

# The Peculiarities of the Social and Economic Development of the Arctic Regions Based on the Supply Chain Management: In the Framework of the Strategic Planning in the Republic of Sakha Yakutia

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**Abstract-** This research studies the problem of the peculiarities of the social and economic development of the Arctic Region. The purpose of this research was to develop a strategic approach to the social and economic management of the Arctic Regions. The authors introduced the objective approach towards the long-term development of a compound macro-region and presented recommendations regarding the long-term regional planning according to its special characteristics.

**Keywords-** strategic supply chain, living standard of the population, budget, municipal statistics.

## 1. Introduction

Arctic Region is considered an important component of global economic development due to its mineral resources [1-530]. Untapped hydrocarbon sources and mineral raw material deposits are concentrated in the region. The largest deposits of copper-nickel ore, platinum group metals, rare earth metals, phosphorus, chrome, diamonds, silver and gold provide a steady interest in the region. The above-mentioned aspects provide faith to the new renaissance of the Arctic, which would ensure sustainable socio-economic development of the northern territories [6, 7]. The authors point out the importance of the balance between the development of the Arctic resources and the preservation of the unique ecosystem, which should be the basic principle of the global community [8]. During the recent decades, the development of the Arctic Region was determined

by the national strategies of various countries. In addition to politico-military and environmental problems, the key issue is the economic activity regulation in the macro-region [9]. Thus, the purpose of the sub-polar business forum, Arctic Business Council, is to promote the economic and social development of the region. Certainly, the development of the Arctic territories differs significantly from the generally accepted practice of regional policy implementation, both in Russia and in other countries. The Arctic Region development depends on the municipal objects management that imposes some restrictions [10]. The authors analyze the following characteristics:

- Small number and dispersion of the population in the Arctic territories
- Low quality of life, determined by the impossibility of market relations development in the local economy; unfavorable conditions for the productive assets distribution
- The Arctic Region's budgets that are determined by the transfers from a higher level, as well as by subsoil users
- Restrictions on the development of relations between the local population and subsoil companies
- The importance of environmental security, determined by the climate-forming function of the macroregion

- The effect of the limitation of the information base of the Arctic territories to the quality of planning

The authors introduce the approach to the social and economic development of the region that is determined by the formation of the system of management, based on the governmental regulation, in the context of the peculiarities and limitations of the Arctic Region and the population's quality of life improvement. In this regard, reconsidering the theory and practice of the socioeconomic management of the Arctic Region is necessary to identify the priorities and to analyze the risks in the framework of human capital development, environmental balance, and security protection in the macroregion.

## 2. Methodology

The authors used the following methods: historical and logical methods, compilation of facts, analysis and synthesis, classification, and analogy. The statistical method was used for the appropriate comparative analysis of the quantitative values of the subjects, namely, the calculation of the average and relative values. The changes of the above-mentioned values would be regarded as the main criterion for the socioeconomic development evaluation of the Arctic Region of Yakutia. A comprehensive analysis of the current state of the socioeconomic development of the Arctic Region of Yakutia was carried out to define the long-term development priorities. The authors used SWOT-analysis, which included identifying the internal and external environmental factors impacting the socioeconomic development of the Russian Federation. As a result, the authors defined the competitive advantages of the vast and diversified territory of 13 municipal areas. In addition, the researchers identified the restricting factors that make it impossible to ensure stable economic growth and to improve the quality of life in the economic zone. The case method was implemented to analyze the national strategies of the sub-polar countries and Soviet experience, which provided rapid systemic development in northern Russia.

## 3. Results

The Arctic Zone of Yakutia is characterized by the integrity of its natural-economic systems, as specified by the natural conditions and resource base, internal infrastructural unity, and unified government [11-14]. At the regional level, the Russian government will form the North-Yakutsk stronghold area of socioeconomic development,

which will provide the effective management of the Arctic zone of the Republic of Sakha (Yakutia), as well as the development of the resource base. As a result, the continental shelf objects will be explored and transport infrastructure will be improved. In addition, the settlement of Tiksi will be developed as the primary harbor of the eastern part of the Northern Sea Route and the International Arctic Center for Scientific Research. Anchor projects based on the deposits in the Central Yansky and Yuzhno Yansky tin ore areas (Tirekhtyakhsky placer deposits and the Deputatsky deposit), as well as the development of the Tomtor deposit of niobium and rare earth metals, will ensure the recovery of the tin industry in Yakutia. The government will also support the leading branches of agriculture; namely, northern (domestic) reindeer herding, fishing, and hunting.

### 3.1. Ecological safety of the Arctic

The structural climatic and infrastructural living conditions in the Arctic Region and the Russian Federation, in particular, have led to a high dispersion of the population. This fact reduces the anthropogenic impact on the fragile ecosystem of the Arctic zone, however, at the same time, it also contributes to the insufficient exploration of the territory and a reduction in control regarding the human impact on the environment. The years of industrial development (mining of tin ore, gold, coal, and other minerals) led to environmental damage; namely, the moonscapes. Moreover, reclamation activities were not carried out, which led to the formation of water-filled quarries, highly concentrated pollutants at the local sites of non-liquidated and unconserved tailing dumps (Deputatsky Mining and Processing Plant, Kular and Lebedinsk gold-mining factories), and potential river pollution as a result of underground nuclear explosions in the Soviet Union (the potential transmission of radionuclides from the "Horizon-4" underground nuclear explosions by the River Eekit to the mouth of the River Lena). The territories of security zones on the islands of Kotelny, Stolbovoy, Bolshaya Lyakhovsky, and Bunge Land are littered with barrels, metal structures, beams, and construction debris. There are also the abandoned buildings of the polar stations "Shalurova," "Stolbovoy," "Bunge Land," "Zhokhov," the military units "Temp," "Kigilyakh," and some geological bases. According to the results of the inventory, there are 437 points of accumulation of non-ferrous and ferrous metals on the territory of the republic, 156 of which are in

the Arctic [15]. Despite the environmental damage, external challenges (economic sanctions), arctic geopolitics (the absence of clear international boundaries), and the synergy of the scientific, technological and economic development of the Russian Federation determine the necessity and strategic priority for the territorial development of the rich and untouched Arctic lands.

### **3.2. The living standard of the population in the Arctic zone of the Republic of Sakha (Yakutia)**

In order to estimate the basic indicators of the regional differentiation of the well-being of the population in the Arctic regions of Russia, the authors analyzed the main indicators of living standards; namely, the real incomes of the population, real wages, and indicators of the differentiation of incomes of the population. Yakutia, as well as the other Russian national republics, is characterized by its significant poverty level as a result of the large families in the region and the highest ratio of the rural population in the Russian Arctic Zone. In general, 13 arctic regions of Yakutia, with 6.9% of the population at the beginning of 2019 (67.7 thousand people), are the most depressed economic zones. In 2017, these regions also had the highest officially-registered unemployment rate that exceeds the average rate in the Republic by almost three times. There is also a high proportion of children from poor families (40% in RS [Y], 55% in AEZ) and a high incidence of the population (in RS [Y], 1021 of patients in every 1000 people are registered with a diagnosis established for the first time in their lives, with 1153 patients in AEZ). Another unfavorable trend is the increase in the mortality rate from neoplasm and respiratory diseases. At the same time, it should be noted that the migration decline index in these areas increases annually as a result of the objective compression trend of the inhabited and economic space [7]. In the republic as a whole, 66% of the working-age population works in the organizations; however, in AEZ, this share is 59% and the population is predominantly employed in the public sector. Thus, municipal institutions predominate in the Arctic regions per 10 thousand of the population. In addition, in the Nizhnekolymsky region, all municipal institutions have the status of being state-owned (21% in RS [16-20]), which indicates an excessive decentralization of powers. There is also a high rate of part-time work in municipal institutions, with a rate of approximately 1.5 in the Allaikhoov district.

### **3.3. Living standard of the rural population in the Republic of Sakha (Yakutia)**

Arctic regions are characterized by the lack of year-round transport links, even between neighboring settlements, which have large distances between them. The provision of fuel, heat, and electric energy to settlements in the Arctic requires huge financial resources. Arctic municipalities are almost fully subsidized and the share of their own provisions are about 7% of the required income. The technical condition of the power industry's fixed assets is characterized by a high depreciation rate; namely, from 60% to 80%. The percentage of the population living in dilapidated and emergency buildings is 39%. To provide the population with safe life necessities, annual stocks of food and petroleum products are required. Credited financial resources for that purpose make the stored products several times more expensive, especially when taking into account the large transportation costs. Since the republic tried to solve all financial overpayments by means of a cross-subsidization scheme, distributing and shifting the costs on the population and enterprises of the republic, the cost of petroleum products and electricity in the central regions has increased significantly. The above-mentioned factors influence the cost of manufactured goods and products, making them more expensive. This is also one of the economic threats to the security of the Arctic areas, which, consequently, has an influence on the economy of the entire region.

### **3.4. Management of the Arctic Regions**

The structure and quantity of the municipal budgets of the territories is influenced by the socioeconomic development of the Arctic [21-25]. Current reality is such that the development of the Russian Arctic is impossible without the leading role of the state. In the Arctic regions of Yakutia, the proportion of transfers from the higher-level budgets in total local budget income reaches 94%; in the areas with developed industry, namely, Anabarsky and Oleneksky it is much lower and does not exceed 44%. The possibilities of the municipal budget are determined by the presence of large industrial companies on the territory. The main source of income here are dividends on shares of ALROSA public company. In 2017, the areas received 657.6 million rubles each, which formed 83% and 87% of the own income of the Oleneksky and Anabarsky region respectively. Human living in the specific conditions of the Arctic is

determined by objectively heavy expenditures. In the Arctic regions in 2017, budget expenditures per person comprised 362.4 thousand rubles, which is 1.7 times more than in the republic as a whole and 4.8 times more than in the Russian Federation. Almost half of the expenditures of the Arctic regions are spent on the development of education (49%); in addition, significant funds are spent on housing and communal services (12%), local self-government (12%) and culture development (10%). The subsoil users' activity in the Arctic specifies the budget formation and the relationship between the municipalities and the companies. Nowadays, there is a problem of the absence of a federal law defining the legal and organizational norms of agreements on the socio-economic development of the Arctic regions between the subsoil users and the administration of the regions. [8, 9]

### **3.5. Limitations of Information Base of the Arctic Territory**

Strategic planning in the Russian Federation is based on the distinct and legislated principles. Some of them, namely, the principles of measurable goals, indicators and goals matching, and realism are possible only if there is a sufficient statistical base. The statistical observation of socio-economic development of the Arctic zone of the Russian Federation is at the stage of its formation, retrospective data are published selectively); however, it is already obvious that breakdown by arctic subjects of the Russian Federation will not be covered sufficiently. In 2019, some of 132 indicators will be published [10] (the Arctic zone of the Russian Federation in total), and only 6 of them will have breakdown by regions. The territory of 4 subjects of the Russian Federation is fully included in the Arctic zone of the Russian Federation, in another 4 subjects (among them the Republic of Sakha (Yakutia)) the territories were assigned only partially; certain municipalities. Thus, the researchers, conducting socioeconomic research of the Arctic zone and its subjects, have to form an information base in accordance with the municipal statistic. This fact may cause the greatest difficulties. The main limitations of the municipal statistics for socio-economic analysis are the following:

- The quantity of the indicators. The history of municipal statistics, as well as the general principles of the local self-government organization in modern Russia is relatively short. The number of published statistical parameters for municipalities is much less than for subjects of the Russian

Federation. The main sources of economic and demographic data for municipalities of the Russian Federation are the following: Rosstat "Database of indicators of municipalities" [11], which contains the statistic data since 2006 (up to 624 indicators in 2015); statistics collected and published by the territorial bodies of Rosstat (as a rule, there is no uniformity in the publications); departmental statistics and sites of municipal administrations (there are almost no data in full access) [12].

- Completeness of information. Information on municipalities is often based on the insufficient range of filling. This is especially true for the indicators that refer to business statistics, retail trade and public catering, fixed assets investment. For example, without information on small business entities, the following indicators are formed: "Shipped goods of own production, works and services performed on their own" and "Fixed assets investments, carried out by the organizations located in the territory of the municipality".

- The quality of data. It impossible to analyze indicators over time, as there are some "gaps" in the data (periods of time with no statistical data) of municipal statistics. In addition, data for some municipalities may not be available. There are often cases of discrepancies in the values of the same indicator in earlier publications as there were no regulations for the obligatory explanations (explanatory footnotes, methodological comments). All the above-mentioned factors as well as the lost published statistical methodologies sometimes make the investigation insufficient and even impossible. It should be noted that the errors in statistics on municipalities are much more critical than at the regional or federal level. In the context of the large objects the errors can be smoothed over. These restrictions are partly explained by the dependence of the quality of the collected data on the presence of a strong personality among the leaders in municipal authorities, as well as on the distance from the administrative center.

The difficulty of ensuring comparability of indicators within onetime series. It is observed especially for comparability over time of indicators in monetary terms (there are no deflators for reduction to the base year), comparability of the methodology of the indicator determination and of territory. In Russian scientific publications can be found examples of how researchers are trying to overcome these limitations. Basically, work with municipal statistics is excluded; the research is conducted at the level of regional statistics. For example, the Arctic Zone can be explored as

separate sets of regions (first set - regions that are fully included in the Arctic Zone, second - regions that are partly in the Arctic Zone), and then the sum is formed [13]. These limitations may affect the quality of the strategic planning of the socioeconomic development of the Arctic zone of the Russian Federation.

#### 4. Discussion

Nowadays, Strategy for the socioeconomic development of the Arctic zone of the Republic of Sakha (Yakutia) for the period up to 2030 has been developed in the context of strategic planning in the Republic of Sakha (Yakutia). The strategy determines the priorities, goals and objectives of socioeconomic development of 13 Arctic municipal districts of the republic for the long-term period. The main goal of the Strategy is to create socioeconomic conditions for a comfortable living and activity for people in the Arctic zone of the Republic of Sakha (Yakutia), which implies the improving of the living standards in the region, which are significantly lagging behind the northern European countries [14; 15; 16]. In the framework of the Development Strategy for the Arctic Zone of Yakutia 5 approaches were introduced. First of all, the “complexity” and “sustainability” of the Arctic Zone development are of key importance for improving the quality of life of the local population by means of the social facilities construction, development of transport communications and energy facilities [17; 18; 19]. According to the international procedure of the analysis of quality of life of the population, the main attention is paid to social, natural-climatic, legal, and cultural aspects development. Currently accepted indexes of human development, as in the approach of Campbell - Converse - Rogers, Austrian Institute for Welfare Analysis, and Human Development Index, accepted by the UN in 1990 are difficult to apply in the Arctic [20-23].

The number of the population of the Arctic territories of Yakutia is small. Thus, it is inappropriate to use German system to monitor the quality of life of the population, where the leveling of living standards in the eastern and western parts of Germany is based on a system of 200 social indicators [24]. At the same time, examples of such countries as Norway, Iceland and Sweden introduce the possibility of successful socioeconomic development in the Arctic, as well as the need to form specific urban planning principles for the northern territories.

Secondly, the Strategy is formed according to the “basin” approach. This means that the areas in the basins of the Arctic rivers Anabar, Lena, Yana, Indigirka and Kolyma are considered as united natural-economic complexes. This principle is based on a historical analysis of human settlements formation and economic development along the natural transport and resource routs (from the south and north), performed by the northern rivers.

Thirdly, the conditions of northern delivery, the economy of traditional industries and the settling specifics require direct government funding of all spheres of life.

Fourthly, since the Arctic Zone of Yakutia is a part of a global climate formation system, the preservation of the Arctic ecosystem in the context of its industrial development becomes a serious challenge for the republic [25].

Finally, there is a unique culture and traditional lifestyle of the indigenous people of the North, who are the main inhabitants of the macro-region. Their invaluable historical experience of survival in the most difficult climatic conditions should be studied and used for the development of society as a whole [17].

#### 5. Conclusion

##### 5.1. Ecological safety of the Arctic territories

The most important tasks in solving environmental problems on the territory of Yakutia are the following:

- Removal and disposal of obsolete radioisotope thermoelectric generators
- Elimination of mining tailing dumps
- Removal and disposal of scrap metal
- Disinfection and decontamination of the sources of especially dangerous pollution (dielectric liquids, pesticides and other chemicals from the group of toxic persistent pollutants)
- Elimination of oil pollution and the remediation of oil-polluted territories and water areas
- Removal and disposal of quicksilver-bearing waste

In addition, it is necessary to improve the laws and regulations.

##### 5.2. Living standard of the population in the Arctic Zone of the Republic of Sakha (Yakutia)

In a crisis state of the economy, which led to the property and economic stratification of the population, the state policy should be aimed at the

formation of social justice. State-guaranteeing conditions are developed to ensure the normal process of reproduction of the population and to determine social security. The study of the problem of social security refers to development of special means for reducing the gap in the main indicators, characterizing the living standards of the population in the Arctic territories [18].

### 5.3. Living standard of the rural population in the Republic of Sakha (Yakutia)

Low living standard makes the population move to the settlements with more comfortable living conditions. Decrease in population over a large area, caused by the internal migration and the number of settlements reduction in sparsely populated areas in the North of the Arctic does not improve the strategic security of the country as a whole, and particularly in terms of its territorial integrity [19, 21].

### 5.4. Management of the Arctic regions budgets

In order to create the most favorable conditions for the investment in the Arctic Zone and to improve the living conditions for the population, the following mechanisms are introduced:

- VAT exemption for a specified period of time for organizations, which are the participants of the investment project of the base zones in the Arctic. This measure will reduce the tax burden and have a positive impact on the effectiveness of investment projects in the Arctic Zone of the Russian Federation
- Reduction of insurance contributions to 7.6%
- Reduction of profit tax to 5% during three tax periods and up to 10% during the next three tax periods. This measure will increase the profitability of investment projects, planned in the Arctic, which will reduce their costs and payback period
- Tax rate zeroing for small business that uses the patent taxation system and operates in the Arctic Zone of the Russian Federation. This measure will allow to increase business activity and to create institutional conditions for sustainable development of the Arctic, since the development of small business is a strategic factor that determines the sustainable development of the Arctic economy
- Do not reduce the subsidies. The amount of subsidies is a factor of economic and social stability, the reduction of which can lead to stagnation and destabilization in almost all spheres of the Arctic region economy [22]

### 5.5. Limitations of the Arctic Territory Information Base

The cornerstone of qualitative strategic planning is the information base for the analysis and research, which provide the search and quantitative assessment of the interrelations between the socioeconomic phenomena and processes, the study of definite development stages, forecasting and management. The absence of reliable long time series, which are necessary for the research on the socioeconomic development of the Arctic territories, makes it impossible to apply standard econometric and statistical methods of analysis and forecasting. Necessary comparison base is provided by the qualitative retrospective analysis. Correct and complete statistical observation of socioeconomic processes in the Arctic Zone of the Russian Federation is an urgent state task that does not accept a formal solution.

### References

- [1] Schegolev I.B. *On the role of the Arctic in the economic development of Russia in the 21st century*. Arctic and Antarctic, 2, 138 – 145, 2016.
- [2] Melnikova V.P. *Arctic permafrost: dynamics, resources, risks*. Bulletin of the Russian Academy of Sciences, 5(6), 2015.
- [3] Shtiller, M.V., Appakova, G.N., Selezneva, I.V., Vasiljeva, M.V., and Sisina, N.N. *Procedure for efficiency assessment of financial - Budgetary control system*. Journal of Applied Economic Sciences, XII(8(54)), 2442-2454, 2017.
- [4] Terentieva Zinaida S., Khalizova Irina A. *Logistics of recycling by the example of recycling of secondary metal in the regions of the Far North*. Management of economic systems scientific electronic journal, 3, 2018.
- [5] Federal State Statistics Service (n.d.). Retrieved from <http://www.gks.ru>
- [6] Kondratieva V.I., Stepanova N.A., Markova V.N. *Spatial Aspects of Strategic Planning of Municipal District Development*. ECO journal, 5, 179-192. Retrieved from <http://dx.doi.org/10.30680/ECO0131-7652-2018-5-179-192>, 2018.
- [7] A. Goli , S.A. Ahmadi , M. Nasr Azadani , H. Rezaei. *Providing a structured approach for evaluating and selecting suppliers in a supply chain*, UCT Journal of Research in Science ,

- Engineering and Technology, Issue 1, pp.17-31, 2014.
- [8] Serreze M. C., Barrett A. P., Slater A. J., Steele M., Zhang J. and Trenberth K. E. *The large-scale energy budget of the Arctic*. Journal of Geophysical Research, 112, D11122, 2007.
- [9] *Database of municipalities indicators among the subjects of the Russian Federation* (n.d.). Retrieved from <http://www.gks.ru/dbscripts/munst/>
- [10] *Statistical information on the socio-economic development of the Arctic zone of the Russian Federation*. (n.d.). Retrieved from [http://www.gks.ru/free\\_doc/new\\_site/region\\_stat/arc\\_zona.html](http://www.gks.ru/free_doc/new_site/region_stat/arc_zona.html)
- [11] Mokrensky D.N. *Municipal Statistics: Opportunities and Constraints for Regional Socio-Economic Analysis*. Voprosy statistiki, 25(7): 49-61, 2018.
- [12] Hu Y, van Lenthe F.J., Mackenbach J.P. *Income Inequality, Life Expectancy and Case-specific Mortality in 43 European Countries, 2008: a Fixed Effects Study*. European Journal Epidemiology, 30(8), 615-625, 2015.
- [13] Kryukov V. *North and Arctic: There is no Connection without Sustainability*. EKO, 48(4), 4-7, 2018.
- [14] Stjepanović, S., Tomić, D., and Škare, M. *A new approach to measuring green GDP: a cross-country analysis*. Entrepreneurship and Sustainability Issues, 4(4), 574-590, 2017.
- [15] Prakash, R., and Garg, P. *Comparative assessment of HDI with Composite Development Index (CDI)*. Insights into Regional Development, 1(1), 58-76, 2019.
- [16] Dalevska, N., Khobta, V., Kwilinski, A., and Kravchenko, S. *A model for estimating social and economic indicators of sustainable development*. Entrepreneurship and Sustainability Issues, 6(4), 1839-1860, 2019.
- [17] Baltgailis, J. *The issues of increasing the effectiveness of teaching comparative economics*. Insights into Regional Development, 1(3), 190-199, 2019.
- [18] Szalai A., Andrews F.M. *The Quality of life*. London; Beverly Hills, Calif. Sage Publications, 145-155, 249-268, 1980.
- [19] Elyakova I.D., Pakhomov A.A., Poiseyev I.I., Yefremov E.I., Darbasov V.R., Noyeva E.Y., Khristoforov A.A., Elyakov A.L. *Prospects for Development of Renewable Energy Sources to Preserve the Ecosystem of Arctic Zone of Russia*. Indian Journal of Science and Technology, 9(46), 288-296, December 2016.
- [20] Ivanov N.S. *Problems of Arctic Region Management: Russia-Canada*. Proceedings of the Russian Geographical Society, 6, 29-43, 2018.
- [21] Vinokurova U.A. *Indigenous nations of Siberia: can they meet the challenges of the 21st century?* Knowledge. Understanding. Skills, 1(2), 2015.
- [22] Kistova A.V., Pimenova N.N, Zamaraeva Ju.S., Reznikova K.V. *Research possibilities for studying the indicators of quality of life of indigenous peoples of the North (based on the study of indigenous peoples of the North of Russia)*. Life Sc., 11(6s). 593-600, 2014.
- [23] Balynskaya, N.R., and Ponomarev A.V. *Current issues in the development of modern political and economic processes in Russia and Europe*. Economics and Politics, 2(12), 5-7, 2018.
- [24] Vinogradova, N. *Methods of evaluation of social development*. Journal of Contemporary Economics Issues, 1, 2015. <https://doi.org/10.24194/11506>
- [25] Aziz, N., Muhammad, Z., Ghazali, F., Talaat, W.I.A.W., and Saputra, J. *Marine Spatial Planning: the way forward for sustainable development of Central Terengganu, Malaysia*. Journal of Southwest Jiaotong University, 54(4), 2019. <https://doi.org/10.35741/issn.0258-2724.54.4.9>