

# Formation of an Effective Model of Transport Corridor in the Territory of the Republic of Sakha

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**Abstract**— The article analyses the formation of the transport corridor "Lensk - Mirny - Suntar - Nyurba - Vilyuysk - Yakutsk" in the territory of one of the north-eastern regions of Russia - the Republic of Sakha (Yakutia). The justification of the significance of the development of the transport corridor for the region is considered as a way to strengthen the unity of the economic space, improve interregional transport and economic relations, to develop entrepreneurship and inter-regional cooperation. Threats that may lead to unforeseen consequences are identified. The long-term dynamic process of spatial development can be regulated using strategic planning methods and innovative development policies. The authors proposed a number of measures to promote an effective model of the formation of transport corridor in Western Yakutia).

**Keywords**— transport corridor, preferences, transit potential, transport policy, strategic planning, Yakutia

## I. INTRODUCTION

The topic of transport corridors has grown relevant and become an important one at transport and logistics conferences. This topic was the subject of several special issues of the journal, such as Research in Transportation Business & Management [1]. Currently, transport corridors are actively forming in Russia. The researchers consider technological, economic and organizational problems of the arrangement of transport corridors in Russia. It is noted that heavy operating costs are associated with empty mileage of rail cars, which are difficult to change [2].

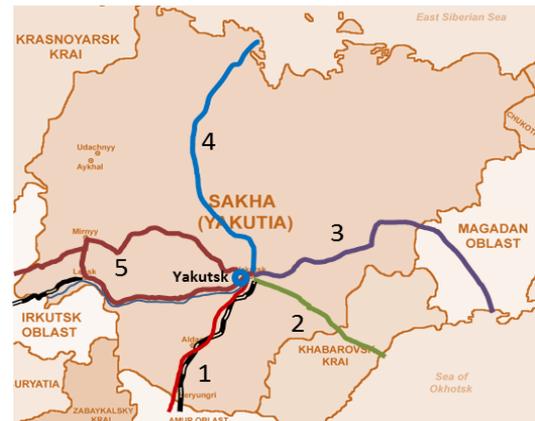
Several modes of transport are often used in transport corridors. Most research in the field of intermodal transport focuses on modelling of intermodal systems, there are case studies on the macro and micro-economic levels. Analysis of causes for selecting transport modes is important in intermodal transport [3]. At the same time, many authors point out that the lack of interaction between different modes of transport causes inefficient competition.

The national model of freight transport demand in South Africa is also of interest, taking into account the logistics costs. Regional specific features impose their conditions on the functioning model of the transport corridor [4].

Certainly, any changes in the transport conditions of the region can influence on it and adjacent regions [5]: the example of Greece shows changes in the foreign trade [6].

This study deals with issues of formation of an effective model of the transport corridor in the Republic of Sakha (Yakutia), one of the most complex and specific regions of Russia.

The socio-economic development and life's activity of the north-eastern region of Russia depends largely on the state and efficiency of transport performance. Yakutia is one of the regions with the most extensive territory, extremely cold climate, where winter temperatures can drop to  $-60-70^{\circ}\text{C}$ . The arrangement of public transportation in hard-to-reach and extremely cold regions of the Arctic is an important topic discussed at various sites for the development of the transport system in Russia.



1 - South corridor 2 – Ayan’s corridor  
3 - East corridor; 4 - Arctic corridor;  
5- Lena-Vilyui ring

Fig. 1. Scheme of projected transport corridors in the Republic of Sakha (Yakutia).

In 2016, the "Strategy for Socio-Economic Development of the Republic of Sakha (Yakutia) until 2030 with the definition of the target vision up to 2050" (hereinafter - the Strategy) was developed, which identifies key projects and areas for long-term socio-economic development of the Republic of Sakha (Yakutia) [7]. The strategy provides for a

set of projects to strengthen the framework for the spatial development of the republic. The development of transport routes involves five areas, including the Lena-Vilyuysk ring: Yakutsk – Pokrovsk – Olekminsk – Lensk – Mirny – Suntar – Nyurba – Vilyuysk – Yakutsk with access to Irkutsk (Fig. 1).

The transport corridor that will connect the Western and Central areas will include highways in the form of the "Viluy" federal road, the "Umnas" regional traffic road and also the Lena and Viluy rivers with associated infrastructure. It is assumed that the transport and economic corridor will provide closer sustainable socio-economic relations between the two economic areas: Central and Western (table 1). Along this thruway there are such growth zones as: Lensk, Mirny, Suntar, Nyurba, Vilyuysk, Verkhnevilyuysk.

TABLE I. CHARACTERISTICS OF THE PROPOSED TRANSPORT CORRIDORS

No	The name of the corridor	Highway	Length, km	Terminal point
1	South corridor	Highway Yakutsk-Aldan-Neryungri-Tynda; railroad Nizhniy Bestyakh-Aldan-Neryungri	1157	Tynda railway station
2	Ayan's corridor	Road Yakutsk-Amga-Ayan	1261	sea Port of Ayan
3	East corridor	Road Yakutsk-Khandyga-Magadan	2032	sea Port of Magadan
4	Arctic corridor	Lena river, access to the Northern Sea Route.	1703	sea Port of Tiksi
5	Lena-Vilyui ring	Road Yakutsk-Vilyuisk-Mirnyi; Road Yakutsk-Olekminsk-Lensk.	1409	the river Port of Ust' -Kut

The arrangement of a regional transport area predetermines the development of a conceptual construct with the aim of developing the most accurate solutions. According to the definition of a number of researchers, the term "transport corridor" is understood to be a totality of all types of main transport with associated infrastructure, operating in a certain direction to provide transportation of a specific cargo traffic (passenger traffic) [8]. In the transport corridors, the requirements for the transportation process, the parameters are unified. The development of generic requirements is based on the digitalization of processes and information exchange [9]. The main purpose of creating a transport corridor is to accelerate cargo traffic (passenger traffic) by ensuring the accurate and well coordinated work of all participants of the transport corridor. If there are duplicate traffic arteries in the transport corridor, an additional economic effect arises due to the redistribution of cargo traffic and the acceleration of the turnover rate of the commodity weights.

**II. RESEARCH METHODOLOGY**

The following methods were applied in the course of this study: mathematical modeling, comparative economic analysis of the effectiveness of different options, expert and predictive appraisals with regard to influence of business and natural climatic conditions of the transport operation. In solving the

problems of optimization of delivery schemes, a multivariate approach was used, focused on the use of existing and promising transport directions.

Industrial enterprises in Western Yakutia are hard-to-reach in terms of transportation. Their location is far from the places of settlement, the delivery of materials, equipment, machinery and other cargoes is carried out by providers of seasonal transport according to rather extensive and multistage flow charts. The construction of transportation facilities in the North is much more expensive. Additionally, high capital costs entail higher investments into operation of transport facilities. Therefore, the choice of optimal traffic flow charts for the delivery of cargoes to industrial facilities with regard to new transport corridors is important today.

The total distance of the transport corridor "Lensk – Mirny – Suntar – Nyurba – Vilyuysk – Yakutsk" is 1409 km. Considering the calendar time of the operation of ice and ferry crossings across the Viluy, Markha, Tyukian and Tannary rivers on the sections of the "Viluy" federal road, the uninterrupted communication time along the transport corridor is currently 259 days (Table 2). In the transitional period of the formation of the transport corridor, it is necessary to use progressive methods of arranging the long-term action winter roads, both in organizational and in technical aspects [10].

TABLE II. LIFE-SPAN OF THE TRANSPORT AND ECONOMIC CORRIDOR "LENSK – MIRNY – SUNTAR – NYURBA – VILYUYSK – YAKUTSK"

Traffic flow chart	Distance, km	Ferry/ice crossing	Average operating time of ferry crossings	Average operating time of ice crossings
Lensk – Mirny	234	-	-	-
Mirny – Suntar	219	over the Viluy river, the 1048th km over the Viluy river, the 956th km	from June 15 to October 05	from November 15 to April 15
Suntar – Nyurba	167	over the Viluy river, the 808th km	from June 15 to October 05	from November 15 to April 15
Nyurba – Vilyuisk	214	over the Markha river, the 752nd km over the Tyukian river, the 702nd km over the Viluy river, the 660th km pontoon crossing over the Chybyda river, the 609th km	from June 15 to October 05	from November 15 to April 15
Vilyuisk - Yakutsk	575	pontoon crossing over the Tangnary river, the 456th km	from June 15 to October 05	from November 15 to April 15

Currently, the delivery of cargoes to Western Yakutia is carried out using traffic flow charts including two seasonal sections: river/ice crossings and winter roads, which are the most expensive in terms of the total logistic costs.

The specified features of cargo delivery dictate the need for concurrence, clear arrangement of all services

(transportation, information, financial, etc.) within the short operating period of transportation networks [11].

Evaluation of variant calculations is carried out at a minimum of logistics costs (C) for the delivery of 1 tonne of cargo:

$$C_i = CE_i / W_j, \text{ roubles/ton} \quad (1)$$

where  $CE_i$  - costs of the enterprise for the delivery of the annual volume (W) of cargo (j) on the i-th transport traffic.

$$CE_i = CT_i + R^{im}_i + K_i * q, \text{ roubles} \quad (2)$$

where  $CT_i$  is the amount of current expenses under the i-th transport scheme.

$R^{im}_i$ -economic losses on "necrosis" of the cargo mass (or costs of immobilization of material resources) for the period of stay in the sphere of circulation under the i-th transport scheme;

$K_i$  - the amount of capital investment in the i-th transport scheme;

$q$  - the rate of refinancing of the Central Bank of the Russian Federation.

Solving the transportation problem concerning the choice of a cargo delivery pattern includes not only minimum transportation charges (CT) for operating expenses for delivery (D), storage (S), loading/unloading (L), but also operating expenses for maintenance of the infrastructure (I) related to cargo delivery:

$$CT_i = \Sigma(D_{ij} + S_{ij} + L_{ij} + I_{ij}), \text{ roubles}, \quad (3)$$

where i - transport scheme,  
j - type of cargo.

Expenses for immobilization of physical resources ( $R^{im}$ ) for the period ( $T_{co}$ ) when the cargo amount (W) is kept in circulation:

$$R^{im}_i = (P * W + C_i) * d * T_{co} / 360, \text{ roubles}, \quad (4)$$

where d - is the interest rate for a loan for cargoes in transit and transportation;

P - is a wholesale price for 1 tonne of the shipped cargo, million roubles.

The total residence time of the cargo mass in the sphere of circulation is calculated by the formula:

$$T_{so} = t + T^s_{so} + T^m_{so} + T^f_{so}, \text{ days}' \quad (5)$$

where

t - travel time (day);

$T^s_{so}$  - average stay time of 1 ton of cargo at the initial point of delivery (day);

$T^m_{so}$  - average stay time of 1 ton of cargo in the intermediate point of delivery (day);

$T^f_{so}$  - the average residence time of 1 ton of cargo at the final point of delivery (day).

The choice of the optimal traffic flow chart for the delivery of cargoes covers a set of issues related to the composition and characteristics of the facilities included into the system, specific operating conditions, technical, economic and performance parameters of their operation, the optimality criterion, the chosen economic and mathematical model that adequately reflects the real situation, the choice of methods for solving tasks in hand [12]. Almost all options of the considered traffic flow charts provide for the need to concentrate material values in the form of stocks. Graphical results of studies of the flow charts, taking into account the peculiar features, can be reflected in the traffic schedule of the aggregate stock along the logistic chain.

Fig. 2 and 3 clearly show the difference in the stock amount for seasonal modes of delivery and the involvement of the year-round section of the traffic road, thus providing for substantial savings on operating assets and money-and-credit resources of the enterprise.

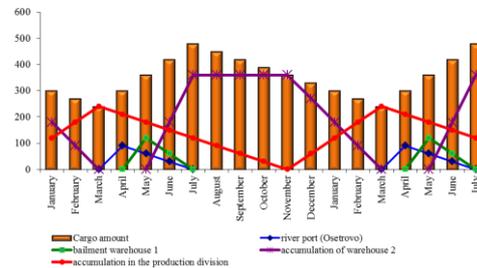


Fig. 2. Stock movement by the pattern: river harbor – winter road.

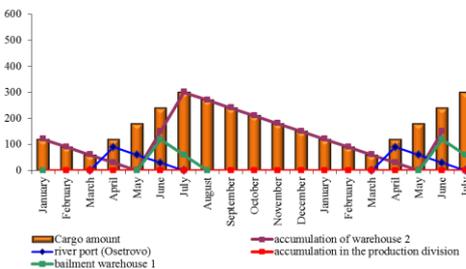


Fig. 3. Stock movement by the pattern: river harbor – motor road.

One of the key issues is the determination of the value of stocks related to the seasonality of the work of traffic flow charts' sections. Prior to the opening of traffic on a seasonal section, a certain stock should be accumulated at the departure point to ensure an uninterrupted shipment throughout the period of its operation. Depending on the specific conditions and delivery schemes, the guideline value of stocks can be up to 360 days and more, both at the arrival points and at the deposit points (for example, in the Arctic Regions). The stocks

amount at each point will determine the amount of required capital investment in the construction of storage tanks and current storage costs.

Costs associated with stocks are divided into three components:

- The costs for immobilization of funds in stocks, which are the valuation base of the funds mass seized for a certain period from the production processes;
- The cost for creating the facilities of supply and marketing organizations;
- The current cost for stock keeping.

The combination of these elements gives sufficiently complete economic characteristics of the costs associated to the need to create stocks and keep them.

In optimizing the logistics activity of the enterprise, it is required to increase the accuracy of analysis and assessment of logistics processes: supply, storage and transportation of product flows. The limited transport accessibility of the territory imposes the specific arrangement of activities and logistics of all enterprises of the region, which have to keep available higher stock levels. Application of logistics problem-solving methods makes it possible to elaborate the efficient cargo delivery patterns, determine the most favourable solutions for development of the transport infrastructure, which may improve the economic outcomes of the company's transport activity.

### III. CARGO TRAFFIC FORECAST AND RAILWAY CONSTRUCTION PROJECTS IN WESTERN YAKUTIA

#### A. Cargo Traffic Forecast in Western Yakutia.

Completion of the construction of the Viluy traffic road provides the republic access to the Baikal-Amur railway line, which completely changes the traffic flow charts of cargo delivery to Western Yakutia and increases its level of transport accessibility to 98%. We have developed traffic flow charts of cargo delivery to the municipal areas of Western Yakutia when putting into operation the Nizhny Bestyakh railway station. Calculations show that for a group of Western Yakutia regions river transport remains the most profitable upon the delivery of large volumes of cargo. For certain types of cargo, the retargeting from Lensk city to Yakutsk city is possible. New transport schemes for cargo delivery will significantly reduce overall logistics costs, that will allow the transport and economic corridor "Lensk – Mirny – Suntar – Nyurba – Vilyuysk – Yakutsk" to become the most competitive when choosing a route by carriers.

The implementation of major projects of oil and gas industry development will be accompanied by large volumes of cargo traffic for the needs of industrial enterprises in Western Yakutia. Estimates suggest that cargo traffic by all means of transport [13] is expected to increase up to 930 thousand tons per year. During the field development (2030) cargo traffic becomes stable at the level of 700-300 thousand tons per year. The range of the potential growth of the cargo base in the regions of Western Yakutia to support the work of

the production sector and newly formed industries is estimated at 2.5–1.6 million tons [14] (Fig. 4).

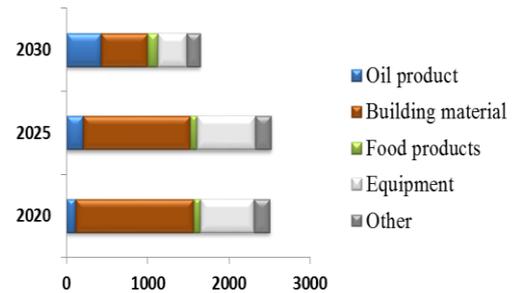


Fig. 4. Forecast of cargo delivery to the Western area of the Republic of Sakha (Yakutia), thousand tons.

The commencement of the iron-ore deposit development in the Olekminsky district will require the delivery of cargo in the volumes shown in Figure 5, which will mainly be carried out by rail from the Baikal-Amur Mainline (BAM) (Khani station). In the future, in this direction, an independent new direction of delivery will be formed, which will make additional adjustments to the distribution of cargo traffic by appointment to Olekminsky and adjacent districts of the Republic [15].

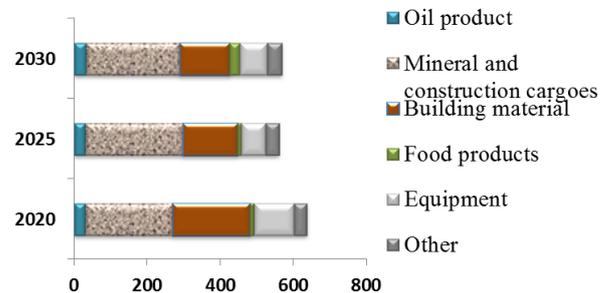


Fig. 5. Structure of the estimated volumes of cargo delivery to Olekminsky district, thousand tons.

The volume of cargo handling in the Lensk port in recent years has made 300-500 thousand tons/year, the maximum processing volumes have reached 1.0 million tons/year. The main cargoes on arrival are technical cargoes and building materials, cement, coal, containers; on departure – containers, timber and lumber. Cargo traffic arriving to Lensk city from railway transport in Ust-Kut (4 days of journey) makes up 70% of the volume of all cargo transportation and 30% of cargo arrives from Yakutsk city (6 days of journey) (Fig. 6).

The effectiveness of these areas can be considered in conjunction with solving the problems of forming year-round transport communications and performing a complex of works on water transport to deepen the channel in the upper section of the Lena river and cargo fleet upgrade. Potential opportunities for the transportation of estimated cargo volumes are permissible under the condition of a radical upgrade, capacity expansion, providing with modern equipment, the availability of a sufficient number of specialized vessels [16, 17].

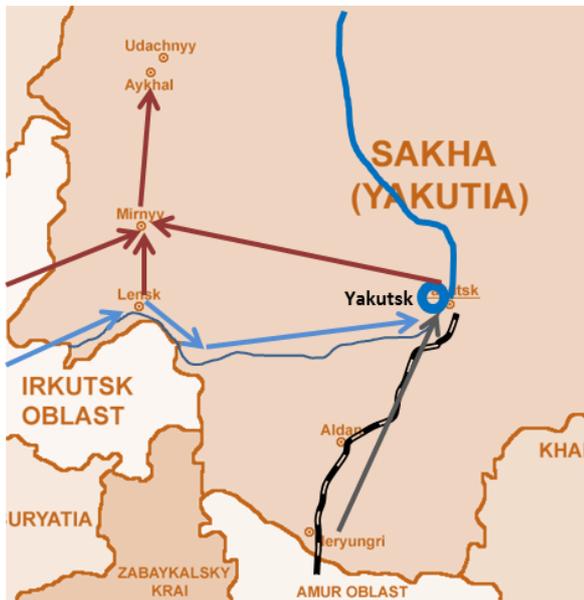


Fig. 6. Promising directions of cargo traffic in the area of the transport corridor.

Necessary measures, including the construction of a modern and new-generation fleet, the creation of navigation and service infrastructure, and the safety-related systems need to start to implement right now. Improving the level of arrangement of transportation by water transport with the aim of reducing the operating range, downtime for loading and unloading is up-to-date with low volumes of cargo traffic. According to the researchers [14, 18], the use of tug-barge trains, when there are 2-3 barges per a pushboat, multiply increases the load and allows to reach the maximum capacity. This practice is rarely used in Russia, moreover, most of the new shipbuilding is represented not by composite vessels (pushboat+barge), but by tankers of the classical type [19]. Under the conditions of low-water periods of the Verkhnelenski basin, this arrangement of transportation is highly relevant.

On the territory of Western Yakutia, the main trans-shipment point is Lensk city, however, it does not use fully logistic technologies, the activity is limited to the functions of the trans-shipment transport hub. Technological processes of the material resources to provide industry and population will change with introduction of new sections of the transport system. It is noted that the transport hubs on the basis of river ports can become logistic trimodal centres for cargo distribution, performing the functions of connecting water, as well as railway and vehicular transport [20]. After completion of the implementation of the planned Strategy [8] activities, the Lena transport hub will assume importance of a multimodal transport and logistics centre, its influence will spread to the Western group of regions, in part to the Viluy group of districts and regions of the oil and gas industry development. Let us consider the projected railway lines in this region in more detail.

**B. Construction of the Khani - Olekminsk Railway Line.**

This railway line is associated with the development of a field located in the Olekminsky district. As noted by experts [13, 20], the economic efficiency of the development of the Tarynnakhskoye deposit is rather high and is at the level of efficiency of the main iron-ore deposits in Russia. With a production volume of 23 million tons of ore per year, it is possible to produce about 7.3 million tons of concentrate with iron content of 68.5% and to process the concentrate into 6.8 million tons of pellets. Simultaneously building rubble can be mined on it in the amount of up to 2 million m<sup>3</sup> per year. After the start of the washing plant and the commencement of development of other deposits, its productivity can grow up to 14.6 million tons of iron-ore concentrate per year, which is expected to be processed into pellets in the amount of 13.5 million tons per year. The labour force of the mining and processing plant once fully operational will reach 13.8 thousand people [15].

In order to ensure year-round accessways to the fields, it is planned to build a railway line from the Khani station (BAM) to Olekminsk with a length of 450 km, initially implementing the first stage of the road: Khani – Tarynnakhsky MPP with a length of 189 km (table 3).

TABLE III. RAILWAY CONSTRUCTION PROJECTS IN WESTERN YAKUTIA.

Project title	Length, km	Construction period, years	Purpose of the construction
Federal railway line Khani - Olekminsk	450	2025-2030	The formation of year-round access ways; delivery of cargoes and export of finished products of enterprises of iron and non-ferrous metallurgy, wood processing enterprises, agriculture.
including Khani - Tarynnakhsky MPP	189	2025-2030	The formation of year-round access ways; delivery of cargoes and export of finished products of enterprises of iron and non-ferrous metallurgy
Lena-Nepa-Lensk	1100	2016 - 2030	Creating a backbone network for the development of oil fields and forest resources

**C. Construction of the railway "Ust-Kut - Nepa - Lensk"**

The construction project of the "Ust-Kut – Nepa – Lensk" cargo-generating railway with a length of 1100 km is associated with the prospect of development of oil-and-gas bearing fields in Eastern Siberia and Western Yakutia. The formation of a complex of oil and gas, gas processing and gas chemical facilities in Western Yakutia is associated with the involvement in economic turnover and expansion of the production of a number of fields in the Nepsko-Botuobinskaya oil and gas area: Talakanskoe, Srednebotuobinskoe, Chayandinskoe, Verkhnechonskoe, Vakunayskoe and others. According to the projection data, the products of the enterprises of the oil and gas processing industry will be delivered by railway, the total volume of cargo transportation in both directions will reach 1.8 million tons.

The construction of the "Ust-Kut (Lena) – Nepa – Lensk" railway is necessary not only for the development of oil, gas and condensate fields, but also for the development of forest resources. The design felling volume of commercial timber in the Lensky District is 4.2 million m<sup>3</sup>. It is planned to create saw-mill enterprises, as well as enterprises for production fuel briquettes from wood waste, the production of plate materials, the production of cardboard products, etc. The "Lena-Nepa-Vitim-Lensk" railway will connect the Irkutsk Region and Yakutia, and will subsequently undertake the transportation of cargoes that are currently transported by river transport. The new railway line will provide the northern delivery, eliminating the problems of shallow water in the upper section of the Lena river.

IV. RESULTS

The completion of the reconstruction of the Viluy federal highway and the construction of bridges are activating year-round cargo delivery for consumers of the Viluy group of districts. Along with the fact that the transport corridors are considered as a way to strengthen the unity of the economic space of the country, to develop entrepreneurship and inter-regional cooperation [21], the threats that may lead to unforeseen consequences are identified (Table 4).

TABLE IV. SWOT-ANALYSIS OF THE TRANSPORT AND ECONOMIC CORRIDOR "LENSK – MIRNY – SUNTAR – NYURBA – VILUYSK – YAKUTSK"

Strong points	Weakness
<ul style="list-style-type: none"> <li>- the main transport artery of Western Yakutia with stable cargo traffic;</li> <li>- the increase in the level of transport accessibility of territories belonging to the group of Western Yakutia;</li> <li>- the year-round access to the Baikal-Amur Mainline Railway;</li> <li>- improving the quality of life of the population;</li> <li>- competitive advantage in transportation: reducing the time of cargo storage and delivery, reducing the time of cargo delivery.</li> </ul>	<ul style="list-style-type: none"> <li>- seasonal road sections: ice and ferry crossings;</li> <li>- washout of soft spots of public roads during a period of heavy precipitation;</li> <li>- low level of provision of transport corridor with motorway service and infrastructure;</li> <li>- weak cellular signal;</li> <li>- lack of economic incentives for doing business in the field of transport and motorway service.</li> <li>- due to climatic changes, the increase of the interseasonal breaks periods is possible;</li> </ul>
Opportunities	Threats
<ul style="list-style-type: none"> <li>- retargeting of navigational savings of business entities in order to reduce logistics costs;</li> <li>- reconstruction of bridge crossings, overhaul of linear-type facilities and bridges;</li> <li>- elimination of infrastructure constraints;</li> <li>- development of entrepreneurship in the field of motorway service;</li> </ul>	<ul style="list-style-type: none"> <li>- possible restrictions on the movement on road sections adjacent to the routes of oil and gas pipelines;</li> <li>- lack of financial tools to maintain the roads within specifications;</li> <li>- reduction of tax revenues due to the overflow of the freight and passenger market to transport companies of neighbouring regions with more favourable economic conditions for doing business.</li> </ul>

One of the possible areas of administrative incentives [16, 22] could be a reduction in the transportation tax, which is currently not favourable to doing business (Fig. 7).

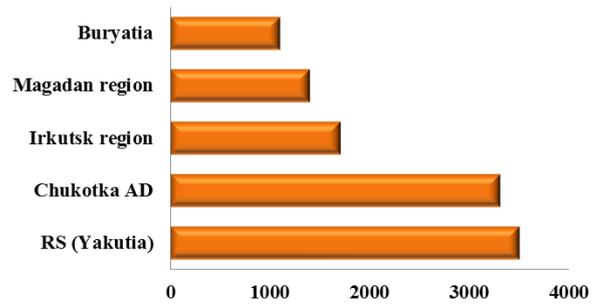


Fig. 7. Comparison of the cost of a patent for the provision of services for the carriage of goods by road (in rubles for 1 month for 1 truck, rub.) [23].

In the economic and social development of the region (or several regions), the transport and economic corridor will have to play a backbone role. Historically, transport communications (rivers, highroads) became natural places of attraction, along which settlements were located, industry developed. Let us cite as an example the creation of the Irkutsk-Yakut post road, the formation of which was stimulated by the introduction of various privileges: tax exemption (tribute), free provision of land, etc. Despite the inconsistency of the introduction of those preferential conditions, it played a certain role in the economically very difficult management of the postal service in rough environments of Yakutia [24, 25].

V. SUMMARY

The justification of the significance of the development of the transport corridor for the region is considered as a way to strengthen the unity of the economic space, improve interregional transport and economic relations, to develop entrepreneurship and inter-regional cooperation. Threats that may lead to unforeseen consequences are identified. The long-term dynamic process of spatial development can be regulated using strategic planning methods and innovative development policies.

According to the researchers, the efficiency of this transport and economic corridor is achieved due to the advantages listed above, plus the effect of the interaction of the parties interested in its creation [16]. The interaction of the parties may be concluded in the regulation of transport, trade and economic activity [25, 26]. The creation of a transport and economic corridor implies, in addition to solving transport and technological problems, the implementation of the following:

- the introduction of favourable administrative regimes;
- introduction of tax preferences;
- providing a range of additional logistics services.

The key directions of transport corridors development, from the perspective of the conditions of the Republic of Sakha (Yakutia), are:

- balanced development of sections of the transport corridor, the lack of infrastructure constraints;

- development of transport and logistics infrastructure;
- elimination of technological barriers associated with the omission of additional cargo traffics;
- introduction of the high-speed transportation technologies;
- formation of competitive tariff policy for transportation of cargoes/ passengers;
- development of financial mechanisms for breakeven operation of carriage providers and related services.

The arrangement of the transport and economic corridor implies, in addition to solving transport and technological problems, the provision of a complex of additional logistics services that contribute both to doing business in the field of transport services and commodity exchange between regions and the development of the economy of the region where this corridor is located. The formation of the transport and economic corridor will contribute to the expansion and intensification of inter-regional cooperation, increasing the mobility of the population.

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