Unified Digital Basemap as a mechanism of digital transformation and improvement of data quality of Land Information System

Vadim DONKOVTSEV, Andrey TARARIN, Russian Federation

Key words: land information systems, interoperability of spatial data, National Spatial Data System, basic spatial data sets, unified digital basemap, digital advance topographic map

Summary. Digital transformation of Russian Land Information Systems (LIS) is aimed at ensuring their digital maturity and improving the quality of spatial data. In this regard, the topic of enriching the data of the Unified Digital Basemap (UDB) with spatial data of LIS is promising. The research is devoted to the need to develop an approach to improve the quality of spatial data of departmental LIS and to analyze the existing problems. The description of the main issues in achieving the consistency of spatial data is given, the differences of sectoral approaches in the description of spatial data when combining them are investigated. Proposals to ensure the relevance of UDB data by maintaining a digital duty topographic map through the integration of LIS data are given. For this purpose it was proposed to develop and introduce additional unified requirements for display of terrain objects in departmental LIS. In general, the implementation of the approach within the framework of the National Spatial Data System will improve the quality of spatial data of departmental LIS and reduce budget expenditures for updating the cartographic basis of the Russian Federation.

INTRODUCTION

Digital transformation of public administration and economy is one of the main development goals of the Russian Federation up to 2030. Digital transformation is defined as a significant modernization of business processes of organizations with the active involvement of information technologies, which can lead to an improvement in the characteristics of the final product, as well as to a reduction in resources and time for its implementation.

In order to improve the efficiency of the economy, the Russian Government approved the program “National Spatial Data System” at the end of 2021, which is a key project of Rosreestr. It is aimed at improving the accuracy and completeness of data, eliminating the fragmentation of information on land and real property, which contributes to the improvement of the business climate, development of territories, improvement of government management and quality of life (Martynova, 2023).

Due to insufficient interoperability of spatial data of land information systems, which form the basis of the National Spatial Data System (NSDS), there are significant limitations on the use of NSDS data by government agencies and citizens.

One of the main solutions to this problem is the Unified Digital Basemap (UDB). The concept of UDB is set forth in the Federal Law “On Geodesy, Cartography and Spatial Data ...”. UDB is referred to the main elements of the spatial data infrastructure and is the cartographic basis of the NSDS and other state information systems operating with spatial data.

Last year the Government of the Russian Federation set an ambitious task to reduce the previously established normative terms (no more than 10 years): to update state topographic

plans on the territory of settlements at a scale of 1 : 2 000 – once every 3 years, state topographic maps of cities at a scale of 1 : 10 000 – once every 6 years. Nevertheless, the issues of efficiency of maintaining the relevance of information on terrain features and realization of a full-fledged address search remain open.

To ensure the relevance of spatial data, the functionality of monitoring of changes in the UDB has been developed on the basis of data from the Unified State Register of Real Property (state border of the Russian Federation, boundaries between the regions of the country, boundaries of settlements, real property units, water objects) and State Information System for Urban Planning Activities (SIS UPA) (geodetic and cartographic materials). The result of such monitoring in SIS UDB is the creation of a map of terrain changes, which is an analog of the advance reference map, the creation of which was carried out back in the Soviet times. In addition, to keep topographic maps up-to-date, the creation of an advance digital topographic map within the framework of integrated topographic monitoring is proposed (Brovko, Sofinov, 2022).

Thus, the current task is to increase the relevance and accuracy of the digital advance topographic map as part of the UDB and to ensure interoperability of spatial data of departmental LIS – suppliers of the National Spatial Data System, which will make it possible to supplement the advance topographic map with relevant data.

Purpose of the research: to develop a methodology to ensure interoperability of spatial data of departmental Land Information Systems (LIS) and their integration for maintaining a digital advance topographic map as part of the Unified Digital Basemap (UDB).

1. DIGITAL ADVANCE TOPOGRAPHIC MAP AS PART OF UDB

The National Standard of Russia defines UDB as a systematized set of spatial data on the territory of Russia, available for open publication.

Completeness and relevance of UDB data to the territory of the country is one of the promising projects of Rosreestr's digital infrastructure development. The main role of the UDB is to create a unified information environment that overcomes the problems of data fragmentation. The system functions as a digital mechanism that simplifies obtaining up-to-date and metrically accurate state data in various formats – in the form of orthophotomaps, topographic maps and plans for state authorities, individuals and legal entities.

The proposal to maintain a digital advance topographic map as part of the UDB is conditioned by the need to reduce the cost of systematic accounting of changes in the terrain and their analysis when making decisions on updating the UDB. The key feature of the advance topographic map is to display the state of terrain units at a time close to real for further interpretation and application in production activities (Brovko, Sofinov, 2024).

As a result of analyzing the UDB composition and state LIS (Tararin, 2021) the comparison of UDB data reflecting real terrain units and spatial datasets of state LIS and other State Information Resources (hereinafter referred to as SIR) containing spatial data was made, the established correspondences are reflected in Table 1, as well as graphically shown on the conventional map in Figure 1. Thus, it is reasonable to consider the possibility of updating information on terrain units on the basis of spatial data of the system in which they are accounted for on the basis of primary documents (Brovko, Sofinov, 2022; Tararin, 2022).

Table 1

Correspondence of UDB data and spatial datasets of state LIS and other State Information Resources (SIR)

UDB data	Spatial datasets	Name of SIR
terrain relief with accuracy corresponding to a scale smaller than 1:50000	-	FSDF*
hydrography and hydraulic structures	on water bodies	SWR*
	hydro-technical and other structures located on water bodies	
industrial, agricultural and socio-cultural facilities	buildings, structures (coordinate description)	USRRP*
	spatial data (intended use of buildings)	FSDP*
state border of the Russian Federation, boundaries between the regions of the Russian Federation		USRRP*
-	municipal boundaries	
settlements	buildings, constructions, construction work in progress	
	settlement boundaries	SIS UPA* FSIS TP*
road network and road structures	road location	USRH*
-	boundaries of specially protected natural reservations	SC SPNR*
tree and shrubbery vegetation	on forest districts, their boundaries, their forest compartments and forest subcompartments	SFR*
herbaceous vegetation, wetlands, other land (sand, rocky placers, disturbed land, etc.)	-	-
tillages	agricultural land boundaries	UFIS AL*
geographical objects names	-	SCGN*

Note: FSDF - Federal Spatial Data Fund, SWR - State Water Register, USRRP - Unified State Register of Real Property, FSDP - Federal Spatial Data Portal, SIS UPA - State Information System for Urban Planning, FSIS TP - Federal State Information System for Territorial Planning, USRH - Unified State Register of Highways, SC SPNR - State Cadastre of Specially Protected Natural Reservations, SFR - State Forestry Register, UFIS AL - Unified Federal Information System on Agricultural Land, SCGN - State Catalogue of Geographical Names

Fig. 1. Correspondence of spatial data of state LIS and other SIR and real terrain units displayed on the UDB

Currently, with the launch of the National Spatial Data System portal the possibilities of using spatial data from state LIS and other SIR can be assessed when they are visualized together with the UDB data. For example, Figure 2 shows the display of information about buildings from the USRRP not available on the UDB, which can be visualized in Figure 3. Accordingly, it is hypothetically possible to imagine that, for example, the information on newly constructed buildings recorded in USRRP can be displayed on a digital advance topographic map, which is illustrated in Figure 4.

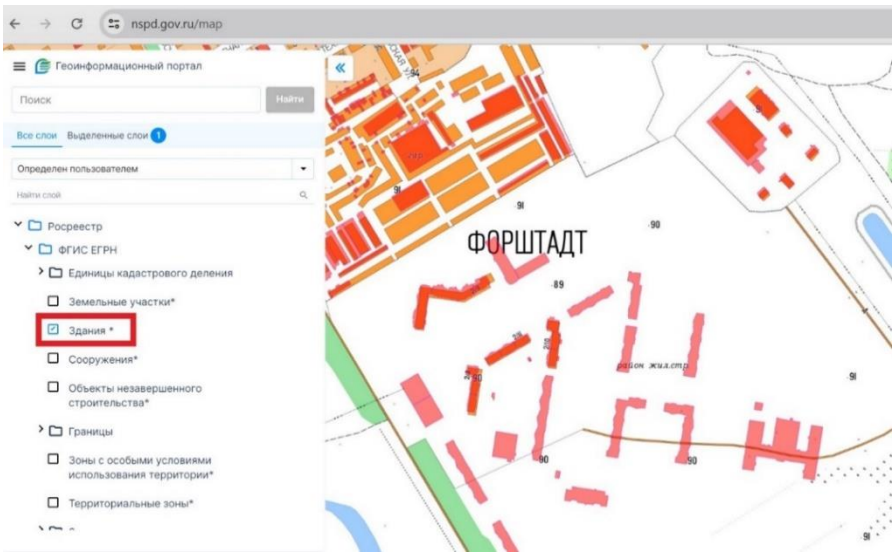

Fig. 2. Display of information about buildings from the USRRP on the UDB substrate for the territory of the microdistrict “Dubki” of the city of Orenburg on the portal of the National Spatial Data System (May 21, 2024)

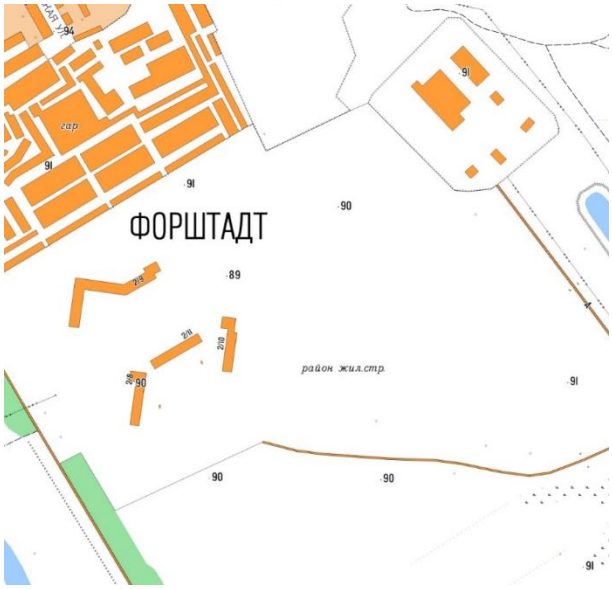

Fig. 3. Display of the UDB data for the territory of the microdistrict “Dubki” of the city of Orenburg on the portal of the National Spatial Data System (May 21, 2024)

Fig. 4. The result of displaying the information about the constructed buildings registered in the USRRP on the UDB substrate for the territory of the microdistrict “Dubki” of the city of Orenburg (May 21, 2024)

It should be noted that a similar approach to the use of sectoral information for monitoring changes in the terrain is traditionally used in topography to identify areas for which it is necessary to update topographic maps and plans. Thus in the Soviet period an advance reference map at a scale of 1 : 100000 was maintained. Currently, as part of the monitoring of relevance, the UDB map of changes is maintained.

It is important to mention that integration of spatial data from different state information resources gives new quality of data and expands the possibilities of their use. For example, integration of information on addresses from the State Address Register and coordinate description of the contours of buildings and structures from the USRRP will allow maintaining an up-to-date address plan.

2. SPATIAL DATA INTEROPERABILITY PROBLEMS

In order to maintain a digital advance map, the issue of interoperability of spatial data of land information systems needs to be addressed to achieve data consistency. In practice, this faces a number of obstacles, including:

1) duplication of spatial data in state information systems
2) differences in sectoral approaches to the description of terrain units
3) accuracy of spatial data

Below we will consider in detail the above-mentioned obstacles to the realization of an advance map.

Duplication of spatial data in state information systems. One of the peculiarities of spatial data integration in the NSDS is inconsistencies caused by their duplication in different state information systems. For example, some information is duplicated in at least four state information systems, as it can be seen from Table 2. The consequences of duplication of information can be considered as an increase in labor costs of operators while maintaining state information systems (inefficient use of budgetary funds) and an increase in transaction and financial costs for consumers in obtaining the specified spatial data (Afanasyeva, 2022).

Table 2

Example of spatial data duplication in different state information systems

<table>
<tr><th rowspan="2">Spatial data</th><th colspan="4">State information systems</th></tr>
<tr><th>1</th><th>2</th><th>3</th><th>4</th></tr>
<tr><td>Boundaries of forestry districts</td><td rowspan="4">USRRP</td><td rowspan="4">SIS UPA</td><td rowspan="4">FSIS TP</td><td>SFR</td></tr>
<tr><td>Water protection zones</td><td>SWR</td></tr>
<tr><td>Specially protected natural reservations</td><td>SC SPNR</td></tr>
<tr><td>Territories of cultural heritage sites</td><td>USR CHS</td></tr>
</table>

Units of administrative and territorial division of the country				UDB

Note: USR CHS – Unified State Register of Cultural Heritage Sites

To overcome inconsistencies in spatial data, it is not always possible to rely only on the priority of the information source. It is necessary to define a system of requirements for spatial data.

Differences in sectoral approaches to the description of terrain units. At the current stage of using digital spatial datasets it is important to come to the use of unified rules of digital description of terrain units used in the UDB and other sectoral information systems, for example, USRRP.

In this case, it is interesting to note the experience of Australian government agencies working together to develop unified, spatially accurate digital land-use data. This work resulted in the creation of a national land-use classification, harmonized data structure, spatial referencing and accuracy (Lesslie, Barson, Smith, 2006).

However, at the moment the contours of buildings in the USRRP may differ from the contours of buildings displayed on topographic plans of the UDB, as different requirements are used to describe structures, buildings and their parts for the purposes of creating topographic maps and plans and maintaining the USRRP. The traditional topographic approach is used to depict buildings on the UDB, which relies on classical conventional signs; information about buildings in the USRRP is displayed on the basis of technical plans, the requirements for which are established by the Order of Rosreestr.

On the NSDS portal, the difference of sectoral approaches in describing spatial data can be easily visualized and a lot of discrepancies can be seen. For example, in Figure 5, the boundaries of forest districts from the USRRP are shown with a dark green contour, while the boundaries of forest districts from the State Forest Registry (SFR) are shown with a dark brown contour. Analyzing the data from the USRRP and SFR, one can see that the contours of the forest districts boundaries do not correspond to each other.

Figure 5 – Visualization of discrepancies between the boundaries of forest districts according to the USRRP and SFR data on the UDB (NSDS portal)

Accuracy of spatial data. SFR data, such as forest management plans, which define the boundaries of forest districts have large tolerances of errors in accuracy in comparison with the USRRP data for land plots that belong to the forest fund lands (Badmaeva, Akunchenko, 2022). In accordance with the Order of Rosreestr, the accuracy of the coordinates of characteristic points on forest survey plans of a scale of 1 : 25000 is 0.0007 meters, while the accuracy of the position of forest units in the USRRP is 0.0002 meters for the specified scale.

3. METHODOLOGY OF APPROACH TO ACHIEVING SPATIAL DATA INTEROPERABILITY

Despite the adopted decisions of the Russian Federation on unification of spatial data of land information systems in a single information system such as NSDS and presentation of uniform requirements to the formats of loaded data to NSDS there is still a long way to go to achieve unification of requirements to spatial data.

As part of data integration in the NSDS, it is important to distinguish between inconsistencies that have accumulated over the past dozens of years in industry-specific spatial datasets and the comparability of spatial datasets being created according to modern regulatory requirements. In both cases it is important to define a consistent system of requirements for spatial datasets and to harmonize, first of all, sectoral regulatory and legal norms.

Further, the newly created sectoral spatial datasets can be coordinated within the framework of inter-system information interaction of the Unified Digital Platform NDSD data providers, for which appropriate regulations are needed. It is also important to complete the transition from analog data to digital spatial data in all sectors, for which it is necessary to switch to the use of modern information technologies, for example, when maintaining advance

topographic plans (Tararin, 2014). To resolve the accumulated inconsistencies, it is necessary to conduct a comprehensive inventory of land (Tararin, Sushkova, Zabaeva, 2020) using a unified spatial basis, for example, orthophotomaps of the UDB. It is also supposed to use artificial intelligence to solve the issues of inconsistencies in spatial data; a similar technology called “Smart Cadastre” to recognize the contours of real property units for the purpose of availability of information in the USRRP and the State Address Register has already been implemented on the territory of several regions of the Russian Federation.

As a result, the approach to achieving spatial data interoperability is as follows:

1. identifying differences in approaches to spatial data maintenance in terms of topographic rules and land information systems;
2. unification of regulatory and legal norms;
3. cross-system harmonization of spatial data requirements;
4. making the full transition to digital technologies;
5. carrying out comprehensive verification of land plots using a common spatial baseline (for example, UDB orthophotomaps) and artificial intelligence technologies.

Implementation of this methodology will provide a unified, accurate and up-to-date system of spatial data, which will increase the efficiency of land management and facilitate interagency cooperation.

CONCLUSION

The following conclusions can be drawn as a result of this research:

1. Achievement of interoperability of spatial data of departmental LIS and their integration for maintenance of digital advance topographic map within the UDB requires digital transformation of departmental LIS maintenance, and, in fact, digital transformation of industry technological processes.
2. In order to implement the proposed approach there is a lot of work to be done, it is necessary to develop and introduce additional unified requirements for the display of terrain units in departmental LIS. For example, for capital construction units in the USRRP it is important to define standards of detailing and format of data representation, which will ensure their correct display as part of the digital advance topographic map.
3. When integrating spatial data of departmental LIS on the basis of the UDB, it is possible to create accompanying cartographic products, for example, an address map (plan) based on data from the USRRP and the State Address Register.
4. The implementation of the proposed approach will improve the quality of spatial data of departmental LIS and reduce budget expenditures for updating the cartographic basis of the Russian Federation.

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BIOGRAPHICAL NOTES

Andrey Tararin has 20 years of experience in the industry. He started his career in 2005 at Nizhny Novgorod State University of Architecture and Civil Engineering as an assistant and postgraduate at the Department of Geoinformatics and Cadastre, as well as a programmer at the UNESCO International Department. Then he worked as a consultant of the Information Technology Department of the Ministry of State Property and Land Resources of Nizhny Novgorod Region, Director of the Center for Urban Planning Support of Nizhny Novgorod, Deputy Head of the Department of Cartography and Spatial Data Infrastructure of Rosreestr. Since 2018, he has been working at the Moscow State University of Geodesy and Cartography, currently the Head of the Department of Real Property Management and Territory Development, and led the project "Personnel Support of NSDS". Since 2021, he has also been working part-time as a researcher at the Public Law Company "Roskadastr", and was the Head of the working group of the "NSDS Methodology" project.

In 2010 he was granted a scientific degree of PhD in Technical Sciences. Currently he is working on a doctoral dissertation on the specialization 1.6.15 - Land management, cadastre and land monitoring in technical sciences on the topic "Scientific bases of spatial data integration of state land information systems".

Member of the GIS-Association, member of the Scientific and Technical Council in the field of geodesy, cartography and spatial data under Rosreestr. Author of more than 100 scientific and educational works, including textbooks "Information Support of Urban Planning", "Spatial Data Infrastructure", "Land Information Systems".

Vadim Donkovtsev, leading analyst of Development Division in the Public Law Company "Roskadastr", participated in defining the list of basic and thematic datasets of the CIS countries Geoportal. He took part in the "Innovator of PLC Roskadastr" contest on the topic "Development of a methodology for updating the Unified Digital Basemap (UDB) based on data from the United State Real Property Register (USRRP) and the State Information System for Urban Planning Activities (SIS UPA)".

Postgraduate student of the Department of Real Property Management and Territory Development at the Moscow State University of Geodesy and Cartography, currently working on a PhD thesis in the specialty 1.6.20 "Geoinformatics, Cartography" of technical sciences on the topic "Development of a methodology for maintaining a digital advance topographic map through information interaction with departmental land information systems (by the example of USRRP and SFR)". He made a report at the International Student Week of Science SWS-2024 on the topic "Evaluation of possibilities of using the data of the USRRP for updating the UDB", where he took second place in the section "Geoinformatics". He made a report at the II All-Russian Scientific and Practical Conference with international participation "GEOFORUM. NIZHNY NOVGOROD. 2024" on the topic "Creation of the advance state cartographic basis: prerequisites and problems of realization". Currently participates in the semifinals of the All-Russian Engineering Competition, presenting his thesis work.

CONTACTS

Vadim Donkovtsev
Branch of the Public Law Company “Roskadastr” Center of Information Technologies “Roskadastr-Infotech”
Enthusiastov highway, 14
Moscow
RUSSIAN FEDERATION
+79296125400
donkovtsev.vg@gmail.com
https://kadastr.ru/

Andrey Tararin
Moscow State University of Geodesy and Cartography
Gorokhovsky Lane, 4
Moscow
RUSSIAN FEDERATION
+79087476043
tammiigaik@gmail.com
https://www.miigaik.ru/