ATLANTIS PRESS

Advances in Engineering Research, volume 188

International Conference on Aviamechanical Engineering and Transport (AviaENT 2019)

Transport and Logistics Systems Development Based on the Transport Modes Comparative Advantages

Borodulina S.A.
Water transport economics Dept.
Admiral Makarov State University of Maritime and Inland Shipping
Saint-Petersburg, Russian Federation,
piter00000@mail.ru

Trofimova L.S.
Organization of transport and transport management Dept.
Siberian State Automobile and Highway University (SibADI)
Omsk, Russian Federation,
trofimova_ls@mail.ru

Chebakova E.O.
Logistics Dept.
Siberian Automobile and Highway University (SibADI)
Omsk, Russia
elena_chebakova@mail.ru

***Abstract* - Optimal configuration of a regional transport and logistics system should be chosen from the standpoint of the goal of regional development, the environmental component of decision-making, and according to the criteria that determine the advantages and disadvantages of a particular mode of transport. The article outlines the main approaches to appreciation of the comparative advantages of certain modes of transport, and transport and logistics systems. The factors influencing the development of transport and industries on the region's economy have been identified. Based on the data obtained from statistics, regional economics, relevant ministries and agencies, as well as rom scientific research carried out by the authors earlier, the results of the research into advantages of the main types of transport have been provided for a number of indicators used in the justification of regional transport systems in line with the problems to be solved. The article provides a step-by-step methodology for assessing the comparative advantages of inland waterway transport. The method of hierarchy analysis to justify the type of transport is recommended, which will lead to the faster achievement of the goal set by the subject, or to identification of the priority way to achieve the management goal and develop the transport and logistics system in the region.**

Keywords: transport and logistics system, region, inland water transport, choice of mode of transport, goals of development of regional logistics.

I. INTRODUCTION

According to the Organization for Economic Cooperation and Development (OECD), increased efficiency of the transport sector of the Russian Federation by 10% will lead to a 0.8% increase in GDP [1]. At the same time, the greatest effect will be achieved in the less developed regions of southern Russia, in Siberia and in the Far East.

The role of transport is also determined by the structure of the regional economics. As an independent industry, transport performs the function of moving goods and cargo by different types of rolling stock. The same transport need can be met by various modes of transport. In market relations, consumers of transport services are interested in the delivery of goods and cargo to the consignee or the passenger to the destination. The choice of configuration of regional transport and logistics supply chains of products often depends on the quality of regional transport infrastructure.

On the other hand, the priorities and interest of regional authorities determine the level of development of the infrastructure of a particular mode of transport in the region based on parameters that are of greatest interest to participants in this market.

II. DATA AND METHODS

According to the research into methodological issues of logistics, transport economics and management, for consumers of transport products, criteria such as transportation costs, speed of delivery, safety and security, regularity of transportation, lot consistency of goods and cargo, etc. are the most important qualitative characteristics. Mostly, in transportation of goods and cargo these quality criteria are mutually determined [2].

In terms of the transport logistics, the criteria for assessing the advantages within theoretical concepts and methods of foreign countries include shipping costs, transportation costs, adherence to delivery schedules, frequency of transportation, safety and integrity of cargo, the carrier’s financial sufficiency, freight forwarding, monitoring the cargo passage, quality of service, convenience of the time of departure of the

goods, the speed of response to the claims, the absence of violations by the carrier [3,4,5].

A review of research papers [6,7,8,9,10] in this area suggests that currently, there are four main approaches to assessing the influence of the transport and logistics infrastructure and of the regional transport logistics in general on the economic development of the region:

1) through the degree of influence on the availability of resource and commodity markets;

2) through transportation costs;

3) by analyzing investment activity in the region;

4) based on surveys of entrepreneurs regarding the degree of importance of the factor of availability and quality of infrastructure in the location of the production facilities.

The first approach suggests that reducing costs and transport time will improve market accessibility, which enables certain regions to make additional profits and increase product competitiveness. This process is characterized by positive implications for rapidly growing regions and regions that noticeably depend on the scale of production, for example, large megacities. Relocation of factors of production may increase the welfare of the region [11].

An approach that involves analyzing investments in the region’s transport infrastructure is based on an assessment of the increase in labor and resource costs. By investing in the transport and communications industries, governments and businesses can benefit from the spatial distribution of production activities. However, modernization of the transport system of the region does not automatically guarantee its accelerated development, especially in those regions where the infrastructure is not yet perfect. P. Rietveld and P. Nijkamp assert the ambiguous impact of the modernization of transport infrastructure on the region's economy.

Thus, the transport and logistics infrastructure has integrated effect on the economic development of the region, both at the macro level and at the level of individual firms using infrastructure facilities. Being one of the leading elements of the production infrastructure, on the one hand, transport ensures the mobility of goods and resources, on the other hand, it facilitates the accessibility of territories, thus providing the opportunity for free movement of goods, resources and population. In turn, regional economic development is the main driving force behind the development of demand for cargo transportation services. Changes in the production structure, growing internationalization of commercial activities affect the nature of infrastructure usage [10].

A review of the theoretical concepts available in the scientific papers concerning the assessment of the impact of the transport and logistics infrastructure on development of a region has shown that most often the assessment is based on the regional investment attractiveness. The author of the study [7] suggested that the transport and logistics infrastructure created in the region should be treated as a type of capital that a region can benefit from in terms of economics and social development.

For example, when assessing the impact of construction of railway infrastructure facilities, the following socio-economic effects for society and the region can be distinguished: agglomeration effect; the effect of employment growth; the effect of regional development; the effect of employment in construction; increasing Russia's attractiveness in terms of foreign direct investment, and tourism development [12].

The *agglomeration effect* implies large-scale investments in transport infrastructure, which generally improve communication between administrative centers and remote areas, thus leading to the centralization of the labor market and the concentration of labor resources. Thus, it can be assumed that the improvement of transport infrastructure will increase the effect for the backward regions of the country, including those located outside the main transport routes [13].

The effect of employment growth involves the enhancement of transport services usage to meet another need (for example, commuting). This will contribute to improving the efficiency of the labor market and the level of economic activity of the population.

The effect of regional development is associated with the accession of vast territories to employment zones, increased labor mobility of the population and, consequently, improved efficiency of labor. Growing transport accessibility is certain to increase the attractiveness of previously remote areas, administrative centers that are poorly involved in the economic activity, which will promote their economic development and an increase in the cost of land and real estate.

Reducing economic damage from environmental pollution and improving road safety are also important socio-economic tasks for the regions of the Russian Federation. In this article, we will focus on the issues of environmental safety and the possible social effect from the development of regional transport and logistics systems.

III. Research

The benefit from transport infrastructure can be determined through output indicators in terms of either volume or cost [14]. Figures 1-2 present data on the financing of infrastructure of the inland waterway transport (IWT), rail transport (RT) and road (automobile) transport (AT) as well as of public federal and regional roads out of budget and extra-budgetary funds, and an output-capital ratio.

The performance of various modes of transport expressed as 10 ton-kilometer and as 1 ruble invested in infrastructure (output-capital ratio) is shown in Figure 2.

The amount of funding for the maintenance and development of federal and regional public roads out of budget and extra-budgetary funds per 10 ton-kilometer of the

road transport freight turnover is 14 times higher compared to the inland water transport and 21 times higher than the rail transport.

Fig.1. financing of infrastructure of the inland waterway transport, rail transport and road (automobile) transport [14]

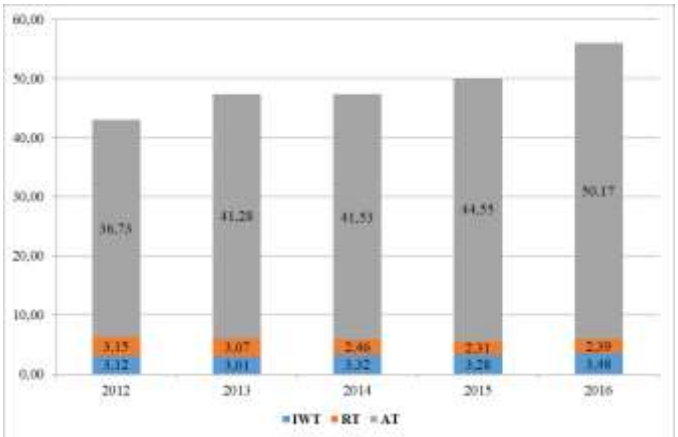

Fig.2. The amount of financing the infrastructure of inland waterway and rail transport, federal and regional public roads out of budget and extra-budgetary funds, billion rubles per 10 ton-kilometer of freight turnover [14]

Reducing the cost of construction and reconstruction, repair and maintenance of railway transport infrastructure in 2014-2016 is determined by the optimization of costs of the Russian Railways OAO. As a result, since 2014, the total cost of maintenance and development of the infrastructure of the inland water transport exceeded the similar costs figures of the rail transport per 10 ton-kilometer of freight turnover [14].

The analysis showed high efficiency of the inland waterway and rail transport compared with significantly lower efficiency of the road transport [14].

When deciding on options for the development of the regional transport and logistics infrastructure, the following conclusions and assessments should be considered:

1. Financing of costs and investments in the infrastructure of the inland waterway transport, as well as funding of overhauling, repairing and maintaining the infrastructure are significantly lower than those for road transport and comparable to that of railway transport.

2. The most expensive type of transport infrastructure is public roads, taking into account the cost of repairs and maintenance per unit of freight turnover.

Effects on regional budgets upon switching from rail and road transport are associated with the possibility of saving the cost of repairing regional and local roads by reducing the traffic of freight vehicles, as well as increasing tax revenues to regional and local budgets.

3. Safety. Accident rate on inland waterway transport amounted to 3.1% of the total rate of transport accidents, while the same indicator for railway transport was 6.3%, and for road transport – 90.6%. The indicator is presented in detail in Table 1 and Fig.3.

In Table 1 we can see the data on the causes and accident rate in transport (by modes of transport).

TABLE I Traffic incidents

Mode of trans-port	Causes of traffic and other accidents	Accident rate in 2016, cases/ %
Rail	malfunctions of the track, rolling stock, alarm systems, centralization and blocking, errors made by dispatchers, machinists, leading to a rolling stock derailment, collision, driving over obstacles at crossings, fires and explosions in the cars	12 / 6.3
Road	violation of traffic safety rules by drivers (speeding, disregard of road signs, wrong way driving and driving while intoxicated), poor road conditions, vehicle malfunction (failure of braking system, steering, running gear).	174 / 90.6
IWT	impact of climatic factors such as hurricanes, storms, fogs, ice, human factor (captains, pilots, crew members), errors in the design and construction of ships.	6 / 3.1

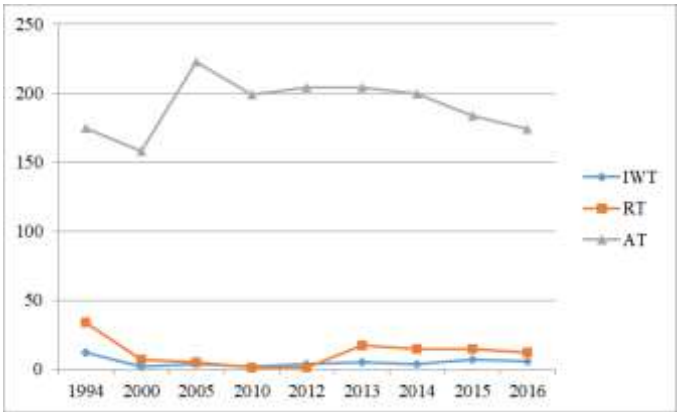

Fig.3. Accident rate by modes of transport, cases

4. The cost of transportation is expressed through the indicators of labor intensity and energy intensity of cargo transportation by different modes of transport

Energy intensity. The specific consumption of labor and material resources for IWT transportation is significantly lower than the same figure for transportation by road.

Switching from road transport to inland waterway mode will reduce specific labor costs from 17.9 to 10.1 man-hours/10^3 equated ton-kilometers.

Specific energy consumption (fuel consumption) per thousand of the specified cargo turnover in the inland waterway transport is several times lower than in the competing transport: for example, the specific energy consumption for inland waterway transport is 24 times lower than that of motor vehicles and is consistent with that of public railway transport. Energy intensity of transportation and consumption of reference fuel is given in Table 2.

TABLE II Intensity of transportation

Mode of trans-port	Fuel and energy resource	Specific consumption, kg of reference fuel/10^3 equated ton-kilometers [15]	Consump tion, million tons of reference fuel	Portion of con-sumpti on, %	Range in terms of eco-nomy
AT (perso nal use cars exclud ed)	Gasoline, diesel, gas, electricity, alternative energy sources	210-215	60.2	32.4	3
RT	Electric power, diesel fuel	6-6.6	15.4	8.3	2
IWT	Diesel fuel, gasoline	8.7-8.9	5.5	2.9	1

Switching cargo transportation from road and rail transport to inland water transport will contribute to reducing the share of energy intensity in the economics in general, and reducing the cost of transportation by saving fuel and energy resources, as well as reducing the cost of transporting freight for cargo owners in the transport and logistics system of the region.

Energy efficiency (Table 3, Figure 4). According to this parameter, the inland waterway transport ranks second among the competing modes of transport. Energy efficiency by modes of transport was distributed as follows: the highest Kt indicator is recorded for rail transportation (158.7 thousand ton-kilometers/tons of reference fuel), followed by inland waterway transportation, with Kt equal to 113.6 thousand ton-kilometers/tons of reference fuel.

Population growth and the level of urbanization create a growing need for cargo transportation and movement, and the growth in the average population of the country leads to a tendency towards heavier usage of motor vehicles, which increases fuel consumption and accompanying emissions. Therefore, the task of creating an efficient transport system, including regulation and redistribution of cargo transportation by modes of transport in the context of a growing fleet of personal use cars, is urgent, which system would meet transportation demand and ensure minimal consumption of energy and resources invested in the development of transport infrastructure [2].

TABLE III Energy efficiency

Mode of transport	Consumption, million tons of reference fuel	Energy efficiency ratio (Kt), 10^3 equated ton-kilometers	Range in terms of fuel effective use
AT (personal use cars excluded)	60.2	4.7	4
RT	15.4	158.7	1
IWT	5.5	113.6	2

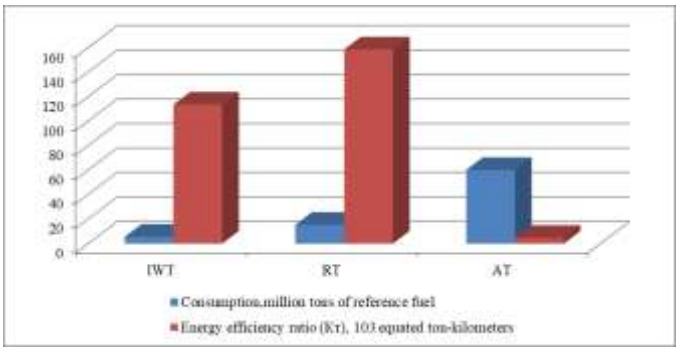

Fig. 4. Comparison of energy efficiency (Kt) by modes of transport, thousand ton-kilometers/tons of reference fuel

Environmental compatibility. The structure of polluting substances by mobile sources by modes of transport is distributed as follows: for road transport – 94%, for river transport – 0.6%, for rail transport – 1.5%.

In particular, in Saint Petersburg, the level of gross pollution associated with the performance of road transport is estimated at 32%, rail transport at 1%, navigable (sea and inland waterway) at 4%.

The coefficient of environmental safety according to the multivariable scoring assessment technique in the Russian Federation in general was 9.1 for IWT, 5.9 for rail transport, and 3.7 for road transport.

The dependence of air pollutant emissions by mobile sources is presented in Table 4.

TABLE IV Pollution emitted by trasport

Year	2006	2009	2010	2013	2014	2015	2016
Emissions, thousand tons	14.9	13.7	13.2	13.6	13.8	13.9	14.3
Freight turnover, billion ton-kilometers, including	2.15	2.05	2.21	2.45	2.55	2.54	2.58
Rail transport	1.95	1.87	2.01	2.20	2.30	2.31	2.34
Road transport	199	180	199	250	247	233	235
Emissions, kg, expressed as 1 thousand ton-kilometer of freight turnover	6.95	6.72	5.99	5.57	5.41	5.50	5.53

Assessment of the advantages of various modes of transport in solving social and economic problems in the region and building regional transport logistics systems is shown in Figures 5-6. Estimates are given from the standpoint of the cargo owner (the customer of the chain of supply) and from the standpoint of the region (the society as a whole).

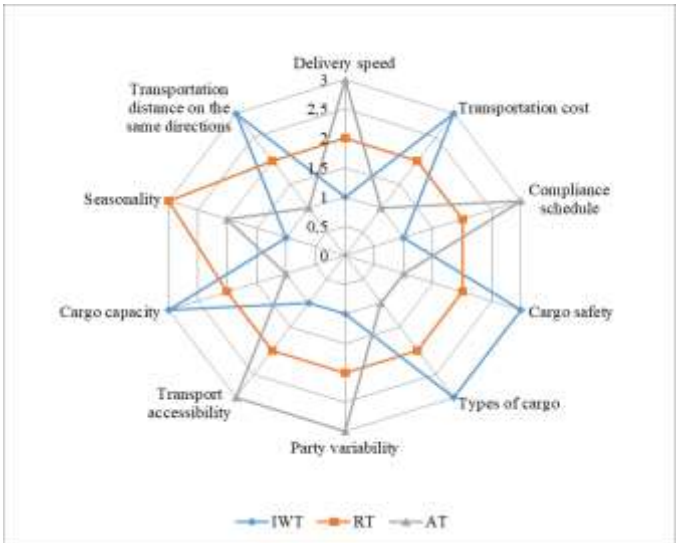

Fig.5. Comparative advantages of various modes of transport from the standpoint of the cargo owner

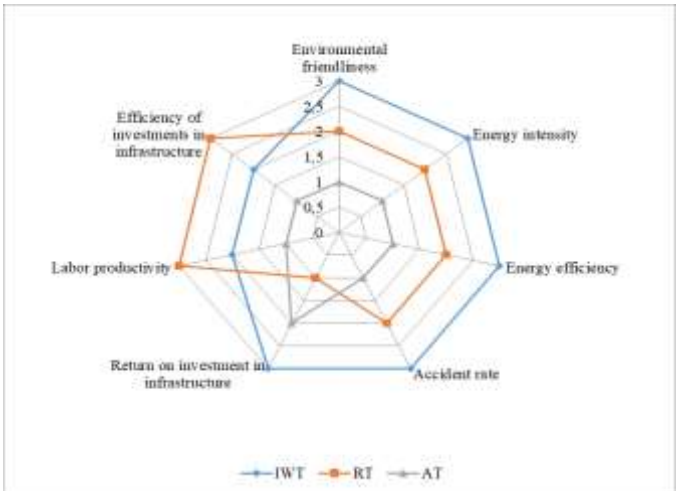

Fig.6. Comparative advantages of various modes of transport from the standpoint of the society

IV Results

The optimal configuration of a regional transport and logistics system should be selected based on the goal of regional development, the environmental component of decision-making, and also according to criteria that determine the strong and weak points of a particular mode of transport.

Thus, for example, the advantages and disadvantages of inland waterway transport (IWT) can be represented by basic parameters such as the time and cost of delivery (cost of transportation for the customer), reliability of delivery (in terms of compliance with the schedule), reliability of delivery (in terms of safety of cargo), the ability to transport various types of cargo, variability of lot compliance, accessibility of transport (in terms of availability of ports, waterways, transport infrastructure facilities), cargo capacity, seasonal fluctuations, environmental friendliness, energy intensity, energy efficiency, traffic safety (in terms of accidents), efficiency of investments in infrastructure, the return on investment in infrastructure, labor productivity.

Transport affects the rate of turnover of investments in the transport and logistics infrastructure, which is of investors' interests, since the rate of development and return on investment determines the efficiency of investments [15]. In this regard, the below stages of the methodology for analyzing the criteria and indicators for assessing the benefits and special aspects of a particular mode of transport can be distinguished when determining preferences in the development of regional transport logistics:

1. Identification of the goals and objectives of assessing the benefits and special aspects of the region's transport logistics.
2. Identification of the subject of the assessment (the customer – the user of the services within the chain of supply; the population of the region – the regional authorities from the standpoint of obtaining a social and economic effect).
3. Setting the goal of assessing comparative advantages.
4. Development of an array of indicators reflecting the method and opportunities of achieving the goal.
5. Evaluation of comparative advantages for different modes of transport.
6. Comparative assessment of modes of transport to be included in regional transport and logistics systems.
7. Identification of the priority vector (by modes of transport).
8. Identification of the preferred way to achieve the goal of the region's transport and logistics system.

At the first stage, the subject should be identified from the perspective of which both the objectives of assessing the comparative advantages of modes of transport (e.g. IWT), and the tasks of managing and regulating transportation business should be defined, which involves the adoption of a set of subsequent decisions and actions. The benefits of the inland waterway transport can be assessed from the standpoint of government agencies and business organizations, i.e. cargo owners, accumulating their own interests and goals, and, therefore, having their own criteria for assessing the inland waterway transport within their goals and objectives. Thus, at the next methodological stage, the goal of assessing the comparative advantages of the inland waterway transport is to be selected and set, based on the following collection of possible goals (Gi, i = 1 ... n):

G1 – rise in commercial efficiency of cargo transportation in the transport and logistics system;

G2 – rise in the efficiency of investments in the transport infrastructure;

G3 – increased transport accessibility for manufacturing enterprises (by types of products);

G4 – improved environmental safety in the region;

G5 – improved energy efficiency;

G6 – improved budget efficiency in terms of replenishment of the budget revenue component;

G7 – other goals.

Other goals can be shaped taking into account external factors for the development of the region and the industry, conditions for the development of the national economy as a whole and its individual sectors, focus on the implementation of new national projects, as well as the current trends in geopolitics and the national economic policy. The goals identified at this stage can be assessed on an individual or common basis. At the next stage, it is advisable to generate an array (set) of indicators to describe both the estimated advantages of the inland waterway transport and the expected results of achieving the previously set goals. A sample set of indicators used to describe the goals and possible outcomes is shown in Table 5.

TABLE IV Indicators and outcomes

Goal	Indicators of assessing advantages (disadvantages) of the IWT	Target controllable indicators (Ii)
G1	The cost of transportation, prices, port charges, time of delivery, reliability of delivery, the ability to transport different types of cargo	Expenses incurred by the cargo owner, cost efficiency
G2,6	Volumes of the IWT carriage, safety (rate of accidents)	Taxes remitted by shipping companies to budgets, effectiveness of capital investments, cost of overhaul, repair and maintenance of infrastructure facilities, capital investments in the construction of the fleet, subsidies from the federal budget, return on capital investments, the rate of employment of the population
G3	Environmental friendliness, energy intensity, energy efficiency, cargo capacity, seasonal fluctuations, safety of transportation	The length of the IWT with guaranteed depths, capital investments in construction, investments in the reconstruction and modernization of river ports, terminals, berths and other facilities of the IWT infrastructure, return on investment, the rate of employment
G4	Environmental friendliness, energy intensity	Emissions of toxic gases and substances, oxygen consumption, thermal radiation parameters, noise level, electromagnetic radiation, vibration, etc.
G5	Energy intensity, energy efficiency,	Specific fuel consumption, consumption of fuel and energy resources, energy efficiency ratio

V CONCLUSION

To assess the priority and vector described at the last methodological stage, the hierarchy analysis method is recommended, which can be interpreted as follows for solving the problem. The main task to be solved at this stage is to substantiate the mode of transport based on the special features and advantages of its operation, which will accelerate the achievement of the goal set by the subject, or to identify the preferred way to achieve the goal of managing and developing the regional transport and logistics system. The top level, i.e. the focus of solving the problem estimates the target controllable parameter (ЦПi) determined for the goal Цi. The criteria, i.e. the second level of the hierarchy, include the П1…Пj. j=1…m parameters characterizing the advantages and features of different modes of transport and characterizing the possibilities of achieving a given value of the target parameter ЦПi.

This method used for data processing can help obtain a priority vector reflecting the high importance in achieving the goal of the mode of transport for which the vector value will be a maximum. In addition, this method makes it clear what a preferred way should be used to achieve the target parameter of the development of the transport and logistics system in the region.

References

[1] K.E. Karataeva, Transport industry as a factor of economic growth in Russia, Russian Institute for Strategic Studies, Moscow, 2014

[2] A.A. Chebotaev, The levels of labor and energy intensity as factors of innovation and business activity of transportation in the economy, Innovative transport, 2017. No. 4 (26), pp. 38-48.

[3] Yu. Nerush, S. Sarkisov. Transport Logistics. Moscow. Publisher: Yurayt, 2016, 352 p.

[4] L.Fedorov, V. Persianov, I. Mukhametdinov, Moscow. Publisher: KnoRus, 2016, 310 p.

[5] V. Gerami, A.Kolik, Management of transport systems. Transportation logistics, Moscow. Publisher: Yurayt, 2015, 510 p.

[6] N.Bogorad, Russia has a huge potential for using inland waterways, Marine Business, 2014.

[7] Yu.N. Golskaya, Assessing the impact of transport infrastructure on the socio-economic development of the region, Yekaterinburg, 2013

[8] E.O. Vydrina, Influence of water transport infrastructure of the region on the socio-economic development of the western Arctic, St. Petersburg, 2015, p. 44

[9] O.A. Denyak, Growth factors of inland water transport in the conditions of the influence of the priorities of the socio-economic development of the region, Science and transport journal, 2014, №1 (8), pp. 34-37.

[10] E.G. Efimova, The role of transport in the economic development of the region: an international aspect, St. Petersburg, SPSU Bulletin, 2009, Vol.1, pp.77-84

[11] P. Rietveld, P. Nijkamp, Transport and Regional Development, European Transport Economics, Ed by J. Polak, A. Heertje. Blackwell Publishers, 1993., p. 134.

[12] Socio-economic effects of HSR for society, Russian Railways website, http://www.hsrail.ru/projects/vsm-1/effects/

[13] Statistical database, environmental protection, Rosstat website, http://www.gks.ru/bgd/regl/b16_54/Main.htm

[14] T.A. Pantina, S.A. Borodulina, Criteria and growth factors of inland water transport competitiveness, Bulletin of Astrakhan State Technical University, Series: Economy, 2018, № 3, p. 68-77.

S.A. Borodulina, L.S. Trofimova, E.O. Chebakova, E.O. Belyaeva, Analysis, planning and management in motor transport enterprises, Omsk: SSHAU, 2017.