate adjustment to the container payload values.

Let us determine whether the well-known economic and mathematical model of the technical complex of container transportation [5, 11] is applicable for solving this problem.

The aim of the work. To develop a mathematical model that describes the optimization problem for determining a rational fleet and parameters of containers and the structure of their fleet, to adjust the payload of containers.

Presenting main material. It is assumed that we know the amount of cargo Q, ton, which is supposed to be transported in containers over a certain period of time, the volumetric mass (density) of the cargo γ, t/m^3, and the transportation distance L, km (determined based on traffic statistics for past periods and prospects for given period of time).

It is also assumed that for container transportation a set «m» of technical means with the corresponding parameters is used, forming a technical complex of the types (elements) described above, and it is possible to use different machines and equipment with different parameters to serve one type of container. Then, under the index «i» we will understand the type of the corresponding technical means (i = 1, ..., m), i. e. container, car, crane, etc.

The number of types of cargo (for example, depending on the volumetric mass γ of the cargo) will be denoted by «u». Then, under the index «e» we mean the type of cargo transported in containers (e = 1, …, u).

The number of ways to organize work with containers (methods of transportation, technologies for loading and unloading works, etc.) will be denoted by «k». Then, under the index «j» we mean the method of organizing work with containers (j = 1, …, k).

According to the methodology for determining the comparative efficiency of capital investments, based on a comparison of the reduced costs by options, the economically viable option is the one that provides the minimum of the reduced costs.

The total reduced costs, as well as in the assessment of any economic activity, for container transportation of goods can be presented in a general form [11]:

$$E_{np} = C + E \cdot K, \tag{1}$$

where C – operating costs, thousand of UAH;

E – the rate of return on invested capital, in fractions of a unit;

K – capital (one-time) costs, thousand UAH.

The total reduced costs for all six types (elements) of the technical complex of the container transport system (J = 1, ..., 6)

$$E_{np} = \sum_{J=1}^{6} E_{np\,J} \tag{2}$$

The total reduced costs for each of the six types (elements) of the technical complex of the container transport system for a given cargo

$$E_{np_J} = \sum_{j=1}^{k}\sum_{i=1}^{m} Q \cdot \left(C_{ij} + E \cdot K_{ij}\right) \cdot \tau_i, \quad J = 1,...,6, \tag{3}$$

where τ_i is a coefficient that characterizes the part of cargo transportation in containers of a given (i-th) type from the total volume of cargo transportation in all types of containers.

The total reduced costs for all six types (elements) of the technical complex of the container transport system for a given cargo

$$E_{np}^{e} = \sum_{J=1}^{6}\sum_{j=1}^{k}\sum_{i=1}^{m} Q \cdot \left(C_{ij} + E \cdot K_{ij}\right) \cdot \tau_i \tag{4}$$

The total reduced costs for all six types (elements) of the technical complex of the container transport system for all goods

$$E_{np} = \sum_{J=1}^{6}\sum_{e=1}^{u}\sum_{j=1}^{k}\sum_{i=1}^{m} Q_e \cdot \left(C_{ij} + E \cdot K_{ij}\right) \cdot \tau_{ei}, \tag{5}$$

where Q_e is the amount of cargo of the e-th type, which is supposed to be transported in containers for a certain period of time; τ_{ei} is a coefficient characterizing the part (share) of transportation of the e-th type of cargo in containers of this (i-th) type from the total volume of cargo transportation in all types of containers.

Specific reduced costs, UAH/ton, for the transportation of goods with specified characteristics in containers with different parameters [11]

$$C = f\left(P_{ni}, q_{y\,i}, \eta_i, \gamma, \delta, \psi_{k\,i}, \tau_{k\,i}, j_i\right), \tag{6}$$

where P_{ni} is the actual gross weight of the freight container, t;

q_{yi} – specific (volumetric) carrying capacity of the container, ton/m^3;

η_i – container tare factor;

γ – volumetric mass (density) of the cargo, ton/m^3;

δ – coefficient taking into account the degree of use of the useful volume of the container (for packaged packaged cargoes, on average δ = 0.7–0.75, for bulk cargoes δ = 0.85 [5]);

ψ_{ki} is a coefficient characterizing the fleet structure, that is, the share of containers of a given (i-th) type in the total container fleet;

τ_{ki} is a coefficient that characterizes the part (share) of cargo transportation in containers of a given (i-th) type from the total volume of cargo transportation in all types of containers;

j_i is the unit settlement rate, UAH, of the variable part of the costs, depending on the given (i-th) type of containers with a given conditionally constant cargo characteristic.

The actual gross weight of a freight container is the dead weight of a freight container together with the weight of the cargo placed in it. The specific (volumetric) carrying capacity of a container q_{vi} is the ratio of its carrying capacity (the maximum allowable weight of cargo in a freight container) to the internal volume of the container (the volume of a freight container limited by its internal surfaces) [3]. The tare coefficient η of a container is the ratio of the container's own weight to its maximum gross weight.

The determination of the values of τ_{ki} characterizing the part (share) of cargo transportation in containers of the i-th type from the total volume of cargo transportation in all types of containers is based on the analysis of cargo flows and the determination of the distribution of transported goods by volumetric weight and sizes of delivery lots. These values can also be determined by the required number of containers of the types in which products can be transported for each category of cargo shipments by their weight (starting from one ton in increments of one or half a ton), based on their characteristics (primarily volume the mass of goods, the dimensions of the packaging of goods or overpacks). Parts (shares) ψ_{ki} of containers of each type are installed in the total fleet of containers, after which the values of τ_{ki} are finally corrected. The unit settlement rate j_i is determined by the measures of work corresponding to the selected natural indicators, depending on the parameters of the technical means that are part of each element of the technical complex of container transportation. The costs for other types (elements) of the complex of technical means of container transportation are determined similarly.

The total reduced costs associated with this variant of the complex of technical means of container transportation can be represented as an objective function:

$$E_{np} = \sum_{J=1}^{6}\sum_{e=1}^{u}\sum_{j=1}^{k}\sum_{i=1}^{m} Q_e \times \tau_{ei} \times \left[aX_{Jij} + bY_{Jij} + cZ_{ie} + A + E\left(dX_{Jij} + eY_{Jij} + fZ_{ie} + B\right)\right] \to \min, \quad (7)$$

where X_{Jij} are parameters whose values are determined by the parameters of technical means and functionally depend on them (for example, on such as P_{Ki} – the average load of a container of a given type (static load), t, $W_{\kappa i}$ – the annual productivity (production) of the i-th type of a working fleet container , ton/year, etc.); Y_{Jij} – parameters determined by the combination of technical means (park structure) and the distribution of the volume of work performed by one or another technical means ($\psi_{k\,i}$, $\tau_{k\,i}$); Z_{ie} – parameters, the value of which is determined by factors that are not part of the technical complex of the container transport system, but interconnected with the type, parameters of technical means and the structure of their fleet (types of containers, packaging methods, types, characteristics of warehouses, bagging machines, etc.; Q_e – the annual volume of transportation of the e-th cargo in containers, t; a, b, c, d, e, f – numerical coefficients calculated according to the current (or prospective) unit cost rates; A, B – cost values conditionally assumed to be constant, not directly related to changing parameters X, Y and Z.

The conditions of the container transportation process can be represented as a system of restrictions [11]:

$$\begin{cases} X_{Jij\min} \le X_{Jij} \le X_{Jij\max}, \\ Y_{Jij\min} \le Y_{Jij} \le Y_{Jij\max}, \\ Z_{ie\min} \le Z_{ie} \le X_{ie\max}, \\ X_{Jij\min} \ge u, \\ X_{Jij\max} \le R, \\ Y_{Jij\min} \ge \psi_{k\min}, \\ Y_{Jij\max} = 1, \\ Z_{ie\min} \ge 0, \\ Z_{ie\max} \le S \end{cases} \tag{8}$$

For example, taking the payload of the P_K container as X_{Jij}, we see that $P_{K\ min} > 0$, since $P_K = 0$ means the transportation of an empty container. It is obvious that the value of u must be equal to the minimum value of the shipment (consignment of the given cargo q_e) transported in the given (i-th) type of container. It can be determined by the terms of delivery, technological standards, the value of the volumetric mass of the cargo γ and the useful internal volume of the container, etc., and must comply with

$$P_{K\max} \le R, \tag{9}$$

where R is in this case the actual loading of the freight container. The useful loading of a container with products with the highest values of γ cannot exceed a certain design limit (carrying capacity P of a freight container – the maximum allowable weight of cargo in a freight container).

Similarly, all restrictions on Y_{Jij} are set. Their size, for example, $Y_{Jij} \to \psi_k$. A container fleet can consist of at least one type of container ($\psi_k =1$), while $Y_{Jij\ max} = \psi_k = 1$. The minimum value will be expressed as a fraction, and should be guided by considerations of the desired calculation accuracy. For example, you can safely exclude from the calculation all containers that are less than 1% in the park. Then $Y_{Jij\ min} = \psi_{k\ min} = 0.01$. For enlarged calculations, it can be assumed that $\psi_{k\ min} = 0.05$.

The penultimate restriction shows that, for example, transportation is allowed without any packaging (for example, in bulk or in the form in which piece goods leave the manufacturer's conveyor) or storage facilities are not required to be rebuilt, etc. In the last restriction, S defines the most durable (expensive) packaging designed for the conditions of transportation for export. The value of S determines the existing (or prospective) containers and packaging. Thus, the objective function (7) expresses the total reduced operating and construction costs for container transportation of a given mass of the e-th cargo (Q_e) with various combinations of containers with different parameters and other technical means (X_{Jij}, Y_{Jij}, Z_{ie}) as part of their complex, which is the material base of the container transport system (taking into account the restrictions imposed on the parameters X, Y and Z).

Conclusions. 1. The interest of Ukrainian grain exporters in the delivery of grain cargoes in batches in containers to ports for transportation by sea is due to increased global demand for grain, the structure of demand and the situation with container transportation.

2. The choice of the optimal variant of the technical complex of container transportation, in the general case, consisting of six types (elements), each of which includes m types of technical means, k ways of organizing work and u types of cargo, can be performed using an optimization linear mathematical model. The objective function is the total reduced costs associated with the functioning of the technical complex of the container transport system. This takes into account the system of restrictions imposed on the model variables by the conditions of the container transportation process. A methodology for

adjusting the payload of containers is proposed for the case when the type and structure of the container fleet do not correspond to custom delivery lots in terms of weight or volume.

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Модель оптимального складу основних технічних засобів контейнерної транспортно-технологічної системи

Метою статті є розробка математичної моделі, що передбачає процедури оптимізації, за допомогою якої можуть бути визначені ефективні типи технічних засобів і їх кількість і структура парку, необхідних для здійснення контейнерних перевезень, в тому числі контейнерів, для коригування корисного навантаження контейнерів.

Технічні засоби контейнерної транспортної системи виділені в шість основних видів (елементів), які утворюють єдиний технічний комплекс. При конкретних розрахунках визначення раціонального типажу і параметрів контейнерів, а також структури їх парку для доставки вантажу (вантажів) слід враховувати, чи відповідає типаж і структура парку контейнерів що приймається величинам потрібних (замовних) партій доставки продукції і вносити відповідні поправки значень корисного навантаження контейнера. Для вирішення даної задачі застосована економіко-математична модель технічного комплексу контейнерних перевезень. Для процесу контейнерних перевезень виділена система обмежень математичної моделі, що враховує умови цього процесу. Критерієм ефективності варіанту вибору (цільовою функцією математичної моделі) виступає значення сукупних приведених витрат при їх мінімізації. Виділено чинники, що визначають питомі приведені витрати при перевезенні вантажів з заданими характеристиками в контейнерах з різними параметрами. Запропонований підхід застосований для випадку невідповідності типажу і структури парку контейнерів рекомендованим партіям поставки за масою або об'ємом і запропонована методика коригування корисного навантаження контейнерів.

Розглянуто передумови формування та функціонування економічно ефективних контейнерних вантажних перевезень в Україні з використанням автомобільного транспорту. Для вибору раціонального типажу і параметрів основних технічних засобів контейнерної транспортної системи та їх поєднань (структури парків) застосований системний підхід, який супроводжується комплексними техніко-економічними розрахунками. Представляється перспективною розробка по даній моделі алгоритму і програми для оптимізації складу контейнерної транспортно-технологічної системи.

транспортно-технологічна система, контейнер, модель, оптимізація, витрати, перевезення, технічний засіб

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Особливості митного оформлення митних процедур

У статті у військовий час представлені способи митного оформлення товарів. Завданнями обліку реалізації експортних, імпортних товарів та розрахунків з іноземними покупцями є: контроль за рухом товарів; постійне спостереження за своєчасним укладанням та виконанням умов зовнішньоторговельних контрактів; контроль за правильним митним оформленням експортних операцій; визначення доцільності самостійного митного оформлення експорту та імпорту товарів підприємством-експортером.

експорт, імпорт, зовнішньоекономічна діяльність митні операції, митні процедури