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ABSTRACT

The leading role of the transport system in the development of northern regions of Russia from the point of view of national strategic interests and basing in the analysis of the features of those regions, has been identified.

The problem of insufficient development of methods for assessing the state of the transportation market in the absence of year-round availability of transport routes has been revealed. Therefore, the concept of polyfunctionality of the transport system of northern regions has been proposed, along with core definitions in its regard. It involves performance

of four core functions (economic, social, environmental, and geopolitical one), as well as of four developing functions (informational, innovative, institutional, and integrative one). Public statistics data required for implementation of the concept, but now unavailable, are identified.

The study shows the possible stakeholders interested in the implementation of those functions at the macro, meso, and micro levels, suggests indicators for assessing the multifunctional system. The research conclusions are developed using brief overview of international practices and data and situation analysis regarding Russian northern regions, particularly Republic of Sakha (Yakutia).

Keywords: transport system, northern regions, cargo turnover, assessment of the transport market, polyfunctionality, adaptation of estimated indicators, statistical information.

Background. The northern regions are of particular interest to the Russian economy in terms of their development. 90 % of coal reserves, 80 % of hydropower resources, large strategic reserves of oil and gas, almost all of the explored rare metals and diamonds, half of the iron ore deposits, 80 % of forest resources and more than 60 % of fresh water reserves are concentrated in these huge territories [1]. Therefore, the first and necessary condition for their viability is an efficient transport system that would ensure the possibility of moving incoming and outgoing, as well as internal material and human flows, and will provide for integrity, security and integration of the lands geographically removed from the center into the common economic space of the country.

The transport system is always multifunctional, consists of a large number of elements with different level of integration. For its development in Russia, regional aspects remain important but insufficiently studied, as any territorial association of infrastructure, routes, vehicles, and agents of the transportation process, which are called to perform realization of transport and economic relations, needs a balanced development of its subsystems and their ability to meet the needs of the population and all the sectors of the economy. The role of the transport system is historically confirmed by the advanced intensive progress of the regions located on the main routes of continental and intercontinental transport communications [2].

With regard to the northern regions, the role of the transport system is increasing, acquiring priority importance in creating a competitive advantage for the territory, since there are more severe living and economic conditions. Effective development of an industrial complex in such an extreme natural-climatic zone can be achieved only with adequate transport accessibility and favorable conditions for labour migration of the population [3].

Objective. The objective of the author is to consider polyfunctionality of the transport system of northern regions.

Methods. The author uses general scientific methods, comparative and economic analysis, evaluation approach, statistical methods.

Results.

Typification of a selected object

Of course, localization of some features of a single territory does not make them deliberately universal. Yet for the tactics of research such a technique is quite suitable. All the more since it's really about a typical Northern region.

The Republic of Sakha (Yakutia) is the largest region of the Russian Federation. In addition, it is the largest administrative-territorial unit in the world. The length of Yakutia in the latitudinal direction is 2500 km, and in the meridian direction the length is

of 2000 km. Over 40 % of its territory is located beyond the Arctic Circle.

The population of the republic as of January 1, 2017 was less than a million (962835) people, of which 65,5 % live in urban, and 34,5 % in rural areas. At the same time, 33,7 % of the total number live in the capital Yakutsk. The average population density in the region is 0,31 human inhabitants per 1 km². Among federal entities in Russia, only the Chukotka and Nenets Autonomous Districts, also from the circumpolar zone, have less population density.

However, the Republic of Sakha (Yakutia) is of particular strategic interest in economic and geopolitical terms. Huge mineral reserves are concentrated in its territory, and the border of the Russian Federation passes through the waters of the northern seas. The obvious disadvantage is that the local economy has long retained a hypertrophied raw materials orientation with an insufficient level of development of production and social infrastructures.

The northern part of the region is washed by the Laptev Sea and the East Siberian Sea, the Northern Sea Route passes through them. There are almost 700 thousand rivers in the republic with a total length of more than 1,5 million km. This determined the leading role of river transport in distribution of domestic cargo flows. In the port of Osetrovo, Irkutsk Region, about 80 % of all cargo delivered to the Republic of Sakha (Yakutia) is transshipped to river transport. The main transport arteries of Yakutia are the Lena River with tributaries Vilyuy and Aldan, rivers Olenyok, Yana, Indigirka and Kolyma. A large part of the territory is located in the permafrost zone, which greatly shortens the period of navigation along these rivers.

The average January temperature here is -35,6°C, the July temperature is of +13,5°C. The absolute minimum temperature in Yakutsk reaches -64°C, and in the region of the «cold pole» of Oymyakon falls to -70°C. Annual amplitude of air temperatures is more than 100°C. The absolute maximum temperature in Yakutsk reaches +38°C, and near the «cold pole» can go up to +35°C [4], which significantly affects the decrease in the depth of rivers in the summer, shifting the beginning of navigation to the end of August and shortening the period of shipping even more.

The need to develop transport infrastructure is determined by the capacity of existing and potential human and material flows.

The main elements of the transport system of the Republic of Sakha (Yakutia), if we follow the usual functional distribution, are:

- a network of waterways (the Lena, Vilyui, Aldan, Yana, Indigirka, Kolyma, Anabar, Olenyok, East Siberian Sea and Laptev Sea);

- a network of federal highways: Lena (B. Never–Yakutsk), Kolyma (Yakutsk–Magadan), Vilyuy (Yakutsk–Mirny–Ust-Kut); regional road network; a network of annually renewable seasonal roads – winter (snow) roads, laid along the channels of frozen rivers;

- air traffic network;

- Amur–Yakutsk railway (Yakut–Berkakit–Tommot junction, Tommot–Nizhny Bestyakh section, which is in temporary operation);

- main gas pipelines: Sredneilyuysky gas condensate field–Mastakh–Berge–Yakutsk and Taas–Yuryakh–Mirny–Morkoka–Aikhal; Eastern Siberia–Pacific Ocean oil pipeline (ESPO) section;

- supporting infrastructure facilities: ports, berths, warehouses, oil refining and gas distribution stations, railway stations, a network of airports (the largest ones are Yakutsk, Tiksi, Mirny, Talakan, Lensk), etc.;

- vehicles of enterprises and organizations involved in operation of vehicles and transport routes;

- transport service systems: points of maintenance and operation of transport (repair bases, gas stations, garages, etc.);

- transport management systems: organizations and enterprises coordinating interaction in the transport system (design, financing, management, etc.).

Transport infrastructure provides connectivity of the economic space of the Republic of Sakha (Yakutia). The economic space in the context of the territorial approach is a rich territory containing many objects and connections between them: settlements, industrial enterprises, economically developed and recreational areas, transport and engineering networks, etc. [5]. Therefore, it is impossible to assess the state of the transport system without taking into account the realities of the economy and the social sphere, which present their full-fledged demand for transport services.

Polyfunctional approach

A considerable amount of research works is devoted to the relationship between the level of development of the transport system and the region's economy [6–10]. At the same time, the transport system is considered as the main supporting branch of the economy. A progressive economy requires an appropriate level of transport infrastructure, which creates the basis for possible specialization and concentration of production, and increases the demand for cargo transportation services.

Another area of research is the measure of the impact of transport system development on development of the economy. From this position, the progress of the transport system contributes to the mobility of labour and production resources, goods, expansion of trade relations and, consequently, increased competitiveness and investment attractiveness of regional economies. And the majority of researchers agree that the dependencies existing here are quite strong.

In the United States, in 1992, a special tool, Transportation Satellite Accounts (TSAs), was created providing a means for measuring the contribution of transportation services to the national economy. They are linked to the system of national accounts and determine the impact of transport on producers, regions, various users and consumers. In contrast to national accounts, satellite transport accounts consider not only the services of the transport sector rendered to third parties, but also the services of own transport of companies and even of households [11]. The method of calculation is based on identifying the share of the same costs in the base price of finished products of enterprises and the share of transportation costs in the retail price of products sold to consumers.

In France, a system of auxiliary (satellite) transport accounts is also used, but the social costs of transport are added to their estimates. In Belgium, such accounts are compiled according to the methodology adopted in France. In Italy, transport accounts have been operating since 1992 according to US

model with the main focus on road transport [12]. However, this technique does not estimate the whole range of functions implemented by the transport system. Incomplete consideration of functions limits the ability to build an optimal development model in the regions, since it does not allow to fully estimate the aggregate demand for transport services.

In this case, instead, it is proposed to use a multifunctional approach that recognizes the priority of multifunctionality of the transport system in assessing its resources and capabilities. Multifunctionality means an aggregate of all socially significant goals and purposes of regional transport, realization of which provides the necessary and sufficient conditions for the balanced development of certain territories of the country.

To implement the designated approach, it is necessary to clearly represent the socially significant functions of the transport system of the region at the macro, meso and micro levels, to explore the relationships and interactions within these functions. The essence of the proposed dependencies is that each function can be fully implemented only when the other functions are adequately developed if at least one of them is not developed, it becomes a restrictive barrier to the use of all others. Each function acquires its own forms of implementation and organization mechanisms depending on the hierarchical level at which it is executed.

The regional transport system is a geographically isolated part of the national transport system, regulated by the institutions of regional and federal authorities and providing the relevant services within the administrative boundaries of the region and its interests [2]. The single regional transport system includes a combination of all modes of transport and agents connected by economic, technical, technological and regulatory interaction. This interaction is a prerequisite for effective provision of transport accessibility of the northern regions, as in the harsh natural and climatic conditions, no mode of transport alone is able to provide all transportation needs. So, road transport is used mainly in winter during opening of winter roads, air transport is used to deliver expensive and perishable categories of goods, river transport serves only the territories along river channels during a limited navigation period, sea transport is used to transport heavy cargoes that do not require special temperature conditions. And only their complex interaction allows to organize a single transport process in these territories. Implementation of functions of the transport system has its projections at the state level as a whole.

Adaptation of functions

As part of the proposed approach to assessing multifunctionality of the transport system in the northern regions, eight functions were identified, four of which are basic: economic, social, environmental, and geopolitical one, and four more are focused on development: institutional, innovation, information, and integrative one.

Let's consider the influence of each of them on development of the region at the macro, meso and micro levels (Table 1).

The economic function at the macro level is implemented in several directions: creation of conditions for division of labour specialization and cooperation of production; ensuring availability of resources and production capacity; expansion of the transit potential of the territory; reduction of total transport and logistics costs in the economy; reducing the degree of uncertainty (risk) of economic activity in areas that depend on transport factors; input flow of budget revenues. For the northern regions, its feature is the need to develop new mineral deposits and cargo flows initiated by this activity. In this connection, in these regions outgoing cargo flow always prevails over incoming (due to the export of raw goods). At the same time, if there is an incoming cargo flow of expensive and perishable goods to ensure the normal functioning of migrant workers served by air transport, then there is no demand for return air cargo load capacity.

Indicators for assessing the economic function of the transport system can be: the share of transport costs in Gross



Concept of polyfunctionality of the transport system

Macro level – country	Meso level – region	Micro level – subjects (districts, municipalities etc.) of the region
<i>Main functions</i>		
<i>Economic</i>		
1. Getting a multiplier effect for development of the economy when investing in development of transport infrastructure. 2. The increase in tax revenues into the federal budget. 3. The increase in the level of employment and mobility of labour (human) resources within the country. 4. Development of specialization of production and ensuring the transport accessibility of the country's production resources. 5. Improving the efficiency of transport and logistics activities within the country. 6. Increasing the use of the country's transit potential.	1. Getting a multiplier effect of development of the regional economy when investing in development of transport infrastructure. 2. The increase in tax revenues into the regional budget. 3. The increase in the level of employment in the region, stimulating labour migration. 4. Ensuring transport availability of resources and production capacity. 5. Improving the efficiency of transport and logistics activities. 6. Expanding the use of the transit potential of the territory.	1. Reduction of transport and logistics costs of individual manufacturers. 2. Reduction of the final cost of goods for consumers. 3. Reduction of delivery time of goods and improving the quality of delivery. 4. Reduction of logistical risks during delivery of goods and, as a result, reduction of the degree of uncertainty of economic activity.
<i>Social</i>		
1. Development of labour migration opportunities and increase of incomes of the country's population. 2. Satisfaction of the tourist and aesthetic needs of the population. 3. Transport support for the country's food security, taking into account the need for food distribution within the regions and its delivery from foreign countries. 4. Meeting the needs of the Emergencies Ministry in provision of transport services at the state level.	1. Development of labour migration opportunities and increasing incomes of the population within the region. 2. Infusion of additional money into the economy of the region due to the increase in expenses of the employed population. 3. Meeting the needs of health institutions in transport services. 4. Meeting the needs of the Emergencies Ministry in provision of transport services. 5. Transport support for food security in regions where there is no possibility or difficulty in producing own agricultural products.	1. Creating normal conditions to meet the needs of the population in labour and household trips. 2. Ensuring availability of social benefits for the population. 3. Satisfaction of tourist and aesthetic needs of the population. 4. Meeting the needs of the population in delivery of food, medicine and fuel in the northern regions.
<i>Geopolitical</i>		
1. Ensuring national security. 2. Ensuring food security. 3. Ensuring transport connectivity of the regions.	Protection of the external borders of the region, which are the borders of the country.	Protection of the population of the region against geopolitical conflicts.
<i>Ecological</i>		
Environmental protection of the country.	Protection of the environment of the region.	Creation of favorable environmental conditions for the population.
<i>Developmental functions</i>		
<i>Informational</i>		
Creation and dissemination of information within the transport system of the region and of the country and its translation into other areas.	Creation and dissemination of information within the transport system of the region and its translation into other areas.	Dissemination of information generated by the transport system among consumers of transport services in the region.
<i>Innovative</i>		
Development and use of innovative technologies in the transport system at the national level.	Development and use of innovative technologies in the transport system at the regional level (development of special technologies for the northern regions).	Development and use of innovative technologies in the transport system for consumers of transport services in the region.
<i>Institutional</i>		
Establishment of legal and institutional mechanisms aimed at ensuring all functions of the transport system at the national level.	Establishment of legal and organizational mechanisms aimed at ensuring all the above-mentioned functions of the transport system at the regional level.	Creation of legal and organizational mechanisms aimed at ensuring all functions of the transport system at the level of users of its services in the region.
<i>Integration</i>		
Integration of regional transport systems into a single national transport system.	Spatial development of regions through involvement and development of new territories.	Integration of all settlements of the region into a single regional transport system with the aim of their balanced development.

regional product (GRP), the share of logistics costs in GRP, the share of transport and logistics costs in the cost of finished products and their retail price in the market, traffic density for all modes of transport in the context of municipal districts, the share of transit flow in the total volume of turnover, etc. In the northern regions the logistics costs will include the cost of transportation of goods, the cost of loading and unloading, additional costs for sorting, taring, handling/transporting, packaging, etc., the cost of storing and depositing goods.

To compare the demand and supply of transport services, the indicator of cargo activity of economic entities can be used, calculated as the ratio of transported goods by all modes of transport. As a universal indicator for assessing the economic efficiency of the transport system of the northern territories, the index method is quite suitable [13]. The degree of uncertainty (risk) of economic activity due to transport and logistical factors is proposed to be estimated as the ratio of the number of supply failures to the total number of realized cargo transportations, as well as risks in the infrastructure and transport network [14].

The social function is realized by providing labour and household trips capacity to the population, sufficient transport accessibility of social benefits, meeting the tourist and aesthetic needs of the population, providing jobs and generating income for the employed population. The features of this function in the northern regions are the territorial remoteness of many settlements from the regional centers and their low population. This makes transport infrastructure development projects low-income. Indicators of the performance of social functions can be the level of transport accessibility of the territory, transport mobility of the population.

The geopolitical function of the transport system is assessed by national security criteria in all its aspects. From the point of view of the northern regions, this function is especially important because of a large extent of state borders passing at the boundaries of these territories. Nevertheless, the main indicator here may be primarily transport connectivity of territories.

Ecological function at any level is manifested in preservation and protection of the environment. For the northern regions, it is expressed through protection from anthropogenic impact of development of the transport system. The situation is evaluated using indicators characterizing the negative impact of each mode of transport on the ecology of the region.

The information function is implemented in the form of creating (generating) data on the transport system of the region and their translation into other areas, as well as receiving and processing feedback information. Information and communication technologies provide the basis for managing the transport system at all levels. For the northern regions, the importance of this function increases due to the need for the speediest transfer of information in the context of rapid changes in natural climatic conditions. Indicators of the information function are availability, timeliness of receipt, speed of receiving and processing information, etc.

An innovative function is the need to create and use the latest technology in the transport system. Such technologies are of particular demand in the northern regions due to the harsh natural and climatic conditions, the relevance of reducing transportation costs and the risks of supply disruptions. Among them there are: use of special multi-link road trains of great length; construction of simplified temporary railways to service small mineral deposits; use of methods for construction of the roadbed from materials that are produced during extraction of raw materials at deposits; development of air cushion vehicles; use of amphibious all-terrain vehicles; use of snow and swamp-going vehicles on soils with low bearing capacity, etc. [15]. The innovative component can be estimated by the indicator of the number of innovative projects for the transport system in the northern regions, by the age of the rolling stock in use, by the amount of funding for sectoral research and developmental works.

Institutional function through expressed in effectiveness of legal and organizational mechanisms aimed at implementation of all previously designated functions. It is characterized by effectiveness of legal measures applied in the northern regions, and their adaptability in relation to local conditions.

Integrative function of the transport system manifests itself in spatial development of territories through involvement into economic activities and development of new lands at the meso-level and integration of regional transport systems into a single national system. For the northern regions, integration of the transport system into a single national system is especially significant in terms of their exploration and development. At international level the scale of integration processes is determined by the laws of globalization, on the one hand, and the political situation on the world stage, on the other hand.

Indicators for assessing the function are the number of isolated sections of transport networks and the number of areas that do not have sufficient transport accessibility.

Development opportunities

The proposed multifunctional approach to assessing the impact of the transport system on development of the region and the country allows, on the one hand, to detail the directions of this influence and further find the possibilities of its mathematical interpretation for each of the functions in question. On the other hand, the new approach will help to develop a strategy for transport systems in the northern regions, taking into account the balanced use of basic and developing functions.

When creating a model for development of the transport system, the aggregate demand for transport services of economic sectors and all interested subjects of the region (population, business, health institutions, emergency services, etc.) is taken into account. Only in this case, it is possible to get the maximum effect from the implemented

system, provided that the aggregate demand for transport services will be equal to the aggregate supply. Assessment of aggregate demand is proposed to be made using the multifunctional model of the transport system of the region. When creating a model accounting for the needs of the northern regions, it is advisable to use the Transportation Network Strategic Investment Tool. It makes it possible, using the functions of geographic information systems, to calculate the optimal transportation costs for various scenarios based on the characteristics of the state of the transport network, transportation rules, types of vehicles [16]. The proposed mathematical model is aimed at optimizing the structure of the transport system of the region basing on distribution of all categories of cargo turnover and other transport services by specific delivery routes, determining the projected demand for transport work and identifying specific projects for the development of a transport system on the basis of the delivery route.

The study showed that transport in the northern regions plays a special role in their development. From the point of view of public administration bodies, expansion of the transport infrastructure resource is a less risky way than other possible growth options [17]. The complexity of assessing the transport accessibility of the northern territories lies in the seasonal availability of routes, which does not allow for calculating their year-round potential with sufficient accuracy [13].

The study revealed certain features and patterns of development of transport systems of the northern regions:

1. Due to the high cost of construction of transport infrastructure (routes, roads) mainly natural transport ways (river, sea routes, winter roads) are used.

2. For delivery of goods, as a rule, several modes of transport are used, requiring storage and transshipment facilities, development of efficient technologies for mixed, intermodal and multimodal transportation.

3. The seasonality of some modes of transport implies the obligatory presence in the transport schemes of delivery of points of accumulation and deposit of goods, which makes impossible the progress of the transport system in isolation from the balanced development of logistics infrastructure facilities.

4. Transportation practices are hampered by the presence of sections of transport networks in the northern regions which are isolated from the common transport system.

5. The distribution of cargo flows along the delivery routes is determined by technical and economic indicators without taking into account assessment of transport risks arising from an insufficient level of development of vehicles [18].

6. Methods for assessing regional transport systems are not applicable to the northern regions due to the lack of year-round availability of transport ways.

These features predetermine the need to develop a special methodology for assessing and forecasting directions of development of the transport system of the northern regions:

- The year-round transport capacity of the transport system should be calculated taking into account seasonality rates, calculated separately for each mode of transport, and in the context of certain sections of the transport network that have the same seasonal accessibility.

- When evaluating multimodal cargo delivery routes, the carrying capacity should be determined by the smallest capacity of a section of this delivery route.

- Evaluation of the transport system can be carried out simultaneously with evaluation of the logistics system, since multimodal routes prevail in the delivery schemes and a mandatory link in the goods delivery chain in the North are storage and deposit points.



• In addition to technical and economic indicators, transport and logistics risks that arise due to the high degree of rolling stock wear and the lagging technical level of the transport infrastructure should be taken into account to compare the efficiency of various delivery technologies.

Conclusions and proposals

The results of the study indicate that to assess the state and forecast development of the transport system of the northern regions, it is necessary to have statistical information that the regional statistical service does not collect and provide, including data on the transport work of medical organizations, units of the Ministry of Emergency Situations, that have a demand for transport services in the region. Without this information, it is not possible to estimate aggregate demand and calculate the corresponding costs.

On the basis of accounting of all the factors considered, a mathematical model should be developed for assessing the state of the transport system in a northern region, its multifunctionality and the degree of implementation of each of the main and development functions. On the basis of a mathematical assessment of the state of the transport system, it is necessary to create a dynamic model for the northern regions, which reflects the needs of the aggregate demand for transport services from all stakeholders and in the context of the product mix of cargo flows.

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