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УПРАВЛІННЯ СИСТЕМАМИ ДОСТАВКИ ВАНТАЖІВ В УМОВАХ ВИКОРИСТАННЯ БАГАТООБОРОТНИХ ЗАСОБІВ КРІПЛЕННЯ

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MANAGEMENT OF CARGOS DELIVERY SYSTEMS IN THE CONDITIONS OF USE OF RETURNABLE SECURING EQUIPMENT

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Анотація

Актуальність. При перевезенні вантажів широко використовуються багатооборотні засоби кріплення у вигляді металевих піддонів, рам та ін. Вони є зручними у використанні та надійними, на відміну від традиційних засобів кріплення, можуть використовуватись багаторазово. Ці переваги обумовлюють економічну ефективність багатооборотних засобів кріплення, але стохастичний характер коливань обсягів відправлень та розташування пунктів призначення призводить до значного зростання їх робочого парку. При тимчасовому зниженні потреби у цих засобах кріплення, вони накопичуються на складах відправників, що ускладнює виконання транспортно-технологічних процесів та призводить до збільшення логістичних витрат на транспортування вантажів. Ця практична проблема обумовлює виконання досліджень для вирішення наукової задачі визначення оптимального розміру робочого парку багатооборотних засобів кріплення з метою ефективного управління процесом доставки.

Мета роботи – розробка методу визначення оптимальної кількості багатооборотних засобів кріплення в системах доставки вантажів.

Метод. Розроблено метод визначення оптимального розміру багатооборотних засобів кріплення, який ґрунтується на логістичному підході, методах статистичного аналізу та імітаційного моделювання. В якості критерія оптимальності запропоновано використовувати загальні логістичні витрати.

Результати. Отримані при проведенні експериментальних досліджень на імітаційній моделі результати показали більшу ефективність у порівнянні з існуючими аналітичними методами. Обґрунтовано економічну доцільність практичного використання розробленого методу на прикладі перевезень продукції металургійного підприємства залізничним транспортом.

Висновки. Аналіз результатів досліджень показав, що при використанні розробленого методу зменшуються витрати на перевезення та експлуатацію багатооборотних засобів кріплення.

Abstract

Timeliness. Returnable securing equipment in the form of metal pallets, frames, etc. is widely used when transporting goods. It is easy to use and reliable, unlike traditional fasteners, can be reused. These advantages make the cost-effectiveness of returnable securing equipment economical, but the stochastic nature of the fluctuations in the volume of dispatches and the location of destinations leads to a significant increase in their operating fleet. With the temporary reduction of the need for this securing equipment, it is accumulated at the shippers' storages, which complicates the implementation of transport and technological processes and leads to an increase in logistical costs for cargo transportation. This practical problem causes research to be conducted to solve the scientific problem of determining the optimum size of a fleet of returnable securing equipment in order to effectively manage the delivery process.

The purpose of the work is to develop a method for determining the optimum number of returnable securing equipment in cargo delivery systems.

Method. The method of determining the optimal size of returnable securing equipment is developed, which is based on logistical approach, methods of statistical analysis and simulation modeling. It is proposed to use total logistical costs as a criterion of optimality.

Results. The results obtained from the experimental studies on the simulation model showed greater efficiency compared to the existing analytical methods. The economic feasibility of practical use of the developed method is substantiated on the example of transportation products made on a metallurgical enterprise by railway.

Результати. Отримані при проведенні експериментальних досліджень на імітаційній моделі результати показали більшу ефективність у порівнянні з існуючими аналітичними методами. Обґрунтовано економічну доцільність практичного використання розробленого методу на прикладі перевезень продукції металургійного підприємства залізничним транспортом.

Conclusions. Analysis of the research results showed that the use of developed method reduces the costs for transportation and operation of returnable securing equipment.

Ключові слова: багатооборотні засоби кріплення, процес доставки вантажів, логістичні витрати, імітаційна модель.

Keywords: returnable securing equipment, cargo delivery process, logistical costs, simulation model.

List

RSE – returnable securing equipment

y_i – costs for the direction of delivery of goods *i*;

a_i – coefficient that includes the cost of cargo operation, transportation, storage, depreciation and repair of RSE in the *i*-th direction;

x_i – volume of cargoes dispatches with RSE;

b – coefficient involving the cost of disposable fasteners and their use;

c_i – total volume of dispatches for *i*-th direction;

n – number of delivery destinations;

$Q_{ск}$ – storage capacity;

$Q_{зк}$ – quantity of RSE;

$t_{д}$ – time for the cargo delivery;

$t_{оч}$ – waiting time for cargo dispatch;

t_{max} – maximum waiting time for RSE;

q_{max} – maximum consignment size of RSE, that return;

$t_{п}$ – time for return of RSE;

$N_{заг}$ – total required quantity of RSE;

N_i – quantity of vehicles for the direction *i*;

$n_{в}$ – quantity of RSE, required for allocation of cargo in vehicle;

t_i – RSE turnover in direction *i*;

T – duration of the operation period of delivery system.

Introduction

Effective management of cargo delivery systems requires solving the problem of determining the optimal size for an operating fleet of returnable securing equipment (RSE). Its solution is possible by using known existing methods for defining the required operating fleet of wagons, cars and other transportation means, loaders, containers. To determine this quantity, it is required to know the number of departures and the time of their turnover on the transportation route. However, it is inappropriate to apply known analytical methods when the stochastic nature of transportation and the additional conditions and restrictions are necessary to take into account. By the logistical approach, considering the possibility of using not only RSE, but also traditional disposable fasteners, it is advisable to use not only technical, but also economic criterion – total logistics costs.

The object of this research is the process of delivery of goods using the RSE, and the subject is the dependence of logistics costs on the size of their operating fleet.

The purpose of this work is to develop a method for determining the optimal quantity of RSE. To achieve it, the following tasks must be solved:

- to develop a method of determining the optimal number of RSE and to establish a model of cargo delivery;
- to carry out experimental researches on the developed model, to obtain dependence of logistical costs on the size of the operating fleet of RSE and to provide recommendations on practical use of the developed method.

1. Problem statement

The purpose of the study is to find the minimum of the objective function as

$$Z = f\left(y_1, y_2, \ldots, y_n\right) \rightarrow \min , \qquad (1)$$

where $y_i = a_i x_i + b\left(c_i - x_i\right)$, if

$$0 \le x_i \le c_i ,$$

$$a_i, b, c_i = const \ge 0 ,$$

$$i = \left(\overline{1, n}\right).$$

Function (1) can be written as:

$$Z = \sum_{i=1}^{n}\left(a_i x_i + b\left(c_i - x_i\right)\right). \qquad (2)$$

The coefficient a_i includes the average of the costs associated with the use of RSE. In a real system, by the stochastic nature of cargo movement, size of the RSE consignment sent from the place of unloading may be reduced promptly in order to accelerate its return. In addition, fluctuations in the volume of shipments determine the nonlinear nature of the duration of accumulation of the RSE consignment and, accordingly, the duration of turnover and the required operating fleet. In other words, instead of the expression $a_i x_i$, it is necessary to use a nonlinear function in the form of $g\left(x_i\right)$, which significantly complicates the search for the minimum of function (2).

In such cases, it is advisable to use approaches based on the use of stochastic discrete-event simulation models.

2. Literature review

The main principles for assessing the efficiency of moving goods from the place of production to final consumption points are the logistical costs of delivering products. The organization of the process of cargo delivery, while minimizing logistics costs is an urgent issue [1-5].

One of the most important issues of transport and logistics servicing of the delivery process is the choice of scheme and method of transportation [6, 7]. Logistical costs for the delivery of goods consist of many components: the cost of cargo operations during the technological process of delivery, in-plant movement and shunting operations [8], transportation by main roads, storage at the enterprise and at transfer points, etc. [9].

The use of simulation modeling of delivery processes is one of the actively developing areas of research [10, 11, 12].

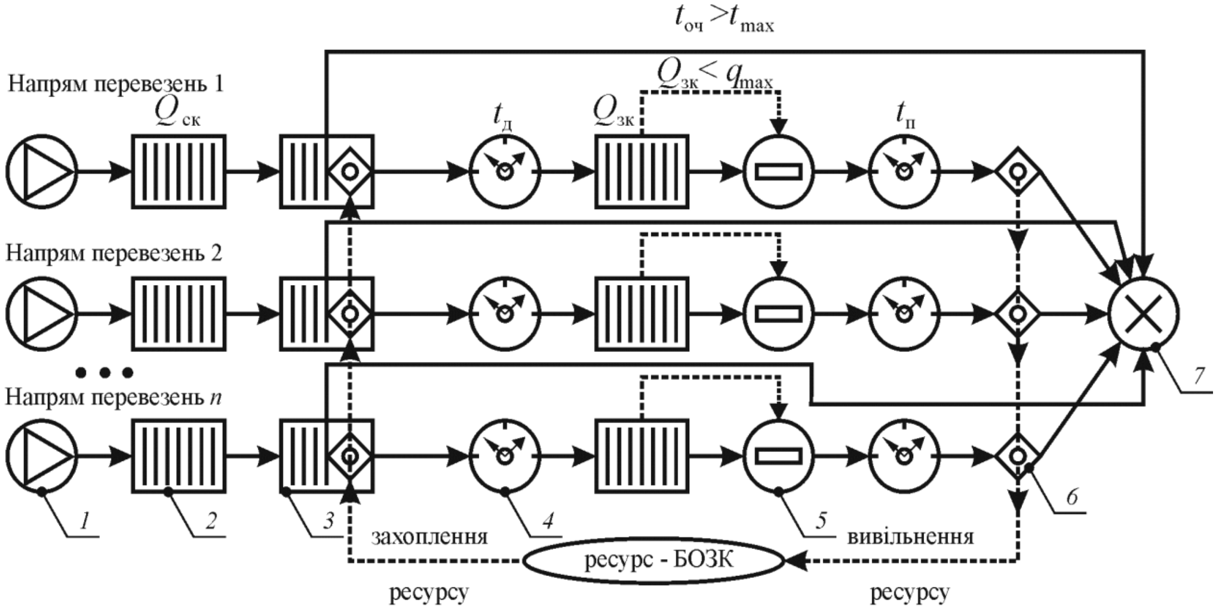
RSE allow placing and fixing cargo items by means of a gripping mechanism without the use of additional technical means, devices and labor costs [13]. But their application leads to additional costs associated with returning for the next loading.

Most well-known approaches to determining the logistical cost of delivering cargo do not involve the cost of return to the enterprise of the RSE manufacturer, which include not only the cost of transportation [15] but also the cost of temporary storage at the destination for consolidation of cargo.

There are various methods for determining the required quantity of technical means for providing transportation of a definite volume of enterprises production [15, 16, 17, 18, 19-22]. However, analytical methods for calculating the need for RSE do not include stochastic changes in the intensity of shipment in certain areas and the possibility of shipment using disposable fasteners.

3. Materials and methods

In order to study transportaion processes, a simulation model was developed in Anylogic software environment, the operational scheme of which is presented in Fig. 1.



Умовні позначення:
1 - генератор замовлень; 2 - черга обслуговування; 3 - пристрій приєднання ресурсів; 4 - пристрій обслуговування; 5 - блокатор замовлень; 6 - пристрій вивільнення ресурсів; 7 - знищувач замовлень.

Figure 1. Diagram of a simulation model of cargo delivery processes using the RSE

The transport consignments are the order in the presented model. Generation of orders can be carried out according to the corresponding initial statistical data by theoretical distribution of stochastic variable. Created orders get into queue that simulates the consignment entering the store. If the resources are available, they are captured by the request and move to a service device that, by delay, simulates the process of delivering the cargo to the destination. If the resources are absence during $t_{оч}$ time, it is considered that the shipment was made using traditional means of fastening; such orders are timed out from the device and destroyed, and their quantity is fixed.

Requests moving along with the resources, after a delay at the time of delivery of the cargo to the station $t_д$, get into the queue, where they wait for collection to an amount that corresponds to the wagon loading capacity for metal pallets. The movement of applications is blocked till this time.

After unblocking, the lot of requests is delayed for $t_п$ time required for returning the vehicle with RSE for the next loading. Resources are released (RSE is placed into the store waiting for loading), orders are destroyed, information on their quantity is recorded.

The model, the scheme of which is presented in Fig. 1, does not involve the possibility of sending RSE in less than the normative in the operational management of the delivery process in real conditions. To realize this possibility, the scheme of the model is changed (Fig. 2).

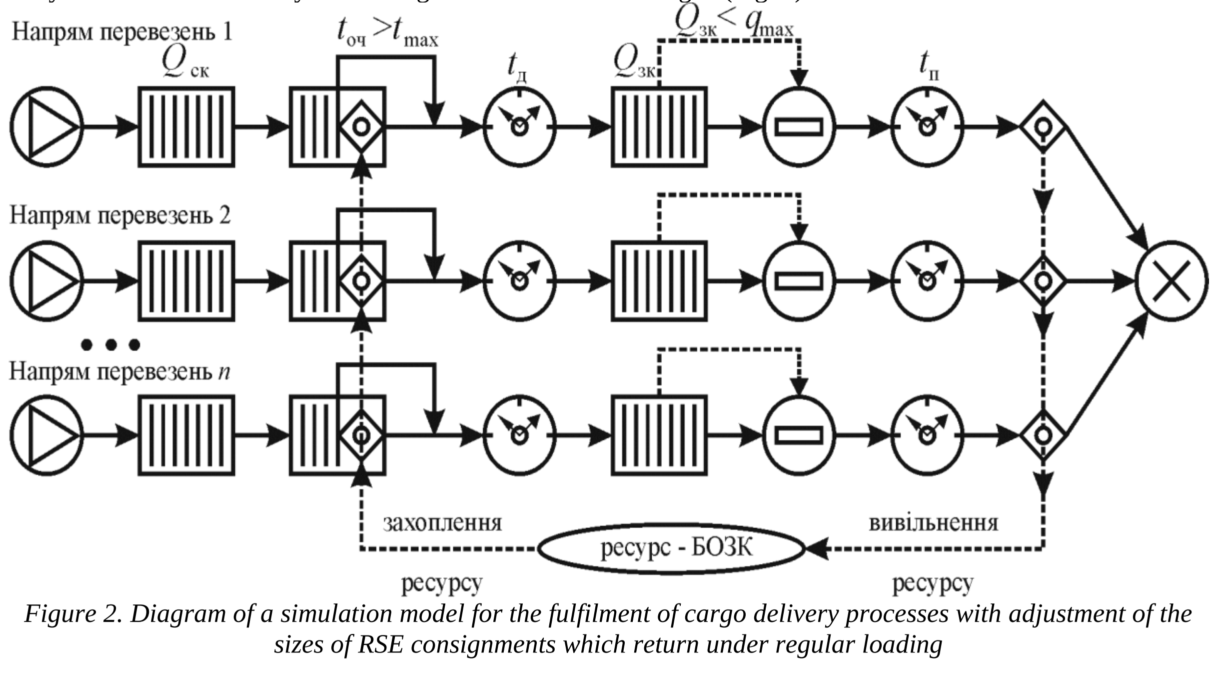


Figure 2. Diagram of a simulation model for the fulfilment of cargo delivery processes with adjustment of the sizes of RSE consignments which return under regular loading

In this model, orders that were unable to capture resources due to their lack are not destroyed, but move with others in the overall processing. As a result, consingments without RSE resources are considered in the amount of the collected consignment. In fact, this means that the more wagons without RSE arrive to their destination, the smaller amount of RSE consignments returned under regular loading accelerating the process. The model involves, due to this, the operational management of the transportation process in real operating conditions.

It is proposed to optimize the quantity of RSE according to the criterion of minimum logistical costs for cargo delivery. These costs are determined by analytical calculations of cost indicators, based on the technical parameters of the transport system functioning, obtained by means of a simulation model. The proposed method unlike the existing ones involves the possibility of goods shipment without RSE and their returning with reduced consignment.

4. Experiments

The study of the process of cargoes delivery with RSE was performed on the example of the cold reduction department №1 of the Zaporizhstal metallurgical plant. The following were used as basic data:

- monitoring of products consignments with RSE in railway wagons;
- monitoring of the RSE consignments awaiting the next loading;
- duration of delivery of wagons with products to the destination station;
- duration of the RSE delivery;
- fares for transportation, loading and unloading, transportation and storage operations, maintenance and repair of the RSE, depreciation deductions for the RSE and the cost of disposable fasteners.

As a result, we should get:

- the dependence of the quantity of disposable fasteners required for the shipment of products on the RSE operating fleet;
- dependence of logistical costs on the size of the operating fleet of RSE.

When imitating the processes of products shipment, the range of the RSE operating fleet varies from 70% to 100% of providing them with all shipments [a1].

The quality of the obtained results is estimated by the economic criterion – the minimum of logistical costs in comparison with the results obtained by traditional methods of calculation.

The scheme of the experiment on the simulation model is presented in Fig. 3.

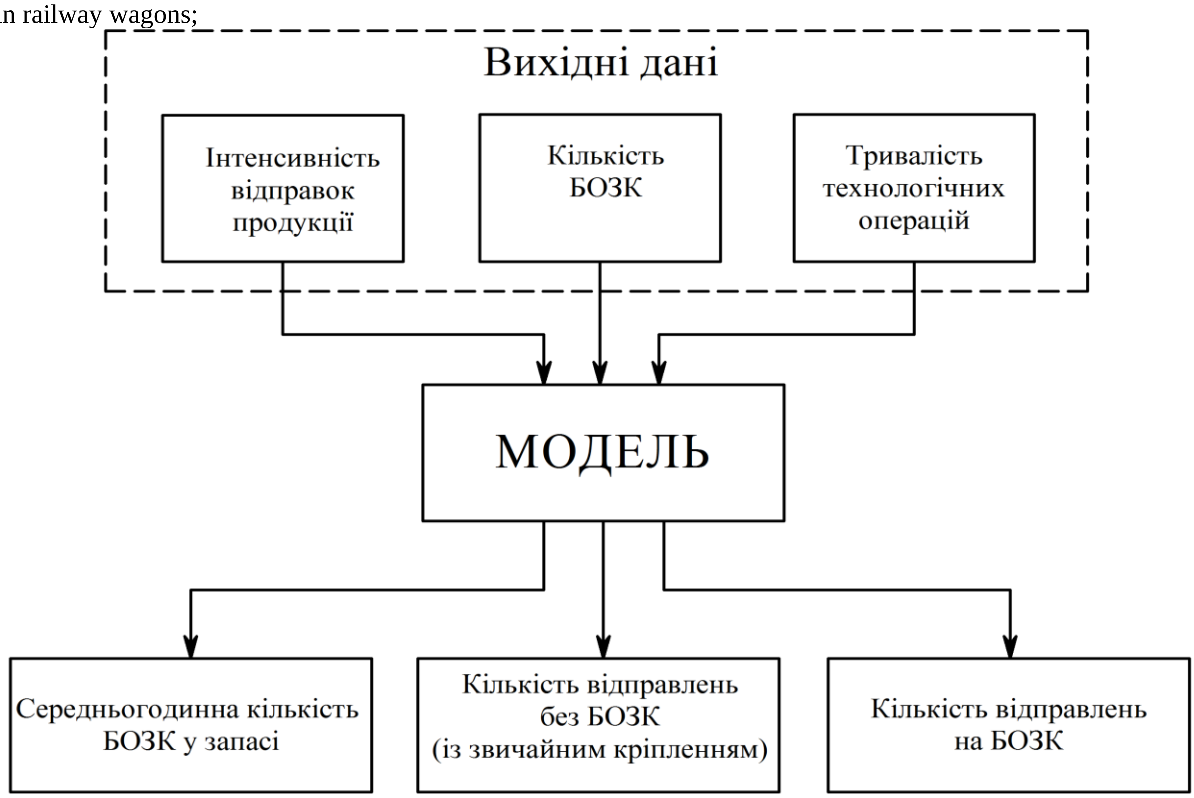


Figure 3. Scheme of the experiment

The raw data on the intensity of the dispatching products is determined by a certain random values distribution law, obtained as a result of statistical analysis of the actual data. The directions with stable freight traffic were identified to study the intensity of the dispatching cargos with the RSE. The random value statistical analysis of the intensity of dispatching metal products with the RSE was performed for each direction of transportation. The data extract was divided into intervals and the percentages of observations that get to each of them were calculated. Fig. 4 presents a distribution histogram of the intensity random value of the dispatching products to one of the destination stations (bar chart – empirical data, the line shows the theoretical distribution).

Figure 4. Analysis of the intensity of dispatching metal products

Empirical data are mostly subject to the exponential theoretical random values distribution law according to graphoanalytical analysis and according to the chi-squared test and Kolmogorov-Smirnov test. The analysis in other directions also proved the possibility of modeling the wagon traffic volume by exponential distribution.

The parameters of the selected laws change according to the planned (predicted) change in intensity. The parameter of RSE quantity (operating fleet) varies step by step in the range from 70% to 100% of their assignment indicator of product dispatchings. The initial value may be taken to be the actual RSE or the value calculated by the traditional analytical method.

The algorithm of the experiment is presented in Fig. 5.

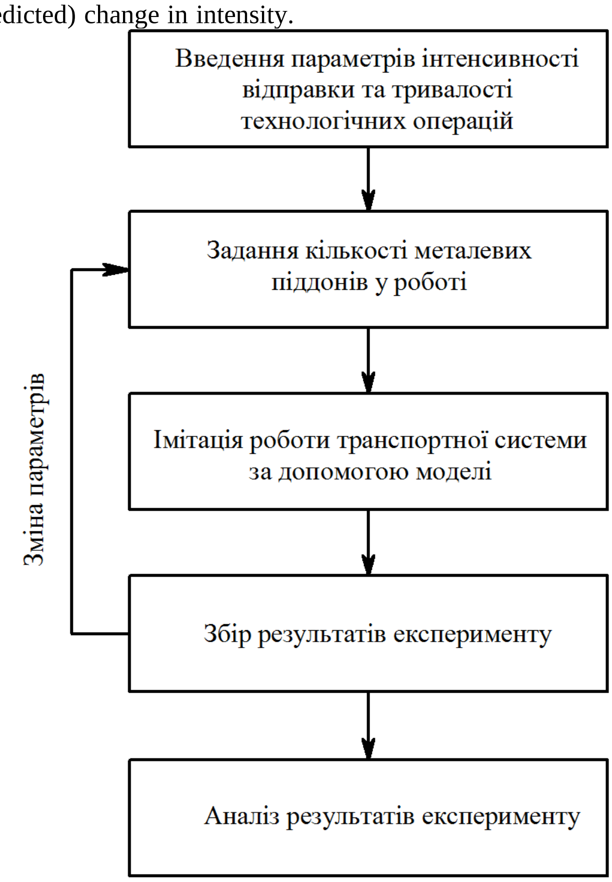


Figure 5. Algorithm of the experiment

The progress of the experiments is monitored by means of histograms shown in Fig. 6

a) 160 units of RSE

b) 180 units of RSE

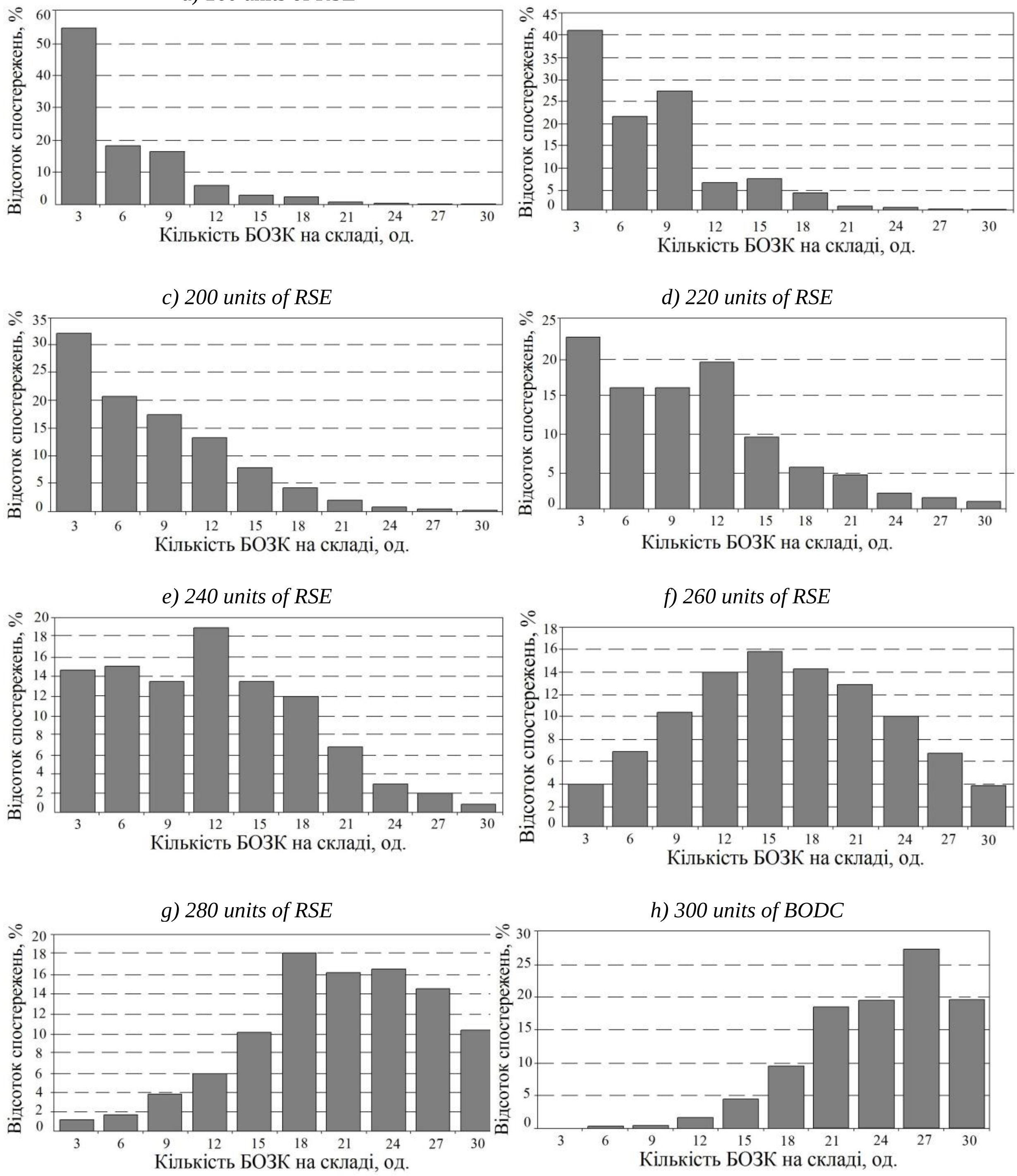


Figure 6. Analysis of the RSE availability in storerage when the size of their total fleet changes

The range and the step of resizing the RSE operating fleet can be determined by visual analysis of the histogram data. Thus, when conducting the experiment on the example of the Zaporizhstal metallurgical plant, the RSE quantity in storage is critically small (55% of monitorings are in the range from 0 to 3 units) at a fleet of 160 RSE units and the RSE is always in storage (not less than 3 units) when the size of the operating fleet is 300 units, and the discharging process is provided100% with their use.

5. Results

The results of the experiment are presented in form of graphs of changes in consignment quantity with disposable fasteners and with RSE depending on the opeating fleet of the latter (Fig. 7).

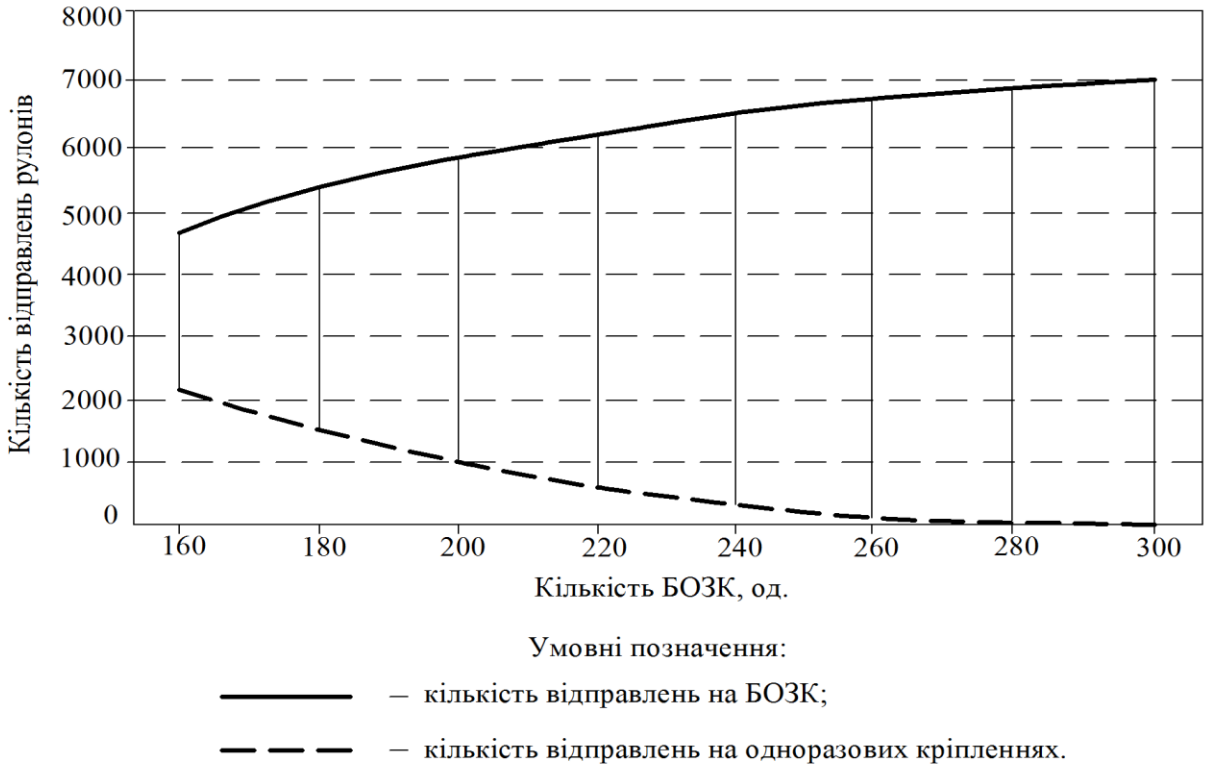


Figure 7. Alternating the number of diaposable and RSE dispatches depending on the operating fleet

6. Discussion

To evaluate the significance of the obtained results, they are compared with the data of analytical calculation of the RSE required number by traditional methods. The current approach is calculated using the formula:

$$N_{\text{заг}} = \sum_{i=1}^{n} \frac{N_i \cdot t_i \cdot n_{\text{в}}}{T}. \quad (3)$$

The value of the optimal size of the RSE operating fleet in the amount of 220 units was obtained using the method (Fig. 8) presented in the article, with the total logistical costs of 13097385 UAH / year. 260 units of RSE are required according to the analytical calculation, the total logistical costs will be 13 327 813 UAH / year. Economical efficiency 230 428 UAH higher (logistical costs reduced by 1.7%) when using the proposed method.

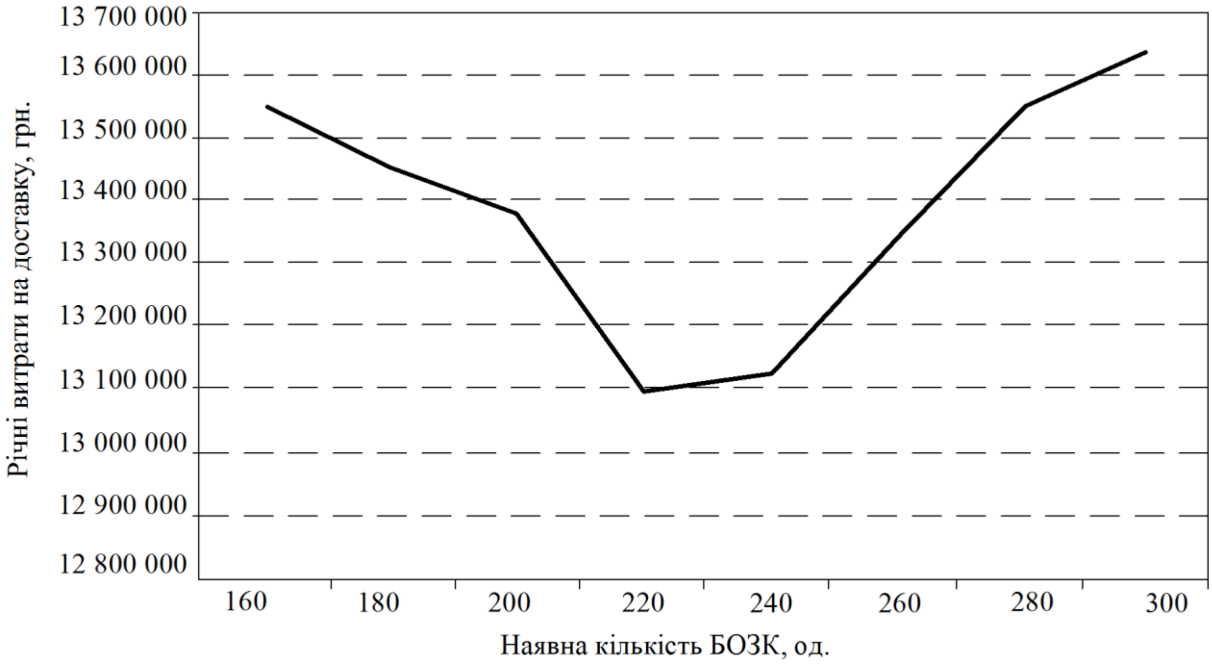


Figure 8. Dependence of the annual cost of products delivery on the RSE operational fleet

The results obtained using the proposed method involve not only the technical parameters of the delivery system, but also the logistical criterion. Therefore, in practical application, a significant economic effect can be obtained at enterprises using RSE. Further studies may be aimed at optimizing the size of the RSE returned under regular loading.

Conclusions

The urgent scientific problem of determination the RSE optimum quantity during the arranging the process of cargo delivery was solved in the course of the performed research. A simulation model of cargo delivery using RSE was developed, which includes fluctuations in the intensity of dispatches, the possibility of using traditional disposable fasteners and the possibility of returning of the RSE in less than the maximum quantuty.

The scientific novelty is the development of a new method for determining the optimal quantity of RSE, which is based on a logistical approach, methods of statistical analysis and simulation modeling. The possibility of using both reusable and disposable fasteners is considered by contrast with existing methods. As a criterion for optimality, it is suggested to use total logistical costs, not just technical performance indicators.

The experimental researches made it possible to obtain the dependence of logistical costs on the size of the RSE operating fleet. When imitating the processes of dispatching cargo, the range of the RSE operating fleet was from 70% to 100% of providing all dispatches with them.

The practical importance of the results is to reduce the cost of cargo delivery. The estimated saving is UAH 230 428, the total logistical costs are reduced by 1.7% when using the transportation example of products of the cold reduction department № 1 in the Zaporizhstal metallurgical plant. The proposed method can be used at enterprises that use RSE when arranging cargo delivery.

Further studies may be aimed at optimizing the size of the RSE returned under regular loading.

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МЕТОДОЛОГИЯ РАСЧЕТА ПОЛИВНОЙ НОРМЫ СЕЛЬСКОХОЗЯЙСТВЕННЫХ КУЛЬТУР

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METHODOLOGY FOR CALCULATING THE IRRIGATION RATE OF AGRICULTURAL CROPS

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Аннотация

В статье рассмотрены вопросы оптимизации режима орошения сельскохозяйственных культур, способы, техники и технологии орошения на основе учета энергетических ресурсов, т.к на протяжении многих лет нерациональное использование поливных норм, способствовало деградации орошаемых массивов. Поэтому в целях смягчения экологической ситуации орошаемого массива, авторами разработаны методологии режима орошения поливной нормы на основе энергетических ресурсов конкретной местности, что благоприятствует установлению дисбаланса в ризосферной зоне.

Abstract

The article deals with the issues of optimizing the irrigation regime of agricultural crops, methods, techniques and technologies of irrigation based on the accounting of energy resources, since for many years the irrational use of irrigation norms contributed to the degradation of irrigated massifs. Therefore, in order to mitigate the ecological situation of the irrigated massif, the authors have developed methods of irrigation regime of the irrigation norm based on the energy resources of a particular area, which contributes to the establishment of an imbalance in the rhizosphere zone.

Ключевые слова: Поливная норма, режим орошения, энергетические ресурсы, экологическая ситуация, дефицит влажности воздуха.

Keywords: Irrigation rate, irrigation regime, energy resources, environmental situation, lack of air humidity.

Введение. В условиях перевода экономики на рельсы интенсификации, повышение эффективности сельскохозяйственного производства зависит от того, насколько последовательно распространяются и осваиваются инновационные технологии, достижения науки и техники. Технология осуществляется созданием оптимальных условий для проведения полного комплекса выработанных наукой приемов поливов и обработки почвы. При-