3D Cadastral Model in Bulgaria

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Key words: 3D, cadastral model, spatial data, services

SUMMARY

The rapidly growing rates of development of large cities and the use of spaces below and above the earth's surface lead to the need to create a 3D cadastre. The registration of rights on 3D properties, which are accurately presented, would protect the rights and ensure the security of the property. There is a need for a more realistic, visual representation of the spatial objects, as well as more complete and up-to-date information about the objects in a certain territory and their characteristics. At the same time, the requirements for modern information arrays of spatial data are increasing. The article examines the possibility of moving from the existing model of the cadastre in Bulgaria to creating a model of 3D cadastre. 3D properties are divided into two main types of objects - 3D physical objects and 3D objects, on which rights are defined. The presentation of the geometry of complex objects and the spatial data acquisition are one of the difficulties that underlies the establishment of a 3D cadastre. Another activity essential for the creation of a new cadastre model is a change in the legislation and its expansion with basic definitions for 3D properties and rights. The task of creating a 3D cadastre and upgrading it with spatial data resulting from the use of modern technologies such as LIDAR and unmanned aerial vehicles is complex, but would support activities in various fields, activities to resolve issues related to property rights and would allowed the provision of administrative services to present the spatial object comprehensively and accurately.

SUMMARY (in Bulgarian)

Бързо темпове на развитие на големите градове и използването на пространства под и над земната повърхност водят до необходимостта от създаване на 3D кадастър. Регистрацията на права върху 3D имоти, които са представени точно, би защитила правата и би осигурила сигурността на собствеността. Необходимо е по-реалистично, визуално представяне на пространствените обекти, както и по-пълна и актуална информация за обектите на определена територия и техните характеристики. В същото време изискванията към съвременните информационни масиви от пространствени данни се увеличават. Статията разглежда възможността за преминаване от съществуващия модел на кадастъра в България към създаване на модел на 3D кадастър. 3D обектите са разделени на два основни типа обекти - 3D физически обекти и 3D обекти, върху които са дефинирани вещни права. Представянето на геометрично сложни обекти и събирането на пространствени данни са едни от трудностите, които стоят в основата на създаването на 3D кадастър. Друга дейност, която е от съществено значение за създаването на нов модел на кадастъра е промяна в нормативната уредба и разширяването ѝ с основни дефиниции за 3D обекти и права. Задачата за създаване на 3D кадастър и надграждане с

пространствени данни в резултат на използването на съвременни технологии като LIDAR и безпилотни летателни апарати е сложна, но би подпомогнала дейности в различни области, дейности за решаване на проблеми, свързани с правата на собственост и би позволила предоставяне на административни услуги за цялостно и точно представяне на пространствения обект.

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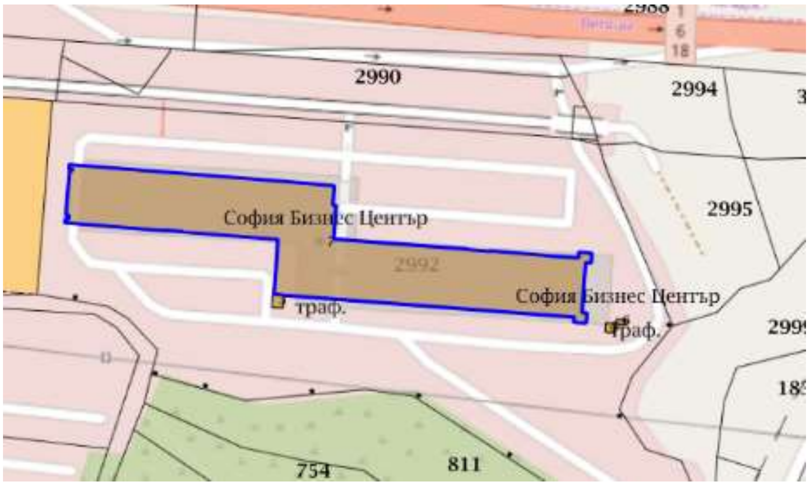
1. REGISTRATION OF REAL ESTATE RIGHTS IN THE CADASTRAL SYSTEM IN BULGARIA

In recent years a multitude of political, economic, environmental and social factors, as well as technological innovations have led to changes in land management methods. Registration of rights and protection of property are becoming increasingly important for achieving sustainable land development. The growing use of space below and above the earth's surface, the increasing number of elements of technical infrastructure, tunnels and multi-storey buildings with different purposes cause the need for 3D registration of cadastral sites.

In the current legislation in Bulgaria there is no definition of 3D property, despite the numerous examples, especially in large cities, where proper registration is required. An example of this is shown in Figure 1- 1a) an excerption from the cadastral map with a 2D image of the building and 1b) photos of the building, which shows that some of the individual sites fall under a street, a shop, a connection to the ring road.



1a)

1b)

Figure: 1 a) the building shown in the cadastral map and b) photos of the building in combination with separate objects from the building and a roadway

Another example of the need of creation of a 3D cadastre is shown in Figure 2.

a)

b)

Figure 2: a) the building and the street shown in the cadastral map and b) photos of the building and street

The 3D cadastre registers real estate rights and restrictions on 3D properties and must provide security of ownership and unambiguous spatial definition. Geometrically complex 3D properties, on which 3D rights are not clearly defined by law, create difficulties, which in turn give rise to the need to build an institutional and legislative framework to facilitate the registration of 3D properties.

According to the Bulgarian legislation the main types of real estate rights are the ownership, the right of superficies, easement/servitude, rights of use and other rights of another's property. The right of ownership is the possibility of a person to own, use and dispose of a certain property factually and legally and to ask all other persons to refrain from influencing it. Property can be public or private. The right of ownership is an absolute real estate right, which guarantees an opportunity for the owner and prevents everyone else from taking advantage of his property. The right of ownership has three powers - use, disposal and possession.

The right of ownership may belong to two or more persons - the state, municipalities and other legal entities or individuals (Article 30 of the Ownership Act). In co-ownership there is no co-ownership of the object, but co-ownership of the right itself.

The right of superficies is established by the owner of the land to a person to build a building and who becomes the owner of the building. Upon establishment of the right of superficies, the owner exercises the power to dispose, and the person to whom the right to build has been conceded exercises the power to use. The right of superficies is established in a certain volume and distances for the specific building and must comply with the norms of the Spatial Development Act. For each construction a building permit is issued for the allowed building area, the total built-up area depending on the number of floors/height of the building.

The right of superficies is a limited real estate right and therefore cannot limit the absolute right of ownership over the land for which it is established. In case the subject, to whom a right of superficies has been found, has built more than the established one, the owner of the land becomes the owner of the superstructure, if it is possible to separate it independently (Article 92 of the Ownership Act). The right of superficies below and above is a special case of the right of superficies.

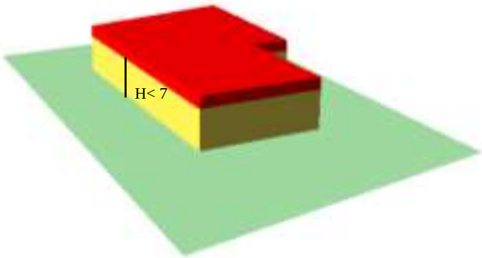


Figure 3: Established right of superficies with a permitted building height H <7 m, presented as a 3D object. The red volume indicates the upgrade.

Easement is a limited real estate right. Easement rights always include the existence of two properties - one dominant property and one service property. The Spatial Development Act regulates the right to pass through a foreign land property by establishing a written contract with notarized signatures.

Restriction of the power of use is described in Art. 108 of the Act on waters - the owners of the properties located higher do not have the right to prevent the natural flow of water and to aggravate the restrictions borne by the lower properties. The owners of the lower properties are obliged to accept the water that flows naturally from the higher properties.

Easement right of water conveyance is settled under art. 112 of the Act on waters, according to which each owner grant water conveyance rights through his property to all who have permanent or temporary need to do this. The right to water conveyance is established by agreement of the owners of the dominant and subservient property, and in case an agreement cannot be reached by an act of the director of the basin directorate.

There are easements that are established for the benefit of a particular activity (and not for a person or property) and are performed for the respective activity, regardless of which legal entity or individual exercises it. They are called quasi-personal easements and an example of them are the easements specified in the Energy Act.

The easements under the Energy Act are related to the right to join to energy network and to restrict the use of the affected properties. The holder of the easement acquires rights to pass and build linear energy sites, enter and pass through affected properties and perform activities for construction and operation of energy sites in them.

Examples of quasi-personal easements are also given in Art. 61 of the Forestry Act, an easement on land properties in forest territories, according to which an easement may be established indefinitely or for a certain period for construction and/or servicing of:

1. Overhead and underground infrastructure for hydrotechnical facilities, water-mains and sewerages, overhead and underground electric transmission network, cables and other supply and discharge conduits of the technical infrastructure, including the adjacent facilities;
2. Telephone, telegraph, radio and other lines;
3. Lifts and tow-lifts - for up to 30 years;
4. The range of facilities from wind generators and photovoltaic parks;
5. Oil pipelines, heat pipelines, gas pipelines, oil product pipelines, overhead and underground pipelines for hydrotechnical facilities for electricity production.

Other easements are:
1. Easement, defined in a plot plan during construction of water supply and sewerage pipelines (networks) and facilities outside the settlements;
2. The easement, determined by plans for regulation of the networks and the facilities of the technical infrastructure;
3. Distances from regulation lines and existing construction.

The inefficiency of the existing cadastral models in presenting the rights, restrictions and responsibilities of the individual owners, parties with interests at stake, increases the need to build a 3D cadastral system. The development of such a system is impossible without a change in the legislation, which clearly reflects the definitions of 3D legal and physical object, as well as rules for the application of the system.

2. 3D CADASTRAL MODEL IN BULGARIA

In Bulgaria the processes of registration of real estate rights, investment design and control of construction, spatial planning require the receipt of services from various administrations. The creation of a spatial database infrastructure does not require the creation of a common database. The data sets can be kept up to date by the specific administration and through the use of standards to carry out the necessary exchange of information between the individual institutions. The establishment of a common model of spatial data will lead both to the facilitation of the administration's activity and to a better service to the stakeholders.
The present study examines the Land Administration Domain Model (LADM), which covers aspects of land registration and cadastre in different international systems and achieves interoperability of the basic model through different procedures according to specific legislation and Building Information Modeling (BIM), which is 3D digital. approach to information management throughout the life cycle of buildings. A proposal has been made for a model of 3D cadastre in Bulgaria. In figure 3 is a diagram of the conceptual model.

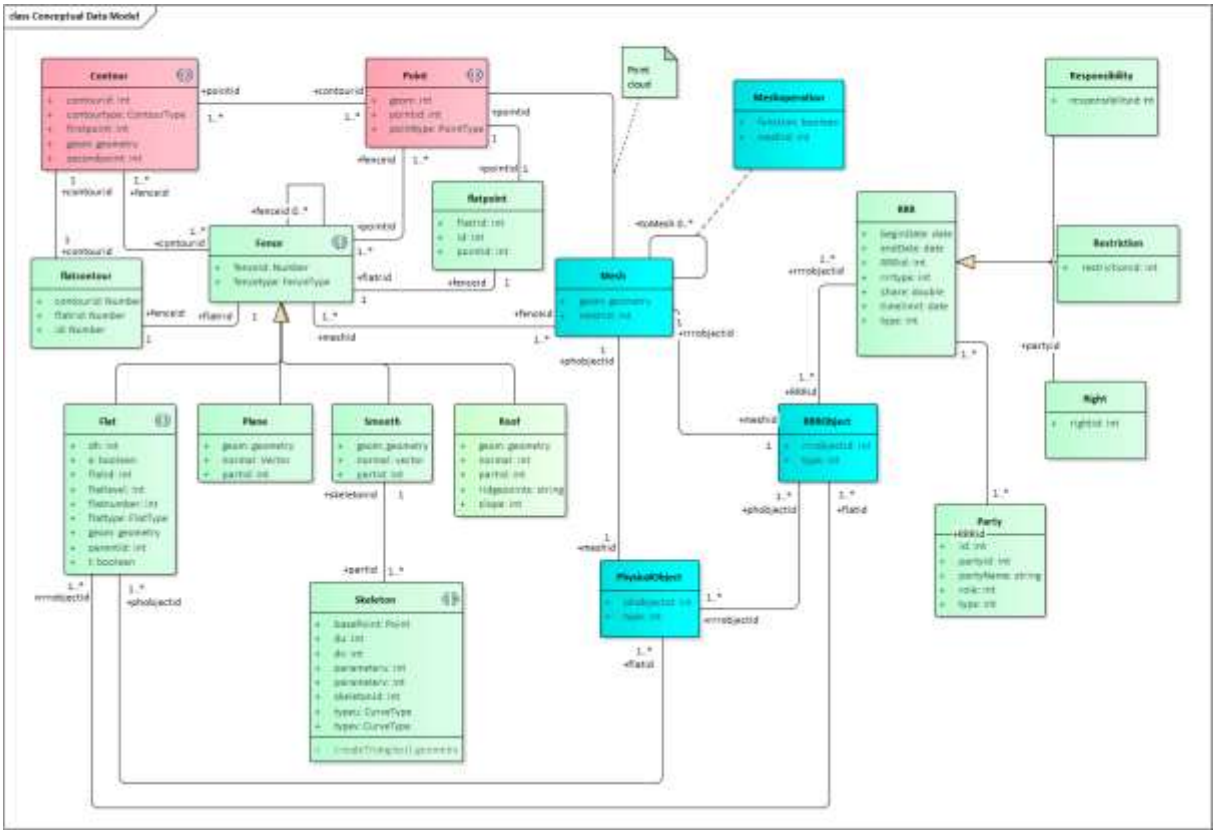


Figure 4: Schema of Conceptual model

The model provides two types of objects - PhysicalObject and RRRObject (spatial objects on which there are defined real estate rights, responsibilities and restrictions).

Figure 5: Physical and spatial object with RRR

In Figure 5 the building represents the physical object and the restriction on the adjacent property is represented by a spatial object, on which real estate rights are defined.

In the conceptual scheme for a 3D cadastre model, the "Point" and "Contour" classes represent classes that are also present in the current cadastre model. With the "Contour" class, boundary lines are presented, which appear at different levels in the model, and with "Point" - the points along the boundary lines or characteristic places.

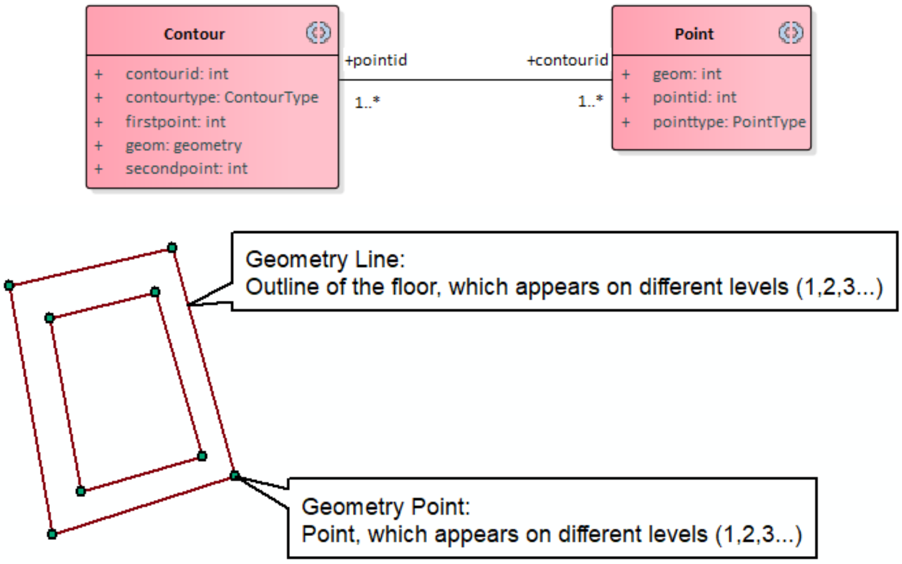


Figure 6: Presentation of points and outlines

For the representation of 3D objects such as physical objects and spatial objects, on which real estate rights are defined, the class "Fence" - enclosing surface has been created. The class has subclasses "Flat", "Plane" and "Smooth".

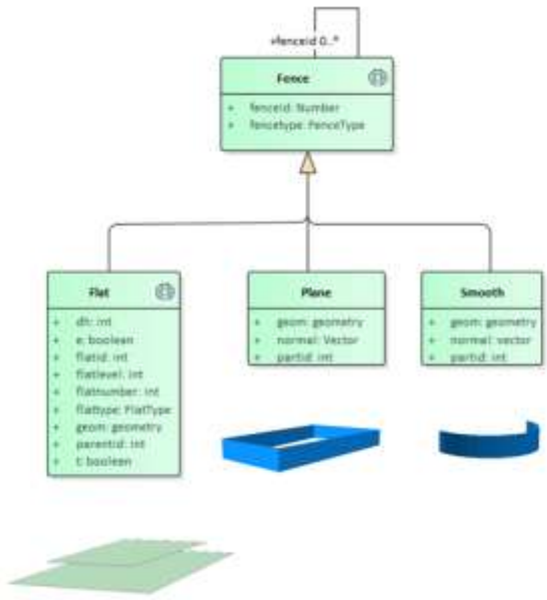


Figure 7: Class "Fence" with subclasses

In the current cadastral map it is not possible to present land parcels located on top of each other (bridge over a river, road over road, etc.). The Flat subclass, which is a 2D polygon, aims to create storeys throughout the cadastral model.

Figure 8: Road junction "Daskalovo"

Figure 9: Presentation of the road junction in the existing cadastral map

With the subclasses "Plane" and "Smooth" 3D plane enclosing surfaces and 3D smooth enclosing surfaces are presented respectively. The most commonly used enclosing figure forming the enclosing surface is a triangle. The proposed model considers the possibility of constructing a 3D object using the extrude method or constructing triangles when constructing 3D objects with more complex geometry.

The second way to create a 3D object is to create a "skeleton" of the constructed object using a local coordinate system with the abscissa v, the ordinate u and the application z. It is essential in creating the skeleton to define the type of curve with which the object is modeled and its parameters.

As already mentioned, when creating a "skeleton", the type of curve that models the object must be determined. Three types of curves (CurveType) have been added to the proposed model - polynomial, Bézier curve and cubic spline catmull-rom. The parameters are determined by the type of curve and for polynomials these are its coefficients, for the Bézier curve of n^{th} degree -

Bernstein polynomials, and for catmull-rom - the coefficients of the polynomial and parameter t, which shows the convexity of the curve in the specific control point.

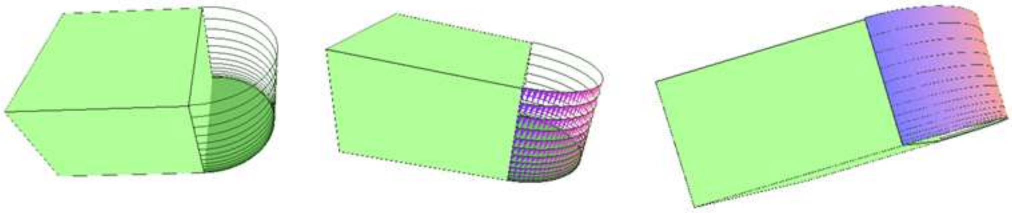


Figure 10: Modeling of a 3D object with the extrude method and with construction of triangles

For the example presented in Figure 10, the two modeling methods proposed in the model are used. One body, the base of which is a rectangle, is built using the extrude. A polynomial of the second degree is used to model the smooth surface. The figure traces the creation of the "skeleton" of the object and the construction of triangles (enclosing figures) between any two adjacent lines of the "skeleton". It is important to say that when modeling a 3D object with a smooth surface, the triangles are created dynamically and are not stored in the database.

The “Mesh” class presents 3D objects, which are constructed of enclosing surfaces and with which buildings, condominiums, various types of restrictions and others can be represented - physical objects and spatial objects on which real estate rights are defined.

The purpose of the 3D cadastre does not differ from that of the 2D cadastre and does not impose different principles of property management to ensure legal certainty. The creation of a 3D cadastre would support activities in various fields, activities to resolve issues related to real estate rights and would allow the provision of administrative services to represent the spatial object accurately. It is also important to be able to combine the cadastral model with other spatial data models - for example, information about floor plans in buildings can be obtained from systems using BIM. This would reduce registration time and provide more complete information about the spatial object.

3. PROVISION OF ACCESS TO SPATIAL DATA SETS AND SERVICES

The main task of creating spatial data models and standardizing them is to provide the end user with services that are more up-to-date and comprehensive. In the field of land resources, the provision of services is performed by different administrations and in most cases one service from one administration is not enough to meet the needs of the end user. Combining different spatial data models makes it possible to provide richer information about the spatial object and provide services from several administrations with just one request. For the effective combination of different spatial data models, the way of creating and disseminating these data is essential.

The main activities for the creation and dissemination of spatial data are divided into groups of institutions that:

- Collect spatial data;

• Support spatial data;
• Perform control;
• Provide spatial data services.

In order to meet the needs of users, it is necessary to build a common infrastructure for spatial data, which will allow the development of network services and the sharing of spatial data. The offered electronic services must meet the modern standards for the provision of spatial data services, such as the OGC standards or the standards of the ISO 19100 series - Geographic information (ISO 19115 - Metadata).

Electronic administrative services are administrative services that are provided to the end user remotely through the use of electronic means. Network services must allow searching and viewing, transforming, making various inquiries and retrieving spatial data between different levels of public authority. The provision of electronic services increases the efficiency of the administration and improves the quality of service to citizens.

In terms of 3D cadastre, the provision of electronic services has a number of advantages over traditional services. 3D models present our environment in much greater detail and allow the volume of property rights, as well as constraints and adjacent objects to be visualized much more clearly. For the purposes of the present study, a 3D service with cadastral data has been developed. An excerpt from the cadastral map of the Lozenets region, Sofia was used for a condominiums. The model of the building was created using the extrude method for each floor separately. A structure has been developed from the created model of the building, which allows for the export of glTF. Visualization of the result - schema of a selected object in the building (in red) in 3D Viewer and attribute information about it in Adobe Reader is presented in fig. 10. Such a service is much better than traditional 2D services only if it is not static and the user can view the object of interest from each party.

Figure 11: 3D schema and attribute information for the selected object

4. SPATIAL DATA ACQUISITION FOR CREATING A VIRTUAL SPACE

The construction of a virtual space in which spatial objects are represented through the use of various presentation technologies and spatial data acquisition methods would support a number of activities related to land management and analysis. It is also possible to implement augmented reality to represent the spatial objects on which property rights and restrictions are defined - for example, the right of superficies with the permitted building height and distances from adjacent properties, restricted areas and other spatial objects. Creating realistic models would help users use the specific system.

Along with traditional methods for spatial data acquisition, LIDAR technologies and unmanned aerial systems are becoming increasingly used in practice. These methods are very effective and allow a detailed presentation of the environment. One of the great advantages of using LIDAR and unmanned aerial systems is the saving of time for spatial data acquisition and postprocessing. They provide high accuracy and precision of the results, as well as great detail. On the other hand, the processing process in laser scanning and unmanned aerial systems also requires high-performance hardware due to the large volumes of the final product.

Figure 12: Model of a building on Tsarigradsko Shosse Blvd. obtained as a result of spatial data acquisition with UAS and postprocessing

When using laser scanning and unmanned aerial systems, it is essential to choose a database management system that allows the storage of large clouds of points obtained as a result of processing and implementation in the created virtual space.

The development of technology also allows the involvement of citizens in the process of collecting spatial data - for example, there are applications for creating digital twins of different spaces, from which sections can be extracted to be used for registration of individual objects.

5. CONCLUSION

Proper management of land resources due to lack of space in large cities, protection of property and proper presentation of real estate rights and restrictions are some of the reasons why the need to create and develop a 3D cadastre is growing. The proposed 3D cadastre model builds on the existing model and aims to combine data from different sources and technologies, as well as be compatible with other spatial data models. The creation of a common spatial data infrastructure will lead to changes in the legal and institutional framework to ensure interoperability between the data sets maintained by the different administrations. The private sector can cooperate in the creation of such infrastructure by providing the results of the various activities to the eligible persons - surveys, amendments to the cadastral map and registers, development of detailed development plans and their amendments. The service of the interested parties with services with spatial data will increase its quality, the time for the implementation of the services will be reduced, and the provided service will be much more detailed.

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BIOGRAPHICAL NOTES

Yanitsa Yankova is graduated student in 2017 at University of Architecture, Civil Engineering and Geodesy, Sofia with major Geodesy, specialization GIS. In 2018 she started her PhD program. Her main interests are related to GIS, cadastre and provision of spatial data services.

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