Adaptive control methods

UDC 004.89 **doi: 10.20998/2522-9052.2021.1.05**

Ihor Butko

SE "State Land Cadaster", Kyiv, Ukraine

THE USE OF GEOSPATIAL INFORMATION BY PUBLIC AUTHORITIES TO SUPPORT THE DECISION MAKING OF MANAGEMENT

Abstract. The article proposes the use of geospatial information to support managerial decision-making by public authorities in the field of reintegration of temporarily occupied territories in Donetsk, Luhansk regions and Crimea. Variants of application of decision support systems in the management of immovable military property of the Armed Forces of Ukraine, the existing algorithms and methods of the decision support system in land relations are analyzed. Proposals are presented to support the adoption of managerial decisions by public authorities on the basis of Earth remote sensing data. The algorithm for the functioning of the decision support system in solving the problems of reintegration of temporarily occupied territories has been improved. The proposed sequence of actions of the method of the process of supporting the adoption of administrative decisions by public authorities in the field of reintegration of temporarily occupied territories using geospatial information, mathematical constructions of category theory and predicate logic. The order of implementation of the sequence of actions of this method is given. By improving and detailing the proposed method, it is possible to form a more effective system for supporting the adoption of managerial decisions by public authorities using geospatial information.

Keywords: geospatial information; Earth remote sensing; public authority; decision support system; DSS; category theory; predicate logic; formalization.

Introduction

Formulation of the problem and research tasks. Unimpeded obtaining of species information on areas and objects of interest and the fact that the necessary information is obtained remotely are arguments for using Earth remote sensing data to solve such a problem as supporting management decisions by public authorities using geospatial information [1, 2]. Earth remote sensing data is practically the only source of objective and operational information due to the impossibility of a direct assessment of the state and development of events and objects in the temporarily occupied territories [2, 3]. Therefore, the most popular information about the current, objective and visual assessment of the area of temporarily occupied territories in the Donetsk and Luhansk regions and in the Crimea is information from remote sensing of the Earth [1-3].

Today, based on Earth remote sensing data, the following activities can be started [1, 2]:

– to generate catalogues and databases about the territory and the enterprise (especially with potentially hazardous production);

– to monitor the current state of territories and facilities;

– to analyze and predict the possible consequences of "management" in the territories;

– to develop comprehensive reintegration plans and solutions in advance;

– etc.

The results of the analysis of economic activities in the temporarily occupied territories can be used in some directions. This is both an analysis of the use of land, industrial and infrastructural facilities, as well as forecasting the necessary measures to be taken for restoration. Lands where military operations took place, or where fortifications were built, require special attention. In this case, it is especially important to assess the safety of the further use of these territories.

Today, during the reintegration of the temporarily occupied territories, it is important to solve many pressing technical problems with the help of information from remote sensing of the Earth. For example, the construction of TV towers for broadcasting Ukrainian broadcasting in uncontrolled territories and the installation of digital repeaters, control of illegal constructions and the like.

Species information (both basic and current) can be simultaneously used in the interests of various ministries and departments. And since at present Ukraine does not have its own spacecraft for remote sensing of the Earth, such a multipurpose use will significantly save both resources for acquiring actual species images and computing resources for their thematic interpretation. It is advisable to oppose the consolidation of the results obtained in the Ministry for the Reintegration of the Temporarily Occupied Territories.

In general, the use of geospatial information should be divided into four areas [2]:

– inventory;

– monitoring;

– operational;

– research.

It is clear that for each type of problem it is necessary to use its own set of input data, which is different in its spatial, temporal and spectral characteristics.

To solve problems, for example, in agriculture, it is quite possible to limit the use of information of medium resolution. However, in the interests of land

inventory, monitoring of industrial, energy, and military facilities, it is advisable to use aerial photography information, which has a high (5 cm) resolution, as reference information (Fig. 1) [4].

Fig. 1. Fragment of the results of aerial photography of the territory of Donetsk region [4]

It should be borne in mind that it is necessary to use not "one-time" shooting of objects and areas of interest, but to analyze the ensemble of images. This group of snapshots will then fill the corresponding catalogs or databases and will allow you to evaluate events in dynamics [5].

Today, to solve the problems of reintegration of temporarily occupied territories, modern information technologies can be used, which are a necessary tool in the development of decision support systems (DSS). DSS use equipment, software, databases, knowledge base and operator's work in order to support all stages of decision-making in the process of analytical modelling [6, 7].

Automation and informatization are the basis for systematizing and bringing relations in the field of reintegration of temporarily occupied territories to European standards. Therefore, the creation of high-performance automation and informatization systems should be based on intelligent information technologies. These information technologies are based on decision support systems. These information systems must have powerful software in the form of appropriate methods, algorithms and models.

Analysis of recent research and publications. When solving the problem of providing proposals for supporting the adoption of managerial decisions by public authorities using geospatial information of temporarily occupied territories, it is advisable to use a DSS. This DSS provides a thorough and objective analysis of a given subject area when making decisions in these difficult conditions [6, 7]. Thus, the DSS by collecting and analyzing a large amount of information from Donetsk, Lugansk regions and Crimea can influence the process of making managerial decisions by public authorities.

Modern decision support systems have emerged as a result of the merger of management information systems and database management systems [8]. As a result, systems have emerged that are maximally adapted to solving the problems of daily management activities. They are a tool to help those who decide. It is important to emphasize that the role of the person who makes decisions remains a priority. And the DSS allows you to replace human resources at the stage of processing and structuring the initial data of geospatial information [2, 9].

With the help of DSS, the choice of solutions can be carried out in certain unstructured and poorly structured tasks. Also in tasks that have many criteria.

DSS can be developed only if there is a database and a knowledge base. Databases are a collection of geospatial data, defined calculations and studies. Knowledge bases contain inference rules, information about human experience and knowledge in a given subject area, which allow you to perform operations on these databases [10].

The paper [11] analyzes the problematic issues of the decision-making process in managing only immovable military property of the Armed Forces of Ukraine. The above classification of DSSs is based on considering their features. This allows you to determine the basic requirements for the functioning of the DSS in the management of real estate military property.

The Unified management system of administrative and economic processes of the Armed Forces of Ukraine is considered. It ensures openness and transparency of the administrative and economic activities of the Armed Forces of Ukraine, optimization of the planning processes, distribution and use of financial, material and other resources to ensure the life of the troops. It is believed that the Unified Administrative Processes Management System of the Armed Forces of Ukraine provides reliable information. This information is necessary for making management decisions by the leadership of the Armed Forces of Ukraine. However, the basis of this system is the information base of only those real estate objects that are on the balance sheet of the Armed Forces of Ukraine. And it is implemented in the real estate military property management subsystem, which has been accepted for permanent operation.

In [12], an algorithm for the functioning of the decision support system in land relations is proposed.

The problem of using only ontological engineering of land relations is considered. Improving this algorithm can also be used to solve the problem of supporting the adoption of managerial decisions by public authorities in the field of reintegration of temporarily occupied territories in Donetsk, Luhansk regions and in Crimea using Earth remote sensing data.

The **goal** of the article is to develop proposals to support the decision making of management by public authorities using geospatial information.

Main material

The decision support system uses information from remote sensing of the Earth to develop solutions and recommendations for the task in the field of reintegration of temporarily occupied territories. This information comes from spacecraft, industrial aerial vehicles (aircraft, helicopters, unmanned aerial vehicles), non-industrial media (aerostats, paragliders, radio-controlled aircraft models), ground-based instruments (ground laser scanners), etc. [2]. This data is received and stored in the central data warehouse, which is part of the hierarchical structure of the DSS. The central data warehouse includes a database and a knowledge base [8].

The knowledge base should contain attributive information about the temporarily occupied territories, objects, owners and reintegration tasks. Knowledge base should consist of models of formalization of law, which can be constructed either by logical or approximate methods, or by their combinations.

For the formal presentation of data in the knowledge base in the decision support system in the development of decisions and recommendations for the task in the field of reintegration of temporarily occupied territories, we will use the approach proposed in the paper [12]. Namely, we will choose the methods of category theory. This is due to the fact that when developing a decision support system, it is necessary to take into account the representation of knowledge in the knowledge base by ontological models.

These methods allow using such mathematical constructions as statements, predicates, etc. in the form of category objects [13]. This feature of category theory, if necessary, allows you to combine mathematical models that describe the subject area, that is, reintegration relations.

In [12] it is proposed to designate the content of knowledge base in the form of a multilevel model – categories of small categories – Cat which are connected by functors – F.

We use the results of paper [12] to develop a sequence of actions for the method of supporting the adoption of administrative decisions by public authorities in the field of reintegration of temporarily occupied territories using geospatial information.

The peculiarity of this category is that its objects $\left\{Ob_1^{Cat}, Ob_2^{Cat}\right\} \subset Cat$ are small categories. The highlighted category Cat consists of two small categories, which are interpreted as follows:

– $Ob_1^{Cat} \equiv K_1$ – a set of laws in the area of reintegration of temporarily occupied territories;

– $Ob_2^{Cat} \equiv K_2$ – a set of schemes for solving tasks in the area of reintegration of temporarily occupied territories, which can be selected in accordance with the specified criteria (rules).

The objects of categories K_1 and K_2 presented in the knowledge base allow for a sequential selection of the law and model, and then put them in compliance $G \subseteq Ob(K_1) \times Ob(K_2)$ (Fig. 2) [12].

The interaction between the objects of the categories K_1 and K_2 is a representation of real tasks in the area of reintegration of temporarily occupied territories, in which:

– $\left\{Ob_1^{11}, ..., \left\{Ob_1^{12}, ..., \left\{Ob_1^{14}, ..., Ob_m^{14}\right\}\right\}\right\} \subset K_1$ – is the boundary of the sets of the categorical model K_1, where $Ob_1^{11}, Ob_1^{12}, Ob_1^{13}, Ob_1^{14}$ are laws, sections, chapters and articles of legislation in the area of reintegration of temporarily occupied territories, respectively;

– $\sum Mor(K_1, K_2)$ – a set of morphisms between small categories;

– $M = \left\{m_1, m_2, ...m_\xi\right\}$, $\xi = \overline{1,h}$ – a set of schemes for solving problems in the area of reintegration of temporarily occupied territories;

– $D = \left\{d_j\right\}$, $j = \overline{1,y}$ – a set of public authorities;

– $S = \left\{s_i\right\}$, $i = \overline{1,t}$ – a set participants in the tasks of reintegration of the temporarily occupied territories;

– $Z = \left\{z_p\right\}$, $p = \overline{1,l}$ – a set of reintegration tasks;

– $G \subseteq \left(D \times S \times Z\right) = \left\{\left(d_j, s_i, z_p\right) \middle| d_j \in D, s_i \in S, z_p \in Z\right\}$ – relations between public authorities, participants in the tasks of reintegration of the temporarily occupied territories and reintegration tasks;

– $G = \left\{g_q\right\}$, $q = \overline{1,\delta}$ – a lot of relations between public authorities, participants in the tasks of reintegration of the temporarily occupied territories and reintegration tasks;

– $m_h = \left\langle s_h, d_q, z_h, g_h \right\rangle$ – scheme of solving in the reintegration tasks.

Based on the knowledge models of objects and subjects of land relations proposed in [12], a decision support process can be carried out, which is presented in the form of a sequence of actions of the method of supporting the adoption of managerial decisions by public authorities using geospatial information. This sequence of actions is shown in Fig. 3.

The sequence of actions for the implementation of the method of supporting the adoption of managerial decisions by public authorities using geospatial information is as follows:

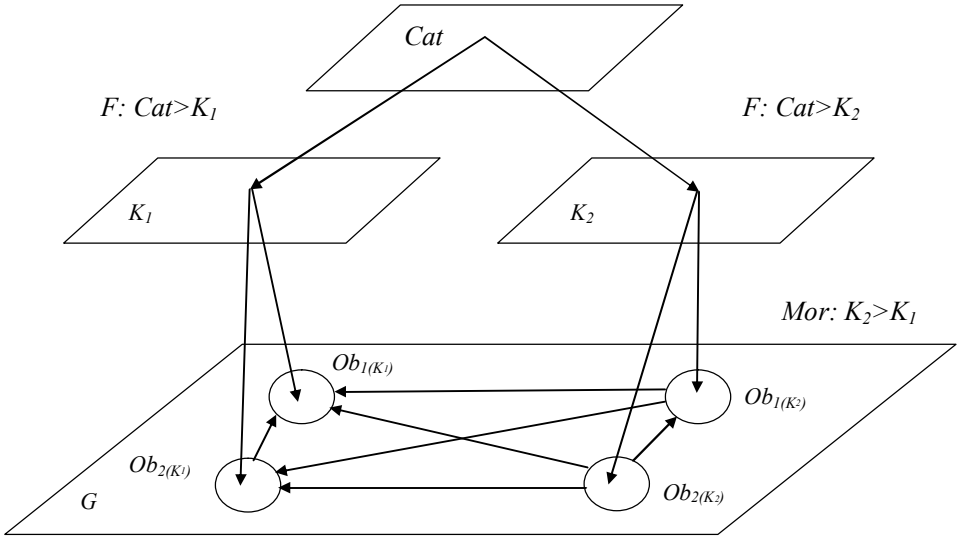

Fig. 2. Multilevel commutative diagram of relations between categories and objects of small categories when solving problems in a decision support system [12]

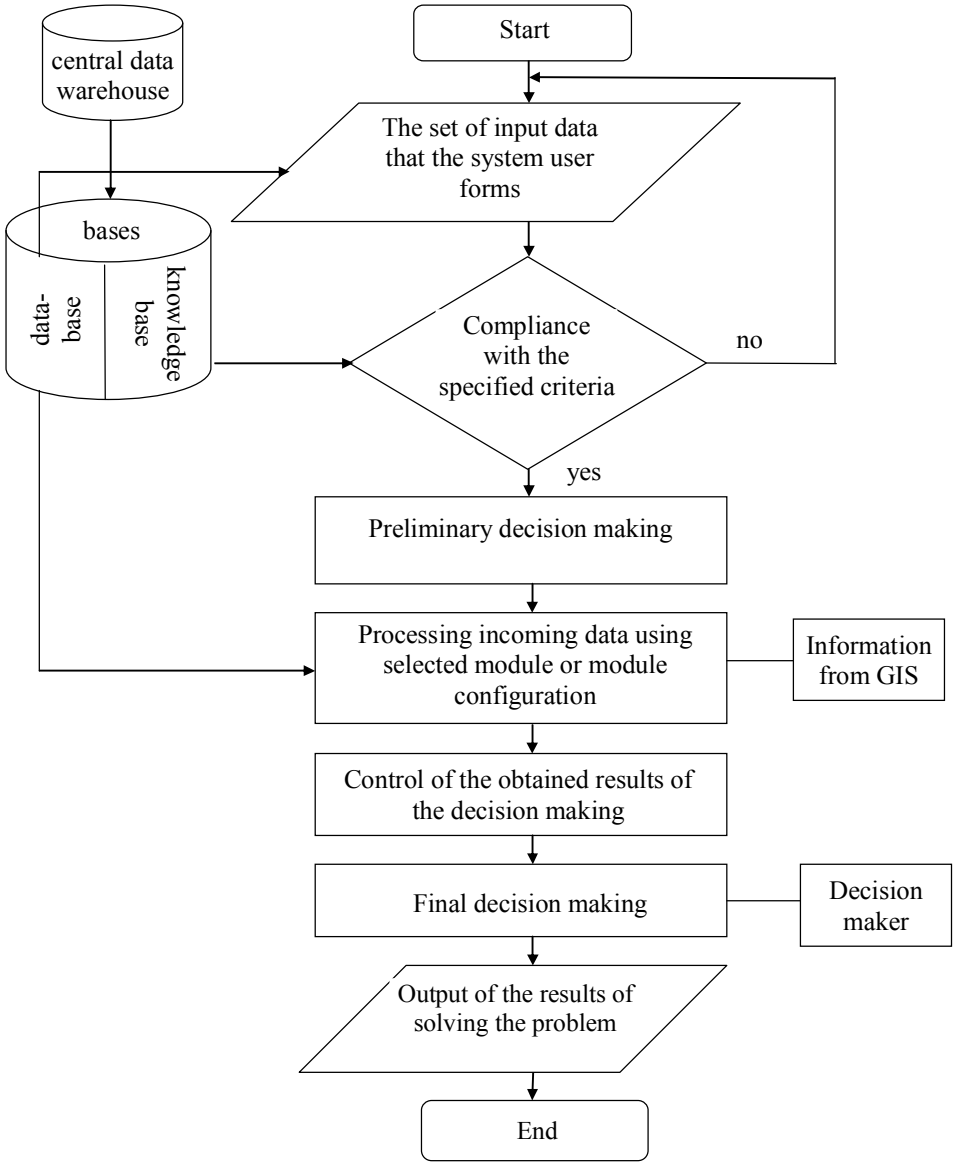

Fig. 3. The sequence of actions of the method of the process of supporting the adoption of managerial decisions by public authorities in the field of reintegration of temporarily occupied territories using geospatial information

– start of the sequence of actions of the method. It determines the need and feasibility of using a decision support system to solve the problem. If they are available, the process proceeds to the next stage of the method;

– formulation of the problem. Formation of a user request in accordance with the attribute data available in the database. At this stage, there is a definition of constraints that allow you to separate acceptable options from unacceptable, and criteria that contribute to the selection of the best of the suitable solutions;

– checking the compliance of the request data with the criteria for their processing. Checking the possibility of using one or another model of the knowledge base. If a discrepancy is detected, a message is generated and the transition to stage of formulation of the problem is carried out to correct the original request;

– preliminary decision making: search for a module or configuration of modules of the decision support system, which is received for servicing the task and the administrator's choice of modules or their configuration for solving the task. This is provided based on ontological models that are presented in the knowledge base;

– processing of data that comes with the help of auxiliary software. It is represented by a module or configuration of modules in the decision support system, which is provided by the administrator. The input data is information from geographic information systems;

– monitoring the proposed solution to the problem of reintegration of the temporarily occupied territories. The decision is corrected if necessary;

– final decision making. The final decision is made with the Earth remote sensing information by the decision maker. And presentation of results in a form and format that is convenient for their analysis by the user;

– the end of the sequence of actions of the method. The final set of resulting data is formed for solving the task that is specified by the user.

The decision support system, which implements the proposed sequence of actions, issues a finite set of recommendations for solving the problem, constraints and criteria for its solution. In turn, the user can use such a system as a means of automating the complex process of organizing reintegration tasks. This will allow:

– to relieve and streamline the work of public services related to issues of reintegration tasks;

– to weaken and, in the long term, eliminate the complete dependence of the solution of reintegration problems on the human factor;

– to increase the degree of objectivity of decisions made in the field of reintegration of temporarily occupied territories.

A decision is considered to be a reasonable set of actions on the part of a decision-maker aimed at an object of interest or a control system, which makes it possible to bring this object or system to the desired state or achieve a set goal.

Conclusion and further research

Thus, the obtained sequence of actions of the method of the process of supporting the adoption of managerial decisions by public authorities in the area of reintegration of temporarily occupied territories using geospatial information.

In future, by improving and detailing the proposed sequence of actions of the method, it is possible to form a more effective decision support system in the field of reintegration of the temporarily occupied territories.

The decision support system, which implements the proposed sequence of actions, issues a finite set of recommendations for solving the problem, constraints and criteria for its solution.

In turn, the user can use such a system as a means of automating the complex process of organizing reintegration tasks.

This will allow: to relieve and streamline the work of public services related to issues of reintegration tasks; to weaken and, in the long term, eliminate the complete dependence of the solution of reintegration problems on the human factor; to increase the degree of objectivity of decisions made in the field of reintegration of temporarily occupied territories.

REFERENCES

1. Merem, E.C. and Twumasi, Y.A. (2008), “Using Geospatial Information Technology in Natural Resources Management: The Case of Urban Land Management In West”, *Africa. Scientific Journal Sensors (Basel)*, Vol. № 8 (2), pp. 607–619.
2. Shikhov, A.N., Cherepanova, E.S. and Ponomarchuk, A.I. (2014), *Geoinformation systems: the use of GIS technologies in solving hydrological problems*, a workshop, textbook. manual, Perm, 91 p.
3. Ališić, I., Mastelić Ivić, S., Tomić, H., and Tomljenović, M. (2014), “Decision Support System to Urban Land Readjustment”, *6th International Conference on Engineering Surveying Prague, Czech Republic*, pp. 143-148.
4. Earth Observing System. High-Resolution Satellite Imagery, available at: https://eos.com/ru/products/high-resolution-images/
5. Pustovarov, V. (2020), “Construction of information technology for development of knowledge base on identification of urban structures on digital space and aerial photographs in the urban environment monitoring”, *Advanced Information Systems,* Vol. 4, No. 3, pp. 70–73, DOI: https://doi.org/10.20998/2522-9052.2020.3.08.
6. Bidyuk, P.I. and Korshevnyuk, L.O. (2010), *Design of computer information systems for decision support*, NTUU "KPI", Kyiv, 340 p.
7. Turko, D.A. (2009), “Taking into account the conditions of uncertainty and risk in the decision-making process in the field of high-tech production”, *Open information and computer integrated technologies*, Vol. 43, pp. 180-187.
8. Terelyansky, P.V. (2009), *Decision support systems. Experience of design*, Volga State Techn. Univ, Volgograd, 127 p.
9. Gamzayev R., Tkachuk, M., and Shevkoplias D. (2020), “Knowledge-oriented information technology to variability management at the domain analysis stage in software development”, *Advanced Information Systems,* Vol. 4, No. 4, pp. 39–47, DOI: https://doi.org/10.20998/2522-9052.2020.4.06.

10. Hou, J., Yuan, Y., Peitao, W., Zhiyuan, R., and Xiaojuan, L. (2017), "Development of a decision support system for tsunami evacuation: application to the Jiyang District of Sanya city in China", *Nat. Hazards Earth Syst. Sci.,* pp.335-343, DOI: https://doi.org/10.5194/nhess-17-335-2017.
11. Galagan, V. I., PolIshko, S. V., and Bondarchuk, S. V. (2018), "Application of decision support systems in the management of real estate military property of the Armed Forces of Ukraine" ["Zastosuvannya sistem pidtrimki priynyattya rishen v upravlinni neruhomim viyskovim maynom Zbroynih Sil Ukrayini"], *Informatization and project management of informatization of the Armed Forces*, Vol. 7 (4), pp. 74—79.
12. Kuhar M.A. (2017), "Algorithm of the functioning of the decision support system in land relations" ["Algoritm funktsionuvannya sistemi pidtrimki priynyattya rishen v zemelnih vidnosinah"], *Informatics and Mathematical Methods in Simulation*, Vol. 7 (4), pp. 325—332.
13. Miller, T. (2019), "Explanation in artificial intelligence: Insights from the social sciences", *Artificial Intelligent*, pp. 1-38, DOI: https://doi.org/10.1016/j.artint.2018.07.007.
14. Tripathi K. P. (2011), "Decision support system is a tool for making better decisions in the organization", *Indian Journal of Computer Science and Engineering (IJCSE),* Vol. 2(1), P. 112–117.
15. Kurbatsky, A.N. and Cheushev, V.A. (1999), *Informational method of analysis and optimization in decision support systems*, Ed. Institute of Technical Cybernetics, Minsk, Belarus.

Received (Надійшла) 30.10.2020
Accepted for publication (Прийнята до друку) 20.01.2021

ВІДОМОСТІ ПРО АВТОРІВ / ABOUT THE AUTHORS

Бутко Ігор Миколайович – кандидат технічних наук, доцент, заступник генерального директора ДП «Центр державного земельного кадастру», Київ, Україна;
Ihor Butko – Candidate of Technical Sciences, Assistant Professor, Deputy gen. dire SE «State Land Cadaster», Kyiv, Ukraine;
e-mail: Ihor.Butko@gmail.com; ORCID ID: https://orcid.org/0000-0002-2859-0351.

Використання геопросторової інформації органами державної влади для підтримки прийняття управлінських рішень

І. М. Бутко

Анотація. У статті запропоновано використання геопросторової інформації щодо підтримки прийняття управлінських рішень органами державної влади у сфері реінтеграції тимчасово окупованих територій у Донецькій, Луганській областях та в Криму. Проаналізовані варіанти застосування систем підтримки прийняття рішень в управлінні нерухомим військовим майном Збройних Сил України, існуючі алгоритми та методи системи підтримки прийняття рішень в земельних відносинах. Надані пропозиції щодо підтримки прийняття управлінських рішень органами державної влади на основі даних дистанційного зондування Землі. Удосконалений алгоритм функціонування системи підтримки прийняття рішень при вирішенні задач реінтеграції тимчасово окупованих територій. Запропонована послідовність дій методу процесу підтримки прийняття управлінських рішення органами державної влади у сфері реінтеграції тимчасово окупованих територій з використанням геопросторової інформації, математичні конструкції теорії категорій і логіки предикатів. Наведений порядок реалізації послідовності дій даного методу. Удосконалюючи та деталізуючи запропонований метод, можливо сформувати більш ефективну систему підтримки прийняття управлінських рішень органами державної влади з використанням геопросторової інформації.

Ключові слова: геопросторова інформація; дистанційне зондування Землі; орган державної влади; система підтримки прийняття рішення; теорія категорій; логіка предикатів; формалізація.

Использование геопространственной информации органами государственной власти для поддержки принятия управленческих решений

И. Н. Бутко

Аннотация. В статье предложено использование геопространственной информации по поддержке принятия управленческих решений органами государственной власти в сфере реинтеграции временно оккупированных территорий в Донецкой, Луганской областях и в Крыму. Проанализированы варианты применения систем поддержки принятия решений в управлении недвижимым военным имуществом Вооруженных Сил Украины, существующие алгоритмы и методы системы поддержки принятия решений в земельных отношениях. Представлены предложения по поддержке принятия управленческих решений органами государственной власти на основе данных дистанционного зондирования Земли. Усовершенствован алгоритм функционирования системы поддержки принятия решений при решении задач реинтеграции временно оккупированных территорий. Предложена последовательность действий метода процесса поддержки принятия управленческих решения органами государственной власти в сфере реинтеграции временно оккупированных территорий с использованием геопространственной информации, математические конструкции теории категорий и логики предикатов. Приведенный порядок реализации последовательности действий данного метода. Совершенствуя и детализируя предложенный метод, возможно сформировать более эффективную систему поддержки принятия управленческих решений органами государственной власти с использованием геопространственной информации.

Ключевые слова: геопространственная информация; дистанционное зондирование Земли; орган государственной власти; система поддержки принятия решения; теория категорий; логика предикатов; формализация.