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Innovative Approach to the Development of the Logistics System of Supply of the Arctic Region Space

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ABSTRACT

This article reviews the basic methodological approaches to the arrangement of the logistics supply of manufacturing, research or tourism facilities based in the Arctic. The main purpose of this article was to optimize the processes of supply the Arctic territories with the use of high-tech approach, which integrates the concept of "green" logistics technology (reverse logistics, in particular) and methods of economic and mathematical modeling for inventory management and planning the purchase of resources necessary to ensure the proper functioning of the Arctic facilities. Taking into account the fact that the Arctic holds interests of many countries and corporations, as well as taking into account the fact that further development of the Arctic must be environmentally responsible, the integration of traditional and new approaches to the arrangement of supply of the Arctic facilities through the use of reverse logistic technologies of economic and mathematical modeling using the correlation-regression analysis were proposed.

Keywords: Arctic, Supply Logistics, Reverse Logistics, Correlation-regression Analysis, Ecosystem, Environmental Responsibility
JEL Classifications: Q57, Q28

1. INTRODUCTION

Development and exploration of the Arctic region is currently unfolding very actively in both scientific and industrial production context. Almost all countries that are part of the Arctic Council have their own strategies for development of the Arctic, but only five countries (Russia, the USA, Canada, Denmark and Norway) have direct access to the coast of the Arctic Ocean. Given that the territorial disputes between the five Arctic states in many respects are still not completed, the competition for the most rapid, effective and large-scale development of the Arctic is constantly increasing (Lukin, 2010; Smith, 2010; Mazur, 2010).

Along with increased competition, there is also diversification of approaches to the exploitation of natural and resource potential (Chater, 2012; Cooke, 2011; UNESCO, 2009; Hodgson, 2007). For example, the US abandoned the development of some deposits of hydrocarbon resources on their part of the shelf in 2015, but did not fold the scientific and research activities. Russia, Canada, Norway and Denmark are planning to develop the Arctic tourism and create a new transport infrastructure (Northern Sea Route, transnational northern transportation network with the arrangement of cross-polar flights). In the meantime, Russia does abandon its deposits on the Arctic shelf, large-scale in development and commercial operation, even despite the fact that many transnational mining corporations have left the Arctic or folded (suspended) facilities for the exploration, development and production of hydrocarbon resources in this region.

Due to the fact that the Arctic will not lose its commercial and scientific appeal in the long run, it can be assumed that the traffic flows in this region will show a constant increase in the near future.

This is primarily due to the fact that it is impossible to conduct commercial or research activities in the Arctic without optimally organized logistics of supply.

2. METHODS

We use an integrated knowledge-intensive approach to optimization of the Arctic logistics in this article, using an environmentally-focused concept and methods of economic and mathematical modeling. The article suggests using correlation-regression analysis for inventory management and procurement planning (Orlova et al., 2015; Box et al., 2015), which allows to define the conditional expectation of one dependent variable (y) as a function of a set of independent variables (x_i) in terms of the n^{th} number of observations taking into account the regression coefficients (β_i) and the random component (ε):

$$y_i=\beta_1+\beta_2 x_2+\ldots+\beta_k x_{ki}+\varepsilon_i, i=1,\ldots,n \quad (1)$$

A special correlation coefficient (r) is calculated in order to identify or determine the relationship between the effective and factorial signs:

$$r=\frac{\sum\left(x-\bar{x}\right)\left(y-\bar{y}\right)}{\sqrt{\sum\left(x-\bar{x}\right)^2\sum\left(y-\bar{y}\right)^2}} \quad (2)$$

It is recommended to use a standardized Wilson formula or one of its modifications to calculate the optimal and economically feasible size of the order for the supply of certain resources (Bowersox et al., 1991):

$$Q=\sqrt{\frac{2CR}{H}} \quad (3)$$

Where:
Q is the optimal size of the order for the supply of resource (resources);
C is costs of order placement;
R is the planned demand for resources (the required number of units);
H is the costs associated with storing the unit of the reserves.

We gave developed the following formulas to calculate the individual parameters of the economic and mathematical model proposed in the article and recommended for inventory management and planning of the resources procurement for the functioning of the Arctic facilities:

$$S=eb-ed+\downarrow et \quad (4)$$

$$T=1-\frac{\sum L}{\sum nL} \quad (5)$$

$$I=\frac{sq}{w} \quad (6)$$

Where:

S is environmental damage from supply to the Arctic facilities and their storage of secondary resources to be exported to the mainland for disposal or recycling, corrected and assessed in terms of value;

T is stability and reliability of resource supplies carried by the logistics aggregator to the Arctic facilities;

I is a coefficient of immobilization of resource reserves at the Arctic facilities;

eb, ed, ↓et are respectively the economic (cost) assessment of the benefit of functioning of the Arctic facility, the environmental damage it causes, and the level of decline in environmental damage per unit of purchased resource or stored reserve;

ΣL и ΣnL are the total amount of supplies of resources to the Arctic facilities carried, respectively, in violation of the terms and conditions of the supply contracts and in compliance with the terms and conditions of the supply contracts;

sq and w are a shaped reserve of resources that are stored at the Arctic facility and the planned demand for resources (units of reserve and units of supply).

3. RESULTS

The World Ocean can be considered as a global transport system, which provides up to 80% of the total cargo turnover transported using the water transport. At the same time, the main burden of the cargo transportation in the share distribution falls on the Atlantic Ocean (Figure 1).

The Arctic Ocean provides only 5% of the world maritime cargo turnover. But at the same time, it is an important transport route for Russia and European countries (Norway, Denmark, Iceland). For example, the Northern Sea Route provides Russia with transportation of about 40 mln tons of various cargoes. At the same time, more than 70% is transportation of dry cargo, the rest is liquid cargo. There is a year-round navigation by the Norwegian coast; the main cargo is fish, liquid and solid hydrocarbons, iron ore and timber. Greenland and Denmark regularly carry out transportation of various cargoes: Greenland supplies fish and mining products, while Denmark supplies food and consumer goods. Coasting trade is very well developed in the coastal waters of Iceland. The North-West Passage (along the coast of North America through the Canadian Arctic Archipelago) is less often used (Tsetlin and Krasnova, 2014, The Arctic Council, 2016).

The Arctic Ocean is also used for the military and defensive purposes. During the Second World War, the path of the Arctic convoys went through the European part. Currently, the Royal Danish Navy and the Royal Norwegian Navy have ships for work in light ice. The Royal Canadian Navy (Coast Guard) includes 11 icebreakers. Russia's Northern Fleet, which is based on the coast of the Barents and White Seas, includes 40 icebreakers, and 5 of them are nuclear. The US Pacific Fleet is not equipped with nuclear icebreakers (it includes a total of 6 vessels equipped for work in heavy ice), but includes nuclear submarines, which carry out both intelligence and research. Russia is an undisputed leader among the Arctic countries by the composition and quantity of the icebreaker fleet units (Figure 2).

One should not forget about the active research work in the Arctic. For example, the International Arctic Science Committee (IASC, 2016) was created in 1990, under which five working groups function on a regular basis (on atmospheric research, on marine research, on social and human development, on the ice cover research, as well as of the water area, the landscapes and biota). During the International Polar Year alone (2007-2008), about 286 different national research programs for the study of the biota and ecosystems of the Arctic and Polar territories were realized. Of them, 85% of all completed projects (i.e. 243 projects) fell for the Arctic countries (USA, Canada, Norway, Finland, Russia, Sweden, Denmark). The exception is Iceland, which has not realized its own projects, but has participated in projects of the European countries (Figure 3).

As such, active research and socio-economic exchange between the Arctic territories and the mainland requires new knowledge-intensive approaches to the construction of the functional logistics of supply, given that nearly all equipment, goods and household items, food, medicines and surgical dressing generally require the arrangement of special supply.

In Russia, northern territories, including the Arctic, have been supplied and are still supplied with the required goods, household items and equipment primarily under the "northern delivery" program. In European countries, as well as in the countries of North America, Polar and Subpolar territories are supplied on a constant basis, but the most important and valuable goods are usually delivered in the spring-summer period, when navigation (air and sea) is not complicated by the harsh climate. In other words, Russia uses target-oriented approach to supply the Arctic territories, while the countries of North America and Europe (European North) use a mixed approach (process of regular supply of Arctic territories includes the programs of delivery of special goods during the spring-summer navigation) (Dudin et al 2016; Lukin 2010; Smith 2010).

At the same time, it should be taken into account that the environmental damage to the Arctic ecosystem constantly increases, in part because goods imported into the Arctic are not always fully utilized (which determines the appearance of the waste that is not disposed of in a natural way and is preserved in permafrost). Besides, the Arctic has already accumulated a sufficient amount of returnable packaging units, as well as disposable and reusable packaging that clutters and pollutes the natural space and water, poisons biota, etc. Therefore, it is objectively obvious that there is a need to change the existing approaches and organization of supply to the construction of the relevant logistics processes.

4. DISCUSSION

The logistics scientific paradigm has changed in recent decades. These changes primarily relate to the greening of building socio-economic functional processes and other processes that directly relate to them. The environmental aspect of the global social and economic development was first raised in the 90s of the last century, which resulted in the concept of "sustainable development" that dominated for two decades. Currently, the concept of "sustainable development" has evolved into the concept of "green economy," which includes the aspect of social equality in addition to the environmental aspect. "Green" or environmentally responsible logistics is a derivative functionality from the "green economy."

Figure 1: Structure of the global marine cargo turnover, 2014-2015. (Lappo and Danilova, 2015; Tarvainen et al., 2015)

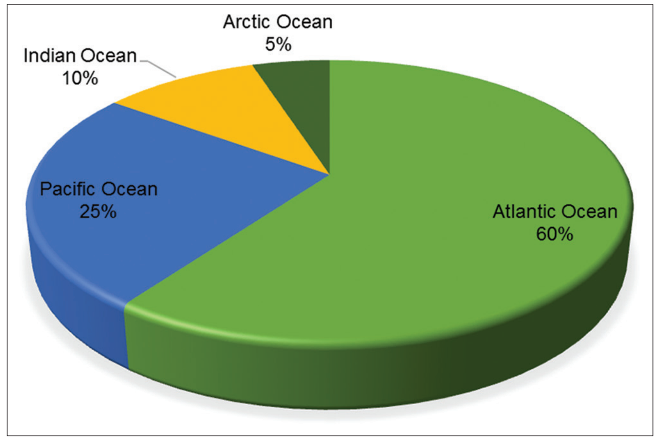


Figure 2: Number of icebreaking vessels in possession of the major Arctic states, 2014-2015 (Lappo and Danilova, 2015; Tarvainen et al., 2015; Tsetlin and Krasnova, 2014)

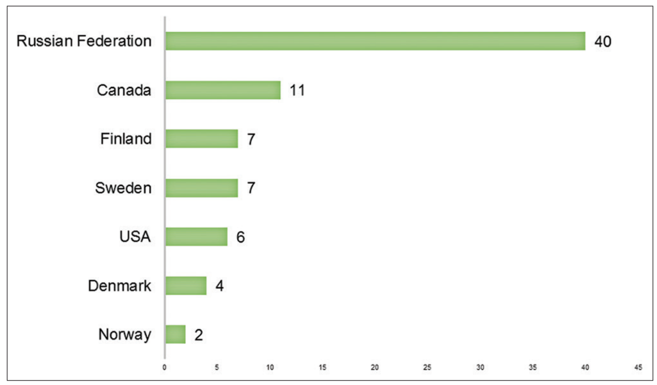
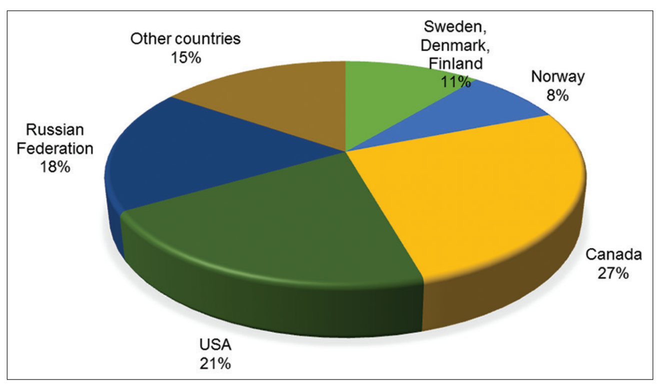


Figure 3: Specific contribution of the Arctic countries to the realization of research projects during the International Polar Year (2007-2008) (IASC, 2016; The Arctic Council, 2016)



Increase in environmental responsibility in the transport and logistics field was called "green logistics" (Chapple, 2008; McKinnon et al., 2015; Ehrhart, 2012). "Green" logistics (including in terms of the development of the transport and logistics potential of the Arctic) is an arrangement of movement of cargoes and passengers and other transport and logistics services, the provision of which to the economic agents and agents of socio-residential sector is carried out with the use of environmentally friendly technologies that do not increase and at the same time reduce the level of anthropogenic and industrial impact on the global ecosystem. The key idea of the "green" logistics, which does not deny the traditional scientific postulates, is to "…deliver more using less…" (Bowersox et al., 1991; Coyle et al., 1992; Apostol, 2012; McKinnon et al., 2015). In other words, green logistics includes two conceptual methodological provisions:

- Firstly, it requires a gradual and systematic abandonment of environmentally harmful and aggressive transport that uses gasoline and similar fuels with a high level of emission of carbon dioxide;
- Secondly, it requires intensification of the use of transport capacity, not only to reduce the pressure on the ecosystem, but also to reduce the burden on the transport and logistics infrastructure, the restoration of which is always characterized by high capacity of capital.

For the Arctic, with its unique and at the same time very fragile environment, the environmentally responsible logistics (including in the context of the supply of the Arctic territories) is an urgent scientific and applied concept. In this context, the logistics solutions can have several basic options:

a. Long-term solutions focused on the complete modernization of transport used in the Arctic (switching to environmentally friendly fuel, avoiding the use of machines non-resistant to the Arctic climate). The solutions to improve transport and logistics infrastructure can also be implemented here (autonomous automated terminals for storing reserves, used cooperatively, etc.);
b. Medium-term solutions focused on reducing the industrial impact, including that associated with the supply of the Arctic territories with essential goods (commodities, food, equipment, etc.). In this case, various forms of collective procurement can be used, as well as phasing out environmentally aggressive environmental aviation and navigation, transition to the fragmented delivery of small cargoes using environmentally friendly biopilot aircrafts;
c. Short-term solutions focused on the current ecological optimization of logistics procurement process through the construction of their most rational models and the use of reverse logistics technologies.

The reverse logistics can be considered as a "green" logistics technology focused on the ensuring, through the collection (accumulation) of the obsolete, corrupted or damaged product, its packaging and transport packing, including for subsequent secondary or tertiary processing (recycling) or for the environmentally safe disposal that does not create an additional industrial or anthropogenic load on the environment (Dyckhoff et al., 2013). In turn, modeling is based on the use of economic and mathematical methods and, in particular, correlation-regression analysis. Since we talked about the multiple regression equation in the method section, then, respectively, it is advisable in the first place to identify the main factors that will determine the optimal amounts of goods and supplies that are necessary to ensure the normal functioning of commercial firms, research expeditions, tourist groups or environmental volunteers.

The second important aspect is that the process of supply should be described by a direct and return flow. Hence, the process of supply of the Arctic facilities with the necessary resources (commodities, raw materials, medicines and other goods) should be as follows (Figure 4). In other words, each supply of the resources to the Arctic facilities should be:

- Firstly, optimized and economically feasible taking into account the required reserve;
- Secondly, rationalized taking into account the reduction of the environmental, transaction and other costs;
- Thirdly, always be described by the presence of a reverse logistics flow (returnable packaging, flawed commodities, items that are out of operation).

At the same time, management of the process of supply and formation of reserves should be described by simultaneous centralization (supply by a specialized logistics aggregator) and decentralization (requirements for the optimal and rational, economically sound volume of the order are set by each Arctic facility independently). In addition, each Arctic facility independently forms a return flow (secondary resources recycling and disposal).

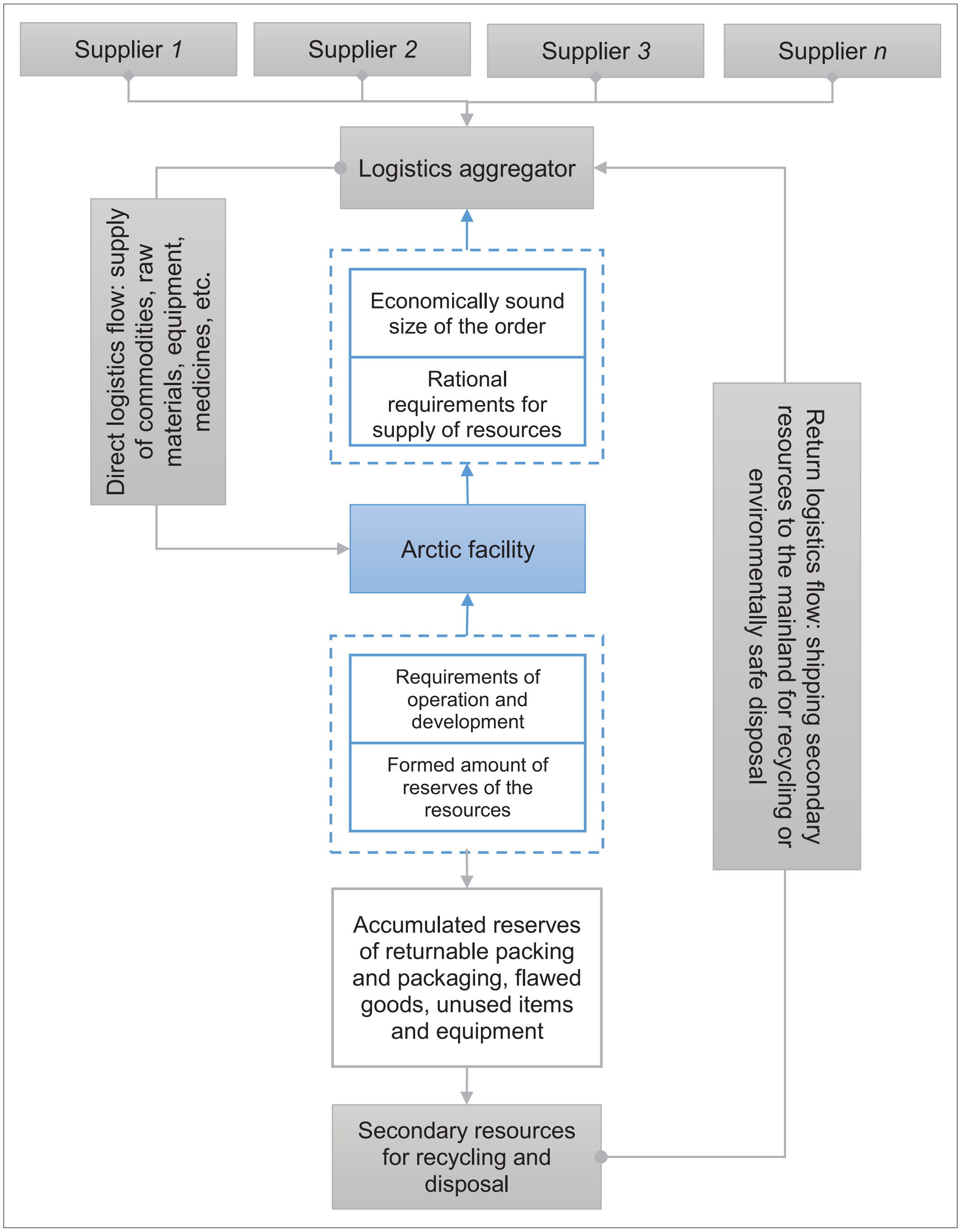
Wilson formula and its modification for the calculation of the optimum size of the order are well known and presented in the method section of this article. Therefore, we are not going to dwell on the methodological approaches to the calculation of the optimal and economically feasible size of the order; we will just take into account that the size of the order for the supply will depend on:

1. The current (formed) size (volume) of the reserve, frequency and certainty of supply;
2. The cost of the physical movement of the cargo in space;
3. The potential environmental damage associated with the delivery of the cargo, as well as the accumulated environmental damage (non-recycled packaging, packing, flawed goods);
4. The willingness of suppliers to use the returnable logistics flow to increase environmental supply and optimization of the logistics process.

In view of the above, we can logically assume that the economic and mathematical model describing the state of reserves, as well as the logistics process of supply of the Arctic facilities with necessary resources (commodities, raw materials, equipment, medicines, etc.), should include the following set of variables:

1. The planned demand for some type of resource for a certain time period (e.g., month, quarter, 6 months, etc.), i.e. the

Figure 4: Model of the process of supply of the Arctic facilities with necessary resources



number of stock units to be purchased (supplied) to meet the needs of functioning of the Arctic facility. This, in accordance with Wilson formula, also takes into account the resource consumption over a certain period, which is reflected in the calculation of the planned and economically feasible size of the order;

2. The estimated and corrected environmental damage in terms of value per unit of reserve/order. Here the difference can be used between the economic evaluation of potential direct or indirect benefits from the operation of the Arctic facility and the economic evaluation of environmental damage associated with the operation of the facility per unit of stock/order. In this case, the estimated environmental damage needs to be corrected (per unit of reserve/order), bearing in mind that the load on the ecosystem of the Arctic will be reduced. This will be achieved through the return logistics flow (coordinated in time with direct logistics flow), during which secondary resources for recycling and/or disposal will be sent to the mainland;
3. The market price of the delivery and storage of the reserve unit, the price includes not only the actual value of the resource, but also the value of its physical movement in space from the supplier to the logistics aggregator and from the logistics aggregator to the Arctic facility;
4. The stability and certainty of supply of resources by the logistics aggregator to the Arctic facility. This indicator is

best calculated as the ratio of the quantity of deliveries carried out in violation of the terms of contracts to the quantity of deliveries made on time and in compliance with the key terms of the contracts;
5. The current level of the reserves of resources (including safety stock in the case of a failure in supply) in terms of quantity, which is in storage at the Arctic facility at a given time;
6. The coefficient of immobilization of reserves of resources, which are in storage at the Arctic facility at a given time. This figure represents the ratio of the current amount of the reserve to the target demand for the resource.

All the necessary formulas for the calculation of the indicators listed above can be found in the methodological section of this article, while we suggest to plan the demand for supply of resources and make decisions on the current reserves on the basis of economic and mathematical model of multiple regression. In particular, let's assume that the n^{th} Arctic facility needs the i^{th} resource, while the demand for this resource and the key variables of the model have been described by the following basic values over the past 27 months (Table 1).

At the same time, we should take into account that the reverse logistics flow for minimization of the environmental damage was used at the n^{th} Arctic facility from the 10^{th} month, which reduced the level of environmental damage from the operation of this Arctic facility, as well as reduced the cost of the delivery of the unit of the reserve of resource. But considering that Arctic conditions cannot guarantee high stability and certainty of supply of resources from the mainland to the n^{th} Arctic facility, the current volume of reserves and the reserves immobilization coefficient also increases. The multiple regression model for this example will be described by the following values of the variables (Table 2).

Table 1: Source data for inventory management and planning the procurement of the i^{th} resource at the n^{th} Arctic facility

Period	Target demand for the resource (amount of purchases), units	Estimated and corrected environmental damage, $ per unit	Price of delivery per unit, $	Stability/certainty of supply	Current volume of reserves, units	Coefficient of immobilization
1	1.019	16.2	305	0.9	31	0.03
2	1.031	16.4	330	0.9	31	0.03
3	1.076	16.5	330	0.9	32	0.03
4	1.124	17	330	0.9	34	0.03
5	1.144	17	331	0.9	34	0.03
6	1.163	18.5	331	0.75	35	0.03
7	1.004	18.6	331	0.7	70	0.07
8	1.017	19.2	331	0.75	71	0.07
9	1.025	19.4	331	0.6	72	0.07
10	1.063	19.5	331	0.75	117	0.11
11	1.187	19	298	0.8	131	0.11
12	1.209	18.3	293	0.8	133	0.11
13	1.215	17.4	290	0.8	134	0.11
14	1.296	16.4	287	0.9	143	0.11
15	1.333	15.3	280	0.9	147	0.11
16	1.387	14.7	276	0.75	153	0.11
17	1.400	14.4	273	0.7	196	0.14
18	1.515	14	273	0.75	212	0.14
19	1.599	13	273	0.6	224	0.14
20	1.602	12.7	273	0.75	224	0.14
21	1.659	12.7	273	0.8	232	0.14
22	1.721	12.5	273	0.55	275	0.16
23	1.800	12.6	273	0.55	288	0.16
24	2.066	12.5	273	0.9	331	0.16
25	2.231	12.1	273	0.9	424	0.19
26	2.503	12.1	273	0.8	476	0.19
27	2.765	12	273	0.7	525	0.19

Table 2: Coefficients of the multiple regression model for inventory management and planning of procurement of the i^{th} resource at the n^{th} Arctic facility

Variable of the model		Coefficients
Y-crossing (target demand for the resource, i.e., target size of the order)		2150.624367
Variable x_1	Estimated and corrected environmental damage per unit of the reserve of the resource	−3.38558792
Variable x_2	Price of delivery per unit of the reserve of the resource	−1.60613002
Variable x_3	Stability and certainty of supply of resources	35.65185294
Variable x_4	Current (formed) volume of reserves of resources	4.577582564
Variable x_5	Coefficient of immobilization of reserves of resources	−5193.523483
Multiple regression model view		

$y\hat{x}=2150.62-3.39x_1 - 1.61x_2 + 35.66x_3 + 4.58x_4 - 5193.52x_5$

The multiple regression model shows that variables x_1, x_2, x_5 will adversely affect the target volume of the order and, respectively, reduce the demand of the n^{th} Arctic facility for the i^{th} resource. In this case, the regression statistics shows that there is a very close connection between the effective and factorial signs in the economic and mathematical model (Table 3).

Next, using the pair correlation, let's construct paired linear regression equations for each factor, and then for an effective sign for the upcoming 10 periods (months). Hence, the predictive model of inventory management and planning of procurement of the i^{th} resource at the n^{th} Arctic facility will have the following form (Table 4).

Thus, the obtained data allow to conclude that inventory management and planning of procurement of the i^{th} resource at the n^{th} Arctic facility require to consider the following:

- Firstly, if the specifics of operation of the Arctic facility does not change, then all other things being equal the demand for the i^{th} resource will increase over the next 10 months by an average of 20-21%;
- Secondly, the corrected and estimated environmental damage will significantly reduce at least by 19% over the period under study, but the procurement costs will reduce by only 10%;
- Thirdly, the stability and certainty of supply of reserves of resources is likely to be insufficiently high, which in turn will cause an increase in the current level of reserves of resources and, accordingly, the level of immobilization of reserves at this Arctic facility.

Table 3: Statistics of the multiple regression model for inventory management and planning of procurement of the i^{th} resource at the n^{th} Arctic facility

Regression statistics	
Multiple R	0.996849189
R^2	0.993708306
Normalized R^2	0.992210284
Standard error	41.84086047
Observations	27

5. CONCLUSIONS

Thus, summarizing this article, we consider it necessary to note that the transition to environmentally responsible logistics supply in the Arctic is an objective necessity. In this case, the solutions on the greening of the logistics of supply of the Arctic facilities (research, commercial or tourist) can be implemented in the short term through the use of reverse logistics technologies. The idea is to create a forward and reverse logistics flows, consistent in time, which will provide both the supply to the Arctic facilities of necessary resources (commodities, equipment, medicines, foods, etc.) and the simultaneous transfer to the mainland of the accumulated volume of secondary resources (accumulated stocks of returnable packaging, packing, flawed goods, unused supplies and equipment), which can create a significant threat to the ecosystem of the Arctic. In this case, the planning of the resource supply and inventory management should be implemented with the use of economic and mathematical modeling. This paper proposes a multiple regression model, which includes five most important variables that determine the sizes of the target procurements of resources based not only on the current formed volume of reserves and the level of immobilization of resources in reserves, but also on environmental damage.

The suggested approach to the organization of supply, construction of logistics processes, as well as to the management of reserves at the Arctic facilities (research, commercial or tourist) can be regarded as innovative and knowledge-intensive. This approach is based on the concept of "green" logistics (including the technology of reverse logistics) with the integration of economic and mathematical methods in inventory management and procurement planning, taking into account such an important parameter as the environmental damage from the supply of the Arctic facilities with resources (research, commercial or tourist).

The authors did not consider separate methodological issues on improving the institutional environment of the arctic logistics and harmonization of national and international organizational, economic and legal approaches to environmentally responsible development of Arctic territories in this article. These and other aspects of sustainable and environmentally-focused development

Table 4: Predictive model for inventory management and planning of procurement of the i^{th} resource at the n^{th} Arctic facility

Period	Target demand for the resource (amount of purchases), units	Estimated and corrected environmental damage, \$ per unit	Price of delivery per unit, \$	Stability/certainty of supply	Current volume of reserves, units	Coefficient of immobilization
28	2182.003	11.8	256.6	0.708	404.924	0.200
29	2234.278	11.5	253.8	0.703	421.220	0.206
30	2286.554	11.2	250.9	0.698	437.516	0.213
31	2338.829	10.9	248.0	0.693	453.812	0.219
32	2391.105	10.7	245.2	0.688	470.108	0.226
33	2443.380	10.4	242.3	0.683	486.404	0.232
34	2495.655	10.1	239.5	0.678	502.700	0.239
35	2547.931	9.9	236.6	0.673	518.996	0.245
36	2600.206	9.6	233.8	0.668	535.292	0.252
37	2652.481	9.3	230.9	0.663	551.588	0.259

of the Arctic as a world heritage will be discussed in more detail in other articles.

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