Geoportal for highways as a basic element of spatial data infrastructure

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Abstract. This article is devoted to the development of geographic information systems, WEB-mapping and information integration into the spatial data infrastructure (SDI). The analysis of the history of the creation of spatial data infrastructure in the world community and in Russia is carried out, the specifics of the development of Web-GIS and SDI are revealed. As part of the study, the analysis of the world experience of using the Web-GIS of highways, as well as the current state of applied geoinformation systems in Russia was carried out. The key issue considered in the article is the development of the architecture of a Web GIS (geoportal) of highways for the purposes of accounting, analysis and systematization of spatial data. The main features of the formation of systems for recording data on highways are determined, the main tasks solved by these systems are given. The automobile road is a complex and lengthy object, which should become the spatial basis for the development of spatial data infrastructure in Russia. A block diagram of the main modules of the geoportal has been developed and proposed. The main functionalities implemented at each stage of the Web GIS operation are highlighted. As a result of the implementation of the proposed architecture of the geoportal, a system of analysis, systematization and management of spatial data of a road enterprise was introduced. The use of a geoportal significantly affects the optimization of the performance of various works on highways. Also, the result of the work (Web-GIS) can be implemented as a system for analysis, accounting and systematization of data on other extended linear objects (power lines, gas pipelines, water pipelines, etc.). A user interface of a geoportal, a structure for storing spatial data, modules for transforming coordinates and information, blocks for loading, analyzing and unloading data have been developed. The proposed architecture is versatile and easy to use, which is a clear advantage over the analog systems described in the study. Further study of the research topic opens up prospects for the rapid development of integrated geoinformation software tools on the Internet and a deeper understanding of the need to develop spatial data infrastructure.

1. Introduction
The formation and improvement of the spatial data infrastructure (hereinafter SDI) is one of the most important topical issues in the transformation of spatial-semantic and temporal information from analog to digital form. Along with the countries of Europe and the United States, in Russia in 2006 the concept of forming the SDI was created. However, further development of this topic continued only in 2019. Thus, Russia in the field of spatial data exchange lagged behind foreign countries by 10 or more years [1].
The basis for the formation of SDI abroad was a network of integrated Web-GIS or geoportals, i.e. geographic information systems located on the Internet providing access to spatial data and providing functions for processing and analyzing these data. Russia also has a wide experience of creating such systems, but they can hardly be called open. Consequently, systems intended for use by a narrow circle of people did not contribute to the formation of the SDI [2, 3].

This article not only reveals the problems of the formation of SDI in Russia, but also contributes to the improvement of systems for analysis, accounting, forecasting and road management. Highways are long-distance transport infrastructure facilities intended for the movement of vehicles and pedestrians. This results in a number of features associated with both individual differences between highways and other real estate objects, and with Russian legislation in relation to the accounting of extended (linear) objects.

Further, the article will consider how the peculiarities of accounting objects are considered in the formation of the architecture of Web GIS, and how important applied GIS are in improving the systems of exchange, visualization, processing and systematization of spatial data.

2. Purpose and tasks
The purpose of this study is to develop a geoportal architecture to provide a road complex enterprise with heterogeneous spatial and semantic information.

The authors have set the following tasks:
- analysis of the current situation in the field of applied geographic information systems in Russia and abroad;
- consideration of the specifics of creating geoportals for highways;
- development of an architecture that takes into account the specifics of the modern legislation of the Russian Federation in relation to linear objects.

3. Applied Geographic Information Systems and Web GIS
Applied geographic information systems contain data from narrow areas of human activity. GIS and geoportals of highways belong to the field of applied GIS; however, their purpose directly depends on the data entered into the system [4]. For instance, for the territories of individual states of the United States, geoportals of highways have been developed that have a user purpose, i.e. they contain data on cultural heritage sites, recreational sites and petrol stations. These systems are actively used by tourists and citizens themselves when traveling around the country.

Unlike the United States, the INSPIRE spatial data infrastructure has been created in the European Union. Designed for specialized purposes, it integrates the sites of countries containing spatial data of heterogeneous objects, including highways. This system is used primarily for accounting and systematization of EU lands [5, 6].

The most famous supplier of software for accounting and road design in Russia is IndorRoad. The list of their developments includes a geoportal created for a narrow number of organizations, access to which is possible only with the use of a login and password. Also, in Russia, separate GIS was created for use by government authorities, but their functionality was not enough to effectively provide information to the road complex.

According to the authors, the European experience in creating a spatial data infrastructure is the most optimal, since the system is formed from a large number of different isolated sites that meet the diverse needs of a person, first of all, providing professional users with relevant spatial and semantic information. It should be borne in mind that for the formation of SDI it is necessary to develop uniform standards and norms for the creation and maintenance of sites for their integration.

Applied geographic information systems play an important role in the creation and improvement of the entire infrastructure, since they allow classifying and sharing information and quickly sending it to the user, while large sites, such as the Public Cadastral Map, store a large amount of information and it can be difficult for the user to navigate such the amount of data, and, specifically, use this data for professional purposes [7-9].
4. Geoportal of highways. Features of creation and functioning

Highways are extended objects, which significantly complicates the process of collecting and systematizing information, since in addition to the roadbed, the road contains a huge number of land plots, artificial engineering structures, road service facilities, as well as land plots belonging to zones with special conditions for the use of territories.

Thus, the geoportal of highways should not contain unnecessary data that would impede the visual perception of spatial and semantic information [10].

One should also take into account the fact that road maintenance is carried out with an orientation to kilometer marks, respectively, the integration of cadastral information (coordinates of characteristic points) with road picketage greatly simplifies the process of analyzing and managing the entire property complex of roads. This feature relates to the field of spatial perception of information; since many employees of road maintenance organizations work with technical passports for individual areas apart from the general picture, it is important to integrate their perception with the real position of land plots on the ground, for more efficient identification of violations and problems and the same prompt solution to them.

Consequently, when developing a geoportal, first of all, it is important to focus on a comfortable and user-friendly interface that provides the necessary range of functionality.

This article discusses the experience of creating a geoportal for federal highways GIS “Central Russia”. This system was created to take into account spatial and semantic data on federal roads. The geoportal being created will ensure the solution of the following tasks:

1. registration of land plots of road right of way;
2. analysis of the legality of the use of land plots on the right-of-way;
3. registration and systematization of data on real estate of organizations;
4. monitoring the use of the right-of-way and roadside, the imposition of restrictions and encumbrances on a land plot in the roadside, detection of the capture of a right-of-way;
5. determination of the book value of the objects of the property complex, the period of normative service in order to make decisions on the need for repairs;
6. creation of a platform for making management, design and operational decisions;
7. geoinformation support of cadastral, monitoring, land management, town planning, inventory and other activities in relation to highways [11-12];
8. creation and storage of information models for capital construction of highways [13-14].

The conceptual diagram of the geoportal architecture is shown in Figure 1.

The geoportal is based on a set of Yandex.Maps API services. Interactive maps have been integrated into the site using the JavaScriptAPI software library. The set of Yandex services provides automatic updating of map data and satellite images, and relieves the system operator of the obligation to update this information.

The main program code of the system was written in the following programming languages: Groovy, Java, TypeScript, Angular 6. Also, during the development of the system, the language of dynamic styles (less), and the language of hypertext markup of the page (html) were used. All information entered on the site is stored in the PostgreSQL database.

The main elements of the geoportal are reflected in the form of a block diagram presented in Figure 2.
4.1 System functionality

At the stage of entering information into the system, the following features are implemented: entering information manually by filling in the appropriate fields; input of information automatically from .XML and .txt files. After uploading files or filling out a form, the system analyzes the data and displays it in the appropriate layer.

At the moment, the system implements such layers as: land plots, capital construction objects, roadside lanes, kilometer poles, municipal boundaries, road service facilities, engineering
communications, topographic plans and information models. Information in layers is displayed in vector form in color combinations that are comfortable for visual perception (Figure 3).

![Figure 3](image_url)

**Figure 3.** Display of spatial information in the system (blue are land plots, orange are capital construction objects, green are roadside stripes)

Also, we implemented a color filter by property types; yellow is for the property of the Russian Federation; red is for permanent perpetual use; black is for objects of permanent perpetual use by the Russian Federation; blue is for easement; green is for other.

At the loading stage, coordinates are recalculated from various local coordinate systems, which allows uploading information about objects located in various constituent entities of the Russian Federation to the website.

The visualization of the system is presented in the form of a cartographic basis for Yandex.Maps and four modules: layer-by-layer organization, work with a map, search, uploading, analysis and downloading of data.

The module for uploading, analyzing and downloading data contains windows for displaying semantic information. The “Additional information” window displays the coordinates of the characteristic points of the object, the “Information” window contains semantic data about the object (address, cadastral number, form of ownership, area, etc.). Using all these elements in combination, the user can analyze comfortably visual and geoinformation.

All data uploaded to the system form various thematic registers of information that are important for tracking all the changes occurring with accounting objects, and also timely tracking violations in respect of accounting objects. These registers are especially important for monitoring and inventorying road lands.

Information is rendered by printing a raster image containing cartographic and spatial-semantic information about the object or by uploading a .csv file, which also contains spatial and semantic information about the object [15-16].

The result of the architecture formation is a geoportal, which is distinguished by an intuitive interface adapted for any user, and a range of functional capabilities that are necessary to provide highways with diverse information. The main feature of the system is its openness, which has not been implemented in analog systems.
This topic was brought up by the authors for discussion in the format of scientific conferences and articles. Also, such authors as Koshkarev A.V., Shevin A.V., Seredovich A.V., Mayorov A.A., Karpik A.P., Boykov V.V. et al. were involved in the creation of geoportals for highways and the formation of SDI in Russia, which indicates the extreme urgency of these problems in Russia.

5. Conclusion

In conclusion, it is worth noting the local practical importance of geoportals of highways for improving the system of analysis, accounting and systematization of spatial data. Despite the general shortcomings of legislation regarding the accounting of linear objects, these systems in any case facilitate the work of organizations involved in servicing highways, as they provide access to up-to-date reliable cadastral information combined with picketage addresses. Thus, the geoportal of highways becomes the basis for geoinformation support of the activities of such organizations.

The formation of SDI in Russia is at an initial level. Scientists, GIS specialists and programmers are just starting serious work in this direction. By forming separate systems and sites with a narrow focus, making them open to citizens, a large system of integrated spatial data is gradually being created by the inductive method.

References

[1] Koshkarev A V, Antipov A N, Batuyev A R, Yermoshin V V and Karakin V P 2008 Geography and Natural Resources 29(1) 18-27
[2] Simmons S 2018 Comprehensive Geographic Information Systems 110-124
[3] Vandenbroucke D, Dessers E, Crompvoets J, Bregt A K and Orshoven J V 2013 Computers, Environment and Urban Systems 38 58-66
[4] Kulawiak M, Dawidowicz A and Pacholczyk M E 2019 Computers & Geosciences 129 26-37
[5] Dmitrienko V E 2015 CAD system and GIS 2(5) 136-145
[6] Kalantari M, Dinsmore D, Urban-Karr J and Rajabifard A 2015 Land Use Policy 49 552-564
[7] Karpik A P 2004 Methodological and technological basis for GIS support of the territories: Monograph (Novosibirsk: Siberian State Academy of Geodesy) p 260
[8] Pouri M J, Hilty L M 2021 Environmental Innovation and Societal Transitions 38 127-139
[9] Youssef A B, Boubaker S, Dedaj B and Carabregu-Vokshi M 2021 Technological Forecasting and Social Change 164 120043
[10] Ciencila A, Sobolewska-Mikulska K and Sobura S 2021 Land Use Policy 102 105204
[11] Papaskiri T V, Kasyanov A E, Alekseenko N N, Semochkin V N, Ananicheva E P and Shevchuk A A 2019 IOP Conf. Series: Earth and Environmental Science 350 012065
[12] Papaskiri T M, Semochkin V N, Ananicheva E P, Zatsepina E A and Shevchuk A A 2020 IOP Conf. Series: Earth and Environmental Science 579 012130
[13] P van der Molen 2002 Computers, Environment and Urban Systems 26(5) 361-381
[14] Kostesh V A, Platonov I A, Chistyakova E A 2019 Proceedings of the Scientific Congress of the 21st International Scientific and Industrial Forum: in 3 volumes pp 300-303
[15] Kostesh V A 2020 Appendix to the journal News of Universities: Geodesy and aerial photography 11 163-165
[16] Kostesh V A, Kolesnikova I K, Marycheva O A 2020 Materials of the international scientific and practical conference Digitalization of Land Use and Cadastre: Trends and Prospects pp 197-201