MODELING OF ASSESSMENT OF A REGION'S NEED FOR CONTAINER TRANSPORTATION

Say, Vasiliy M., *Ural State University of Railway Transport (USURT), Yekaterinburg, Russia.*
Kochneva, Daria I., *Ural State University of Railway Transport (USURT), Yekaterinburg, Russia.*

ABSTRACT

The article is devoted to development of a model for substantiating a region's need for containerization of cargo transportation. The model includes two interrelated elements: a method for substantiating container suitability for cargoes and an imitation algorithm for planning of the region's need for containerization. The planning of the need for containerization links the demand of enterprises for transportation (taking into account the levels of product container suitability) and the available resources of the container transport system (terminals, container fleet, rolling stock). Further development of the model assumes assessment of costs and benefits of the region from development of the container system. Verification of the simulation model at the example of Sverdlovsk region demonstrates its efficiency and adequacy of reality.

Keywords: *container transportation, containerization, container suitability of cargo, social and economic system of the region, development of the region, resources, simulation model, organization of interaction.*

Background. *To date, the level of containerization of dry cargo in the world by some estimates exceeds 70% [1–2]. In Russia, this figure is only 5,3%, but it is growing at a rapid pace – over the past decade, the containerization coefficient on the network of domestic railways has doubled[1].*

Let's stress: containerization now affects not only transportation of so-called container-suitable goods. Containers carry a wide range of raw materials, including bulk cargoes, metals, liquefied gas. This led to a significant increase in the demand for container infrastructure in the regions and contributed to rapid development of the container market.

At the same time, in the absence of coordinated programs for development of container infrastructure, market development takes place spontaneously. Each company pursues only its own economic interests, which often leads to an imbalance in development of terminal capacities in the region, emergence of irrational empty container flows and a decrease in efficiency of the regional container system as a whole.

This, in turn, negatively affects development of those sectors of the economy of the region that are consumers of services of the container transport system.

That is, there are obvious facts when there is a need for a methodology for assessing the region's demand for container transportation, taking into account the interests of transport companies and local businesses, territorial economic and social characteristics, uneven cargo flows and other restrictions.

Objective. *The objective of the authors is to consider modeling of assessment of a region's need for container transportation.*

Methods. *The authors use general scientific and simulation methods, comparative analysis, mathematical methods, graph construction, modeling methods.*

Results.

Existing approaches

Works devoted to modeling of container transportation can be divided into two groups. The first group summarizes research results related to individual links of the container system: terminals, dry and sea ports, container transport. For them, for example, regression models [3], methods of hierarchical modeling [4], «ant» optimization algorithm (ant colony optimization) [5], discrete-event modeling [6], stochastic and dynamic programming [7], linear programming [8], multicriteria optimization [9–10], etc. are used.

The second conditional group of studies relates to organization of interaction of links of the container transport system under market conditions; in this area, cluster analysis [11], game theory models [12–13], supply chain management concept [14–15], agent simulation [16–17] and others are used.

Those models and approaches are based primarily on the interests of individual companies, while the interests of the regional container system as of a whole remain in the background. However, container suitability of products is more important for analysis of containerization of the region.

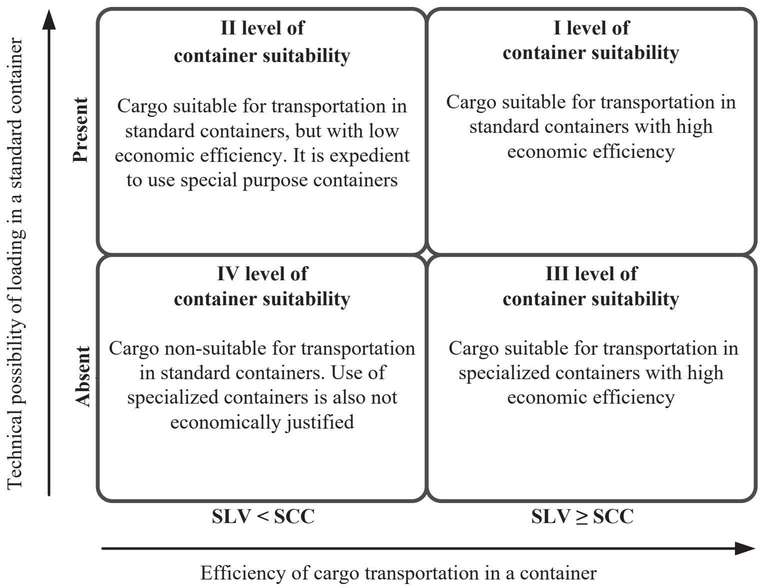
In scientific sources, various approaches to classification of cargo for container-suitable and container-unsuitable types are presented. Thus, in [18] it is indicated that a product is container-suitable, if its technical parameters and physico-chemical properties allow using a container. That is, in this case technical classification criteria prevail.

In a number of sources, for example in [19], a cargo is considered as container-suitable, if its transportation in a container is economically feasible, that is, a cargo, transportation of which is technically possible in a container, but is not economically justified, can be considered as container-unsuitable.

In addition, the scientific literature presents some approaches to quantification of container suitability. The papers [20, 21] are of particular interest. The authors propose to evaluate a degree of container suitability of products on a scale of 0 to 1 based on three criteria: technological, transport-logistics, and economic. According to the technological criterion, the possibility of cargo transportation in a standard container is estimated without additional costs for equipment; the transport-logistics criterion takes into account efficiency of transshipment operations in case of container transportation in comparison with other modes of transportation; economists prefer to determine a degree of container suitability by comparing tariffs for transportation in containers and without them.

Thus, the technique [19] is seen as one of few attempts to quantify validity of container suitability. Its main drawback, however, remains the need to take into account a large number of parameters that require constant updating. In addition, the possibility of using specialized containers that allow significantly expanding the range of goods is not taken into account.

[1] Report of PJSC TransContainer for 2016 [Electronic resource]: https://www.trcont.ru/. Last accessed 01.02.2018.



Pic. 1. Container suitability matrix of goods.

Substantiation of container suitability

The value of a container flow is mainly limited by the volume of container-suitable cargo in the region both for loading and unloading. In connection with development of specialized containers, the nomenclature of suitable cargo has significantly expanded. Therefore, container suitability for cargo should be evaluated in conjunction with a type of a container. According to the classification accepted in the international practices [22], all containers are divided into universal and specialized by purpose. Universal containers, in turn, are divided into standard and special purpose containers (open top, platform containers, etc.). Specialized containers include tank containers, bulk containers, refrigerated containers, etc.

To assess and predict the containerization potential in the region, taking into account the indicated approaches [18–21], the following procedure for determining container-suitable cargoes is proposed.

All types of transported products are differentiated according to two criteria of container suitability: technical possibility of loading cargo into a certain container and economic efficiency of transportation. We will evaluate economic efficiency from the point of view of the utilization rate of container capacity by cargo, since this indicator determines the need for container fleet and directly affects transport costs.

The degree of filling the container volume by cargo is determined through the specific loading volume (SLV, m^3/t). If the specific loading volume exceeds the specific cargo capacity of the container (SCC, m^3/t), this indicates the possibility of full utilization of capacity. Otherwise, it is a heavy cargo, transportation of which in a standard container has less economic efficiency.

It is proposed to distinguish four levels of container suitability of products.

<u>I level</u> – absolutely container-suitable products, these are cargoes, convenient for transportation in standard containers with high economic efficiency. Their specific loading volume exceeds the specific cargo capacity of a standard container. We will classify various lightweight packed-piece goods as belonging to this group.

<u>II level</u> – goods suitable for loading into standard containers, but not ensuring the full use of container cargo capacity, which makes their transportation less efficient. The use of standard containers for such goods is justified if in the region there are redundant empty containers waiting to be loaded back. Otherwise, for goods of this type it is more economical to use special purpose containers (such as Flat Track (container-platform) or Open Top (container without top)). We will classify various general heavy loads, for example, metals, heavy machinery and equipment in this category.

<u>III level</u> – cargoes, suitable for transportation in specialized containers with high economic efficiency. This includes various light bulk cargoes (for example, grain), convenient for transportation in bulk containers, and bulk cargoes that can be transported in tank containers.

<u>IV level</u> – container-unsuitable products. They include cargoes, transportation of which in containers is technically difficult and economically unjustified. They include heavy bulk cargo (for example, cement, ore, coal).

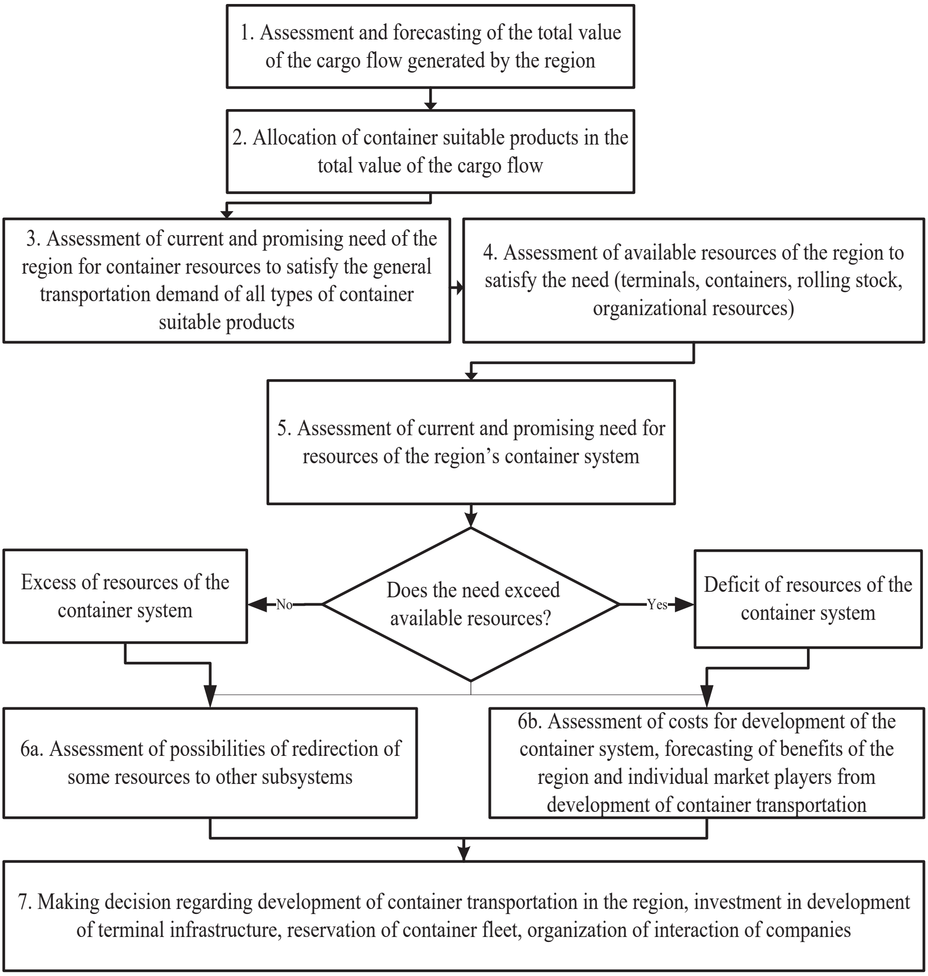
To illustrate classification of goods according to the said criteria, a container suitability matrix was drawn up (Pic. 1).

The proposed product typology in terms of container suitability allows for the simplest and most straightforward classification of all cargoes in the region and assessing containerization potentials for local conditions. The methodology can be detailed and expanded.

Mathematical formalization of the model

The level of containerization of a cargo flow is usually evaluated through the containerization coefficient, which in the most general form is written as

$$k_{cont} = \frac{Q_{cont}}{Q_{total}}, \qquad (1)$$



Pic. 2. Algorithm for justifying the region's need for development of a container transportation system.

where Q_{total} – total volume of cargo transportation in the region, t; Q_{cont} – volume of transportation of goods in the region in containers, t.

In addition to the number of containerized cargo, the volume of transportation in the region is limited by the degree of development of the container infrastructure. Then we write the coefficient of containerization as a functional:

$$k_{cs} = F(Q_{total}, q, A, H, P, d), \quad (2)$$

where q – number of container-suitable cargoes in the region; A – available container fleet; H – terminal network capacity; P – available rolling stock fleet for container transportation; d – other container flow restrictions.

The indicated parameters are unstable in time, subject to random changes and influence of external factors. Therefore, in order to justify the level of containerization of the region, as well as to justify the intervals for changing the factors that affect it, it is necessary to create an imitation model that allows repeated production scenarios reflecting the process of using the container system in the region.

Pic. 2 shows a block diagram of assessment of the region's need for development of a container system.

We formalize the steps of the above algorithm.

At the first stage, it is necessary to determine the total amount of a cargo flow generated by the region.

Let Q_t be a value of a cargo flow generated by the region over a period of time t as a sum of N types of cargo q_{it}.

The amount of a cargo flow q_{it} is characterized by mass, direction, indicator of specific loading volume and loading characteristics, that is, each outgoing cargo flow can be written as a vector (tuple):

$$Q_t = \sum_{i=1}^{N} \overrightarrow{q_{it}}(w,l,u,g), \quad (3)$$

where w – mass of a cargo flow, t; l – direction of shipment of a cargo flow, takes values from 1 to L; accounting for this parameter helps rational planning of loading of passing containers;

u – specific loading volume of cargo, m^3/t; the parameter is needed to determine a rational type of a container and calculate a required number of containers;

g – characteristics of the method of loading of the goods; in the framework of the methodology, we will distinguish two characteristics: g = 1, if the cargo assumes a standard container without additional costs, g = 0, otherwise.

At the second stage we will distinguish container suitable loads in the total volume of transportation. In accordance with the proposed methodology, we introduce the notation: let $q_t^I, q_t^{II}, q_t^{III}, q_t^{IV}$ – cargoes of I–IV levels of container suitability generated in the region during the period t. Then the total value of the region's cargo flow is:

$$Q_t = \sum_{i=1}^{N} \overrightarrow{q_{it}} = q_t^{\mathrm{I}} + q_t^{\mathrm{II}} + q_t^{\mathrm{III}} + q_t^{\mathrm{IV}}. \qquad (4)$$

When developing a simulation model, we will take into account that the demand for container transportation of goods $\overrightarrow{Q_t}$, unsatisfied in the period t, can be postponed for implementation at the time t + 1. At the same time, in the conditions of competition in the market of transport services with probability p cargo can be transported by another mode of transport. The probability value p depends on the specificity of the market in the region, as well as on the magnitude of the accepted model time t. Thus, the amount of demand for container transportation in tons at time t is: $\overrightarrow{Q_t} + \overrightarrow{\Delta Q_{t-1}} \cdot (1-p)$, where $\overrightarrow{\Delta Q_{t-1}}$ – deferred demand, p – probability of switching a cargo flow to an alternative mode of transport.

<u>The next third stage</u> – assessment of the total resource requirements (containers, terminals, rolling stock) to meet the region's demand for container transportation. Considering the existence of different sizes of containers (20- and 40-foot), we take the twenty-foot equivalent (TEU) as the units for measuring a container flow and the processing capacity of terminals.

Let D_{ct} be the region's need for containers at time t, expressed in TEU. Given the possibility of using different types of containers is:

$$D_{ct} = D_{dct} + D_{sdct} + D_{sct}, \qquad (5)$$

where D_{dct} – the region's need for dry cube, TEU;

D_{sdct} – the region's need for special dry cube, TEU;

D_{sct} – the region's need for specific cube, TEU.

In order to meet the demand for container transportation of goods of I level of container suitability, dry cube needs can be evaluated in the amount of:

$$D_{dc\,t}^{\mathrm{I}} = \frac{\sum_{i=1}^{N} ((w_{it} + \Delta w_{it-1}(1-p)) \cdot u_i)^{\mathrm{I}}}{R_{dc}}, \qquad (6)$$

where $_{it}$ – weight characteristics of the i-th cargo of I level of container suitability, t;

u_i^I – specific loading volume of the i-th cargo of I level of container suitability, m³/t;

R_{dc} – cargo capacity of dry cube, m³.

To meet the demand for container transportation of goods of II level of container suitability, dry cube (TEU) will be required at the amount of:

$$D_{dc\,t}^{\mathrm{II}} = \frac{\sum_{i=1}^{N} (w_{it} + \Delta w_{it-1}(1-p))^{\mathrm{II}}}{W_{dc}}, \qquad (7)$$

or special dry cube (Flat Track or Open Top) will be required:

$$D_{sdc\,t}^{\mathrm{II}} = \frac{\sum_{i=1}^{N} (w_{it} + \Delta w_{it-1}(1-p))^{\mathrm{II}}}{W_{sdc}}, \qquad (8)$$

where W_{dc}, W_{sdc} – load capacity of dry cube or special dry cube, t.

The choice of a type of a container for this category of cargo is due to the presence of an excess container fleet in the region and will be considered at the next stages.

To satisfy the demand for container transportation of goods of III level of container suitability, specialized containers of the variety v (Tank Container, Bulk Container, Ref Container) are required in the amount of:

$$D_{sc\,t}^{\mathrm{III}}(v) = \frac{\sum_{i=1}^{N} ((w_{it} + \Delta w_{it-1}(1-p)) \cdot u_i)_v^{\mathrm{III}}}{R_{sc}(v)}, \qquad (9)$$

where $R_{sc}(v)$ – load capacity of a specialized container of the variety v, m³.

The need for terminal infrastructure and fitting platforms will be expressed through the established need for a container fleet. That is, for cargo processing of an estimated container flow terminals with total processing capacity for the period t (TEU) will be needed:

$$D_{ht} = D_{ct}. \qquad (10)$$

To satisfy the given demand for container transportation of cargoes of I–III level of container suitability at the time t, fitting platforms are required in the amount of:

$$D_{pt} = \frac{D_{ct}}{k}, \qquad (11)$$

where k – parameter that determines capacity of a fitting platform; for 40-foot platforms k = 2, for 60-foot k = 3, for 80-foot k = 4.

<u>At the fourth stage</u> we will estimate the resources of the region to meet a given demand.

Let A_t – be containers available at time t after their unloading in the region, including:

$A_{dc\,t}$ – number of dry cube in the region at time t, TEU;

$A_{sdc}(v)_t$ – number of special dry cube in the region at time t, TEU;

$A_{sc}(v)_t$ – number of specialized caontainers of the variety v at time t.

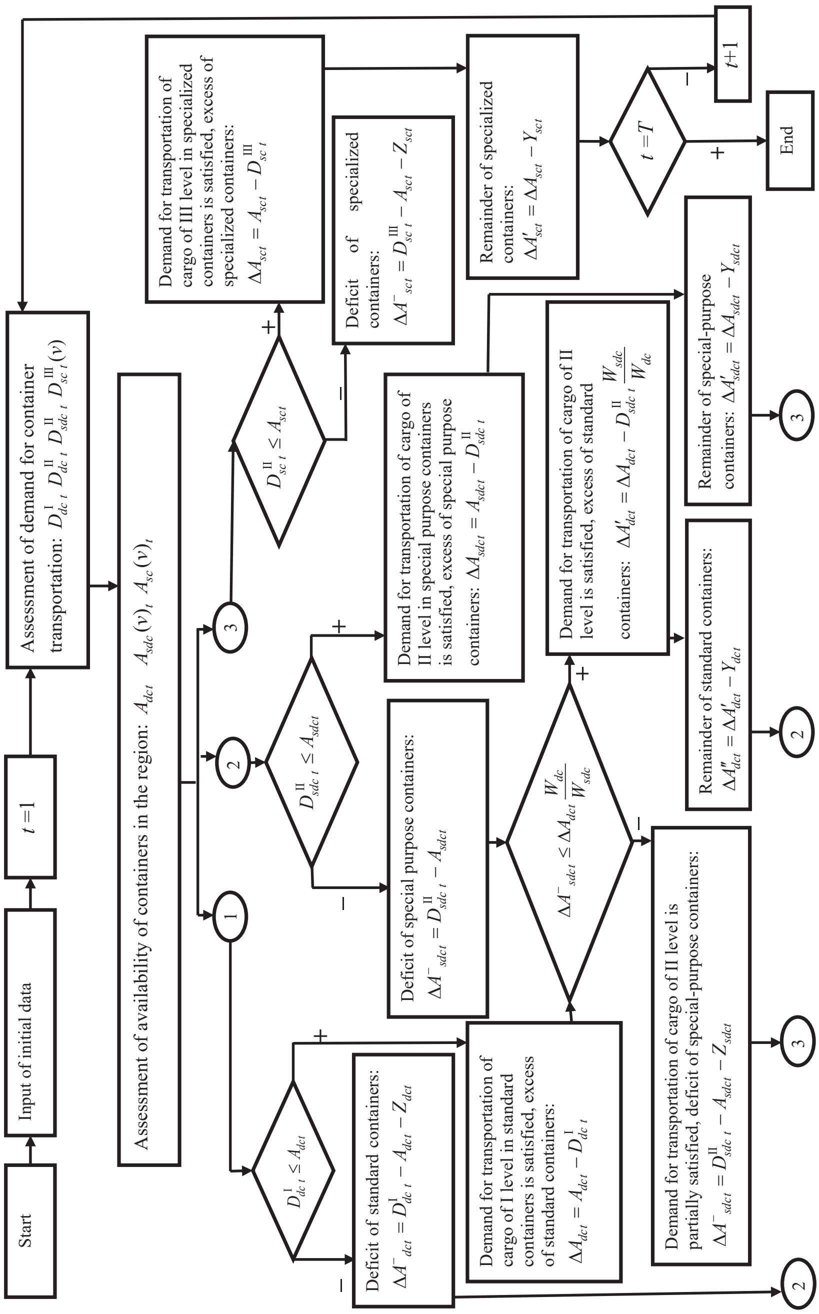
In this case, for each type of container, the characteristic of a shipment direction should be highlighted. Part of the containers intended for loading can be sent in any direction. This concerns a fleet owned by large companies with a developed terminal network (for example, PJSC TransContainer). We will call such containers «free» (A_t^{fr}). Also in the region there could be containers, which after unloading should be returned to the owner in the direction l. This, as a rule, concerns import containers and containers of international shipping companies. We agree to call such containers «returnable» (A_t^{rev}).

Taking into account the containers released after unloading at time t and the remainder of unclaimed containers ΔA from the period t – 1, the expression for determining in the model the presence of a fleet of containers in the region will take a form:

$$\begin{aligned} A_t = {} & (A_{DC\,t} + A_{SDC}(v)_t + A_{SC}(v)_t)_{fr} + (\Delta A_{DC\,t-1} + \Delta A_{SDC}(v)_{t-1} + \\ & + \Delta A_{SC}(v)_{t-1})_{fr} + (A_{DC\,t} + A_{SDC}(v)_t + A_{SC}(v)_t)_{rev\,l} + \\ & + (\Delta A_{DC\,t-1} + \Delta A_{SDC}(v)_{t-1} + \Delta A_{SC}(v)_{t-1})_{rev\,l}. \end{aligned} \qquad (12)$$

Similarly, we formalize the availability in the region of platforms for transportation of containers (TEU): $P_t = P_t + \Delta P_{t-1}$.

Let's imagine capacity of the terminal network of the region for the period t (H_t) as a sum of capacity of M terminals. Assessment of the region's need for a terminal resource takes into account the amount of an incoming flow that the terminal system receives:



Pic. 3. Algorithm for simulating satisfaction of the region's need for containers.

$$H_t = \sum_{j=1}^{M} (H_{jt} - B_{jt}), \qquad (13)$$

where H_{jt} – processing capacity of the j-th terminal for the period t, TEU; B_{jt} – value of an incoming container flow of the j-th terminal for the period t, TEU.

At the fifth stage, to estimate the deficit or surplus of resources, we compare estimation of the total demand for container transportation (stage 3) with the resource constraints of the container system (stage 4).

The maximum volume of container transportation that can be provided by the system will be determined by the smallest value of the resource potential and available demand, i.e.:

$$Q_{cont} = min(D_{ct}, A_t, P_t, H_t). \qquad (14)$$

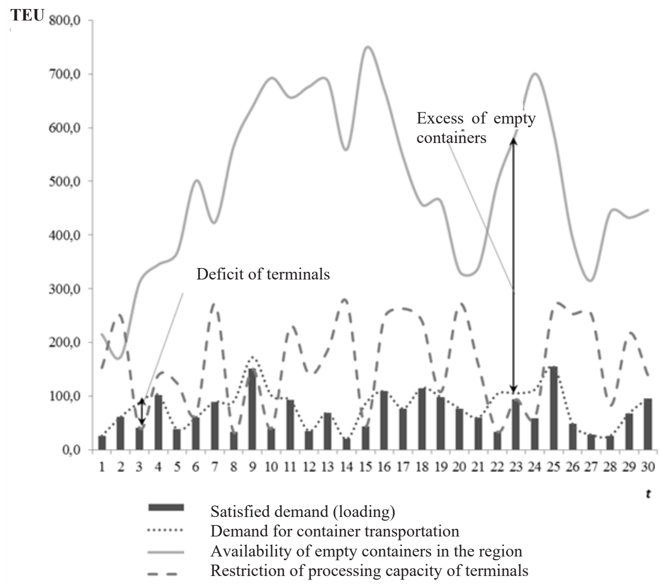
If $Q_{cont} = D_t$, within a given period of time, the demand for container transportation is fully satisfied, the container system is capable of ensuring the export of container-suitable products of all levels. Otherwise, it is required either to create a reserve (within the available opportunities), or to invest in development of a particular resource.

The magnitude of the need for reservation or development of a scarce resource is determined by

Table 1

Initial data of the simulation model of meeting the region's need for container transportation

Parameter	Value
Incoming laden container flow, TEU/day	$B_{jt} = 213 + 42R$
Demand of enterprises of the region for container transportation, TEU/day	$D_{dc\,t} = 67 + 16R$
Incoming empty container flow, TEU/day	$Z_t = 6 + 1{,}5R$
Outgoing empty container flow, TEU/day	$Y_t = 135 + 12R$
Total capacity of container sites, TEU	$E = 8500$
Processing capacity of terminals, TEU/day	$H_t = 1013$
Reserve of processing capacity of terminals to support import/export and sorting of containers	0,5



Pic. 4. The result of calculations using the model of satisfaction of the region's demand for container transportation, t = {1,2,...30}, N = 1.

the difference between the demand for a certain resource and its availability.

Given the variability of the types of containers with which the need can be met, we propose the following algorithm for estimating the deficit or surplus of containers in the region:

1) satisfaction of the need for standard containers, special containers, specialized containers is assessed, that is, for each type of a container, the condition is checked:

$$D_{ct} \le A_t, \quad (15)$$

if availability of containers in the region exceeds the demand for them, there is a surplus, otherwise – a deficit;

2) when there is a shortage of special-purpose containers and an excess of standard containers, the possibility of satisfying the need for transportation of goods of II type of container suitability by standard containers is assessed;

3) a deficit or a surplus of each type of containers in the region at time t is assessed,

in case of surplus of containers:

$$\Delta A_t = A_t - D_{ct} - Y_t; \quad (16)$$

in case of deficit of containers:

$$\Delta A_t^- = D_t - A_t - Z_t, \quad (17)$$

where Y_t – outflow of an empty container flow from the region; Z_t – inflow of an empty container flow to the region; while Y_t and Z_t – variable quantities, the value of which is justified during the playback of the model.

The demand unsatisfied at time t or excess of containers is transferred to the next stage of calculations.

4) the calculation is repeated iteratively from t to T to show the processes of accumulation of excess containers in the region and/or unmet demand for container transportation.

The calculation algorithm is shown in Pic. 3.

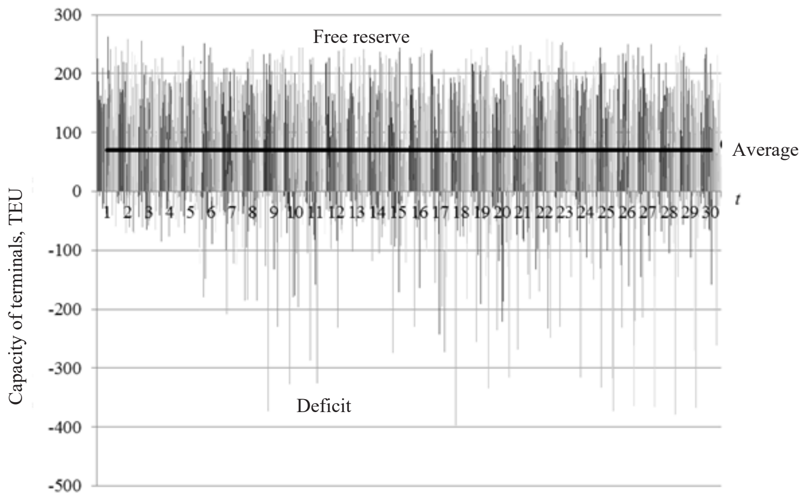
The presented algorithm allows simulating the process of meeting the need for containers in the region, assessing deficit and/or excess of containers of a certain type and, as a result of playing the model, justifying the value of an empty container flow and the level of reservation of the container fleet.

The proposed simulation model contains the following assumptions:

1) the possibility of using standard containers for transportation of goods requiring special transportation mode with the use of special equipment (for example, «flexi-tank» for transportation of bulk cargo in a standard container) is ignored;

2) the priority of loading of containers of different owners on different terminals is ignored.

Similarly, a model is developed for assessing the need for terminal infrastructure in the region, while in case of deficit of terminal capacity, options for



Pic. 5. Experiments to determine demand for the terminal resource of the container system, t = {1,2,...30}, N = 100.

improving the organization of work at the terminal and expansion of the terminal network are analyzed, which is the task of individual scientific studies and partially is examined in [23–24]. And this development of events may require significant investment.

At the sixth stage of the algorithm costs and benefits from development of containerization should be compared, this will allow us to justify the level that will ensure the greatest economic effect for the region and for companies that are part of a regional container system. A model for assessing the impact of containerization on the economy of the region is given in [25].

Verification of the model

To verify the simulation model, we set the initial data on the basis of information on functioning of terminal operators in Sverdlovsk region[2] and the value of container flows obtained in [24], taking into account extrapolation for the current period (Table 1).

The result of the calculation using the model is shown in Pic. 4. To approve the algorithm, we assume that the terminal system of the region processes only standard containers and has three resource limitations: processing capacity of terminals, capacity of container sites, availability of empty containers in the region.

In Pic. 4 it can be seen that the value of the satisfied demand for container transportation does not exceed the demand presented or the resource limitation of the container system, this corresponds to the real notions of its functioning.

The result of approbation of the model showed that, given the initial parameters in the region, excess of empty containers predominates (that is justified by excess of unloading over loading) and there is a periodic deficit of the terminal infrastructure, which manifests itself at the time of occasional bursts of the value of the processed container traffic. To estimate the average level of this deficit, we will carry out N tests of the model (Pic. 5).

The experiment showed that for given initial parameters, the average free reserve (excess) of processing capacity of terminals in the region would be 69 TEU. At the same time, with a 95% probability of reliability, we can state that the terminal capacity deficit will not exceed 132 TEU, and the surplus excess will not exceed 271 TEU. That is, it is legitimate to conclude that for the region in question there is a need to develop a terminal infrastructure to increase its capacity by 132 TEU per day, this will eliminate system failures during peak periods. In addition, it can be stated that an increase in demand for container transportation by an average of 69 TEU per day (other parameters being constant) will lead to depletion of a free terminal resource.

Conclusion. *The demonstrated methodological approach to assessing the region's need for development of container transportations includes three interrelated methods: a method for classifying container suitable products, an imitation algorithm for justifying the region's need for container resources, and a methodology for assessing the impact of containerization on the economy of the region.*

The classification procedure for container suitable products distinguishes four levels of container suitability, depending on two criteria: technical possibility to load a cargo in a certain container and economic efficiency of transporting a particular cargo in a container. The proposed methodology allows to maximally simply and uniquely differentiate all the goods of the region and evaluate the potentials of containerization.

An imitation model for assessing the region's demand for container resources (container fleet, terminals, rolling stock) links the need for transportation (taking into account the levels of container suitable products) and the available resources to meet the demand. The proposed algorithm helps to solve the following problems:

- *assess the need for reserving various resources in the region to meet the overall demand for container transportation;*
- *plan the amount of sending excess or ordering of scarce empty containers and rolling stock;*
- *forecast the need for developing resources to meet future demand.*

The method of assessing the impact of containerization on the economy of the region makes it possible to justify the necessary level of development of the resources of the container system, which will provide its participants with the greatest economic effect.

---

[2] Ural logistics association. Official website [Electronic resource]: http://noula.ru/. Last accessed 01.02.2018).

Verification of the model demonstrates its efficiency and validity.

REFERENCES

1. Boşneagu, R., Coca, C. E., Sorescu, F. Sea Global Containerized Trade. Present and Future. *EIRP Proceedings,* 2015, No. 10, pp. 360–368.

2. Wagener, N. Intermodal transport in Europe – opportunities through innovation. *LogForum,* 2014, No. 10, pp. 371–382.

3. Chou, Ch., Chu, Ch., Liang, G. A modified regression model for forecasting the volumes of Taiwan's import containers. *Mathematical and Computer Modeling,* 2008, Vol. 47, Iss. 9–10, pp. 797–807. DOI: 10.1016/j.mcm.2007.05.005.

4. Rozmarynowska, M., Smolarek, L. Hierarchical Model of Container Ports Throughput. *International Journal on Marine Navigation and Safety of Sea Transportation*, 2015, No. 4, pp. 461–466. DOI: 10.12716/1001.09.04.01.

5. Wang, L., Zhu, X. Rail mounted gantry crane scheduling optimization in railway container terminal based on hybrid handling mode. *Computational Intelligence and Neuroscience.* 2014 [Electronic resource]: https://www.hindawi.com/journals/cin/2014/682486/. Last accessed 29.06.2018. DOI: 10.1155/2014/682486.

6. Yanchenko, A. A., Malikova, T. E., Volnov, I. N. Development of a model for the study of the effect of zoning of a container terminal on efficiency of its operation [*Razrabotka modeli issledovaniya vliyaniya zonirovaniya konteinernogo terminala na effektivnost' ego raboty*]. *Vestnik of Admiral Makarov State University of Maritime and Inland Shipping*, 2017, Iss. 4, pp. 704–713. DOI: 10.21821/2309–5180–2017–9–4–704–713.

7. Parshina, R. N. Methodology of organization of trans-Siberian international container transportation Europe–Asia in transit through Russia. D.Sc. (Eng) thesis [*Metodologiya organizatsii transsibirskih mezhdunarodnyh konteinernyh perevozok Evropa–Azia tranzitom po Rossii. Dis... dok. teh. nauk*]. Moscow, 2013, 455 p.

8. Kos, S., Zenzerović, Z. Model of Optimal Cargo Transport Structure by Full Container Ship on Predefined Sailing Route. Promet–Traffic–Traffico, 2007, No. 16, pp. 15–20. DOI: 10.7307/ptt.v16i1.568.

9. Twrdy, E., Beskovnik, B. Productivity simulation model for optimization of maritime container terminals. *Transport Problems*, 2009, No. 4, pp.113–122.

10. Tan, C., He, J. Integrated Yard Space Allocation and Yard Crane Deployment Problem in Resource-Limited Container Terminals. *Scientific Programming.* 2016 [Electronic resource]: https://www.hindawi.com/journals/sp/2016/6421943/. Last accessed 29.06.2018. DOI: 10.1155/2016/6421943.

11. Rezer, S. M., Moskvichev, O. V., Moskvicheva, E. E. Optimization of the model of formation and functioning of the container-transport system of the country [*Optimizatsiya modeli formirovaniya i funktsionirovaniya konteinerno-transportnoi sistemy strany*]. *Transport: nauka, tehnika, upravlenie*, 2016, Iss. 7, pp. 3–7.

12. Chen, X., Zhu, X., Zhou, O., Wong, Y. D. Game-Theoretic Comparison Approach for Intercontinental Container Transportation: A Case between China and Europe with the B&R Initiative. *Journal of Advanced Transportation.* 2017 [Electronic resource]: https://www.hindawi.com/journals/jat/2017/3128372/. Last accessed 29.06.2018. DOI: 10.1155/2017/3128372.

13. Li S., Zhang W., Tang L. Grey Game Model for Energy Conservation Strategies. *Journal of Applied Mathematics.* 2014 [Electronic resource]: https://www.hindawi.com/journals/jam/2014/765805/. Last accessed 29.06.2018. DOI: 10.1155/2014/765805.

14. Belbo, H., Talbot, B. Systems Analysis of Ten Supply Chains for Whole Tree Chips. *Forests,* 2014, No. 5, pp. 2084–2105. DOI: 10.3390/f5092084.

15. Nikolashin, V. M. Logistic principles of container transportation and optimization of supply chains of goods [*Logisticheskie printsipy konteinernyh perevozok i optimizatsii tsepei postavok tovarov*]. *Transport: nauka, tehnika, upravlenie*, 2009, Iss. 1, pp. 28–30.

16. Intihar, M., Kramberger, T., Dragan, D. Container Throughput Forecasting Using Dynamic Factor Analysis and ARIMAX Model. *PROMET – Traffic & Transportation,* 2017, No. 5 (29), pp. 529–542. DOI: 10.7307/ptt.v29i5.2334.

17. Rakhmangulov, A. N., Muraviev, D. S. Evaluation of development directions of the systems «seaport–»dry» port» by the simulation method [*Otsenka napravlenii razvitiya system «mosrkoi port–»sukhoi» port» metodom immitatsionnogo modelirovaniya*]. *Vestnik of Ural State University of Railway Transport*, 2016, Iss. 3, pp. 54–72.

18. Hirschmann, T. R. The containerized freight system as a means of production distribution: analysis and prospects, N.Y.: Ithaca, 1970, 234 p.

19. Wijffels, R. H., Vrebos, J. European transport law. Antwerpen, Belgium: R. H. Wijffels, 1966, 613 p.

20. Moskvichev, O. V., Nikonov, Yu. S. Evaluation of the potential and perspectives of the container transport system development [*Otsenka potentsiala i perspektiv razvitiya konteinernoi transportnoi sistemy*]. *Zheleznodorozhniy transport*, 2013, Iss. 4, pp. 37–39.

21. Nikonov, Yu. S. Method of determining container serviceability of products. *World of Transport and Transportation*, Vol. 13, 2015, Iss. 3, pp. 184–190.

22. Monios, J., Bergqvist, R. Intermodal Freight Transport and Logistics, Boca Raton, USA: CRC Press, 2017, 280 p.

23. Say, V. M., Kochneva, D. I. Increase of efficiency of works on the terminal [*Povyshenie effektivnosti rabot na terminale*]. *Vestnik of Ural State University of Railway Transport*, 2011, Iss. 4, pp. 52–57.

24. Kochneva, D. I. Increase in efficiency of functioning of regional container transport-logistical system. Ph.D. (Eng) thesis [*Povyshenie effektivnosti funktsionirovaniya regionalnoi konteinernoi transportno-logisticheskoi sistemy. Dis... kand. teh. nauk*]. Yekaterinburg, USURT, 2012, 138 p.

25. Kochneva, D. I. A model for assessing the impact of a container transport and logistics system on the regional economy [*Model otsenki vliyaniya konteinernoi transportno-logisticheskoi sistemy na ekonomiku regiona*]. *Vestnik of Ural State University of Railway Transport*, 2017, Iss. 4, pp. 114–119. ●

Information about the authors:
Say, Vasiliy M. – D.Sc. (Eng), professor of the department of Track and railway construction of Ural State University of Railway Transport (USURT), Yekaterinburg, Russia, VSay@usurt.ru.
Kochneva, Daria I. – Ph.D. (Eng), associate professor of the department of World economy and logistics of Ural State University of Railway Transport (USURT), Yekaterinburg, Russia, dana_rich@mail.ru.

Article received 28.06.2018, accepted 29.08.2018.