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DEVELOPMENT OF A UNIFIED MODEL OF GEOINFORMATION SYSTEM FOR CITY PLANNING AND INTEGRATION

Zaalishvili V.B.[1], Kanukov A.S.[1], Melkov D.A.[1], Makiev V.D.[1], Dzobelova L.V.[1]

[1]Geophysical Institute of Vladikavkaz Scientific Center of Russian Academy of Sciences, Russia

*Corresponding Author, Received: 7 April 2018, Revised: 24 May 2018, Accepted: 18 June 2018

ABSTRACT: On the basis of modern technologies, an information database of seismicity and seismic risks has been created in the information system designed for city planning which includes maps of detailed seismic zoning (DSZ) of the Republic of North Ossetia-Alania and the map of seismic microzonation (SMZ) of the territory of Vladikavkaz. Evaluation methods of social and economic losses from possible earthquakes of different intensity are considered and a methodology for seismic risk assessment is developed. An algorithm for introducing the methodology for seismic risk assessment into information systems designed for city planning is proposed on their basis. Developed system is easily modernized and is the basis of a modern constantly updated information database that combines the results of all directions of the city planning for the cities and populated areas of North Ossetia, and it can also include any information that has a spatial reference, which makes it possible to include organically these data to the Federal All-Russian Information System.

Keywords: Seismicity, Information System, Database, Seismic Risk

1. INTRODUCTION

Geoinformation modeling is currently still a relatively young field of scientific research that covers a wide range of issues related to the creation and the use of geoinformation systems (GIS-systems), the data and objects presented in GIS, as well as the application of mathematical methods and algorithms in these systems. GIS - systems include DBMS (database management systems), graphics editors presented in vector or raster format, various analytical tools that allow using them in cartography, geology, geophysics, ecology and many other areas.

For providing the life comfort and safety of citizens, public authorities at all levels and in all countries are obliged to ensure the operation of infrastructures of various types. Managing physical infrastructure requires the organization of links between different systems and, accordingly, the information infrastructure. Spatial Data Infrastructures (SDI) play an important role because the information about the location of one or another object plays a key role in the management of all systems that are controlled and managed by public authorities, such as roads, utility networks, health systems and others. Like most types of infrastructure, SDI also provides a platform for the economic development of a country or region.

According to the Building Code of Russian Federation, Information System Designed for City Planning (ISDCP) are a systematized set of documented information about the development of territories, building stock, land plots, capital construction objects and other information necessary for the implementation of urban planning [1].

In a general sense, ISDCP is a metasystem (system of systems) [2], which provides information support for the variety of different life support and development processes of the city. Such a complex system includes several classes of software: GIS (Geographic Information System), EDMS (electronic document management system), DBMS (database management system), EARMS (electronic administrative regulations management system), SICS (system of information classification and coding), web portal, it also organizes access to IEIS (interagency electronic interaction system).

2. DEVELOPMENT OF THE UNIFIED MODEL OF GEOINFORMATION SYSTEM DESIGNED FOR CITY PLANNING

The purpose of information systems designed for city planning maintenance is to provide government bodies, municipal authorities, individuals and legal entities with reliable information necessary for the implementation of urban planning, investment, and other economic activities as well as land management.

In our opinion, information on the seismic hazard of the territory, which is fundamental for construction in seismically hazardous areas, holds a special place.

Seismological investigations for various purposes, including the tasks of the construction industry, have been carried out in our country for more than a century. Seismic hazard assessment is usually reduced to the calculation of the maximum possible seismic impacts that must be taken into account in case of construction in seismic regions. Seismic hazard is reflected in the maps of seismic zoning of a certain territory [3-6]. Depending on the tasks and necessary detail of seismic hazard mapping three levels of seismic zoning are considered in our country: general seismic zoning (GSZ) - for the entire territory of the country; detailed seismic zoning (DSZ) - for the limited areas and individual regions; seismic microzonation (SMZ) - for cities, settlements and construction sites.

As a result of numerous investigations on seismic hazard assessment in 2006-2013, the original maps of detailed seismic zoning (DSZ) of the Republic of North Ossetia-Alania, maps of seismic microzonation (SMZ) of the territories of cities and large settlements of North Ossetia-Alania [7-12] have been created by the Geophysical Institute. It is obvious that cartographic materials should correspond to the world level, applicable to the spatial data, and, first of all, it must have the opportunity of direct inclusion in any modern information system.

The existing automated systems designed for city planning, the cadastral system, as well as other information resources, were considered. In the result of the carried out investigations, we developed the structural-functional model of ISDCP that allows creating an information system for the needs of the user, while maintaining compatibility with other products built according to this model, as well as a number of already existing systems (Fig. 1).

The Web Map Service (WMS) specification has been selected in order to develop a Web service. The WMS protocol is the standard of the Open Geospatial Consortium (OGC) and is supported by the most of applications. Most of the special software for the development of cartographic web services on the Internet is created on the basis of OGC specifications. The Geoserver was chosen as a basis, as a product that meets all the necessary requirements. It is also compatible with the web resource of a unified information system Seismic safety of Russia.

A server that runs under the freeware operating system Ubuntu Server 16.04 was chosen as a platform for the software complex that is being created.

Web interface for accessing and visualizing the service data (based on OpenLayers) was developed. This is necessary functionality to view probabilistic maps of seismic hazard of the territory of North Ossetia-Alania and maps of seismic microzonation.

When entering the main page, the user needs to be authorized to access the data. Authorization is two-level, but it is transparent to the user i.e., the user only needs to enter login/password and then the system itself will perform authorization not only in the web service but also in the Geoserver.

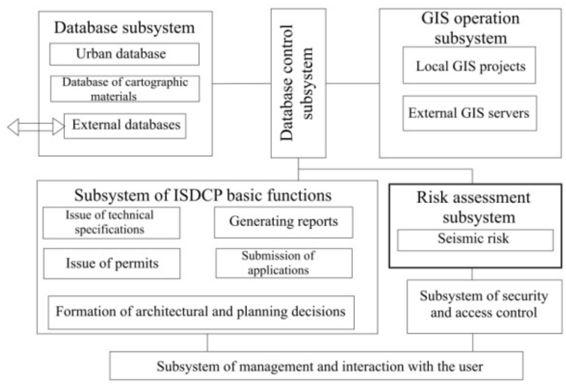

Fig.1. The developed structural-functional model of ISDCP

Then the map of seismic microzonation of the territory of Vladikavkaz is loaded (Fig. 2a). On this page, the search for an object is carried out at the address, with the selection of the corresponding section of the map (Fig. 2b).

Using the navigation buttons, you can zoom out or zoom in objects, as well as navigate through the map, while in the lower left corner there will always be a scale ruler, the scale of which depends on the degree of approach to the map. By using the switches of the layer visibility in the map display control area, the user can only view the information of interest, for example, cadastre information (Fig. 2c).

The user can attach any information to each object on the map in the form of a file or attributive information. An example is the inclusion of the building stock of Vladikavkaz into the information system of a seismic risk database (Fig. 2d). The map of detailed seismic zoning of the territory of the Republic of North Ossetia-Alania is presented in a similar way, with appropriate user options.

To display the data, the corresponding SLD-styles have been developed [13]. With the help of PostGis, the function of object search by the address is realized. Other new technologies, such as web 2.0, AJAX and others, are also used in the development.

During the research, security issues were considered and an appropriate system for providing information and access rights differentiation for users of the system was developed.

The use of the encrypted HTTPS protocol makes it possible to minimize the possibility of unauthorized access to data. Using an asymmetric RSA encryption algorithm with a key length of 256 bits makes unpractical an unauthorized access by direct selecting the key. Usage of the signed certificate allows using the maximum degree of protection of the data transmission channel, making the hacking procedure extremely difficult.

Detailed study of the urbanized areas is required for the prediction of possible consequences of earthquakes or other disasters. At the end of the 20th century, assessment methods of seismic risk of the existing buildings and structures were developed in Russia. These programs took into account numerous objective and subjective factors affecting the level of seismic risk of the urbanized territories.

One of the methodologies was developed by Prof. S.Yu. Balasanyan in 1991 [14]. After eight years of successful work, the strategy was approved by the Government of Armenia in 1999 as a state program. According to this methodology, in case of a strong earthquake the largest contribution to the scale of possible losses is made by the following components: seismic hazard of the territory, population and its density in the areas of high seismic hazard, territory of zones with buildings and structures, which have low seismic resistance in comparison with the level of seismic hazard.

The definition of the risk of seismic losses (RSL) was calculated using the formula

$$RSL = KR*KS*KP \quad (1)$$

where KR is a risk rating that takes into account the intensity of the seismic impact; KS is a vulnerability rating of buildings located within the studied area; KP is a coefficient of the vulnerability of people located within or near the objects under investigation.

Another forecasting technique is the development of a rating assessment of soil conditions and seismic risk of the territory. The creation of a rating assessment of engineering-geological, hydrogeological, geomorphological and other features of soil conditions was conducted for Vladikavkaz for the first time. Rather a large district of the city, Kuibyshev Street and the adjacent quarters was chosen as the object of the study.

The seismic vulnerability rating of all six quarters was determined by taking into account soil conditions and on the basis of the method of expert assessment [15].

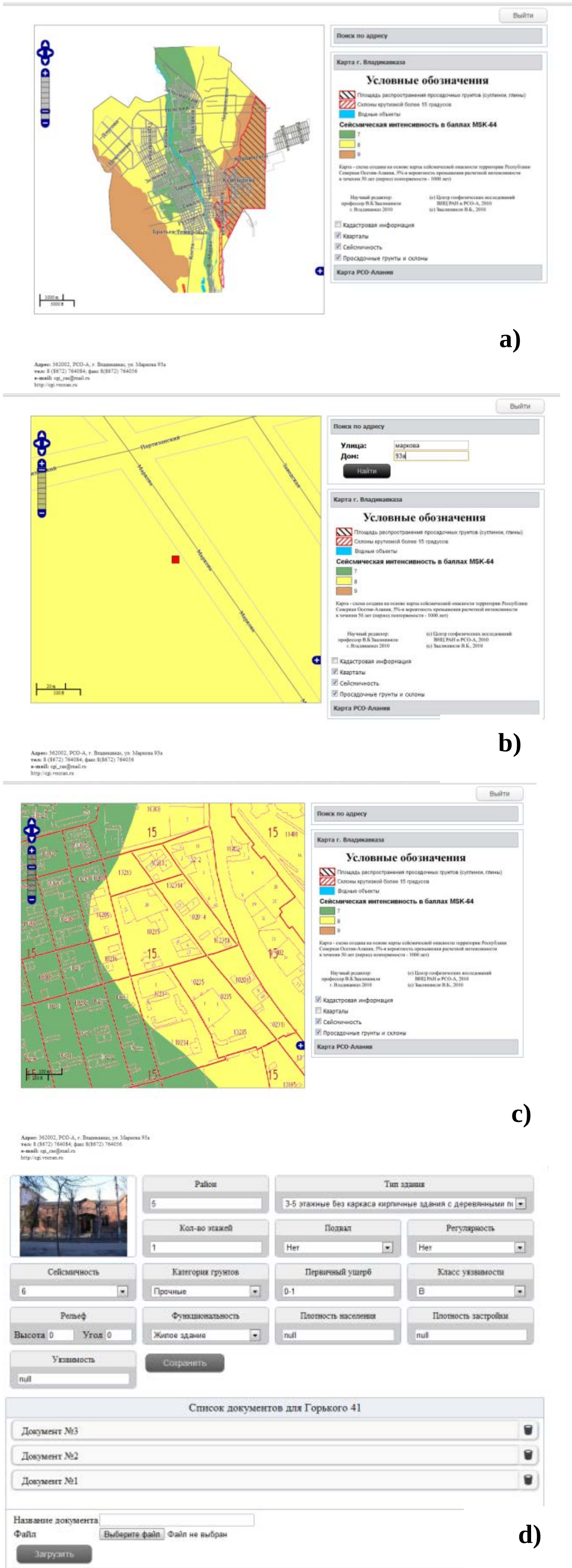

Fig. 2 a) The main page of the web service with the map of Vladikavkaz; b) Realization of the function of object search by the address; c) Cadastral information output; d) Database of seismic risk of building stock

According to the developed approach [16], the set of soil conditions is divided into several levels of seismic vulnerability. Three such levels were used for this case. Each level corresponds to the values of hazardous factors that form a seismic vulnerability (Table 1). This classification is based on the experience of the past earthquakes. In other words, as was noticed above the so-called expert evaluation was used. Then, to each value of the factor was assigned its weight rating, also established from the past experience.

Each factor was evaluated on a three-point scale, where 1 corresponds to the least influence of this factor on the deterioration of the rating status of the site, and 3 corresponds to the largest (Table 2). The worst soils are the foundation soils of the first and the second quarters.

To calculate the vulnerability rating, the following ratio was used:

$$W_y = W x D \qquad (2)$$

The used seismic hazard of the territory is a hazard assessed by the level of SMZ (seismic microzonation), which determines the formation of the calculated intensity or an earthquake effect [17]. In other words, the worse the soil conditions of a building foundation are the higher seismic risk. Thus, the connection between soil conditions and the effect of seismic hazard is clearly evident.

Table 1 Rating indicators of soil characteristics in the territory of Vladikavkaz

	No.*	Seismic vulnerability, D			Weight rating, W
		1	2	3	
Endogenous and exogenous conditions of the site	1	7	8	9	3
	2	< 0.01	0.01 – 0.05	> 0.05	1.5
	3	no	middle level	strong effect	3
Soil conditions	4	>800	400-800	80-400	1,5
	5	> 10	5-10	< 5	2
	6	< 50	5 – 150	> 150	0.5

*Where: 1 - Territory seismicity (MSK-64, point); 2 - Spatial distribution (density) of faults (km\km); 3 - Active geological processes; 4 - S-wave velocity in soils (Vs, m/s); 5 - groundwater level (hgwl, m), 6 - slope angle (relief) (degree)

Table 2 Rating assessment of soils on the territory of Vladikavkaz

No.	Seismic vulnerability of quarter, D					
	1	2	3	4	5	6
1	3	3	1	1	1	1
2	2	2	2	2	2	2
3	3	3	2	2	1	1
4	3	2	2	1	1	1
5	3	1	1	1	1	1
6	2	2	2	1	1	1
Max. vulnerability rating, $W_{v,max}$	32.5	27	18	16	13	13
Relative vulnerability rating, $W_v/W_{v,max}$	0.94	0.78	0.52	0.46	0.37	0.37

The seismic risk rating of all 6 sites, based on Balasanyan's method was also determined.

At seismic impact equal to 7 points of the MSK-64 scale, the seismic risk rating was:

- Vesna RSL=0,875,
- Balkinskiy drive-Pionerov street RSL=0.35,
- Pionerov street – Lermontov street RSL=1.038,
- Lermontov street – Frunze street RSL=0.43,
- Frunze street – Lenin street RSL=0.92,
- Lenin street – Terek river RSL=0.95.

Analyzing the obtained values, one can conclude that this technique gives not quite correct results for the investigated territory. As the soil conditions were not taken into account in this approach, it was logical to assume that on the Vesna area, where only the buildings of type D are represented, the risks will be minimal, that isn’t confirmed by calculations. At the same time, the neighboring site (Balkinskiy drive-Pionerov street has a much lower risk value with all the worst indicators. This is connected, first of all, with the fact that the buildings represented on the Vesna area are not found anywhere else, that is one of the special cases in which formula (1) gives incorrect results.

Thus a methodology for seismic risk assessment of the territory on the basis of the method of expert assessment had been developed.

Besides, it is necessary to take into account possible economic damage in the information systems designed for city planning. The total economic loss L is calculated as the sum of the individual types of damage for all zones of different intensity:

$$L_i = \sum_{j=1}^{j} S_{ij} \times V_{ij} \times C_{ij} \quad (3)$$

where S_{ij} is the building stock density of j-type in the zone with intensity i; V_{ij} is an average vulnerability of an individual object; C_{ij} is an average cost of an individual object.

In order to determine a full economic damage, we additionally must take into account the losses due to a damage and (or) destruction of urban infrastructure, as well as the social damage.

According to the expert assessment, additional damage as a result of 7 points earthquake will increase by 20% and for 8 points it will increase by 40%.

The map of the engineering and geological zoning of Vladikavkaz, covering the questions of geological structure, hydrogeological conditions, lithology, morphology, tectonics, and the distribution of the various types of soils on the considered area was created by the Geophysical Institute as a result of numerous investigations. The areas that characterize various depths of pebbles or the thickness of clay and loamy cover on pebbles, which is the main parameter determining the seismicity category according to SNiP-II-7-81 *, are singled out on the territory.

The developed system is used as the basis of the system of geoinformation modeling of geological objects. A differentiation of soil groups with different determinant parameters, characterizing the category of soils based on their seismic properties (SNiP-7-II-81 *), was carried out on the basis of the analysis of physical and mechanical properties in order to integrate the database of geological information into the developed geoinformation system.

The purpose of the mapping of the engineering and geological structure of Vladikavkaz was the following: first, the compilation of a general idea of the lithological and geological structure of the investigated territory and the determination of a general hydrogeological specification of the area; secondly, sampling of the exploring workings that correspond on their parameters (location, depth, opened section, presence of laboratory testing) to the purposes and tasks of seismic microzonation for the subsequent use in the construction of maps and sections.

A GIS-project “Database of geological information of Vladikavkaz territory” was created.

The topographical basis in the form of the contours of quarters, streets, main contours of the Terek River and the anthropogenic load was obtained from the existing thematic maps.

There are created three types of the thematic maps: a map of the factual material, a map of isohypses and depths of the pebbles roof, a map of engineering and geological zoning.

Thematic maps are created with the accompanying databases.

On the map of the factual material, only one layer of “mine workings” is represented with the following fields: a type of a mine (well, trench, pit, wellhole), the index (mine number and index of the type), the field is issued for signature on the map; a mine number.

The map of engineering and geological zoning also contains the information about the mines. In addition, the following information is provided: the information about slopes with a steepness of more than 15 degrees (polygonal layer, without attributive data), soil categories on seismic properties in accordance with the existing requirements of SNiP II-7-81*.

The subsequent prospects for the development of the created geocoded databases are reduced to the spatial analysis of attributive information. On its basis the following is possible: creation of the continuous fields with functions for detailing and updating of the information based on the newly received data (i.e., detailing), creation of an advance compilation, overlay with information about hazardous anthropogenic objects, overlay of information about the depths of the roof of aquifer and lenses, solving of the other spatial problems.

The description of the soils is given for all wells in the GIS-project. This information is collected to the database of geological information, formed as a shapefile with a spatial reference of each well.

In conclusion, it should be noted that the developed system is easily modernized and is the basis of a modern constantly updated information database that combines the results of all directions of the city planning for the cities and populated areas of North Ossetia, and it can also include any information that has a spatial reference [18-22], which makes it possible to include organically these data to the Federal All-Russian Information System.

3. CONCLUSIONS

At present, along with electronic document management systems (EDMS), the geoinformation systems (GIS) are the necessary part of the national administration. The adoption of the City-planning Code led to the creation of many information systems designed for city planning (ISDCP). Strong regulation is extremely inefficient and blocking development and “self-improvement” of the systems. At the same time, the protocols for data exchange between systems should be regulated. It takes into account security requirements; develops metadata structures. Such as it implemented in the Russian cadaster electronic system (roscadastr.com), which is the most flexible Russian geoinformation system due to the practical necessity and demand.

There was developed the information model of ISDCP that allows creating an information system for the needs of the user while maintaining compatibility with other products built according to this model, as well as a number of already existing systems. The WMS protocol (as a WMS-service) allowed using data in many applications, both of public services and private users. WMS and WFS protocols are the standards of the Open Geospatial Consortium (OGS) and are supported by the most applications.

Using the WMS protocol allows getting an access to the data on seismicity and risks in the form of information section both in own developed products and in products of third-party developers.

On the basis of modern information technologies, a database of initial seismicity of different levels of the territory of the Republic of North Ossetia-Alania (detailed seismic zoning) and the territory of Vladikavkaz city (seismic microzonation) was created.

The areas that characterize various depths of pebbles or the thickness of clay and loamy cover on pebbles, which is the main parameter determining the seismicity category according to Russian Building Code SNiP-II-7-81 *, are singled out on the territory of Vladikavkaz.

A differentiation of soil groups with different determinant parameters, characterizing the category of soils based on their seismic properties was carried out on the basis of the analysis of physical and mechanical properties and formed special GIS-project “Database of geological information of Vladikavkaz territory”, which includes the information on wells drilled on the territory of the city with a detailed description of the soils.

The use of the developed methodology of seismic risk assessment allows calculating the soil rating and the seismic risk of the territory. To realize this methodology, in the information system designed for city planning in the Republic of North Ossetia-Alania we have developed an algorithm for introduction the methodology of seismic risk assessment into any ISDCP. This algorithm realizes the possibility of soil rating and seismic risk calculation, as well as possible social and economic losses for any investigated area and allows identifying the most vulnerable areas.

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