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Abstract. The article is devoted to the questions of optimizing the regional organizational and economic system of marine vessels reproduction. Challenging climatic and economic conditions of Russian marine vessels operation make this topic relevant and call for modern managerial approaches to the reproduction processes in the Russian industry. The article focuses on the research and practical problems of reduced economic efficiency of vessels reproduction due to the influence of regional and economic conditions for their operation and repair. The purpose of this research is to review the regional peculiarities of optimizing the marine vessels reproduction from the organizational and economic points of view. One task of the research involves testing the author's methods for cost calculation that reflects the increase in the fleet reproduction achieved through combined optimization of ship building and ship repair programs as exemplified by the fishing fleet of Primorsky Region. The authors have applied the ideas of modern efficiency theory and the shipbuilding and ship repair concepts in Russia to justify application of the methods that involves determining the optimal annual number of vessels based on the effective operation coefficient depending on the area. Calculations show that optimization of the vessels number and upgrading of the major industrial facilities of the marine fleet can result in the total saving of 1.3% including savings on repair by 47.2%.

1. Introduction

Study of the regional peculiarities of ship reproduction takes a special niche in the modern global science. On the one hand, it is connected with the general condition of the global shipbuilding and ship repair that are going through the period of intensive development and technological innovations. On the other hand, it is explained by the geographical, social and economic peculiarities of every country involved in reproduction of marine vessels and their striving for increased competitiveness of national civil fleet operation.

Regional factors of marine vessels reproduction are or paramount importance to the major countries located in several climatic zones and/or operating their marine vessels in challenging conditions (for example, Arctic and Antarctic): Russia, the USA, Canada and China. However, Russia is more than any other country interested in solving the problem of regional challenges in reproducing the engineering facilities since the country occupies the biggest territory stretching from the south to the north and from the east to the west.

Russian marine vessels are operated in various geographical regions that have very different natural, climatic and economic conditions. The Russian seaport register lists 67 ports in eight sea basins situated on the shores of 12 seas, three oceans and the Caspian Sea. The Baltic ports carry the major part of cargo turnover in Russia; the Northern and the Far Eastern sea basins are the fastest developing regions of sea transportation: the Northern Sea Route plays a very important role; this region has the coldest and most severe climatic conditions on the globe.

Unlike other countries, Russia incurs higher ship operation and repair costs due to the two major factors: severe climatic conditions (an objective, exogenous factor) and high average age of the vessels (a subjective, endogenous factor). Both factors result in higher depreciation rates and reproduction costs; it is impossible to eliminate the first factor; however, elimination of the second one will mitigate the consequences of the first one.

Therefore, the subject matter of the research is relevant and calls for modern approaches to solve the problem of marine vessels reproduction with consideration for the regional conditions of operation and repair. The article is aimed at perfecting the methods of factoring the regional peculiarities of optimizing the marine vessels reproduction with due account for organizational and economic contexts. An important task of the article involves testing the author's methods for increasing the fleet reproduction efficiency by combining the programs of ship building and ship repair optimization as exemplified by the fishing fleet in some Russian Federation regions. In the research, reproduction is interpreted as reimbursement of vessel operation and repair costs (simple reproduction) as well as upgrading or replacing of depreciated and/or obsolete ships when repair is cost-inefficient.

2. Scientific approaches and methods to solve the problem of marine vessels reproduction

The need for factoring regional conditions in reproduction of engineering resources was first set forward in 1960s in the USSR as part of regional engineering policy development; then it was defined as a relevant research objective. The works of Soviet researchers from 1980-1990s were devoted to optimization of the regional structure of reproducing the marine vessels operating in various climatic conditions; the studies were mostly aimed at developing the differentiated rates of depreciation for the overhaul repair, planning and centralized regulation of reproduction and renewal of the equipment park [1; 2]. This concept was defined as follows: "Operation of transport vessels in northern seas as well as operation of local and auxiliary service vessels in freezing ports has no impact on their operation time; however, it requires higher costs of overhaul repair" [3].

Regional differentiation of depreciation rates for overhaul repair was based on the need for ensuring standard operation time of vessels regardless of their operation place [4]. Differentiation of depreciation rates for overhaul repair by establishing special coefficient in effect was aimed at concealing the inefficiency of marine vessels repair in northern conditions. In particular, the depreciation rates adopted as of 01.01.1975 included the following multiplying coefficients: 1.1 – for the transport vessels operating in Primorsky Region, 1.2 – for Khabarovsky Region, Magadan, Sakhalin and Kamchatka; 1.5 – for fishing fleet vessels operating in Primorsky and Khabarovsky Region, 1.9 – in Sakhalin and 2.0 – in Kamchatka [5]. This approach to "perfecting" of ship repair resulted in increasing of the already high costs in severe conditions of the Russian Far East. For example, in Kamchatka the depreciation rate for overhaul repair of the transport refrigerators with over 65-meter hauls was 14% thus increasing the absolute depreciation rate from 11.2% to 18.2% while the renovation rate was invariable 4.2%. As a result, this depreciation rate implied the operating costs for only 5.5 years and this operation time is a priori unacceptable for marine navigation.

The current Russian planning of marine fleet reproduction still relies on the depreciation-dependent operating life. On January 1, 1991, the overhaul repair rates were cancelled and companies were allowed to conduct repairs according to their own principles. However, since standard operation time of vessels hasn't changed substantially, we can make a conclusion that real repair costs in a percentage correlation with fixed assets value have changed insignificantly as well.

Modern global science looks at various aspects of optimizing the marine vessels reproduction; in general, it involves the following areas:

1. *Research of general trends in ship construction and repair in the countries and their regions*. Nowadays ship construction is a well-developed industry with severe competition in all segments [6–9]. Due to its high versatility and capital intensity, vessels reproduction is an important object of researches aimed both at development of technologies and perfection of social and economic tools for ship building and ship repair management [10; 11].

2. *Analyzing the influence of technological and economic factors on the condition of vessels exploitation and opportunities for their reproduction in the territorial (territory, country, region) aspect*. Studies show that the more technologically developed a country is, the less the condition of its marine vessels depends on any managerial and/or economic problems. Developed countries look into the territorial aspect of ship reproduction and repair in the context of counteracting the natural aggressive environment (waves, wind, ice) in order to improve the maritime logistics, reduce the risks for ships and crews and also reduce the environmental risks [12–15]. In developing countries, the territorial problems of vessel reproduction are mostly caused by administrative, organizational and economic issues. In BRIC countries (Brazil, Russia, India, and China) in particular the reproductive capacity of the shipping industry is constrained by the lack of inter-regional and interindustry researches in ship construction and repair thus causing gradual ageing and the sea fleet deterioration: in China over 40% of ships are over 20 years old; in Russia 90% of the fishing vessels are well beyond their standard service life [16–18].

3. *Assessment of financial costs of marine vessels reproduction and renovation*. The subject of such researches includes various calculation models of preliminary, industrial, operational, reconstructive and liquidation costs in ship construction and repair [19–20]. Researches about the influence of depreciation, new engineering solutions, ecological requirements, methods of vessels decommissioning for further reproduction in major countries show that costs of servicing, repair, renovation and decommissioning of vessels mainly depend on the development phase in shipping industry and the type of territorial organization of ship building and ship repair systems (for example, industrial facilities, port zones, clusters etc.) [21–23].

This comprehensive research base of organizational and economic issues of ship building contributes to the future studies. However, there is no clear economic mechanism in Russia to solve the problem of factoring regional peculiarities of marine fleet reproduction. This is especially obviously in the conditions of growing demand for shipbuilding products. The real need of Russian shipping companies in domestic and mixed navigation vessels is about 400 units, and Russian fishing companies – over 700 units [24–25]. In this country, high costs of ship reproduction are considered unavoidable, but this situation in the industry cannot be called satisfactory.

3. Increasing the efficiency of regional fleet reproduction: methods and problem solving algorithm

The author's approach to this problem is mostly reliant on standard principles. Different climatic, transport, geographic and economic factors of ship operation have a direct impact on the efficiency of their reproduction, repairs included.

It is obvious that the efficiency of fleet reproduction in northern regions is lower than in the south and west (Europe). On the one hand, it is attributed to severe (extreme) climatic conditions that change the consumption factors to the worse: the deterioration rates and repair costs are higher. On the other hand, it requires greater transports costs for delivering materials and fuel to the ship repair facilities and increases labor costs and crew supplies.

When ships are repaired in other regions, the efficiency of fleet reproduction decreases due to additional costs for travelling to repair facilities and back to the place of operation. Travelling time reduces the operating fleet capacities in this region thus requiring a bigger quantity of ships for performing the tasks.

The nature of fleet reproduction in every region can be defined by formulas with due regard to the regional value appreciation. Every region has a specific character of reproduction depending on the transportability of units. Small mobile vessels – both transport and fishing – are not built in the

northern territories; they are only repaired there. New vessels for the northern fishing fleet come from the southern regions of the country [26].

Long-term observations in one of the biggest sea basins in Russia – the Russian Far East – show that ship repair costs (simple reproduction) vary depending on the region. The observation period covered 2003-2015 in Primorsky Region, Khabarovsky Region, Sakhalin and Kamchatka. The research involved fishing vessels since they withstand the greatest impact of regional reproduction conditions. The regional appreciation influence on decreasing the fleet reproduction efficiency is shown by special coefficients calculated based on the decrease in the efficient (effective) time costs in specific regions and age groups that were described in our previous works [27]. Government calculations show that the specific labor intensity of production in Russian shipbuilding and ship repair is 3-5 times higher than in foreign enterprises, and the repair time of ships is 2-2.5 times longer [28]. The calculations performed by the authors show that repair of medium fishing vessels based in Primorsky and Khabarovsky regions becomes inefficient (according to the existing system of planned preventive repairs) in the age of 16-20 years old; in Sakhalin and Kamchatka – in the age of 11-15 years old (tables 1, 2).

Table 1. Increase in the total reproduction costs of medium-size fishing fleet (by age groups of vessel class "medium fishing freezing trawler") per 1 ton of fish yield (%).

Age group, years	Primorsky, Khabarovsky regions	Sakhalin	Kamchatka
< 5	100	100	100
6-10	63	81	83
11-15	87	107	113
16-20	118	162	175

Source: Authors' results.

Table 2. Increase in the total reproduction costs of medium-size fishing fleet (by age groups of vessel class "388-m fishing trawler") per 1 ton of fish yield (%).

Age group, years	Primorsky, Khabarovsky regions	Sakhalin	Kamchatka
< 5	100	100	100
6-10	76	85	81
11-15	96	112	106
16-20	114	129	134

Source: Authors' results.

Therefore, the ships that are operated and repaired in the northern conditions withstand an additional regional cost increase in addition to the naturally higher costs of age-related repair. The region-related increase in the repair cost adds to the natural costs and the moment when repair becomes inefficient in special regional conditions comes before the regulatory depreciation rate of the vessels mentioned above (up to 20 years).

The regional increase in repair costs is a major factor that results in accelerated rates of fleet renovation in the north since other factors that reduce the reproduction efficiency have similar effects on both new and old vessels. So, calculations of the need for restoring the major production sea fleet facilities based on regional coefficients of effective operation time define the program of optimizing the reproduction efficiency. Hence, the authors suggest the methods of increasing the fleet reproduction efficiency by comprehensive optimization of ship building and ship repair programs. The methods involve determining the optimal average annual number of ships of different age groups that have to be included into the ship repair program and accelerated renovation program. The major

criterion for ship number optimization is the effective operation time depending on the district. It is considered unfeasible to repair the ships that are beyond their regulatory operation time; these ships are to be either decommissioned or replaced within the program of accelerated renovation. The main hypothesis is as follows: optimization of ship quantity will minimize the repair and operation costs exclusive of depreciation and liquidation costs and ultimately will increase the efficiency of reproduction system in the industry.

The relevance of factoring age groups of vessels can be objectively explained by the fact that older vessels have higher operation costs, shorter inter-repair cycles and navigation time regardless of their operation region. Every age group of vessels is assigned an effective operation time coefficient and a specific value of total unit costs. Higher age groups have lower effective operation time coefficients and higher unit costs.

The methods are tested in order to prove the hypothesis that the ship repair and operation costs can be substantially reduced by optimizing the quantity of vessels in accordance with the total effective operation time and accelerated program of ship renovation. The calculation of ship building and ship repair programs based on these methods involves three stages:

1) defining the current total annual costs of fleet reproduction and operation;

2) calculating the total reproduction costs that have to be included into the ship repair program;

3) defining the cost savings as a result of a comprehensive optimization of ship building and ship repair programs.

Primorsky region was taken for reference since this region is a national leader in transport and fishery development. The methods were tested with the data on big and medium-size fishing trawlers since they are most often repaired at the regional industrial facilities (both maintenance and overhaul repair) (table 3).

Table 3. Cost optimization for reproduction of fishing trawlers in Primorsky region (RF),thousand c.u.

Variables	Calculation methods	Final value for region	Including the age groups in operation			
			< 5 years	6-10 years	11-15 years	16-20 years
1. Average number of vessels (prior to optimization)	Fleet data	93,5	2,6	13,8	50,3	26,8
2. Total annual costs of fleet repair and operation (prior to optimization)	Fleet data	52 154	885	5 766	27 101	20 432
3. Total unit costs of repair and operation (prior to optimization)	*line* 2 / *line* 1	557,8	340,4	417,8	538,8	762,4
4.Operational commissioning costs for a new vessel per one new vessel annually (including construction, repair and operation exclusive of depreciation)	Assessed by authors based on fleet data	1 055	-	-	-	-
5. Operation time with regard to regional conditions (% of operation time fund)	Assessed by authors based on fleet data	51,8	68	59	51	48
6. Effective average annual number of vessels in operation (ship repair program)	*line* 1 · *line* 5	48,4	1,8	8,1	25,6	12,9
7. Total annual costs of vessels repair and	*line* 3 · *line* 6	27 625,1	612,7	3 384,2	13 793,3	9 834,9

operation included in the ship repair program						
7.1. including repair costs		13 536,3	90,1	907,0	5958,7	5900,9
8. Number of vessels beyond efficient repair timeframes	*line* 1 – *line* 6	45,1	0,8	5,7	24,7	13,9
9. Liquidation costs of vessels that are beyond repair time frames	*line* 8 · 100	4 510	80	570	2 470	1 390
10. Average annual number of vessels in operation included in the accelerated renovation program	*line* 8 · *line* 5	25	-	-	-	-
11. Additional costs for fleet restoring	*line* 10 · *line* 4	26 375	-	-	-	-
12. Total costs of optimal fleet reproduction	*line* 7 – *line* 9 + *line* 11	51 490,1	-	-	-	-
13. Saving of costs per unit	*line* 2 – *line* 12	663,9	-	-	-	-
14. Reduction in total costs	*line* 12 / *line* 2	1,3%	-	-	-	-
14.1. including reduction in repair costs		47,2%	-	-	-	-

Source: Authors' results.

Calculations in table 3 show that optimizing the number of vessels and restoring of major production facilities of the fleet based on the regional coefficients of effective operation time can result in total savings of 1.3%. This seemingly insignificant efficiency however involves a qualitative transformation of the fleet and its substantial renovation: current operation and repair costs are reduced by almost 50%.

4. Results of the methods testing

Researches about the regional influence on the efficiency of marine vessels operation and testing of optimizing the reproduction costs methods have led to the following conclusions about increasing the reproduction efficiency in the industry.

1. Ship repair has to be viewed as a natural consequence of ship building. Ship building and ship repair objectively form a single organizational, economic and engineering system – a system of reproduction that provides for the target production fleet capacity. Ship repair provides for the simple reproduction since the vessels capacity, as a rule, remains unchanged. Products of the ship building industry provide both for the accumulation fund defined by the planned rates of extensive reproduction and for the fund of replacing the decommissioned vessels.

2. Efficiency of ship building and ship repair can be increased by optimizing the structure of industrial programs and, hence, by optimizing the marine fleet reproduction. Minimization of ship building costs, repair costs and operation cost exclusive of depreciation and liquidation costs is the main criterion for the system's efficiency.

3. Age of vessels is a major though not the only factor that reduces the efficiency of fleet reproduction. Unfavourable regional conditions accelerate the natural ageing of vessels, increase the operation and repair costs, and shorten the inter-repair cycles (navigation time) as well as reduce the maintainability of vessels.

4. Vessel reproduction can be optimized only through the progress in science and technologies: increasing the capacity of newly-constructed vessels and decreasing their operation costs. Ship building involves high initial costs of creating ships; therefore, ship repair costs can have a big impact on their operation efficiency. On the one hand, modernization of management systems aimed at

reducing the repair costs and enhancing the repair quality increases the efficiency of the fleet simple reproduction. On the other hand, technological modernization of ship repair aimed at creating vessels with higher maintainability is a source of extensive reproduction in ship building thus also increasing the efficiency of the whole industry.

5. Conclusion

The calculations and methods suggested by the authors show the possibility of substantial saving of ship repair and operation costs alongside with great prospects of fleet renovation. These economic approaches to the ship building and ship repair involve an extensive type of reproduction through intensive factors implementation.

The relevance of this theme will keep growing. Nowadays, the Russian fishing fleet includes 2.5 thousand different-purpose vessels; the age of over half of them exceeds 20 years. Despite the need for fleet renovation, Russian companies keep purchasing used foreign vessels. This stagnation in the Russian engineering industry can be ended by shifting the demand towards the Russian shipbuilders. Within this context the questions of marine vessels efficient reproduction will be of paramount importance.

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