

# Improvement of port operations efficiency of the Arctic Maritime Transport Route

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**Abstract**— the Russian Federation Government Program "Transport System Development" includes different activities on technical maintenance of water routes and hydraulic structures, maritime traffic search-and-rescue aid, shipping navigation and surveying facilities for the Northern Sea Route lines. The aim of this work is studying year-round performance efficiency improvement of the Russian Arctic Maritime Transport Route (AMTR) including shore infrastructure which affects reducing port operations during transportation of cargo. In order to achieve this goal comparative analysis of implementation of investment projects for shore infrastructure development is presented in the article. There is an example of an innovative project for introduction of an automated loading facility. Based on the given data on activities for improvement of port operations efficiency and according to experts about 20% improvement is possible.

**Keywords**—transport route, Arctic Zone of Russia, industry, maritime transport, sea ports, infrastructure

## I. INTRODUCTION

Russia faces an important task of developing the Arctic Zone and the Northern Sea Route and this problem should be solved based on the general principle of strategic planning: from the future to the present, and this principle fundamentally differs from the principle of forward planning: from the past to the future.

Let's define the mission and objectives of developing northern maritime transport infrastructure of Russia. Mission is achieving smooth activity of the Arctic Zone territories. Objective is providing year-round shipping traffic along the Northern Sea Route lines within the established time limits.

The aim of this work is to study year-round performance efficiency improvement of the Russian Arctic Maritime Transport Route (AMTR).

Sea transport is a very important sustaining means of many northern territories of the Russian Federation. Thanks to sea transportation which provides delivery of necessary products and removal of new outcomes of productive activity there exists year-round extraction, production and exportation of oil, nickel, cuprum, tin and many other natural resources.

The Russian Federation Government Program "Transport System Development" (subprogram "Marine and Inland Water Transport") includes different activities on technical maintenance of water routes and hydraulic structures,

maritime traffic search-and-rescue aid, shipping navigation and surveying facilities for the Northern Sea Route lines.

According to the program it is planned to increase the volume of transportation along the Northern Sea Route up to 63.7 mln tons by 2020, the project also provides increasing the level of technical equipment capability of the Northern Sea Route lines up to 40.5%. The program also provides activities on developing major sea ports including Arkhangelsk and Murmansk. [1].

Improvement of economical efficiency of transportation with simultaneous sharp increase in the volume of cargo transportation along the Northern Sea Route can be achieved only by simultaneous increase of cargo turnover and reduction of transportation unitary cost. [3, 6]

Quite a number of publications are devoted to prospects, objectives and problems of developing the maritime transportation system of the Northern Sea Route. A substantial contribution into in-depth study of this question was made by Federal State Unitary Enterprise "Krylov State Research Center", Public Company "Central Design Bureau Iceberg", Joint Stock Corporation "Shipbuilding and Ship repair Technology Center", CNIIMF, Russian Transport Academy, Admiral Makarov State University of Maritime and Inland Shipping, and others. Among different studies on the subject one could lay emphasis on works of the following scientists: A.A. Aleksashin, E.M. Apollonov, S.I. Bujanov, A.V. Istomin, Yu.F. Lukin, V.M. Pashin, V.N. Polovinkin, V.I. Peresyphkin, V.V. Ruksha, Tsoy L.G., etc.

Analysis and generalization of scientific works of foreign and native authors on the subject, despite their broad spectrum, shows that in scientific literature the problem of managing strategic planning of development of the Arctic Maritime Transport Route amid global competition has been underreported to this date.

## II. MATERIALS AND METHODS

Dynamics of development of the Arctic Maritime Transport Route stated by decision documents can be achieved by providing distinct correlation between state strategic tasks and specific ship building tasks including validity of claims to marine facilities and optimization of their cost indicators.

Program-targeted goal planning may serve as a methodological basis for this correlation.

The article is based on data of the Federal State Statistics Service, the Federal Agency of Subsurface Resources Management of the RF, the RF Ministry of Transportation, Rosatomflot, Public Company Sovcomflot, Rosmorport, Gecon Analyst Company.

### III. RESULTS

The strategy of ship-building development up to 2020 and further [2] includes separate economical and technical indicator values for transport maritime objects of the Northern Sea Route (table 1):

TABLE I. PROJECTED CHANGES OF INDICATOR VALUES.

Indicator value	Change
reduction of power consumption in the course of maintenance	10 - 15%;
reduction of weight characteristics	10 - 15%
improvement in icebreaking capability	20 - 25%
improvement in economic efficiency of transportation	by a factor of 1.2-1.4

Therefore we admit that the indicator value of transportation activities efficiency along the North Sea Route, “Эп”, is equal to 1.4.

The basic requirement of the projected dynamics of the transport system development is the indicator “Increase in the volume of cargo transportation along the Northern Sea Route up to 63.7 mln tons by 2020” stated in the Russian Federation Government Program “Transport System Development” [1].

Taking into account the target indicator - the volume of cargo transportation along the Northern Sea Route ( $V_{ГР}$ ) - it is suggested to take the following value as the indicator value of efficiency ( $\text{Эп}$ ):

$$\text{Эп} = V_{ГР} / C_{\Pi} \quad (1),$$

where:

$C_{\Pi}$  is total expenses of ship-owners and the State (yearly total costs).

Thus:

$$C_{\Pi} = V_{ГР} / \text{Эп} \quad (2).$$

As the costs can be divided into costs of movement operations,  $C_{ДВ}$ , and costs of port operations,  $C_{СТ}$ , then:

$$\text{Эп} = V_{ГР} / (C_{ДВ} + C_{СТ}) \quad (3).$$

Improvement of transportation efficiency and increase in the volume of cargo transportation are stated in the strategic plan of the Northern Sea Route development. Therefore, yearly costs of cargo transportation which correspond to the other preset parameters remain unknown.

Let us create a mathematic model of determining the specific quantity of costs which makes it possible to achieve the determined strategic goals.

$$X_1 * \text{Эп} = X_2 * V_{ГР} / X_3 * (C_{ДВ} + C_{СТ}) \quad (4)$$

where:

$X_1$  – coefficient of change of transportation efficiency;

$X_2$  – coefficient of change of cargo transportation volume;

$X_3$  – coefficient of change of yearly costs of cargo

transportation.

When coefficient values are equal to:  $X_1 = X_2 = X_3 = 1.0$  it is stated that the condition of variables included into the mathematical model corresponds to their current value.

Let us apply to formula 4 coefficient values which correspond to strategic plans.

$X_1 = 1.4$  (maximum value of planned increase in improvement of transportation along the Northern Sea Route efficiency);

$$X_2 = \frac{60 \text{ mln tons (planned volume of delivered cargo)}}{4 \text{ mln tons (current volume of delivered cargo)}} = 15;$$

$$X_3 = ? \quad X_3 * (C_{ДВ} + C_{СТ}) = 15 * V_{ГР} / 1,4 * \text{Эп}$$

Wherefrom:

$$X_3 = \frac{15 * V_{ГР}}{1,4 * \text{Эп} * (C_{ДВ} + C_{СТ})} = 11 * V_{ГР} / \text{Эп} * (C_{ДВ} + C_{СТ}) \quad (5)$$

Therefore, when the planned volume of delivered cargo increases up to 60 mln tons and cargo transportation efficiency increases by a factor of 1.4 it is required to decrease yearly specific transportation expenses by (11/15) nearly 25%.

Where  $X_1 = 1.2$  (minimum value of planned increase in improvement of transportation along the Northern Sea Route efficiency):

$$X_3 * (C_{ДВ} + C_{СТ}) = \frac{15 * V_{ГР}}{1,2 * \text{Эп}}$$

Wherefrom:

$$X_3 = 15 * V_{ГР} / 1,2 * \text{Эп} * (C_{ДВ} + C_{СТ}) = 12,5 * V_{ГР} / \text{Эп} * (C_{ДВ} + C_{СТ}) \quad (6).$$

Therefore, when the planned volume of delivered cargo increases up to 60 mln tons and cargo transportation efficiency increases by a factor of 1.2 it is required to decrease yearly specific transportation expenses by (12.5/15) nearly 17%.

$$C_{\Pi} = (C_{ДВ} + C_{СТ}) \quad (7).$$

Port operations cost is defined by being equipped with port infrastructure. Expert estimation has demonstrated that signification of movement operations within total costs is 0.7 and signification of port operations within total costs is 0.3.

Let us consider implementation of the project of an automated loading terminal (ALT) as an example of increase in port operations efficiency. The terminal is meant for transmitting oil-products from a shore-based terminal to oil tankers with a capacity of  $D = 90$  thousand t in ice conditions of the Northern Sea Route (NSR):

– distance from a shore tank to the ALT located at the depth of  $\approx 500$  m is about 5000 m;

– speed of oil-products pumping according to project data is  $V = 3000 \text{ m}^3/\text{hour}$  (time spent on full filling of an oil tanker is  $\approx 30$  hours);

– total pipeline length is  $\approx 5500 \text{ m}$ , length of the pipe from the ALT to the buoy of the second type (with a swivel) is  $\approx 450 \text{ m}$ ;

– length of a flexible oil-pumping pipe (e.g. 601AA for oil H\B 10 bar, 601AA152686EE0 ALFAGOMMA152 6 168 6.61 10 150 760 30 80 6.82) with a locking device [9] for filling a tanker is  $\approx 150 \text{ m}$  [11].

The absence of an ALT makes it necessary to use shallow-draft (bunker) tankers for loading large-capacity marine transport vessels.

Expenditures on freight of bunker tankers (BT) and icebreaker ships when reloading from an offshore tank farm – terminal (OTF) to an Aframax tanker is presented in table 2.

The average time for a bunker tanker (BT) to pass a track section of 5 km with an average speed of  $(6.4 \div 12.5 \text{ knots}) 10 \text{ knots}$  ( $V_{cp} = 1.85 * 10 = 18.5 \text{ km/hour}$ ) from an OTF to a high-capacity tanker, ice class, Aframax size, is equal to 0.27 hours. Therefore we can admit:  $T_n \approx 0.3$  hours.

Mooring of a bunker tanker to the oil terminal should be performed under the following conditions [7]:

- coming into the berth with extreme caution,
- in order to avoid impacting, rubbing, ship collision, pudding fenders should be used;
- the terminal berths should be equipped with properly functioning wooden or rubber fender guards.

The peculiarity of a tanker mooring to the terminal is that shipboard and shore pipelines must be joined: thus, well-coordinated work of tow boats, shore and shipboard line-handling crews under the guidance of a pilot is required. Pipeline fitting is performed with the help of shore hosing devices.

Cargo operations in the berthing facility are connected with the danger of polluting the water area with oil-products in case of connecting hoses blowout, deck scupper spillover of freight. For that matter, oil basin fencing devices are applied in oil harbors.

The time spent on mooring-unmooring (preparation for filling) of each bunker tanker using a tow boat in the *port*, is equal to [8]:  $T_{un} \approx 1.34$  hours.

The time spent on *harbor* mooring-unmooring of each bunker tanker with a high-capacity tanker is [8]:  $T_{up} \approx 1.34$  hours.

The speed of pumping oil *into a tanker* with 10000-17000 deadweight is  $V_{mm} = 1200-2200 \text{ m}^3/\text{hour}$  [13] (the average speed is  $2000 \text{ m}^3/\text{hour}$ , the time of filling a low-tonnage tanker is 5 hours, without preparatory works, therefore the full time of filling is approximately equal to:  $T_3 \approx 5$  hours)

The speed of pumping (offloading) oil *from* a low-tonnage *tanker* into a tanker, with deadweight 90000 by analogy is  $T_8 \approx 5$  hours.

Thus, the total time required for transportation and loading-unloading of 10000 tons of oil-products on each bunker tanker from an offshore terminal into a high-capacity tanker will be approximately equal to:

$$T_{\text{бз-в}} = T_n + T_{un} + T_{up} = 0.3 + 5 + 5 + 1.34 + 1.34 \approx 17 \text{ hours.}$$

Taking into account time for the bunker tanker “return” trip (into the port) the full cycle is:  $T_y = 17.3$  hours.

TABLE II. EXPENDITURES ON FREIGHT OF BT, AFRAMAX AND ICEBREAKER SHIPS

Expenditure indicator	Freight cost for 1 BT, rubles/day	Freight cost for 1 BT, \$/day	$\Sigma$ freight cost for 3 days, rubles	$\Sigma$ freight cost for 3 days, \$
Bunker tankers freight	359,784	5,700	3,238,060	51,300
Freight of an icebreaker ship for BT	9,070,344	143,740	27,211,032	431,220
Aframax freight	4,418,000	70,000	13,255,200	210,000
Freight of an icebreaker ship for Aframax	13,700,000	217,047	41,100,000	651,141
Total			84,804,292	1,343,541

Expenditures on the ALT and an icebreaker ship when reloading from an OTF to an Aframax tanker within the period of 1.3 days (table 3, providing that the time for mating-separating of a tanker and the ALT is 1 hour the time for loading will be  $TALT = 30+1=31$  hours  $\approx 1.3$  days):

TABLE III. EXPENDITURES ON FREIGHT OF BT, AFRAMAX AND ICEBREAKER SHIPS

Expenditure indicator	Freight cost for 1 pc, rubles/day	Freight cost for 1 pc, \$/day	$\Sigma$ freight cost for 1.3 days, rubles	$\Sigma$ freight cost for 1.3 days, \$
Aframax freight	4,418,000	70,000	5,743,400	90,992
Freight of an icebreaker ship for Aframax	13,700,000	217,047	17,810,000	282,161
Total			23,553,000	373,153

So, expenditures for loading one Aframax tanker using a BT are: 84,804,292 rubles and using an ALT: 23,553,000 rubles. Therefore, difference is (economy of using an ALT):

$$R\Sigma = 61,251,292 \text{ rubles} \approx 970,395 \text{ \$}. \quad (8)$$

Expenditures on creating the ALT infrastructure are  $C_3 \approx 432.40$  mln rubles.

Let's divide the ALT implementation costs by the cost saving total:

$$\Theta\phi = 432,400,000 / 61,251,292 = 7.06. \quad (9)$$

Thus, we can make a conclusion that the company using an ALT will get profit starting from loading the eighth Aframax tanker.

#### IV. DISCUSSION

First of all, efficiency of port operations depends on such factors as availability of a port, its infrastructure, the necessity to provide unloading equipment, unloading speed, weather conditions, the necessity to involve additional supply vessels, and also on the nature of cargo: volume-weight characteristics (bulk cargo (crushed stone), measurement cargo (cabins, tanks), stowing dimensions (cargo within loading gauge/oversized cargo), hazard class

(hazardous/nonhazardous cargo), cargo requiring special transport conditions (a plate).

The State and private enterprises conduct significant efforts for improving efficiency of port operations by constructing new and modern northern sea ports and technical re-equipment of operating ports. [4, 5, 12, 13]

The following investment projects which are being implemented in the Arctic Zone of Russia can be specified as an example (Table 4.).

TABLE IV. INVESTMENT PROJECTS IN THE AZR

Project Name	Project Capacity	Cargo classification	Implementation cost	Implementation timeline
Sabetta sea port construction	17.6 mln tons.	Condensed natural gas (CNG), gas condensate	Sabetta port: 102.9 bln rub., including: 71.3 bln rub. (federal budget resources). 31.6 bln rub. (investor resources)	2012–2018
Construction of CNG Arctic CNG-2 sea terminal for transshipment	Projected volume of transshipment of CNG – 16.5 mln tons.	Condensed natural gas (CNG), gas condensate	About 70 bln rub.	2016–2025 Phase 1 start is possible in 2022–2023
Construction of a terminal for oil transshipment from the Newport facility	8.5 mln tons.	oil	10.9 bln rub. (at the investor's own expense)	2013–2016
<b>Reconstruction of port infrastructure objects of the second cargo district in Murmansk sea port</b>	2 mln tons	Bulk cargo ore mineral, imported alumina	-	2013–2017
<b>Reconstruction of the second cargo district objects in Murmansk sea port</b>	3.7 mln tons	coal	-	2014–2017
Reconstruction of Naryan-Mar sea port.	port cargo turnover increase by 350 thousand tons by 2020	wood, coal, mineral raw materials, containers, general cargo	3.7 bln rub.	Engineering design –2018. Reconstruction – until 2019–2020
Construction of a multi-purpose and special-purpose transshipping complex in Indiga port	Up to 5 mln tons implementing Pechora CNG project	CNG, oil, oil-product. supply cargo. - can be used as a transport hub of	1 stage – 353 mln rub.	Scheduled - 2025

		Pechora CNG project (Rosneft/Allte)		
Construction of an oil terminal on Tanalau Cape	oil terminal capacity 5 mln tons. (up to 7.3 by 2030)	Oil	5.8 bln rub.	by 2025
Construction of a deep water area in Arkhangelsk sea port	deep water area with the total cargo turnover of 20 mln tons per year. (according to optimistic declared projections – 37.5 mln t./year, confirmed basis – 10 mln t.)	Timber, cellulose, coal, equipment, metals, bulk cargo, oil-products, industrial and food products	The investment volume is being determined with a potential investor, Poly International	An agreement on joint implementation of the project with Poly International Holding Co.,Ltd has been concluded. (China) 2016.
Construction of a coal terminal in Beringovsky sea port (Bay of Arinai)	a coal terminal with a capacity of 10 mln tons per year	coal	5 bln rub.	2016–2019

\*Source: Rosmorport data on investment projects and Strategy of development of sea port infrastructure up to 2030

Except construction and modernization of ports and port equipment actions are being carried out on introducing technical and organizational measures, e.g. such as reducing mooring-hosing operations, increasing unloading productivity, reducing the time for paperwork, reducing minimum time for “weather slots” used by transport vessels, etc. [10]

Based on the given data on activities for improvement of port operations efficiency and according to experts about 20% improvement is possible, that is  $I\Theta c=1.2$ .

## V. CONCLUSION

1. The State has evolved a strategic plan for developing the Arctic Zone of Russia and the Arctic Maritime Transport Route and turning tramp shipping into regular year-round shipping.
2. Taking into account the target indicator – the volume of cargo transportation along the Arctic Maritime Transport Route per year – it is suggested to take the ratio between cargo turnover and yearly total costs as the indicator value of transportation efficiency.
3. The efficiency of cargo transportation along the NSR depends on the total volume of transported cargo and total expenses of ship-owners and the State taking into account tariff rate for ice channeling.

4. Transport costs are composed of movement and port operations costs.
5. Based on the given data on activities for improvement of port operations efficiency and according to experts about 20% improvement is possible.

#### REFERENCES

- [1] State Program of the Russian Federation "Development of the Transport System" (approved by the Russian Federation Government Decree of April 15, 2014, No. 319).
- [2] Shipbuilding industry development strategy up to 2020 and further (approved by the ministerial Decree of the Russian Federation Ministry of Industry and Energy of September 6, 2007, No. 354).
- [3] A.V. Abramov, M.Yu. Alekhin Methodological principles of support of including an extra-functionality element into the transport system. Economics and Enterprise, No. 7, 2017
- [4] A.V. Abramov, M.A. Zagorodnikov Prospects of innovation development of the Russian Arctic Zone. Transport routes. St.Petersburg State Maritime Technical University, 2017. ISBN 978-5-88303-564-6
- [5] M.A. Zagorodnikov, The problems of developing sea infrastructure of the Russian Arctic Zone: RNPk materials "Investments economy and financial consulting". – SPb.: Publishing house of St. Petersburg State Maritime Technical University, 2015.
- [6] M.A. Zagorodnikov, I.M. Kalinin New prospects of the NSR development // Economic sciences. 2016. No. 2.
- [7] Sea site. [Electronic source]. – Available at: URL: <http://seaman-sea.ru/tankera/601-shvartovnye-operacii-tankera.html>.
- [8] Technological design standards for sea ports. RD 31.3.05-97. [Electronic source]. – Available at: URL:[http://www.infosait.ru/norma\\_doc/8/8953/index.htm](http://www.infosait.ru/norma_doc/8/8953/index.htm).
- [9] Technological design standards for oil product suppliers (oil delivery terminals), Departmental Norms of Production Engineering 5-95. [Electronic source]. – Available at: URL:[http://www.complexdoc.ru/ntdpdf/483330/normy\\_tekhnologicheskogo\\_proektirovaniya\\_predpriyatii\\_po\\_obespecheniyu\\_neft.pdf](http://www.complexdoc.ru/ntdpdf/483330/normy_tekhnologicheskogo_proektirovaniya_predpriyatii_po_obespecheniyu_neft.pdf)
- [10] V.I. Peresypkin The Arctic sea transport system is of great importance. [Electronic source] – URL: <http://www.arctic-info.ru/ExpertOpinion/Page/the-arctic-marine-transportation-system-is-essential>
- [11] The site of Polistirolbeton-SPb company.[Electronic source]. - Available at: URL: <http://www.polistirolbeton.spb.ru/>; <http://p-bloki.ru/price>.
- [12] Kikkas, K., Romashkina, E. Potential Opportunities for the Arctic Transport Space (2018) 180 (1), 012016.
- [13] A.Yu. Smirnov, A.V. Abramov Elaboration of the strategy of shipbuilding industry development in the context of digital economy. Research and practice conference "Digital transformation of economy and industry" (INPROM-2019) p. 174-179
- [14] Vessel-hour rates of marine vessels loading-unloading. Technological design standards for oil product suppliers (oil delivery terminals), Departmental Norms of Production Engineering 5-95. Appendix 4. [Electronic source]. - Available at: URL: [http://www.complexdoc.ru/ntdpdf/483330/normy\\_tekhnologicheskogo\\_proektirovaniya\\_predpriyatii\\_po\\_obespecheniyu\\_neft.pdf](http://www.complexdoc.ru/ntdpdf/483330/normy_tekhnologicheskogo_proektirovaniya_predpriyatii_po_obespecheniyu_neft.pdf)