The concept of creating a digital clone of the Arctic territories

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Abstract. In the article, the concept of creating a digital clone to support the development of the Arctic territories, based on the representation of the territory in the form of target subspaces and modelling of the development of the territory in the form of a three-level model, is presented. The Arctic space is divided into target subspaces in accordance with the institutional-functional approach. In other words, the Arctic space is represented by a combination of systems, structures and their functions. The Arctic space comprises a holistic system, in which each element performs its relevant function. The function of the Arctic space consists in the ability to meet specific social needs. Human activities in the Arctic space are organised on the basis of institutions. In a general sense, the entire Arctic space can be said to consist of institutions and functions. The first level of the model represents the branch structure of the economy of the Arctic region. The second level consists of the target subspaces: “territories for the extraction of mineral resources”, “territories for recreational purposes”, “territories for fishing”. The third level shows the relationship between the target subspaces and the country's economy.

Keywords: digital clone of the development of the Arctic territory, target subspaces, institutional-functional approach, development of the Arctic territories, model of the development of the Arctic territories

1. Introduction

The north-polar economy of the Arctic territories of Denmark, Iceland, Canada, Norway, Russia, the USA, Finland and Sweden consists mainly of mining, oil and gas production, fishing, reindeer herding, seal hunting, arts and crafts, as well as the tertiary sector of the economy, including transport, communications, trade, tourism and healthcare. The economic situation in the circumpolar Arctic is distinct from that obtaining in other world regions. Although the formal economy is based around the large-scale exploitation of natural resources, traditional hunting and gathering, fishing and animal husbandry also remain significant activities for the northern peoples. Mining and fishing opportunities in the North have increased significantly over the past two decades with the advent of climate warming, which helps to facilitate access to such resources. Another consequence of climatic changes in the Arctic region has been an increase in fish stocks. It is expected that the ocean will continue to become more accessible.

An analysis of the use of the natural potential of the Arctic regions requires the development and use of a digital clone for the development of the Arctic territories, taking into account the characteristic features and significance of the natural potential of the Arctic regions for the world community. It is against this background that the present article sets out to: (a) to demonstrate the
conceptual provisions of the digital clone of the development of the Arctic territories, including the representation of the territory in the form of target subspaces and a model of such target subspaces; (b) a demonstration of the concept of the digital clone on some target subspaces. The Arctic territories of Canada, presented in the form of Arctic subspaces and models of interest, are considered as a real object.

2. Methods

2.1. Representation of subarctic territories as a set of target subspaces
To develop the concept of creating a digital clone of the Arctic territories, an institutional-functional approach is used to identify the target subspaces and their development. A detailed description of the institutional-functional approach can be found in the work of N.I. Didenko and others [1].

The general conceptual idea of organising and managing the development of the subarctic space involves representing the space in the form of a set of target subspaces, the theoretical justification of which is described in the above work [1].

By subspace we refer to a part of the Arctic space having a number of distinctive properties (attributes) that allow for the functional division of the subarctic territory, as well as being characterised by a specific development goal.

Among the possible types of target subspaces that make up the subarctic space, the following can be distinguished:

a) Base cities – large and medium-sized settlements and production points, of which, at present, there are not so many in the Arctic space of the Russian Federation.

b) Mobile shift camps – one of the approaches to the development of the Arctic territories, where the organisation of permanent domestic, cultural, educational and other types of infrastructure can be difficult and economically disadvantageous. Mobile shift camps are usually located near mineral deposits or in areas where construction and maintenance of infrastructure facilities is taking place.

c) Territories associated with the extraction of mineral resources. These territories are understood in terms of deposits and industrial facilities constructed for the extraction of minerals. We emphasise once again that the concept of “territories for the extraction of mineral resources” is not limited to the definition of a deposit of a resource (i.e., accumulation of minerals); however, explored or prospective deposits, where the direct extraction of resources has not yet begun, do not belong to the category of this target subspace.

d) Territories associated with fisheries. This concept does not exclusively consist in the variety of aquatic resources available for fishing; the target subspace includes facilities and infrastructure for commercial fishing.

e) Territories associated with recreational activities. These territories include such objects of tourist interest as nature reserves, national parks, zones of eco-, ethno- and extreme tourism, as well as other attractions of the Arctic space that form the network of Arctic tourism. Thus, the division of the Arctic space into subspaces will be functional in nature: each type of subspace performs different functions in accordance with its inherent attributes comprising inherent and necessary properties, i.e. the functional approach serves to highlight the type of subspace. The consideration of subspace as an institution helps to facilitate the design of a programme for the development of that subspace.

2.2. Modelling the development of the Arctic space
The development of the Arctic space is presented in the form of a three-level model. The purpose of building the model is to demonstrate the validity and applicability of this model for the conceptual provisions in creating a digital clone of the Arctic territories.

The model is constructed on the example of the Arctic space of Canada. The Arctic space of Canada is presented in the form of a three-level model. The first level represents the branch structure of the economy of the Arctic regions. It is assumed that there are three industries operating in the Arctic Canada. The second level comprises target subspaces. It is also assumed that there are three target subspaces. The third level shows the relationship between the subspaces and the country's economy. The model of each level has endogenous (resulting) and exogenous (influencing) indicators.
Moreover, endogenous (resulting) indicators of the previous level become exogenous (influencing) indicators of the next level.

The system of three equations of the first level (1) in the form of production functions shows the dependence of the volume of production of three industries \(Y_{t1-1}, Y_{t1-2}, Y_{t1-3}\) from factors of production \(X_{t1-1}, X_{t1-2}, X_{t1-3}, X_{t1-4}, X_{t1-5}, X_{t1-6}\).

\[
\begin{align*}
Y_{t1}^{1-1} &= AX^{1-2}X^{1-3}Y_{t1-1}^{1-1} \\
Y_{t1}^{1-2} &= AX^{1-3}X^{1-4}Y_{t1-1}^{1-2} \\
Y_{t1}^{1-3} &= AX^{1-4}X^{1-5}Y_{t1-3}^{1-3}
\end{align*}
\]

The system of three equations of the second level (2) represents the selected target subspaces. Endogenous variables of the first level \(Y_{t1-1}, Y_{t1-2}, Y_{t1-3}\) become exogenous variables in the second level model.

\[
\begin{align*}
Y_{t2}^{2-1} &= a_0 + a_1 Y_{t1}^{2-1} + a_2 Y_{t1}^{2-2} + a_3 Y_{t1}^{2-3} + a_4 X_{t1}^{2-1} + a_5 X_{t1}^{2-2} \\
Y_{t2}^{2-2} &= a_0 + a_1 Y_{t1}^{2-1} + a_2 Y_{t1}^{2-2} + a_3 Y_{t1}^{2-3} + a_4 X_{t1}^{2-2} + a_5 X_{t1}^{2-3} \\
Y_{t2}^{2-3} &= a_0 + a_1 Y_{t1}^{2-1} + a_2 Y_{t1}^{2-3} + a_3 Y_{t1}^{2-2} + a_4 X_{t1}^{2-3} + a_5 X_{t1}^{2-5}
\end{align*}
\]

The system of three equations of the third level (3) shows the influence of target subspaces on the Canadian economy.

\[
\begin{align*}
Y_{t3}^{3-1} &= a_0 + a_1 Y_{t2}^{3-1} + a_2 Y_{t2}^{3-2} + a_3 Y_{t2}^{3-3} + a_4 Y_{t2}^{2-1} + a_5 Y_{t2}^{2-2} \\
Y_{t3}^{3-2} &= a_0 + a_1 Y_{t2}^{3-2} + a_2 Y_{t2}^{3-3} + a_3 Y_{t2}^{3-1} + a_4 X_{t2}^{3-1} + a_5 X_{t2}^{3-2} \\
Y_{t3}^{3-3} &= a_0 + a_1 Y_{t2}^{3-3} + a_2 Y_{t2}^{3-3} + a_3 Y_{t2}^{3-3} + a_4 X_{t2}^{3-3} + a_5 X_{t2}^{3-4}
\end{align*}
\]

Endogenous indicators of the third level: \(Y_{t3}^{3-1}\) – GDP of Canada; \(Y_{t3}^{3-2}\) – foreign trade turnover of Canada; \(Y_{t3}^{3-3}\) is the human development index of Canada. The exogenous variables of the third level include endogenous indicators of the second level.

2.3. Target subspaces of the Canadian Arctic

For the second level, the following target Arctic subspaces were selected: “territories for the extraction of mineral resources”, “territories for recreational purposes”, “territories for fishing”.

2.4. Methodology for obtaining the coefficients of a three-level model for the development of the Arctic space

The technique includes various information processing procedures, a detailed description of which can be found in [2], [3].

2.5. Data

For analysis, we used statistical information on economic reports for Canada [4], on the development of the economy in the North of Canada [5], statistics from the Canadian national statistical agency [https://www.statcan.gc.ca], associations of mining of Canada [6], the Nunavut Bureau of Statistics [http://www.stats.gov.nu.ca], the Northwest Territories Bureau of Statistics [http://www.statsnwt.ca] and the Yukon Bureau of Statistics [http://www.eco.gov.yk.ca].

3. Result
Implementation of the developed methodology allowed us to obtain the following form of the three-level model (4), (5), (6).

Level 1:

\[
\begin{align*}
Y_{1}^{1-1} &= 12.5 X_{1}^{1} - 5.84727E-16 X_{1}^{1-1} \\
Y_{1}^{1-2} &= 3.3333 X_{1}^{1} - 1.0902E-15 X_{1}^{1-1} \\
Y_{1}^{1-3} &= -21.30774013 X_{1}^{1} - 6.798864549 X_{1}^{1-1} - 5.01021022
\end{align*}
\]  

(4)

Level 2:

\[
\begin{align*}
Y_{2}^{2-1} &= 0.16 + 0.18 Y_{2}^{2-1} + 9.8 E - 0.6 Y_{2}^{2-2} + 0.014 Y_{2}^{1-1} - 0.0016 X_{2}^{2-1} + 0.00032 X_{2}^{2-2} \\
Y_{2}^{2-2} &= 79.989 - 85.3 Y_{2}^{2-1} - 0.08 Y_{2}^{2-2} + 0.81 Y_{2}^{1-2} + 0.76 X_{2}^{2-2} - 1.95 X_{2}^{2-3} \\
Y_{2}^{2-3} &= 5.3 + 1.13 Y_{2}^{2-3} - 0.25 Y_{2}^{2-3} + 0.005 Y_{2}^{1-3} + 0.0029 X_{2}^{2-4} - 1.11178325425059 E - 0.6 X_{2}^{2-4}
\end{align*}
\]  

(5)

Level 3:

\[
\begin{align*}
Y_{3}^{3-1} &= 1251.3 + 0.94 Y_{3}^{3-1} + 0.539 Y_{3}^{3-2} - 2873.7 Y_{3}^{2-3} - 201.46 Y_{3}^{2-1} + 0.103 Y_{3}^{2-2} \\
Y_{3}^{3-2} &= 2542.55 - 0.11 Y_{3}^{3-1} + 0.25 Y_{3}^{3-1} + 0.0073 Y_{3}^{2-2} - 0.24 Y_{3}^{2-3} + 0.137 Y_{3}^{3-2} \\
Y_{3}^{3-3} &= 0.857 - 0.048 Y_{3}^{3-3} - 3.7 E - 0.6 Y_{3}^{3-3} + 0.00016 Y_{3}^{2-3} + 0.005 Y_{3}^{3-3} + 7.64 E - 0.7 X_{3}^{3-4}
\end{align*}
\]  

(6)

The three-level model comprises the core of the digital clone of the development of the Arctic territories. The digital clone of the development of the Arctic territories comprises a digital representation of interconnected subprocesses occurring in the Arctic territories, aimed at helping decision-makers to select the best options for the implementation of various subprocesses, as well as in some cases to optimise processes themselves. The concept of a “digital clone”, which has emerged from discourses around the fourth industrial revolution, is aimed at helping decision-makers more rapidly identify problems, predict their results and thus make informed decisions.

4. Discussion

The general problem considered in the article can be referred to in terms of the development of the concept of a digital clone for the development of the Arctic territory. The digital clone of the Arctic territory, which comprises a digital representation of the processes occurring in the Arctic territory, can help to select the best options when executing various processes. The digital clone is designed to help decision makers identify problems faster, predict their outcomes and make the right decisions.

From our perspective, the digital clone of the territory presents a dynamic digital profile of this territory, containing both a priori and a posteriori data on the processes occurring in the Arctic territories, which are changing over time.

Here we will briefly consider the existing research related to the areas of research covered in the article. These are divided into general and specific categories. Frequently discussed problems include the following: the development of the Arctic territories, the representation of the Arctic territories in the form of identified subspaces, the institutional-functional approach. Particular problems included modelling the development of the Arctic territories, the development of digital information technologies and their impact on development.

General problems of the Arctic are addressed in the works of N.I. Didenko, V.I. Cherenkov [7], D.F. Skripnuk [3], O. Kleptsova [8], E.S. Romashkina [9], S.A. Atroshenko [10], Mukunda M. Gogoi et al. [11], V. Merkulov [12], N.A. Konakhina [13], E.A. Afonichkina, A.I. Afonichkin [14], V. Glukhov, Y. Klochko and others [15], [16]. The works of Silkina G and others are devoted to particular problems [17], S. Kozmenko et al. [18], A.V. Gudkov et al. [19], V. Kozlovsky et al. [20].
We find modeling of the development of the Arctic territories in the works of N.I. Didenko [2], [1], K. Kikkas [21], A. Novoselov et al. [22], Vladimir Glinskiy et al. [23], S. Antipov [24].

We can find a characterisation of the simulated subspaces in T.D. Prowse, C. Furgal, F.J. Wrona and J.D. Reist [25], R.F. Tallman, M.J. Roux and Fisk A [26]. Analysis of the impact of investments in digital information technology on increasing production productivity was reflected in studies carried out by many researchers. A possible connection between investments in information technology and an increase in production productivity was discussed by S.A. Dyatlov [27], Yuji Tou and others. [28], Peterson K. Ozili [29], Tomi Dufva and Mikko Dufvab [30]. Erik Brynjolfsson, Shinkyu Yang [31] failed to find a positive relationship using information from 1980 to 1990. Paul A. Strassman [32], Daniel E. Sichel and Stephen D. Oliner [33] concluded that investment in computerisation leads to unexpected productivity gains over time. Using the method of production functions in a sample of 1294 US firms, Erik Brynjolfsson and Lorin M. Hitt [34] concluded that the regression equation showed a positive result. Melville [35] in 2004 showed that investments in ICT technologies affect productivity, but that the extent of their influence depends on the macroeconomic conditions of the country.

5. Conclusion
Based on a review of the reviewed publications, the presented work is the first in which the concept of a digital twin of the Arctic territories is introduced.

From our perspective, the digital clone of the Arctic territory presents a dynamic digital profile of this territory, containing both a priori and a posteriori data on the processes occurring in this space, which are changing over time. The digital clone is based on a huge amount of data underpinning various indicators of objects and processes existing and occurring in the Arctic territories. Analysis of the accumulated data allows the development of the Arctic territories to be considered from various angles, to obtain information on development options, as well as to reach certain conclusions about the need to make changes to the processes.

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