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Substantiation of an Indicator System for Assessing the Transport and Logistics Potential of Regional Water Transport

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ABSTRACT

The article discusses the issues of substantiation of the system of indicators for assessing the transport and logistics potential of regional water transport. The relevance of this problem is due to the insufficient elaboration of the rationale and the absence of a comprehensive set of quantitative indicators characterizing this sector of economic activity. The objective of the study is to develop proposals for organizing a multicomponent monitoring system based on mathematical tools to accurately reflect the current state of the water transport complex, considering its development directions. Mathematical analysis was used as the primary methodological approach. The empirical foundation of the study comprises scientific works of prominent economists. The main outcome is the development of a three-component model of the transport and logistics potential of the regional water transport complex, enabling the calculation of a composite indicator — its integral assessment — which is valuable for further theoretical analysis. This model can also be used by executive authorities of Russian Federation regions for making prompt management decisions.

Keywords: mathematical characteristics; multicomponent monitoring; transport and logistics potential; water transport; region; coefficient; integrated assessment; port infrastructure; port-industrial, industrial, distribution components

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INTRODUCTION

The study of the mathematical characteristics of the transport infrastructure condition in the region, which includes water arteries and maritime areas, is dedicated to the fundamental research of such prominent scientists as A.M. Andronov [1], G.A. Golts [2], I.V. Maksimey [3], S.A. Tarkhov [4]. Subsequently, their works were structured from typological and methodological perspectives by A.N. Kiselenco, N.A. Tarabukina, E. Yu. Sundokov, and others [5].

The basis of the analytical operations conducted included methods such as quantitative description of the phenomena under study from a statistical perspective, assessment of relationships between multiple variables using mathematical models, study of patterns in random phenomena, and so on. The researchers drew conclusions that included an assessment of the rationality of both the utilization of investment funds (directed at improving the region's transport system) and the formation of freight and passenger transportation (taking into account the population density in a given subject of the Russian Federation) and others.

At the same time, the issue of multi-component monitoring of the real state of affairs in the water transport complex and the directions of its development based on mathematical tools is currently not receiving due attention.

The study of the causes and conditions affecting the use of the logistics capabilities of this transport cluster allows for the identification of its main areas of activity:

- port and industrial;
- industrial;
- distribution.

In order to find key approaches and tools for determining the profitability level of the region's water transport, it is advisable to apply a universal concept that encompasses all the aforementioned directions, such as "transport and logistics potential", which should not be considered an equivalent of the term "transit potential". They should undoubtedly be distinguished and separated from each other.

The second of the aforementioned concepts was most accurately described in the work of N.G. Kudryashov and A.A. Nechay [6], presenting "transit potential as an acceptable combination of own resources and capabilities for accompanying cargo flows and passenger flights passing through domestic routes". At the same time, the priority remains the generation of a list of service offerings in transport logistics.

In this regard, it becomes evident that the categories under consideration have different natures. The fundamental difference lies mainly in the positioning of transport and logistics potential as a set of resources and capabilities related to a regional-level entity.

The transit potential, in turn, is based on intersubjective and transnational vectors of functioning.

In this regard, the article examines the transport and logistics potential of the region's water transport complex as the object of study.

RESEARCH METHODOLOGY

The authors of the study propose to apply a three-level evaluation system used in econometric theories (including by A.A. Chaliyev [7]).

In the paradigm of this assessment model, the powerful (sustainable) transport and logistics potential of the region's water transport complex corresponds to mathematical characteristics situated within the framework of natural[1] digital indicators with a trend towards growth.

[1] Natural indicators represent data corresponding to optimized conditions in a significant period of time.

As for the weak (unstable) potential, in this case, numerical expressions go beyond these limits when approaching a decrease.

Thus, it is the multi-component analysis of the three aforementioned directions that can provide the opportunity for an objective characterization of the water transport complex of the region and the conduct of a rating assessment of the subjects of the Russian Federation, taking into account the state of their transport and logistics potential.

RESEARCH RESULTS

Problem analysis

Administrative territories with predominant transport and logistics potential should obviously be among the first to claim state and commercial investments, as well as the integration of transport systems through the application of artificial intelligence and the automation of production processes, since these regions are expected to become the locomotives of innovative development across all sectors of economic activity.

In turn, areas that do not possess such potential can try to improve their econometric indicators by participating in the implementation of various state programs for the formation of territories of advanced socio-economic development (TASED), where preferential approaches to economic activities, simplified registration rules, and other benefits are applied.

When selecting an algorithm for assessing the transport and logistics potential of the water infrastructure of a particular subject of the Russian Federation, the determining factor will be the identification of a number of characteristics that most fully reflect its condition.

For this purpose, the authors of the present article studied the degree of development of this topic by other researchers. As a result of the analysis of scientific works [8–11], it was established that the water transport system can be considered depending on the state of its potential:

- in interregional and interstate aspects, that is, at the macro level;
- in the regional aspect, that is, at the meso-level.

The ideas of theoretical development of the approach to assessing the transport potential of the regional system are noteworthy, as

Table

Classification of components for assessing the transport and logistics potential of regional water transport complex

Name	№	Component group
Transport and logistics potential of the region's water transport complex	1	Port-industrial
	2	Industrial
	3	Distribution

Sourse: compiled by the authors.

evidenced by the scientific works of several scholars, including O.N. Larin, E.R. Latypov, V.V. Vyazovsky, L.P. Kirichenko, and others [10, 12–16]. These authors analyses the issues of the impact of external and internal factors and the optimization of the order of creating the logistics infrastructure of the territory, using a problem-solving method based on identifying the most effective ways to divide the specified problem (morphological features) in order to determine their combined sets.

Analyzing the list of prerequisites affecting the backbone industries of the water transport complex of a particular federal subject, one can identify components that are advisable to use in its evaluation. It is proposed to use three categories of indicators (*Table*).

It is evident that the groups presented in the *Table* have stable connections and influence each other in one way or another — for example, the port-industrial component on the industrial one and vice versa. This circumstance allows us to propose the thesis of their mutual correlation, which must be taken into account in further calculations.

Having selected the three main components of transport and logistics potential, we determine the key indicator in each fraction, based on the characteristics of the state and development of the transport sector as a whole and its impact on the economic life of the region and the country.

The foundational platform for identifying numerical evaluation characteristics will be a symbiosis of analytical, heuristic, and experimental methods, based on a combination of existing data sets on quantitative and qualitative parameters, (including those compiled into corresponding reports).

Mandatory requirements for determining the key parameter will be:

• imperative of equidirectionality: the growth of the total digital expression of the selected indicator indicates an overall increase in potential;

• requirement for a limited maximum value at the upper limit: in subsequent calculations, it is rational to rely only on characteristics with some finite value ("ceiling" of the upper value).

The fulfilment of the specified conditions is necessary because the selected digital indicators will later be integrated into a single final index. Then, when the final parameter of this combined marker is derived over the specified period, it will be possible to conduct a correlation analysis of the state of the specified transport and logistics potential and determine its trends.

Justification of the proposed indicators

The first fraction of indicators defines the port-industrial component of the transport complex of the water routes of the country's region. This is a set of terminals, buildings, structures, vessels, and equipment located within the territory of sea or river ports and used for the activities of transporting goods and carrying passengers.

Using these indicators, it is possible to assess the level of competitiveness of the water infrastructure, which is capable of not only meeting the demands of domestic clients and foreign transiters but also ensuring that the Russian maritime and river fleet achieves global standards and corresponding profitability.

The study of sources dedicated to this topic indicates a high level of work carried out by Russian scientists — Yu.A. Lepekhin, E.D. Pasyuk, M.I. Klassovskaya [17], and others.

Today, the key factor in improving the hydraulic structures of berths is the integration of IT processes into their operation, which requires both significant capital investments and trained personnel [17].

Due to the specifics of the activity, the berthing system can be represented as a mass service system, where consumers are in line to receive loading and unloading services (taking into account the duration of the service). It is important to consider that its non-provision may be due to either an excess in the number of requests (ships waiting in line) compared to the total number of sea or river berths, or the maximum size of the waiting queue.

The number of groups of riggers is limited by the capacity of the ship's cargo holds, as well as the technical capabilities for conducting terminal and warehouse operations.

In this regard, the key indicator in this group will be the *speed of service*.

For the purpose of understanding all the rigging processes occurring at the docks, it is advisable to use a system of equations and concepts to describe and predict them — below are the author's explanations related to this.

The average interval before the start of loading (unloading) is directly dependent on the period of terminal operations and the number of berthing facilities for mooring ships.

The average duration of a request in the queue (the duration of the transport vessel's stay at the dock or pier) is the sum of the average interval until the start of loading (unloading) and the average time required for rigging operations.

It is obvious that the speed of service acts here as an indicator determining consumers' evaluation of the performance of all the mooring equipment.

The author's proposal for deriving this coefficient is based on the idea that this speed should be directly proportional to the number of involved crews (groups) of stevedores and berths and inversely proportional to the average duration of a request in the queue:

$$k_{pi} = \begin{cases} \frac{n}{t_r} \text{if } n = m \\ \frac{m}{t_r} \text{ if } n > m \end{cases}, \quad (1)$$

where k_{pi} — coefficient of the port-industrial component; n — the total number of sea or river berths; m — the number of rigging crews; t_r — average duration of a request in the queue.

The situation where $m > n$ is not considered due to economic impracticality.

The numerical characteristics of the second group pertain exclusively to the industrial component of the circulation of the water transport complex of the region, directly interacting with all sectors of the national economy.

Its characteristic (excluding the volume of transported products) is the *freight turnover*, i.e., the total volume of expedition activities for the movement of goods, expressed in ton-kilometers (t*km).

At the same time, it must be acknowledged that this criterion is likely to be incomplete (subjective) — primarily because it does not take into account the transportation period of goods and industrial products from the manufacturer to the end consumer.

After conducting a review of the scientific literature on the research topic [6, 13, 14], the authors of this article draw a well-founded conclusion about the significant impact of the industrial characteristics of the water transport complex on the economic activities of the subject of the Russian Federation and the potential for its development through the transportation of goods on international routes.

It is quite clear that the industrial potential of the maritime and river infrastructure of any territory is directly dependent on the industrial products produced by its enterprises, which is reflected in the overall volume of the gross regional product (GRP) and,

consequently, in the gross domestic product (GDP) of the entire country.

GRP is a criterion that represents the difference between the output of goods and services and intermediate consumption, and is used to measure the contribution to GDP of an individual producer, industry, or sector of the economy. A. A. Nechay and N. G. Kudryashov [6] introduced a criterion for the purpose of general economic evaluation of international transportation (regardless of the means and methods of movement), which shows the turnover of cargo in ton-kilometers attributable to GDP:

$$d_T = \frac{\sum QL}{GPD}, \quad (2)$$

where Q — the aggregated weight of cargo transported along international transport corridors (ITC) passing through the territory of a subject of the Russian Federation; L — the length of the ITC within a specific administrative-territorial unit of the state; d_T — indicator of freight turnover in ton-kilometers per GDP.

Thus, for the purpose of evaluating the industrial component of the subject's transport and logistics potential of the water transport complex based on a comprehensive and objective approach (as well as the obtained criterion d_T), taking into account the specifics of maritime and river cargo transportation in each individual region, it is quite reasonable to operate with such a criterion as the industrial component coefficient, which shows the volume of water transport cargo turnover attributable to the transport sector in the region's GRP:

$$k_i = \frac{TW_v}{d_T GRP}, \quad (3)$$

where k_i — industrial component coefficient; TW_v — the volume of cargo turnover in water transport; $d_T GRP$ — the share of transport in the region's GRP.

The criterion $k_{i,}$ in the authors' opinion, most fully reflects the industrial component of the water transport sector at the meso-level and meets the previously stated requirements for selecting quantitative data. In this regard, it can be applied in the developing evaluation framework.

The criteria of the third group show the state of distribution activities in a particular administrative-territorial entity of the country. The importance of this component is due to the fact that, on a global scale, the share of logistics costs accounts for 13–14% of GDP. In the Russian Federation, this indicator is higher — it ranges from 12 to 25% [18].

Monitoring scientific research on the subject of the study provides grounds to assert that the term "regional logistics system" is inseparable from the concept of "regional logistics potential". Distribution activity and its key characteristics at the meso-level were studied in sufficient detail by Ya. Yu. Pavlova [19]. By studying the patterns of statistical analysis of socio-economic phenomena, she identified particularly important factors influencing the growth of distribution activity, considering it from a regional perspective.

According to Rosstat data, the researcher established mutual dependence (determined correlation coefficients) of different (and frequently occurring in real life) criteria, and also assigned a rating to each subject of the Russian Federation by calculating the weights of these factors [19] (4):

$$R_j = \sum_{j=1}^{k} r_j \beta_j , \quad (4)$$

where R_j — logistics rating of the j-th region of Russia; r_j — the place occupied by the region in

the ranking of Ya. Yu. Pavlova; β_j — weight of factors; k — number of factor samples.

Thus, for calculating the third criterion, which characterizes the distribution component of the transport and logistics potential, it is quite acceptable, in the authors' opinion, to use the aforementioned rating of the subjects of our country based on the quality of conditions for logistics development.

The application of the proposed ranking scheme in the developing methodology for assessing transport and logistics potential does not contradict the second requirement for criterion selection due to the existence of an established rating.

At the same time, the specific feature of the latter is that the higher the rank, the worse the conditions for the development of logistics in the administrative-territorial entity of the countries. This circumstance contradicts the first requirement for selecting criteria.

To apply Pavlova's rating list in the developing methodology, it needs to be accommodated. In accordance with the provided arguments, the third criterion k_d — the distribution component coefficient, which shows the logistical component of the transport and logistics potential of the region's water transport complex, taking into account formula (4), will have the following form

$$k_d = \frac{1}{R_j}. \quad (5)$$

k_d essentially responds to both statistical theory (using the standardized regression coefficient) and expert assessments, which undoubtedly reinforces its objectivity.

CONCLUSIONS

As a result of the conducted research to evaluate the transport and logistics potential of the water transport complex of the administrative-territorial entity of the country, three key criteria were selected:

1) k_{pi} as a port-industrial component;
2) k_i as an industrial component;
3) k_d as a distribution component.

The transport and logistics potential was presented in the form of a three-component model, and its integral assessment (final indicator) is calculated as a generalized value of selected criteria (qualifying each fraction of the components) taking into account their weighting coefficients:

$$\varphi = x_1 k_{pi} + x_2 k_i + x_3 k_{d,} \quad (6)$$

where φ — transport and logistics potential of the region's water transport complex; x_1, x_2, x_3 — weight coefficients.

$k_{pi,}$ k_i and k_d most objectively characterize the transport and logistics potential of the regional water transport complex, as they fully reveal its main components. The prospective modification of the established model involves the specification of the weights of each of the effective components, with the testing of the proposed methodology on specific examples in the subsequent works of the authors of this study.

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Authors' declared contribution:
V.S. Chebotarev — development of the concept of the article, formulation of the research hypothesis, interpretation of the results.
O.L. Morozov — problem statement, selection of sources, critical analysis of literature, development of model structure, drawing conclusions.
D.V. Nazarychev — substantiation of the choice of indicators, development of a calculation scheme, analysis of theoretical provisions on the research topic.

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