The Northern Sea Route in the system of international transport corridors as a logistic basis for the development of Arctic resources

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Abstract. The paper assesses the significance of the Northern Sea Route for the development of Arctic resources and discusses the methodology for comparing potential transport corridors connecting Northern Europe and Southeast Asia. Due to the characteristics of the transport routes, including the length, travel time and fuel consumption, the authors were able to state the contents of the methodological analysis in several stages, at the end of which, using the optimal mathematical model, autocorrelation and multicollinear analysis, the conditional variance of a number of resulting indicators was estimated and the decision was made about using the model of autoregressive conditional heteroscedasticity (Arch) for forecasting. The paper contains the conclusion that the Northern Sea Route (NSR) is the most attractive waterway between Northern Europe and Southeast Asia, not only due to its distance and geographical factors, but also considering the economic feasibility of using this route for transportation of extracted minerals.

1. Introduction

The Arctic Ocean with its transport options and subsoil resources both on the ocean shelf and near the coastal areas means a lot to the economy of the Russian Federation in the bright prospects of its development. So, for example, huge reserves of natural resources in the form of oil and gas are discovered in the shelf zone of the seas of the Arctic Ocean, and there are rich ore and coal deposits in the bowels of the continent [1].

The Arctic Ocean plays a particularly important role in various components of the economic activity of coastal regions. The resources necessary for production operation are delivered across the Arctic Ocean and the extracted minerals and finished goods – results of economic activities of enterprises are exported. Figure 1 shows the main oil and gas fields in the Arctic zone.

2. The potential international transport corridors in the Arctic Ocean and their alternatives

The assessment of specific priority infrastructure projects in the NSR system should be based on the benefits of the meridian conjugation of these corridors. In this case, the effect of synergy will be taken into account, since external alternative directions of development can make up a single and complementary system [2].
Figure 1. Oil and gas deposits in the Arctic.

There is an opportunity along the entire length of the Arctic Ocean to lay two of the most significant and large-scale international transport corridors – the Northern Sea Route along the coast of Russia and the Northwest Passage along the coast of Canada. They are an alternative to the South Sea Route through the Suez Canal. The Northern Sea Route in conjunction with the northeastern and northwestern Arctic corridors is presented in figure 2.

The Northern Sea Route is the shortest waterway between Northern Europe and Southeast Asia. The length from Northern Europe when passing through the seas of the Barents, Kara, Laptev, East Siberian, Chukchee and Bering is 7.6 thousand nautical miles, while the route from Northern Europe to Southeast Asia through the Suez Canal will be 15.7 thousand miles, and when sailing from Northern Europe to Southeast Asia around Africa, it is needed to overcome 18.3 thousand nautical miles. But there is a main problem related to the fact that approximately 4.2 thousand nautical miles of the NSR are covered with ice. The passage of this segment accompanied by an icebreaker requires from 15 to 20 days [4].

The forecast regarding the prospects of the Arctic in terms of corridors for transportation for the next 10-20 years can be formed due to the following factors:

- due to climate warming on the Earth over the past 5–10 years, ice in the Arctic is constantly melting;
- Asia’s acute need for energy carriers makes the states of this region to look for new sources and faster ways to deliver energy carriers via the NSR;
- the Arctic has a great potential for tourism, fisheries and science;
- Russia’s growing role in the development of the region including the construction of nuclear and diesel icebreakers and ice class vessel [2].

2.1. Advantages of the Northern Sea Route in comparison with the Northwest corridor along the coast of Canada

Speaking about the role of Russia, it is worth noting that our country is trying to turn the Northern Sea Route into a transport highway competing with the Suez Canal. There are 4 icebreakers in the Arctic, and another one, the most advanced and efficient, is under construction [3]. Also along the NSR route from Chukotka to the Barents Sea nine rescue and fire-fighting centers are being created, equipped with helicopter equipment for prompt response and assistance.
2.2. Problems and barriers to the development of the Northern Sea Route

With all the advantages, there are a number of inconsistencies and problems. The fact is that by 2030 the North-West corridor will not be completely free of ice, but in 2030–2035 the ice complications will take place in the Russian part of the Arctic. The reason is cyclical climate change. Moreover, today the Northern Sea Route mainly carries coal, oil products and liquefied natural gas (LNG), that is, goods that are always in demand. At the same time, there are a lot of shortcomings in such transportations: high insurance costs, low ship speeds, the need to strictly comply with safety rules, high environmental risks, etc. For the optimal development of the route, powerful icebreakers and highly developed coastal infrastructure are needed. State bodies at the federal level and in those entities that are of great importance for the NSR should obviously jointly develop a real strategic program for the development of social infrastructure, identifying territorial priorities for creating a regional network of objects of this infrastructure [5].

3. Methods of comparing transport corridors

At the first stage, the goal of the analysis is formulated as consideration of international transport corridors, the choice of a mathematical model that will describe the dependence of the Arctic between indicators, assess the degree of development of the corridor, and also allow transport corridors with each other to be compared.

The second stage is to justify the indicators. The resulting indicator – the volume of transit is selected. The article considers the mineral resources of the Arctic subsoil as priority cargoes. The

Figure 2. Northern Sea Route on the map of the Arctic region in the context of comparison with the North-East and North-West corridor.
indicators, that similarly described the processes under consideration, were chosen. These include the following indicators: gross domestic product; the number of ships/vessels passing through the channel, characterizing the intensity of the channel loading, its transit capabilities; the average cost of passage/transit through the channel characterizing the attractiveness of the channel in terms of the transit of goods through it.

At the third stage the information on the selected indicators was collected. Each indicator represents a time series. In the analysis of time series, stationary time series are important, the probabilistic properties of which do not change over time.

Therefore, at the fourth stage, the stationarity analysis of each time series was carried out. The stationary time series is characterized by the following four properties:

- the mathematical expectation of the stationary series \( E(y_t) \) is constant, i.e. the average value of the time series around which the levels change is a constant value;
- the dispersion of the stationary series is constant. It characterizes the variation in the levels of the time series relative to its average value;
- autocovariance of a stationary series with lag 1 is constant, i.e. the covariance between the values of \( x_t \) and \( x_{t+1} \), separated by an interval of 1 unit of time, for stationary series of autocovariance depends only on the value of lag 1;
- autocorrelation coefficients of the stationary series with lag 1 are constant. For time series that do not meet the specified properties, i.e. non-stationary, first-order differences were found. The transformed series were assumed to be stationary.

At the fifth stage, a model was selected displaying the transport corridor. The model consisted of one equation:

\[
Y_t = a_0 + a_1 \times y_{t-1} + a_2 \times y_{t-2} + b_j \times x^k_{t-j} + \Delta
\]  

In equation (1) \( Y_t \) is the indicator of the transit volume in the period time \( t \), and, \( y_{t-1}, y_{t-2} \) is the indicator of the volume of transit in the period of time \( t - 1, t - 2 \). The variables \( x^k_{t-j} \) in equation (1) are individual for each of the transport corridors:

- for the Southern Sea Route: \( x^1_{t-j} \) the EU GDP, \( x^2_{t-j} \) – the number of vessels passing through the canal, \( x^3_{t-j} \) – the average cost of passage through the canal.
- for the Trans-Siberian Railway: \( x^1_{t-j} \) – GDP of the EU, \( x^2_{t} \) – the number of containers passing through the Trans-Siberian Railway, \( x^3_{t-j} \) – average costs for transit along the Trans-Siberian Railway.
- for the Northern Sea Route: \( x^1_{t-j} \) – the EU GDP, \( x^2_{t-j} \) – the number of vessels passing through the route, \( x^3_{t-j} \) – the average cost of passage along the route.
- for the Northwest corridor: \( x^1_{t-j} \) – Canada’s GDP, \( x^2_{t-j} \) – the number of vessels passing through the corridor, \( x^3_{t-j} \) is the average cost of passage along the corridor.

At the sixth stage, only the autocorrelation coefficients between the northern rows \( y_t \) and \( y_{t-1} \) and the correlation coefficients between the rows \( y_t \) and \( x^k_{t-j} \) were determined. Based on the obtained values of the correlation coefficients in the model, the corresponding levels of the time series were extremely left. The statistical significance of the correlation coefficients was checked using Student’s t-test [6].

At the seventh stage, multicollinear analysis was performed, i.e. the pair correlation coefficients between influencing indicators were determined.

If the relationship between the two transport indicators is significant (> |0.9|), then one of them can be eliminated, which will simplify the analysis. The statistical significance of the correlation coefficients was checked using Student’s t-test.

At the eighth stage, using the module “regression analysis” SPSS-19, the coefficients of the equations were found. The statistical significance of the equations was checked using the F-test. The statistical significance of the equations coefficients was checked using the Student’s t-test.
At the ninth stage, the conditional dispersion of series of the resulting indicator was estimated and a decision was made to use the model of autoregressive conditional heteroscedasticity (ARCH) for forecasting, and the coefficients of the Arch model were also found [7].

Autoregressive conditional heteroscedasticity (ARCH – Auto Regressive Conditional Heteroscedasticity) is a model used in econometrics for analyzing time series in which the conditional (by the past values of the series) dispersion of the series depends on the past values of the series, past values of these dispersions and other factors.

The autoregressive conditional heteroscedasticity model is used in econometrics to analyze time series in which the conditional dispersion of a series depends on past values of the series and past values of these dispersion. In our case, high coefficients of determination indicate a strong dependence and the need for a rectifying analysis. When assessing regression models, this circumstance is interpreted as the correspondence of the model to the data.

When conducting a regression analysis, after the regression coefficients are found, the calculated value of Y series and the difference between the actual value of Y and the calculated value for each year in the ninth period from 1 to T can be determined, thus, obtaining a new time series $U^2_t$.

Let us imagine a model of ARCH in the form:

$$U^2_t = \left( c_0 + c_1 \times U^2_{t-1} + c_2 \times U^2_{t-2} + c_3 \times U^2_{t-3} \right)^{1/2}$$

where $U^2_t$ is the square of the remainder at time $t$; $t$ is a point of time that takes the values from 1 to T; $c_0, c_1, ..., c_n$ are the coefficients of the ARCH model. In our case, $U^2_t$ is the square of the difference $Y_t$ actual – $Y_{pt}$ calculated. That is, for the further work, we will need the time series $U^2_t$, which we can get by raising to the square the values $(Y_t - Y_{pt})$. At the tenth stage, the forecast value for a year or two or more can be determined. At the eleventh stage, corridors are compared and conclusions are drawn. Thus, using data that is in the public domain, we can give an equation, the principle of which is described above, for each sea corridor in the following form:

South Sea Route
$$U^2_t = (4366.57 + 0.348 \times U^2_{t-1} - 0.083 \times U^2_{t-2} - 0.111 \times U^2_{t-3})^{1/2}$$
Trans-Siberian Railway
$$U^2_t = (4370139040.447 + 0.501 \times U^2_{t-1} - 0.401 \times U^2_{t-2} - 0.08 \times U^2_{t-3})^{1/2}$$
Northern Sea Route
$$U^2_t = (0.120 + 0.329 \times U^2_{t-1} - 0.396 \times U^2_{t-2} - 0.350 \times U^2_{t-3})^{1/2}$$
Northwest Corridor
$$U^2_t = (5.424 + 0.142 \times U^2_{t-1} - 0.140 \times U^2_{t-2} + 0 \times U^2_{t-3})^{1/2}$$

4. Conclusion
A comparison of various international transport corridors (ITC) for the movement of mineral resources and hydrocarbons is carried out. The most important ITC can be considered the Southern Sea Route – through the Suez Canal. Potential ITCs that might pass through the territory of Russia include the Trans-Siberian Railway and the Northern Sea Route. The NSR is the shortest route and the shortest sea transit corridor between Northern Europe and the Asia-Pacific region, which runs along the seas of the Arctic Ocean. At the same time, it is necessary to assess the capacity of local mineral markets to predict the long-term utilization of the NSR [8].

A methodology for the comparative analysis of ITC was developed. The methodology involves the collection of information, model selection, dispersion, correlation, regression analysis. The choice of function is made – the autoregressive model with a distributed lag is selected. The degree of tightness of the relationship between the resulting indicators and factors is determined, using the dispersion analysis, the degree of influence of effecting factors on the transit volume is defined. The significance of the analysis performed is verified – the model is recognized as significant, the effecting factors are
important for the resulting indicators. The degree of accuracy of the model is checked by the time period. The proposed model can become the basis for the justification of investment projects for the development of Arctic mineral resources taking into account the logistical competitiveness of the Northern Sea Route in the system of international transport corridors.

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