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Alexander P. Karpik[1], Dmitry V. Lisitsky[2], Aleksey G. Osipov[3], Vyacheslav N. Savinykh[4]

ANALYSIS AND EVALUATION OF THE RESOURCE POTENTIAL OF A TERRITORY USING THE METHOD OF GEOCOGNITIVE MODELING

ABSTRACT

The relevance of the study consists in the new subject matter and details of geospatial support for the procedure of strategic planning in the development of regions under conditions of digital transformation. The objective of the study is to present the ideas, new views, and innovative approaches to the use of geospatial data, information, and knowledge in evaluating territorial resources and in substantiating the possibility of applying the method of geocognitive modeling to analysis of the resource potential of territories with a view to strategic planning of their social and economic development. The issues of using geospatial knowledge about a territory, of revealing and presenting territorial characteristics influencing a territory's evaluation, balanced and efficient use of the natural resources, material, technological, human and other potentials were investigated. Findings of the study: analysis of one of the main trends in territorial development over the recent years (intensive use of geoinformation, geoinformation systems, geospatial knowledge, and geospatial analytical data in planning and management of countries and regions) was made. Formal interpretation of the evaluation and use of territorial resources as objects of a single economic system is proposed. Based on formal logical analysis, a theoretical multiple presentation of the process of analyzing the value of a territory from the viewpoint of its industrial use and spatial opportunities is made. The concept of a geo-fragment is used as an elementary unit of geospace in which industrial and/or natural processes take place and interaction of the objects of different industrial fields occurs. Theoretical and practical meaning: a new geocognitive method of evaluating various properties of a territory is proposed, including the degree of development, knowledge, and being fit for comfortable living of people and other territorial aspects. The technological interpretation of the proposed method for assessing the economic value of regional resources is provided. Conclusion: geospatial activity in the territorial context is becoming an important factor in planning territorial development when optimizing the distribution (redistribution) of territorial resources by way of complex interaction of industries and clusters. The study opens up opportunities for further development of the methods, approaches and technologies of formation and use of geospatial knowledge and geocognitive technologies.

KEYWORDS: geodata, geoinformation model, geocognitive modeling, geo-fragment, strategic planning, territorial development, geospatial industry

INTRODUCTION

One of the main trends in territorial development over the recent years consists in expanded use of geoinformation, GIS, geospatial knowledge, and geospatial analytical data in

[1] Siberian State University of Geosystems and Technologies, Plakhotnogo St., 10, 630108, Novosibirsk, Russia, *e-mail:* **rector@ssga.ru**

[2] Siberian State University of Geosystems and Technologies, Plakhotnogo St., 10, 630108, Novosibirsk, Russia, *e-mail:* **dlis@ssga.ru**

[3] Siberian State University of Geosystems and Technologies, Plakhotnogo St., 10, 630108, Novosibirsk, Russia, *e-mail:* **a.g.osipov@ssga.ru**

[4] Novosibirsk State Technical University, K. Marx Prospect, 20, 630073, Novosibirsk, Russia, *e-mail:* **savinslav@inbox.ru**

planning and management of countries and regions. The UN consistently recommends to all countries, and primarily developing countries, to take measures to develop and improve the mechanisms of managing national geospatial information, in order to improve the activities of the decision makers in the governments, institutions and organizations, to ensure coordination among the existing opportunities and the infrastructure of the national institutions.

The experts committee of the UN, supported by the World Bank, has developed the Integrated Geospatial Information Framework – IGIF, which is viewed as a complex platform of geospatial information, based on national needs and conditions. The framework presents comprehensive strategic ideas for national social, economic and ecological development and is being successfully used in more than 100 countries [1, 2, 3]. Russian studies also conclude that it is expedient to create such a system in Russia [*Karpik*, *Obidenko*, 2021].

The estimated effect from expanding the field and scope of using geospatial information is ensured by integrating different flows of information relating to territories on a single basis of location of the objects of natural and cultural environment[4], spatial analysis of the presence of resources and productions and of forming geospatial knowledge. The geospatial sector of the economy lies in the base of the ecosystem meant to integrate the multitude of various sources of data, to provide improved analytical opportunities in the real-time mode, to ensure transition from data to knowledge services to solve the actual problems, as "the real value for a user is knowledge obtained from the data", and "technologies and innovations of 4th Industrial Revolution generate new business models and a new economy of knowledge, based on data, applications/analytical data and the existing knowledge".[5]

Following these recommendations in various countries of the world, geoinformation and GIS are being widely used in the broad range of geospatial tasks to be solved; for example[6], in multiple (1000) GIS projects, including 10 GIS projects relating to business and commerce, 17 – projects in economics, 26 – in geostatistics, 34 – in planning land use, 41 – in oil and gas applications, 38 – production of natural deposits, etc. The first GIS projects are emerging for the purposes of spatial planning of territories, for example:

– intersection of spatial analysis with economics (spatial econometrics);

– measuring the degree and scope of economic globalization using the international trade data;

– distribution of productions in space considering the transport expenses and the mobility factor;

– investigating the interaction between the geographic proximity to innovation industry resources and the profitability of stocks (index of geographic innovations);

– determining economic parameters for business, industry and demography on the basis of radius, movement and proximity (economic base indicator).

[1] Integrated Geospatial Information Framework Part 1: The Overarching Strategic Framework. Web resource: http://ggim.un.org/meetings/ggim-committee/8th-session/documents/part%201 -igif-overarching-strategic-framework-24july2018.pdf (Accessed 10 Jan 2020)

[2] Integrated Geospatial Information Framework (IGIF) Part 2. Web resource: https://ggim.un.org/ IGIF/part2.cshtml (Accessed 10 Jan 2022)

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[4] Policy paper Unlocking the Power of Location: The UK's geospatial strategy 2020 to 2025. Web resource: https:// www.gov.uk/government/publications/unlocking-the-power-of-locationthe-uks-geospatial-strategy/unlocking-the-power-of-location-the-uks-geospatial-strategy-2020-to-2025 (Accessed 10 Jan 2022)

[5] GKI Report 2020: Advancing Role of Geospatial Knowledge Infrastructure in World Economy, Society and Environment. By Geospatial World - 04/08/2021. Web resource: https:// www.geospatialworld.net/ knowledge-resources/advancing-role-of-geospatial-knowledge-infrastructure-in-world-economy-society-and-environment/ (Accessed 10 Jan 2022)

[6] 1000 GIS Applications & Uses – How GIS Is Changing the World. Web resource: https:// gisgeography.com/ gis-applications-uses/ (Accessed 10 Jan 2022)

Similar examples are also provided in the articles[1, 2, 3]. However, there is an opinion that the ESG component "the environment" is still critically under-investigated" for the financial industry[4]. The perspectives of using geospatial knowledge[5] are even more promising because the surrounding geospace "is in the focus of human activity and economic growth, and the more knowledge we have about the environment, the better and wiser political decisions we can make, make reasonable investments and make a well-informed choice of the way of life"[6], and "people and machines seek knowledge, not data for decision-making"9.

The transition from the spatial data infrastructure (SDI) to geospatial knowledge infrastructure (GKI) is also relevant, "which can be used for integration, analysis, modeling, aggregation, merging, data exchange, as well as for the organization and delivery of data on disciplines and organizations"[7]. Special importance and the perspectives of this development were emphasized at the GKI Global Summit held in February 2021, at which 2119 leading researchers and specialists got together to study geospatial knowledge[8].

Russia also conducts research and development in the field of the geospatial industry on the formation and use of geospatial knowledge [*Savinykh,* 2016; *Mayorov*, 2016; *Tsvetkov*, 2016], on the implementation of cognitive methods and approaches in spatial modeling [*Bolbakov*, 2019; *Tsvetkov*, 2020] and in the creation of cognitive (geocognitive) maps [*Antonov*, 2020; *Yankelevich, Antonov*, 2019], including in the geospatial support of military operations [*Elyushkin*, 2019].

In this regard, the issues of using geospatial knowledge for supporting he processes of strategic planning of territorial development under conditions of digital transformation are becoming more important, as it contributes to raising their level and efficiency, ensures the possibility of considering different characteristics of the environment based on geoinformation technologies, objective revealing of the synergistic effect from interaction of industries in the territory in question, considering different characteristics of a territory, primarily of its value, degree of development, knowledge, being fit for comfortable living of people and priority industrial use. In our opinion, this will also allow compensation [*Kryukov* et al., 2020] of the "insufficiently complete reflection in the prediction tools of certain important factors, determining the economic behavior and the insufficiently adequate modeling of interaction of these factors" and contribute to the development of the tools of macroeconomic, multi-industrial and regional analysis and prediction. The basic component for planning territorial development are geospatial knowledge databases (e.g. the European INSPIRE directive on development of a database built on geospatial knowledge on many subjects for the territory of the EU based on Esri software has been adopted and is being used)[9].

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[1] 67 Important GIS Applications and Uses. Web resource: https://grindgis.com/blog/gis-applications-uses (Accessed 10 Jan 2022)

[2] What is the value of GIS and its difference from other technologies? Web resource: https://www.dataplus.ru / news/arcreview/detail.php?ID=27904& SECTION_ID =1122& print=Y (Accessed 10 Jan 2022)

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[9] Geospatial Technology and Information for Development. Web resource: https://www.worldbank. org/en/topic/ land/brief/ geospatial-technology-and-infor mation -for-development (Accessed 10 Jan 2022)

MATERIALS AND METHODS

In this study, the authors take efforts to substantiate the possibilities of using the method of geocognitive modeling in analyzing the resource potential of territories for strategic planning of their geospatial development in the digital era.

The issues of forming geospatial knowledge, revealing and presenting territorial characteristics influencing a territory's evaluation, balanced and efficient use of natural resources, material, technological, human and other potentials constitute the subject of our study. For this purpose, we performed theoretical analysis and used formal logical tools of the theoretical multiple presentation of the process of geocognitive modeling from the viewpoint of assessing the economic value of the regional resources.

Here we will consider the general setting of the problem of geocognitive modeling to analyze and assess the resource potential of a territory by the example of generating and using geospatial knowledge (geoknowledge) of the economic value of a territory in strategic planning of its development. Under the economic value of a territory, we understand its certain significance (actual and potential) in the system of economic relations and using its resource potential of the industries and economic entities. In addition, we used the concept of a systemic approach to the common use of a territory by the subjects of economic activity and ruled out a separate approach to planning the artificially created environment. That ensures creating a new value in the economy, and for this purpose, geospatial analysis should be more multi-disciplinary and give up the model of commercial competition for the model of joint action[1]. It is necessary to ensure more active information exchange among organizations, in order to understand the influence of their work beyond the limits of their systemic boundaries, to use synergy and to mitigate tradeoffs, as well as to work together to achieve global goals.

To make a generalized theoretical multiple presentation of the process of geocognitive modeling under study, it is reasonable to set the task of assessing the value of a territory in the following way:

1. There is a region – the territory that is to be evaluated from the viewpoint of its economic value;
2. There is a basic geoinformation model of the territory in question (taken, for example, from the Integrated Mapping Base of Russia);
3. There are industrial arrays of information about natural resources and objects of the sector-specific industry located in the given territory, including industrial databases;
4. There are industrial models of assessing the value of territorial resources implementing industrial knowledge in the given area;
5. There are geoinformation technologies ensuring geospatial integration of the general geographic and industrial data, creating the geospatial models of the territory, making geospatial analysis, and generating the geospatial twin of the given territory;
6. It is necessary to assess the value of the territory considering the interests of the industries using the territorial resources and the geospatial characteristics of the given territory.

We consider the geoinformation model of a territory inscribed into a rectangle with the vertices which have the coordinates of A(0, 0), B(0, H), C(L, H), D(L, H), where H, L are the lengths of the rectangle.

Suppose the rectangle ABCD is divided, according to certain substantiation, into squares that are equal for their area. Let us designate geo-fragment *Gf(i, j)* of a territory which comes into the square with coordinates of the left lower corner *(i, j)*, where *i* is the number of square sides taken as the length, and *j* is the number of the square sides taken as the width from the origin of coordinates (0, 0). Hence, the center of geo-fragment *Gf(i, j)* will be located in the point with coordinates (*i*+0,5; *j*+0,5).

[1] The Power of Place: Geospatial is transforming our world. By Luca Budello. Web resource: https://www .geospatialworld.net/ blogs/geospatial-is-transforming-our-world/? utm_source= Mailer+Subscribers&utm_ campaign=74837262d6-GW-Newsletter _EMEA_12_ Oct&utm_medium=email&utm_ term=0_7eab4439d7-74837262d6-139500538 (Accessed 10 Jan 2022)

Suppose there are certain experts E_k, carriers and accumulators of the industrial knowledge of industry *k* about the accessible territory, where $k = \overline{1, n}$, and n is the number of industries claiming the territory. Under the original condition of the industrial knowledge base k regarding the territorial value of geo-fragment *Gf(i, j),* the following tuple (1) will be considered as consisting of two vectors of the same dimension:

$$B_{ijk}^{0} = [\overline{D}_{ijk}^{0}; \overline{C}_{ijk}^{0}], \tag{1}$$

where $\overline{D}_{ijk}^{0}$ is the vector of the number of objects belonging to geo-fragment *Gf(i, j)* and located in the zone of responsibility of industry *k*,

$\overline{C}_{ijk}^{0}$ is the vector defining unit value of the number of objects belonging to geo-fragment *Gf(i, j)* and located in the zone of responsibility of industry *k*.

The result of the scalar product of the two latter vectors designated as U_{ijk}^{0} will be assessment (2) of the territorial value of geo-fragment *Gf(i, j)* in the original state of the database of industrial knowledge k, i.e.:

$$U_{ijk}^{0} = \left\langle \overline{D}_{ijk}^{0}, \overline{C}_{ijk}^{0} \right\rangle. \tag{2}$$

Thus, we can obtain the final assessment of the territorial value of geo-fragment *Gf(i, j)* with the original state of the database of industrial knowledge about it for all the industries using formula (3):

$$U_{ij}^{0} = \sum_{k=1}^{n} U_{ijk}^{0}. \tag{3}$$

As the general base of industrial knowledge of the territorial value of geo-fragment *Gf(i, j)* for all the industries involved, the following tuple should be considered:

$$B_{ij}^{0} = [B_{ij1}^{0}; B_{ij2}^{0}; ...; B_{ijn}^{0}]. \tag{4}$$

Resulting from working with this tuple, the access to which should be obtained by the experts from all industries, each industry obtains a possibility of correcting its interests in accordance with the new information regarding the interests of other industries regarding the territorial value of the same geo-fragment *Gf(i, j)*.

As a result, we expect obtaining the corrected general database of industrial knowledge of the territorial value of geo-fragment *Gf(i, j)* for all the industries involved, which will be presented by the already updated tuple:

$$B_{ij}^{1} = [B_{ij1}^{1}; B_{ij2}^{1}; ...; B_{ijn}^{1}]. \tag{5}$$

We can calculate the corrected assessment of the territorial value of geo-fragment *Gf(i, j)* with the updated state of the database of industrial knowledge about it for all the industries using formula (6):

$$U_{ij}^{1} = \sum_{k=1}^{n} U_{ijk}^{1}. \tag{6}$$

The latter expression is the result of the first iteration of coordinating the interests of the industries in obtaining the general assessment of the territorial value of geo-fragment *Gf(i, j)*. If necessary, such iteration can be repeated.

To substantiate such necessity, the relative sensitivity factor showing how sensitive the overall territorial value estimation for geo-fragment Gf(i, j) is to an interest coordination procedure should be calculated using the formula (7):

$$\sigma_{ij}^{1} = \frac{\left|U_{ij}^{1} - U_{ij}^{0}\right| * 100\%}{U_{ij}^{0}}. \tag{7}$$

For example, if the sensitivity factor σ_{ij}^{1} is rather high, the interest coordination procedure for industries in relation to geo-fragment *Gf(i, j)* should be repeated.

Suppose we obtain the overall territorial value estimation related to each geo-fragment Gf(i, j) belonging to rectangle ABCD. These evaluations are easy to present as a matrix (8):

$$U^1 = \begin{pmatrix} U^1_{00} & U^1_{i0} & U^1_{T0} \\ U^1_{0j} & U^1_{ij} & U^1_{Tj} \\ U^1_{0S} & U^1_{iS} & U^1_{TS} \end{pmatrix}. \quad (8)$$

Let us denote the maximum element of the matrix as (9):

$$M = \max \left\{ U^1_{ij} \right\}_{j=0,\dots,S}^{i=0,\dots,T}. \quad (9)$$

Let us calculate the rating R^1_{ij} in scores to indicate the territorial value of each geo-fragment *Gf(i, j)*, which is part of rectangle ABCD in accordance with Table 1:

Table 1. Calculation of the rating of the territorial value of geo-fragment Gf(i, j)

$U^1_{ij} \in$	[0, M/5)	[M/5, 2M/5)	[2 M/5, 3 M/5)	[3M/5, 4M/5)	[4M/5, M]
R^1_{ij}	1	2	3	4	5

As a result, the matrix of score ratings of the territorial value of geo-fragments *Gf(i, j)* (10) will be obtained:

$$R^1 = \begin{pmatrix} R^1_{00} & R^1_{i0} & R^1_{T0} \\ R^1_{0j} & R^1_{ij} & R^1_{Tj} \\ R^1_{0S} & R^1_{iS} & R^1_{TS} \end{pmatrix}. \quad (10)$$

Using this matrix, we can assess the score rating of any area of the territory, which is the part of rectangle ABCD, calculating it as the average territorial value in scores of the geo-fragments located in the area. For this purpose, we will consider the minimum coverage of the entire region *Reg* with the indicated geo-fragments of some administrative-territorial unit of rectangle ABCD, the rating of which is to be calculated. Let us designate this coverage as *P(m, r, l, h)*, where for covering geo-fragments *Gf(i, j) m* is the minimum value of coordinate *i*, *r* is the maximum value of coordinate *i*, *l* is the minimum value of coordinate *j*, *h* is the maximum value of coordinate *j*, if the condition $Gf(i,j) \cap \mathrm{Re}\,g \neq \varnothing$ is met.

Let us designate the δ_{ij} share of the territory of geo-fragment *Gf(i, j)* in crossing with the administrative-territorial unit *Reg*, with $0 \leq \delta_{ij} \leq 1$, and $\delta_{ij} = 0$, if $Gf(i,j) \cap \mathrm{Re}\,g = \varnothing$. Then the average weighted rating of the administrative-territorial unit *Reg* designed as *RPReg*, can be calculated using the formula (11):

$$RP\,\mathrm{Re}\,g = \frac{\sum_{i=m}^{r} \sum_{j=l}^{h} R_{ij} \cdot \delta_{ij}}{\sum_{i=m}^{r} \sum_{j=l}^{h} \delta_{ij}}. \quad (11)$$

The theoretical multiple interpretation of the process of geocognitive modeling (1)-(11) may be shown as the following sequence of actions relating to assessment of the potential economic value of a territory.

1. Groups of industrial experts (expert communities) are formed for each particular industry (including geospatial industry) capable of assessing the economic value of resources at the given territory used or planned to be used by the given industry.

2. A network of inter-industrial interaction of experts is created, ensuring exchange and integration of industrial knowledge and joint generation of the territorial knowledge.

3. Using GIS tools, the experts of the geospatial industry divide the basic geoinformation model into a set of individual geo-fragments (geometric or other, for example, on the boundaries of municipalities), the size and the configuration of which are determined by the size of the region in question [*Karpik* et al., 2021].

4. For each geo-fragment, the experts of the geospatial industry using GIS tools determine the general geospatial characteristics like the area of forests and swamps, ruggedness of the landscape, the length of separately navigable and unnavigable rivers, railways and motor roads having hard pavement, etc.

5. For each geo-fragment, the experts of the geospatial industry using GIS tools determine the characteristics of its geospatial position in relation to the available infrastructure and the objects of the entire region and/or megaregion. For example, indicated is the average distance between a geo-fragment and the nearest thoroughfares, such as railways, automotive roads, navigable rivers, seaports, and airfields.

6. Using the basic geoinformation model of the territory, each group of industrial experts makes industrial theme strata for all the geo-fragments containing natural and industrial resources located in each geo-fragment, and, if a fragment contains a part of the object resource in question, the share of the value is calculated in proportion with the size of this part in relation to the size of the entire object.

7. Using the industrial geoknowledge models, the groups of industrial experts make economic assessment of the potential value of the industrial resources of each geo-fragment separately for each industry.

8. The obtained industrial assessments of the value of each geo-fragment are uploaded into the network of inter-industrial information interaction to ensure assessment of potential inter-industrial use of a territory.

9. Groups of experts in the field specify the potential value of geo-fragment territories considering inter-industrial interaction and the potential synergetic effect.

10. The geospatial industry experts determine the integrated parameter of the actual or potential value of each geo-fragment by summing individual industrial parameters of assessing the value of a territory considering the characteristics of its geospatial position.

11. Based on the scale of the values of integrated parameters, clusters are formed of the integrated parameters of the value of a territory.

12. The results of forming clusters of the integrated parameters of the value of a territory in the GIS environment are depicted as geoinformation models and are visualized as a thematic map of the geospatial knowledge of a region.

RESULTS AND DISCUSSION

The geoinformation models developed may be presented as objects of the territory knowledge database, reflecting the modern understanding of the resource potential of the region in question, including its individual subsystems, with a view to the present and future roles in solving the problems of social and economic development. In its turn, this creates the basis and the feasibility of deploying artificial intellect systems for evaluating territories.

Based on the analysis of the strategic planning processes and of the used information materials, we hypothesize that the extent of geospatial data, information, and knowledge application to handling analysis, evaluation and prediction tasks depends on the level of economic problems solved: be that microeconomics or macroeconomics, the role of geoknowledge is growing, while the part geoinformation and especially of geodata are playing is diminishing.

The methodological approach described may be used for evaluating different characteristics of a territory, including its development, knowledge, and being fit for comfortable living of the people, priority industrial use and other aspects.

It is to be noted that the geocognitive approach is most efficient when analyzing and predicting development of complex geospatial-economic systems. Its peculiarity consists in applying the methods of quantitative analysis, together with developing model structures based on subjective vision of the situation. Each stage of the work is based on the solution obtained by the researchers, and its result determines the relevance of the model. It is to be emphasized that geocognitive models cannot replace the models of other types and classes. Such models can occupy their niche as part of the economic, geographic and mathematical pool of tools used in geographic and economic research, including solution of prediction tasks.

Further development of the methodology of the geocognitive approach to the study of the problems of the geospatial economy will allow researchers to develop tools both for forming complex programs of regional development and for making predictions and substantiating solutions in managing the arising problem situations.

CONCLUSION

The study performed discloses one of the possible variants of solving the task of using the geocognitive approach in the processes of social and economic planning of territorial development. It opens up the perspective for further studies and for developing the methods, approaches, and technologies of forming and using geospatial knowledge and geocognitive technologies. The research in this area is in the early phase and should continue and develop. Especially promising is the profound analysis of the phenomenon of the geospatial knowledge and the possibilities of its use in strategic planning.

The results obtained by the authors are preliminary in many ways. Further study of the possibilities of geocognitive modeling are required to substantiate economic decisions and the regulatory policy, primarily in choosing its priority directions.

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