ГОДИШНИК НА УНИВЕРСИТЕТА ПО АРХИТЕКТУРА, СТРОИТЕЛСТВО И ГЕОДЕЗИЯ СОФИЯ

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3D PRESENTATION OF CADASTRAL OBJECTS

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ABSTRACT

The paper examines the possibility of future development of a 3D presentation of the cadastral objects, taking into account the current state of the cadastral system in Bulgaria.

The prerequisites, the possibilities and the means for realization and application of 3D cadastre in Bulgaria are clarified as well as the challenges to its realization. Problems concerning the design of an efficient system for land administration, possible technologies and standards for realization of 3D cadastre are described.

Three possible implementation examples are proposed, including different methods: through the capabilities of ArcGIS, JavaScript and WebGL. A web based application for cadastral data services based on an HTML has also been developed.

1. Introduction

This paper is part of the master thesis of Kristina Galabova.

The main purpose of the cadastre is to show objects of cadastre, to identify them and to connect object and subject by the property rights. It is important this role of the cadastre to be retained and upgraded by the modern technologies which are available nowadays.

The current task which the Bulgarian cadastre faces is complete creation of the 2D cadastre for the whole territory, because the 3D presentation is based on 2D. It can be assumed that the first steps in this direction are made by applying European directives about infrastructures for spatial data (INSPIRE). Various specialized data are necessary for creation of most of the themes.

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It is necessary some tasks for the design of the application for 3D presentation of the objects of the cadastre to be solved:

- Analysis and structuring of the initial data, description of the steps of the creation of suitable database and data transformation;
- Description of the web based application.

2. Cadastre 2014 – What is Made in Bulgaria?

Cadastre 2014 is a report, published in 1998 by FIG working group (commission 7). The working group was working between 1994 – 1998 and has defined trends in cadastral development for the next 20 years.

The report of the World Bank for 2014 examines the state and development of 11 eastern European ex-socialist countries, among which is also Bulgaria, and these countries are part of the first 20 countries all over the world as the most favorable for business and effective registration of land property. There is an evaluation of the country economics about realization of the six statements in Cadastre 2014.

Statement 1: *Cadastre 2014 will show the complete legal situation of land, including public rights and restrictions*

Figure 1. Level of achievement of statement 1

Restitution activities are made, but cadastral maps and registries are still not complete and the land register is not finished yet. Cadastral parcels that are object of business transactions are registered in land register. There is a slow progress about showing the complete legal situation and the reason is the change of [4] by 2014 that claims: "Art. 2 (2) *The cadastre includes and: 4. Data about restriction zones on cadastral parcels. (3) These data are shown on the cadastral maps and are registered in cadastral registries*". According to [10]: "Art. 24, (2) *Registers about restriction zones and objects of the information-administrative maps are designed and upgraded*". In [5], Art. 78 the content of the project about restriction zones is specified as well as the content and the structure of the register of the restriction zones. It is expected to achieve some results after these changes are applied.

Statement 2: *The separation between 'maps' and 'registers' will be abolished*

Figure 2. Level of achievement of statement 2

In Bulgaria, there is minimal conformity with that statement. The digital cadastral model contains graphical part (cadastral map) and attribute part (cadastral register of cadastral parcels). The registration system of the cadastre and land register is still dual [6].

The information systems of the cadastre and land register are made as distributed data bases in 28 cadastral offices and 113 regional courts where the information about cadastral parcels and land rights at every moment is stored [11].

Statement 3: *Cadastral mapping will be dead! Long live modelling*

Figure 3. Level of achievement of statement 3

This statement is achieved. The cadastral map and registers are made and updated in digital format.

It is necessary to extend the existing 2D model to 3D model in order to show complete legal situation of cadastral parcels along with the restrictions, which are 3D in many cases.

Statement 4: *'Paper-and-pencil cadastre' will have gone*

Figure 4. Level of achievement of statement 4

This statement has considerable realization during the last years due to the announced Public Procurements about cadastral maps and registers.

The available maps of the restored properties are created and upgraded in digital format and soon they will be added as a cadastral map, which means that this statement will be achieved very soon.

Statement 5: *CADASTRE 2014 will be highly privatized! Public and private sectors are working closely together*

Figure 5. Level of achievement of statement 5

The Geodesy, cartography and cadastre agency (as representative of the state) is responsible for cadastral activities. It is written in Art. 8 of [4] – *"The cadastre and the land register are public. The cadastral map and cadastral registers are property of the state".*

The private sector creates and updates the cadastral map and cadastral register (in some cases it is possible to control the activities), but the state assigns and administrates it. The Geodesy, Cartography and Cadastre Agency is responsible for the whole process of creation and updating of cadastre.

Statement 6: *CADASTRE 2014 will be cost recovering*

Figure 6. Level of achievement of statement 6

It is achieved because the taxes which are collected for the services of cadastre and land register provide the possibility for self-financing.

3. Necessity of 3D Presentation of the Objects of Cadastre

3.1. Preconditions for Implementation and Usage of 3D Cadastre

Nowadays Bulgarian cadastre is 2D, which is a precondition for incomplete presentation of the objects of cadastre and the reason about the arising of some problems, such as:

- Dispersion of the information about effective and sustainable land use. There is bilateral relationship between information system of cadastre and land register, but there are data which are in separate information systems (such as data about underground network, digital terrain models, etc.). This is precondition for duplication and inhomogeneity of the information. If there is a provision of data exchange between the different systems, cadastral data services would be easier to provide and there would be precondition for development of 3D cadastre;
- Restricted registration of the objects of cadastre – property rights sometimes are 3D and they should be restricted not only in 2D.

Some of the reasons which impose 3D presentation of the objects of the cadastre are:

- The registration of the legal state of complex infrastructure and densely built-up areas can only be presented to a limited extent by existing 2D systems;
- Registration of overlapping and intersecting objects;
- Increasing the technical infrastructure above and below the ground;
- Increasing the underground parking lots, buildings above roads, separate object over bridges, overpasses, underpasses, multi-level buildings, etc.;
- Usage of 3D approaches at other fields (3D GIS, laser scanning, 3D planning) makes three-dimensional cadastral registration technologically feasible [8].

Urbanization and industrialization exert more and more pressure on land use and the need to increase space, such as the increasing complexity of infrastructure, and require registration of legal status (private and public) that can be presented limited by the existing 2D cadastral registrations. 2D cadastral systems cannot manage and show the 3D rights, restrictions and responsibilities in space. One of the most important challenges for them is the management of 3D rights, restrictions and responsibilities, including the 3D cadastre.

3D cadastre is next stage of cadastral development not only as possibility to include all cadastral parcels, but as an instrument that assures more quality data about objects of cadastre from the point of view of accuracy, visualization, possibility for calculation of heights, volumes, spatial zones of restriction, responsibility and etc.

The task about initiation of standards for model description and data transfer is actual task for the current spatial information systems.

Many countries all over the world work hard in the field of 3D cadastre. Bulgaria as a full member of the European Union is obliged to observe European legislation. The infrastructure for spatial information is part of it [2] and as a result of it, there is approved *Law on Access to Spatial Data*. It regulates development of the national geoportal for spatial data, which will be connected with the European geoportal. For the realization of a large number of themes specialized data is needed, which can also be considered as a first step towards the development of a 3D cadastre [7].

3.2. Data for 3D Cadastre Realization

In order that the registration of the full legal status (including rights, restrictions and responsibilities) of the cadastral parcels to spatial (physical) object should be possible, it is necessary to present a legal object, which is part of the space. The legal object (legal land object) is a piece of land in which homogeneous conditions exist within its outlines. The purpose of cadastre is to identify a spatial with a legal object, but this is not always possible (building right, which is restricted property right) [9].

The right of ownership – the absolute property right unconditionally belongs to rights registration.

The following ownership restrictions are used in Bulgaria:

- **Right of superficies** – a restricted property right on a foreign cadastral parcel, which allows a person to construct a building in a foreign land property on the basis of a legal transaction. According to the Bulgarian property right, there are three forms of superficies:
  - The right to build on already existing building;
  - When something will be built "adjacent" to existing building in the same cadastral parcel;
  - When something will be built under the adjacent terrain.

- **Easements:**
  - *Temporary roads* – each cadastral parcel should have an exit on a public road. They are determined on the basis of a written contract with notary certified signatures of the stakeholderes. In cases when the owners can not reach a contractual agreement, this is made by an order from the mayor of the municipality;
  - *Passing through a foreign property* – it is possible in case that several conditions are present – there is not any other technical solution or another technical solution is clearly economically inexpedient. The right shall be established by a written contract concluded between the owners of cadastral parcels with a notary certification of the signatures;
  - *Building of deviations from networks through foreign property* – aggravation of a property by means of deviations from common networks and facilities of the technical infrastructure (system of facilities and linear engineering networks of transport, water supply, heat supply, gas supply, telecommunications, etc.). This easement is established exceptionally when there is not any other technical possibility or another technical solution is clearly economically inexpedient. It is established on the basis of a written contract with a notarized signature of the stakeholders.

- **Responsibility**
  - Concession – "*The right to exploit an object and/or a service of public interest granted by a concessionaire to a dealer – concessionaire against the concessionaire's obligation to build and manage and maintain the concession object or to manage the service at its own risk*" [5];
  - Lease – "*the lessee is obliged to provide the tenant for the temporary use of the object of the contract and the lessee to make a certain lease payment*" [3].

- **Restriction zones**

According to the last changes in the Law on Cadastre and Property Register *"In the cadastre, there are restriction zones on the land properties which are result of easement or*

restriction, based on a normative act, an administrative act or a contract". Many of the various specialized objects impose restrictions on the objects of the cadastre, although the presence of the specialized object itself is not required. Some larger groups of restriction zones, which in some cases can also be considered as responsibilities, are:

- Restriction zone in protected territories and zones – derive from the Protected Areas Act and the Biological Diversity Act;
- Restriction zone in areas for territorial planning protection – derive from the Black Sea Coast Planning Act;
- Restriction zone for overground and underground pipelines and facilities – the easement areas around the different types of networks are specified in various regulations – the Water Act, Ordinance № 16 for the easements of the linear objects, Ordinance № 5 for the procedure and the way of determining the size, distribution and special regime of the easements of the electronic communications networks, facilities and the related infrastructure;
- Restriction zone on roads and railways (easements) – derive from the Roads Act and the Railway Transport Act;
- Restriction zone on waters, water objects and facilities – derive from the Water Act and other sub-normative documents;
- Restriction zone of cultural heritage constraint – derive from the Cultural Heritage Act.

The various protected areas for nature, noise, pollution and other restriction zones illustrate restrictions on the ownership of immovable property and at the same time the responsibility of the respective operator (company / administration) [8].

According to [1] *"…The restriction zones are territories on, above and below the surface, formed around a spatial object that is not object of the cadastre. Restriction zones may be territories defined by pipelines and facilities or boundaries of a general development or detailed development plan. Territories with the same durable purpose may also be represented as restriction zones. In general, the restriction zones are other spatial objects that change the use of cadastral parcels and impose restrictions on it.*

Restriction areas shall be determined by administrative or regulatory act or contract and on the basis of data provided for spatial characteristics of the area. In the case of plotting restriction, these data are the dimensions of the facility and the size of the buffer zone around it. In the case of a restriction stemming from the Master Plan, these are the boundaries of the development zones…"

4. Examples

4.1. Analysis and Description of the Source Data

The used source data about practical realization are as follows:

- Digital cadastral map (in Bulgarian CAD format) of the part of the Serdika quarter, Sofia city in coordinate system 1970, including polygonal, network and point objects;
- Contour lines (DWG file) for the same quarter in coordinate system "Sofiyska" with 3D polylines;

- Underground network (DWG file) about sewerage network (linear objects) and shafts (point objects) and water network (linear objects) and fire hydrants (points) in "Sofiyska" coordinate system.

In order to unify data in common coordinate system, a transformation of the source data to ETRS89 (EPSG code – 4258) is made. Where it is necessary, a projection UTM 35 (ETRS89/UTM zone 35N, EPSG code – 25835) is used.

4.2. 3D Presentation of the Objects of Cadastre by ArcGIS

The shape files about the objects of cadastre are exported (*.shp) – cadastral parcels, buildings and self-contained objects in a building.

A file database is created in ArcCatalog and all objects of the cadastre are imported in a dataset. The coordinate system of the dataset is ETRS89 (4258).

The data structuring is the next step. A large amount of object classes in their attribute data contain incomplete information which necessitates the restructuring of the attribute information. A re-structured shape file is created. Two new fields are created. The first field is the "Type" field, which describes the type of object – cadastral parcel, building or self-contained objects in a building, and the second field is "Height" in which the height of the buildings is calculated. The height is calculated as the "BRET" field (number of floors) is multiplied by 3,00 m (as an average height of one floor). The result of the request is shown in Fig. 7.

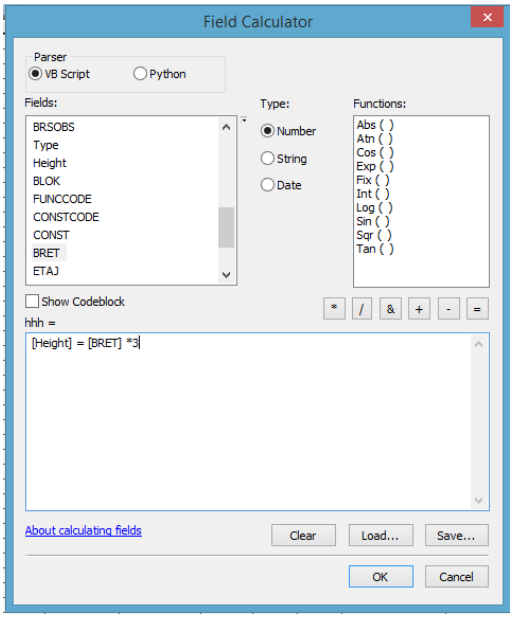

Figure 7. Calculation of the building heights

In the ArcMap environment, all object classes (Cadastral parcels, buildings and self-contained objects in a building) are merged and data projection (ETRS89/UTM zone 35N, EPSG code – 25835) is set. The structured new shape file is loaded into ArcScene for 3D viewing and the result is shown in Fig. 8.

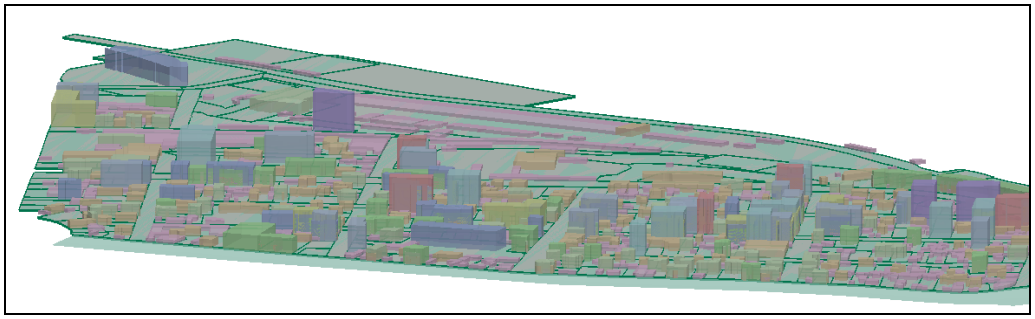

Figure 8. 3D visualization of the objects – side view

By capabilities of ArcScene, terrain model is created from the dwg file which has been transformed in advance from the "Sofiyska" Coordinate System into the ETRS89/UTM Zone 35N. The result of the created terrain surface is shown in Fig. 9.

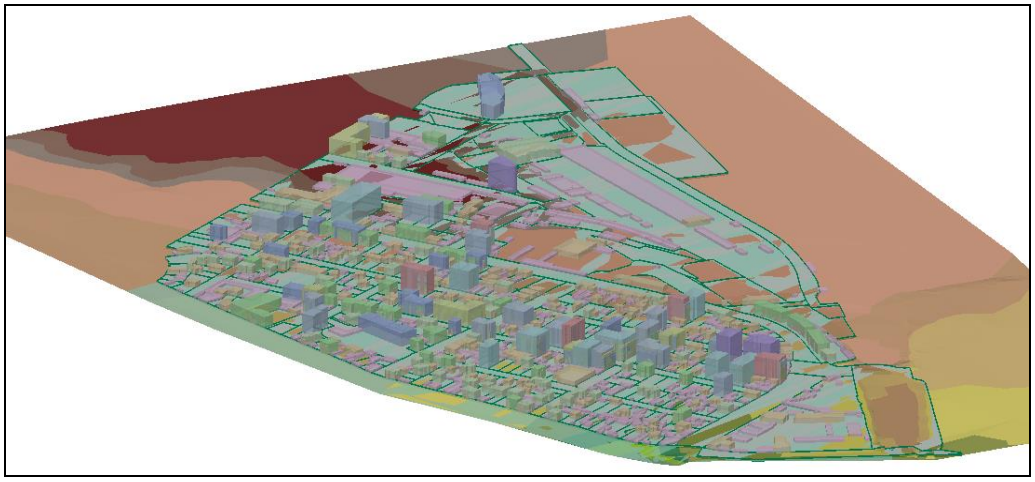

Figure 9. Terrain model

Underground network data are also transformed from "Sofiyska" Coordinate System into the ETRS89/UTM Zone 35N. The point objects are directly imported after the transformation as shape files. For determining the restriction zones of the linear objects (water and sewerage network) three shape files are made – data file with contour lines and two data files with linear objects from the underground infrastructure.

For the creation of the buffer zones of the linear segments of the water network it is necessary to be offset bilaterally, corresponding to the diameter of the pipe increased with 60 cm. The result is a buffer, which is unified restriction zone for whole water network. The same operation is repeated for sewerage network. In order for the restriction of the cadastral parcels to be determined, it is necessary to create an intersection between the corresponding buffer zone and cadastral parcels.

The unified model with terrain surface, 3D cadastral parcels and building, water and sewerage network and the restriction zones, water stops and shafts is shown in Fig. 10.

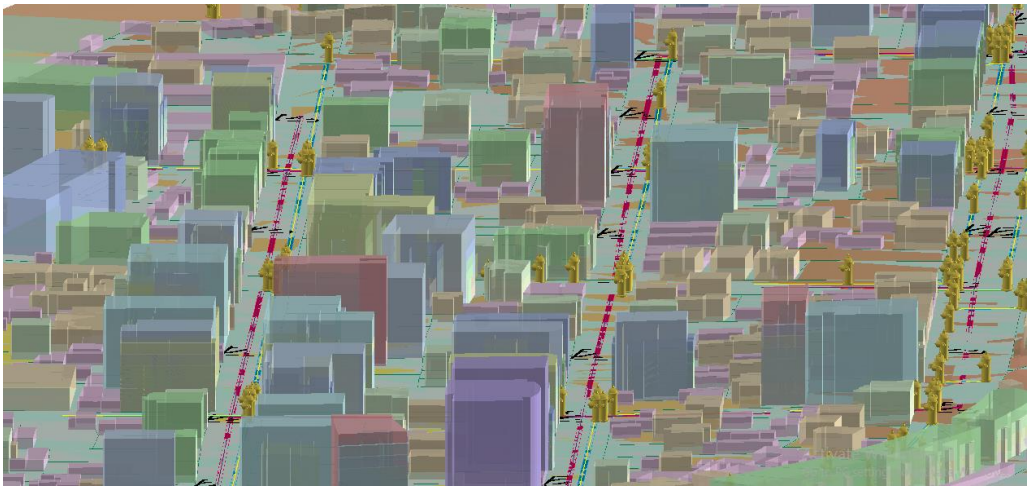

Figure 10. Unified 3D model of the objects and restriction zones

4.3. 3D Presentation of the Objects of Cadastre by JavaScript и WebGL

In order to realize 3D presentation of the objects of the cadastre with the tools of JavaScript and WebGL, again as a source data the file integrating the cadastral parcels, buildings and the self-contained objects in a building is used. The projection coordinate system is UTM, zone 35N (EPSG code: 25835), which is a standardized coordinate projection system. A GeoJSON file is created using QGIS software.

The next step of implementation is loading the file into the computer memory using JavaScript and using specific JSON class methods. An HTML file has been created for this purpose. In HTML, it is possible to specify the file in JSON format and to load the file into structures in the machine's memory.

For the creation of the objects of the cadastre, two types are used: 1) lines for the boundaries of cadastral parcels and 2) volumes for buildings and self-contained objects in a building.

For programming with WebGL, there are developed JavaScript libraries that allow the conversion of images into a canvas. The library uses three.js (www.threejs.org).

Fig. 11 shows the result of loading the HTML file into an Internet browser, and Fig. 12 – the result after importing the GeoJSON file.

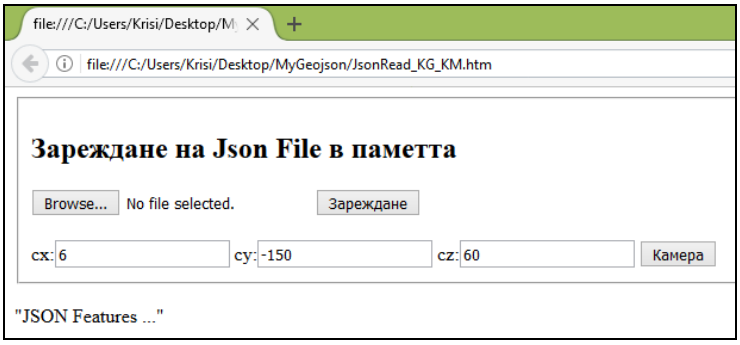

Figure 11. Result of loading the HTML file into an Internet browser

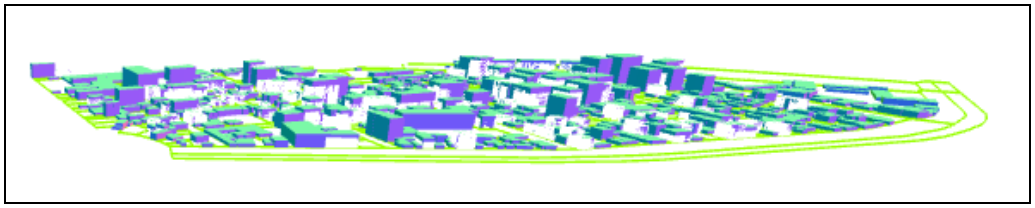

Figure 12. 3D view of objects – result after import of GeoJSON file

4.4. Cadastral Map and Registers Data Services

In order to realize the example again as a source data, the file integrating the cadastral parcels, buildings and self-contained objects in a building is used. The used coordinate system is UTM is ETRS89 (EPSG code: 4258).

The publishing of the data is made by GeoServer software, (http://geoserver.org/), local installation on http://localhost:6080. It enables the implementation of Web Map Service (WMS) and Web Feature Service (WFS) and it is a Java based software server that enables users to visualize and edit geospatial data. Designed for interoperability, GeoServer publishes spatial data from any source using the Open standards. It is possible to input data that can be visualized in an accessible web environment. It is possible to input data directly received as a final product in ArcGIS environments – ESRI shape files, as well as other data from different object-relational database management systems. GeoServer creates a layer that records all data and allows various operations to be performed. GeoServer works with multiple coordinate systems using the EPSG database (the European Petroleum Survey Group). GeoServer enables viewing of data in a dynamic environment, as well as visualization of attribute information for user-selected objects. The support of the different data visualization formats in the web environment is very strong. The KML and GML standards are mainly used for visualization, but Open Layers visualization and a number of other formats are also possible. In addition to these ready-made visualizations, it is possible to create custom styles or edit existing ones. It is possible to publish vector or raster data.

The visualization of the imported data in GeoServer is shown in Fig. 13.

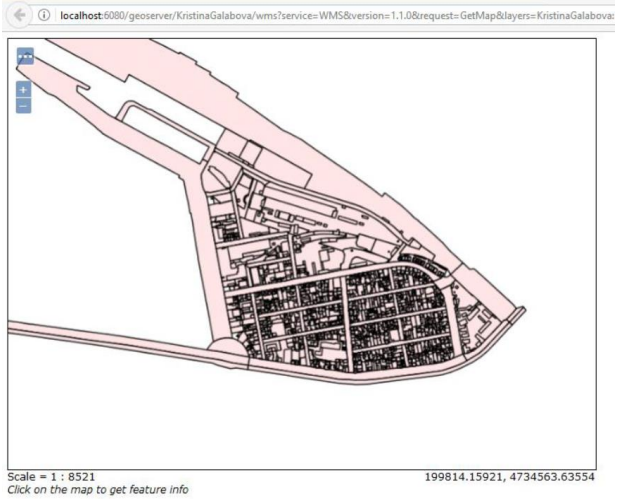

Figure 13. Visualization of the published data

The next step is developing an HTML document with a text editor. The client application is HTML, which is available from the client's Internet browser through:

Localhost: 6080 / geoserver / www / cadMap_KG_KM4.html, which is displayed in Chrome, Mozilla, or other Internet browser. The code of the html page includes the following sections:

- header;
- map;
- information.

The final result is shown in Fig. 14.

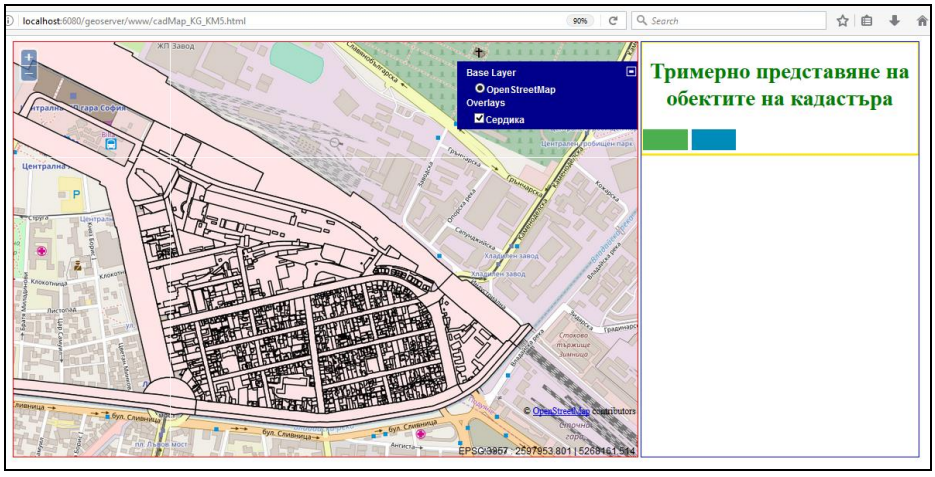

Figure 14. Result of loading HTML file

There are two possibilities for obtaining information about an object – obtaining information about a selected object from WMS layer and 3D visualization of selected objects.

4.4.1. Obtaining Information about a Selected Object from WMS Layer

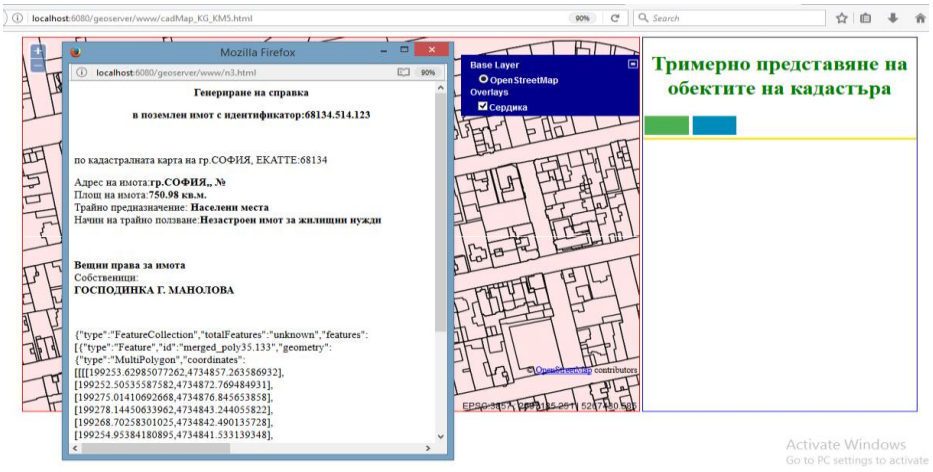

Figure 15. Generation of a report for a randomly selected object in a separate window

For the purpose, a variable is created and it specifies, when selecting an object, to read information from a URL WMS layer (named: cadastre_im) and the format in which the information can be obtained – GeoJSON. A function is created to get information in a new window that links to another HTML file. In Fig. 15 the result for a randomly selected cadastral parcel is shown.

4.4.2. 3D Visualization of Selected Objects

Four functions for 3D visualization are added to the main code. An additional HTML file is created for 3D visualization of the objects of the cadastre after selection using a rectangle. The geometry of the objects of the cadastre - cadastral parcels, buildings and self-contained objects in a building is also described, using the characteristics of the respective object and the material that describes it.

The result of HTML file is graphically shown in Fig. 16 and Fig. 17.

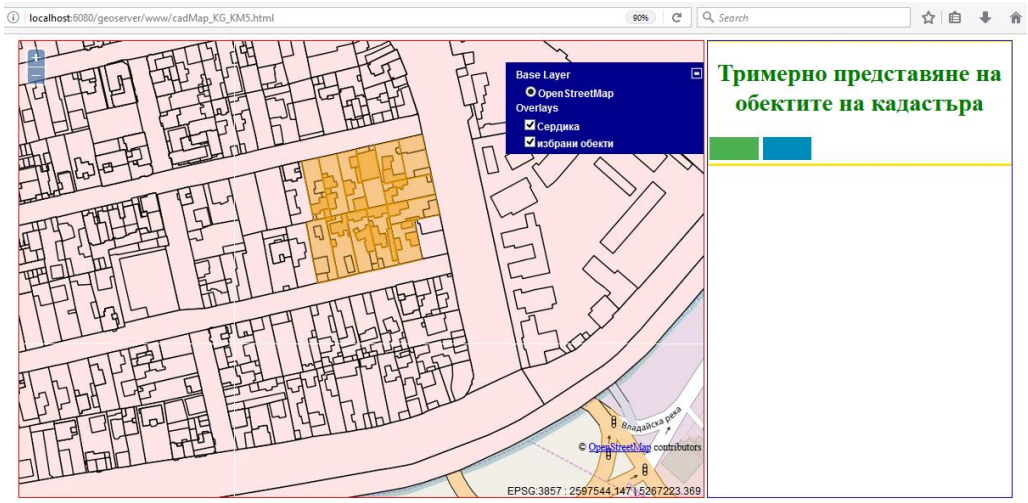

Figure 16. Rectangle selection

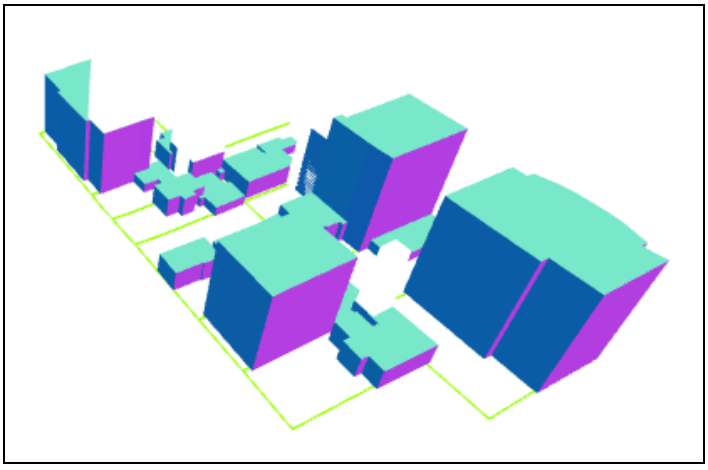

Figure 17. 3D visualization of the selected objects

5. Conclusion

Many countries all over the world are working hard for the development of a modern method of presenting the objects of the cadastre by implementing standards and formats. The reason for the above is that it facilitates the combination of cadastral spatial data with same data of other systems. Another reason is the complete description of both spatial objects and the full legal description of rights, constraints and responsibilities.

The creation of a 3D cadastre has many advantages, including an increase in possible solutions, which are currently a problem for the cadastral system, the increase of the provided services, etc.

Another important stage in the realization of such a cadastre is the creation of a well-thought-out and structured legal framework describing clearly and precisely the procedures, activities, data exchange formats, etc.

Information on the third dimension allows better presentation of the objects of the cadastre, their location and interaction with other objects.

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ТРИМЕРНО ПРЕДСТАВЯНЕ НА ОБЕКТИТЕ НА КАДАСТЪРА

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Ключови думи: *3D кадастър, ГИС, поземлена администрация, услуги с данни от кадастъра*

РЕЗЮМЕ

В статията е разгледана възможността за бъдещо развитие на тримерно представяне на обектите на кадастъра, отчитайки актуалното положение на кадастралната система в България.

Изяснени са предпоставките, възможностите и средствата за реализация и приложение на тримерен кадастър в България, като са взети предвид и предизвикателствата пред реализирането му. Описани са проблеми, засягащи създаването на ефективно работеща система за поземлена администрация, възможни технологии и стандарти за осъществяване на 3D кадастър.

Предложени са възможни примери за реализация, включващи различни методи: чрез възможностите на ArcGIS, JavaScript и WebGL. Разработена е и уеб страница, за услуги с данни от кадастрална карта и кадастрални регистри, основаваща се на HTML стандарт.

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