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CONCEPTUAL BASES OF GEOINFORMATION MODELING RESTRICTION ZONES AND THEIR REGISTRATION IN THE LAND AND URBAN CADASTRE

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Problem definition

Restriction of rights in land use belongs to one of the most essential mechanisms of land relations regulation in modern system of land management and implementation of public interest for the protection and sustainable use of natural resources.Creation of the state land and urban cadastre raise a problem of legal, methodological, technological and other aspects of establishment and registration of these restrictions in modern multipurpose GIS-based cadastres.

Analysis of recent research and publications relating to this problem

In recent years, the number of research and publications on the problems of using GIS for determination of restrictions, development of land and urban planning documentation and geospatial data, suitable for registration in modern cadastral systems, has significantly increased both in domestic and foreign professional journals. In developed countries, the relevance of these tasks associated with the reform of the cadastral activity influenced by the widespread implementation of GIS technologies, the transition from a fiscal and legal to multi-purpose cadastres as part of national spatial data infrastructures (NSDI). Main directions of cadastral field reforming are formulated in a Cadastre 2014 concept of International Federation of Surveyors. The state of it's implementation in different countries is covered in [25].The first provision of Cadastre 2014 determine, that multi-purpose cadastre has to show complete legal situation abouland, including public rights and restrictions. Comments to this provision *indicates* that *"growing world population and development of new technologies leads to intensive use of natural resources, including land. Following the social need to protect natural resources from total consumption, damage or destruction it is necessary to define limit for existing absolute rights on using natural resources."* Public rights are efined by state legislation in the form of restrictions on private rights (regulations) for the use of natural resources, including land, to ensure their protection and management.

Regulations are usually developed in different government institutions by the type of natural resources. During traditional "paper technologies" huge amount of restriction plans, which were kept in various departments, created the problem of considering the restrictions during private rights registration.This lead to negative impact on the situation with regulations compliance, and with the protection of natural resource use subjects in their business and investment activities.This is especially appear in land use - with state guarantees on the rights registered in the cadastre, the owner faced with a number of regulatory restrictions in zones, where his property is located.

Through the use of GIS technology in the field of spatial planning and zoning paper restriction schemes and zoming plans become a digital cartographic models. It made them accessible to a wide range of stakeholders in the Internet, and most importantly has created an economically acceptable technological conditions of their registration in spatial databases of modern cadastral GIS.According to Cadastre 2014 concept restriction zone will receive the status of legal land objects, which are mandatory to registration in multi-purpose cadastre.

Experience of Switzerland, where previous researches have revealed the existence of 150 types of restrictions, is described in [23] as "best practice" of creating cadastral information system with restrictions registration *(Cadastre* on Public-Law Restrictions *or PLR-Cadastre).Relying on the technical capacities and political expediency, Swiss PLR-cadastre PLR-registration is limited to 17 types of regulatory zones. Technically and conceptually PLR-cadastre is based on the same principles as traditional cadastre. Each of the 17 zones require consistent and determined data model. Each restriction zone recorded in a separate data layer. It allows to define clearly all restrictions and obligations for each land parcel. Elements of PLR-cadastre are creating in compliance with the four principles of "concept of common data integration," adopted to achieve interoperability of spatial* data in Swiss NSDI.

It is worthwhile to say about the experience of multi-purpose cadastre creating in Estonia. It is first post-Soviet country, that implemented database of land use restrictions for the whole territory of a country. [24]

Almost all EU countries finalize their transition to multi-purpose cadastre like Cadaster 2014, intensive work is underway to create a European Spatial Data Infrastructure INSPIRE [25]. Topic sections about restriction protective zones are included in the priority information resources of INSPIRE. They have detailed technical specification with conceptual data models, feature catalogs, rules of digital description, mapping rules and requirements for metadata, quality and data collection technologies [23].

The problem of rights restrictions has a keen interest in national researches due to formation of the State Land Cadastre (SLC), in which information about restrictions also subject to mandatory registration [1, 2, 4]. The adoption of new regulations on urban development, guidelines on the composition and content of the zoning plan and creation of a modern urban cadastre also increased the interest to this question[3, 5, 6].

The references list for this article reflect the most typical research trends in this problem. The monograph [11] formulates theoretical principles of zoning of land in Ukraine. Works [10, 16, 20] analyze the legal aspects of land use in restriction zones and the ways of legislation improvement in this area. Papers [12, 14, 18, 19, 21, 22] consider the improvement of methodological and technological support of restriction zones determination in respect to special aspects of certain types of restriction objects with the latest technologies for acquiring their spatial characteristics. Works [13, 15, 17] are devoted to the application of GIS technology for restriction zones modeling for certain types of restriction objects.

In [8, 9], the authors made their first attempt in the domestic practice to systematize the issue of integration of data and cartographic material of land use plans of settlement, various types of urban planning, land management, land evaluation documentation and data of land cadastre inventory for zoning with application of GIS technology.

Open questions of the common problem

In general, publications in domestic professional journals are characterized by seeking technical and technological solutions of complex and urgent problems for Ukraine - creating a large volume of geospatial data for registration restriction zones in SLC. This is even more difficult due to constant resource shortage and lack of:

electronic registers of restriction objects and their spatial characteristics;

actual urban planning and land use documentation for these objects and restriction zones around them;

relevant digital topographic base covering the whole territory of the country;

appropriate regulatory, institutional and financial support, required to perform a large amount of work to create a registry of hundreds of thousands restriction objects (table 1) and the areas around them for the whole the country with an area of about 603.7 thousands km$^{2.}$

Presenting the main material

Legal aspects of zoning. Land use right is a legal possibility of a subject to carry out an economic activity and other direct use of land to generate income and other tangible and intangible benefits, based on useful properties of the land.But land use rights are not absolute, they are part of the rights, obligations and restrictions (Fig.1). According to part 7 of article 41 of the Constitution of Ukraine the use of property shall not cause harm to the rights, freedoms and dignity of citizens, interests of society, aggravate the ecological situation and the natural qualities of land.

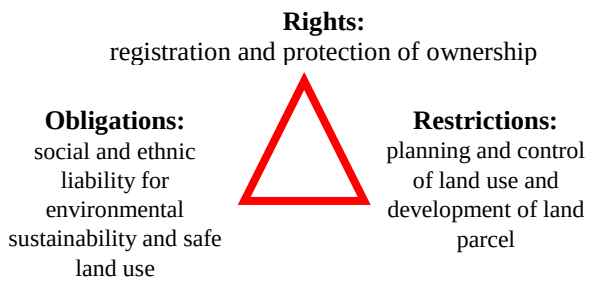

Fig. 1. "Right - Obligations - Restriction " in land use

The main principles of land use restrictions are the following: the admissibility of ownership restrictions only in public interest; fair compensation to owners for losses; restrictions on the basis of and within the law; equality of all owners before the restrictions; judicial protection of property rights.Thus, the main principle of land law is to ensure parity of private and public interests.

One of the main mechanisms for implementation of rights limitation is the establishment of zones of special land use (ZSLU). *The special land use - a regime of land use, which limits certain other types of business (or) legal activity in areas of special land use, in order to guarantee the rights of land owners, protect people from the harmful effects of industrial and other facilities with a special regime of production activities.*

Usually ZSLU are set around restriction objects. The Law of Ukraine "On State Land Cadastre" define restriction object (RO) as *"an object* of natural or artificial origin (water body, the object of pipelines, energy facilities, cultural heritage objects, military, another object defined by law), under which and/or around of which, due to its natural or acquired properties, in accordance with the law the restrictions in land use are set "[2].

Table 1

Statistical data on some types of restriction objects in Ukraine

Name of the object / characteristic	Value
Number of rivers	3039
The length of rivers	more than 100 thousand km
Number of lakes	6904
Total area of lakes	61,72 km^2
Number of ponds	22,3 thousand
Total area of ponds	170 thousand hectares
The length of the pipelines, including:	45,725 km (5 place in the world)
- gas pipelines	37 000 km
- oil pipelines	4514 km
- oil product pipelines	4211 km
The length of powerlines 6 - 750 kV	more than 1 million km
The length of the main railroad tracks	21640,4 km (3 place in Europe)
Number of industrial enterprises	55 thousand
The number of settlements with cultural heritage objects (CHO)	about 9400
Total number of CHO requiring	70 thousand

investigation and registration	
The number of settlements that are included in the list of historical populated places	401
Protected areas (biosphere reserves, nature reserves, parks, natural monuments, nature reserves, etc.), total	83,774 objects, (total area of protected areas 2.8 million hectares)

The current system of setting ZSLU, formation, registration and use of data about these restrictions in Ukraine is characterized by the following problems:

a lot of RO types ang large total number of RO;

fragmentation of the legal provision on the order of ZSLU establishing, because this field is regulated by several laws of Ukraine and many industry rules and regulations for the type of RO;

focus of regulations on traditional (paper) technologies of land cadastre and planning documents development;

Rules of order of SLC [4] contains a list of information about restrictions in land use that are introduced in the SLC [5]:

1) the name and code (number) of restriction (as a whole and for individual outlines);

2) restriction outlines with coordinates of turning points and length;

3) restriction area (as a whole and for individual outlines);

4) a list of prohibited activities and responsibilities to perform certain actions with reference to the regulations, which set the restriction, restriction validity period;

5) a description of restriction object (if available), including: name; restriction boundaries of the object with coordinates of turning points and length; area (as a whole and for individual outlines); characteristics that lead to the restriction;

6) information on the documents, which set the restriction (name, date and number of decision on approval of land use documentation, which set the restriction, name of the governmental body, that adopted it, date of restriction validity), electronic copies of such documents.

Note that this Order and other regulations, including Interim guidance [7], doesn't define the requirements for coordinate accuracy of the restriction object boundaries and the boundaries of restriction zones, scales the output topographic maps and scales of created cadastral maps and plans of encumbrance and restrictions on land use.In practice, the graphical part of land management and/or planning documentation on establishing the boundaries of restricted zones is developed as restriction shemes at different scales from 1:10 000 to 1:1 000, depending on the zoning object area (map of the whole city or individual enterprise or economy).Usually this documentation (especially for large cities and districts), is developed without coordinates land parcels boundaries because of their absence and/or complexity of procedures and institutional barriers to obtaining them at the center of the SLC, even after the publication of public cadastral map Ukraine on SLC geoportal.

GIS technology of preparation of ZSLU digital models based on existing cartographic documents. Due to low relevance and sketchness of zones on existing cartographic material, GIS technology of ZSLU digital models creation in addition to traditional stage of scanning and vectorization of RO and ZSLU boundaries includes additional operations on refinement coordinates of vector models based on current cadastral plans with the boundaries of land parcels and large scale topographical plans such as 1:2000 for rural areas and 1:500 for cities.To illustrate the content and results of these operations Fig. 2 represent an example of the output vector model boundary refinement of protection zone of historical and cultural monument according to objects of cadastral and topographic plan.

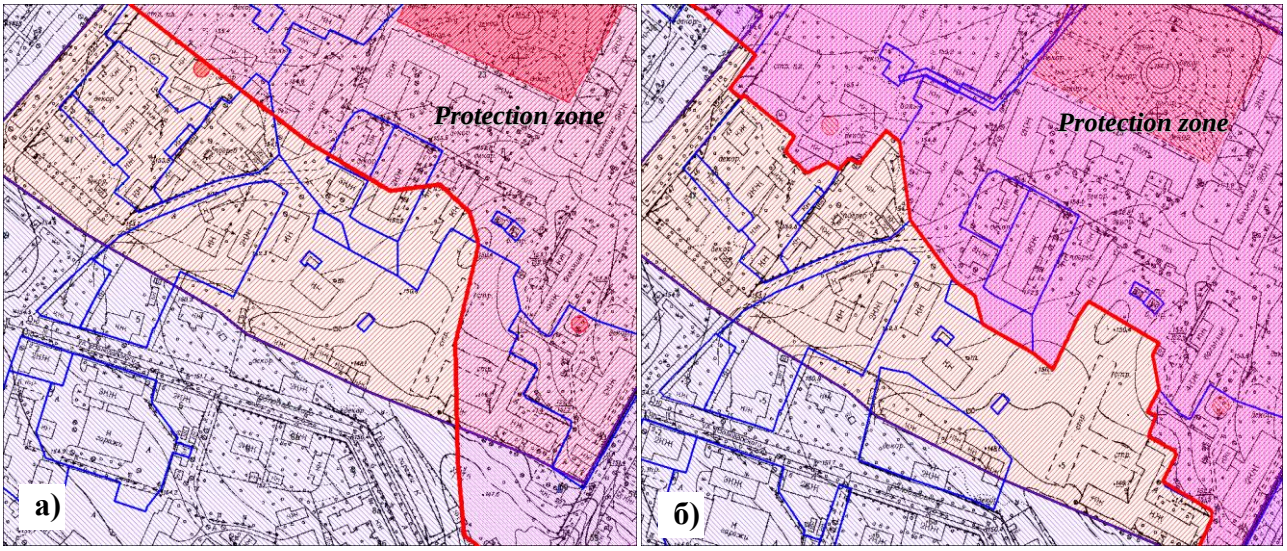

Fig. 2. Example of refinement and topological agreement of protection zone boundaries of historical and cultural monument

a) combining a vector model of protection zone from the city General Plan in scale of 1:10000 with topographical plans and land parcels boundaries (blue contours) at 1:500;

b) protection zone with a refined and topologically consistent geometry based on the boundaries of land parcels

Traditional GIS technology of vector data models creation should be used to convert information from existing paper maps and plans in ZSLU digital models. However, documentation on land management and planning documentation on zoning is outdated, and for most restriction objects it is missing at all. This determines the relevance of tasks of updating and/or developing documentation and creation of ZSLU geospatial data using GIS technologies.

The new paradigm of GIS use in land-cadastre activities. First of all let's pay attention to the paradigm shift in the use of GIS for development of urban planning and land cadastre documentation.The contents of this new paradigm is defined in the provisions of Cadastre 2014 with metaphors [25]:

Provision 3. Cadastral mapping will die. Long live modeling!

Provision 4. The principle of "paper + pencil = cadastre" should disappear.

Comments to thyse provisions states that

GIS technology will be the normal tool for cadastral work. The real low cost solutions are possible only when this technology is supported by flexible administrative procedures.

Developed countries, developing countries and countries in transition period, require models of existing situations to address population, environment and sustainable land use.

Current cadastre should provide basic information model. Surveyor of the world must think in terms of models and use modern technologies to manage them.

The key to this new paradigm is the primacy of cadastral objects geospatial modeling with using GIS for development of urban planning and land cadastre documentation. In other words, the target product should not cadastral maps and plans, and geospatial models of real objects, which are registered in cadastral GIS databases. Paper cadastral maps and plans do not disappear, they are transforming into the result of user query to spatial database.

An important components of these "flexible administrative procedures" are standards and technical regulations, which regulate the use of new GIS technologies for modeling. These regulations first of all determine not requirements for paper maps and plans of land and cadastral documentation, but technical specification of spatial models and feature catalogs, requirements for data structure, formats, accuracy ad topological consistency and other details and procedures to ensure the quality of data and create conditions for the achievement of interoperability.INSPIRE technical specifications,based on the concepts of International Standards ISO 19100 Geographic information/Geomatics, are good example of such regulations.

Current legal documents of Ukraine in the field of urban development is more suited to the new paradigm of GIS use, compared with the documents governing the land cadastre activities. So the Law of Ukraine "On regulation of urban development" [3] directly determine that planning documentation developed in paper and electronic media on the updated cartographic basis in digital form as profile geospatial datasets in the state geodetic coordinate system USC-2000 and the single classification and coding system for construction objects to create urban cadastre databases, and profile geospatial datasets should be submitted to urban cadaster of appropriate level no later than 30 working days after approval of planning documentation.

The guideline of the composition and content of the zoning plan [6] determine that Zoning is being developed with the use of GIS technology in digital form on actualized cartographic base at 1:2000 scale.For graphic elements of zoning connections with town planning regulations with reference to the text part are established. Analog graphical zoning schemes are printed in scale of the general plan of settlement (from 1:10000 to 1:2000 depending on the size of the settlement).

So, the developers of regulatory documents clearly identified the requirements for resolution of (accuracy) digital models of zoning objects, which is the primary target of zoning, and requirements for its cartographic representation as part of planning documentation. We will not burden the reader by comparisons and finding a similar understanding of standards and technical regulations in the land cadastre activities, but they are absent or have unclear definitions that leads to ambiguous interpretations.

Conceptua fundamentals of ZSLU modeling. Usually restriction zones are established as a certain regulatory size-defined buffer zone regarding the size of the territory or design lines of artificial structures of restriction objects.Formation of buffer zones around spatial objects belongs to the classic problems of geoinformation modeling, which can be formally represented as the operating function of buffer analysis:

$$ZSLU => BZ => FGIS\ (RO\_Type,\ RO\_Param,\ RO\_Brd\ [,\ RO\_CL],\ IZ,\ SP), \quad (1)$$

where *ZSLU* - boundaries of a zone, created as buffer *zone (BZ); FGIS* - GIS functions to build a buffer zone depending on: the type of restriction object *RO_Type* and a certain set of its characteristics *RO_Param*, containing information on RO category (such as production capacity, pipeline diameter, *etc.);* RO_Brd - border (boundary) of RO object and perhaps its structural lines *RO_CL*, defined in the regulations as a reference line for ZSLU formation (eg, pipeline center line or projection of outer wires of power lines, *etc.);* LZ - regulatory size of the zone; *SP* - a subset of additional geospatial analysis functions that can be used in the modeling based on the type of RO, including:

- analysis of morphological characteristics of relief, for example, to model coastal strips of water bodies;
- multivariate analysis, for example natural landscape factors analysis to determine ZSLU for protected landscape;
- spatial distribution analysis, e.g. analysis of cultural heritage objects in establishing their protection zones and others.

There are following main tasks for the implementation of operational function (1) in instrumental GIS environment:

formation of normative database (NDB) on the basis of legal documents, technical regulations and procedures for ZSLU establishment;

development of formalized knowledge base on rules of establishing ZSLU around different types of RO using RO database and geospatial analysis functions;

creation of spatial database of restriction objects;

development (if necessary) additional specialized software for ZSLU modeling, automation of preparation and production of relevant documentation and exchange of file for ZSLU registration in the cadastral system.

Conceptual model of NDB of ZSLU (Fig. 3) takes into account the real situation in the legal, regulatory and technical provision of ZSLU establishment.

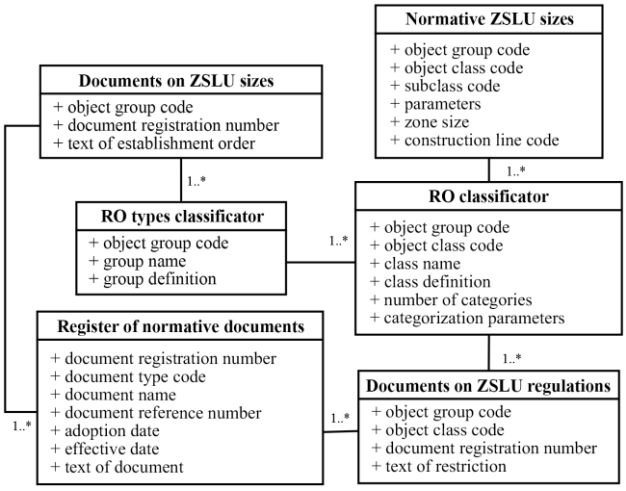

Fig. 3. UML-chart of ZSLU normative database

Each type of restriction objects can have several regulations that determine the size of ZSLU. For example, soem Ukrainian laws define maximum size of zone for cretain type of RO, and the orders (rules, guidelines), approved by the Cabinet of Ministers or other relevant governmental body, differentiate the size of the zones according to group and category of RO, its size, power or of potentially dangerous effects on the environment. It is advisable to perform physical implementation of NDB in universal database management system (DBMS). It allows its cross-platform reuse in different instrumental GIS. This requirement is conditioned by the fact that the creation of NDB of ZSLU GIS modeling is very time-consuming task. It requires organizing and ordering of several dozens of legal, regulatory and technical documents for more than a hundred types and categories of restriction objects.

NDB should be an information resource, which is centrally maintained, updated and used in multipurpose cadastre system and supplied to interested companies, involved in the creation of geospatial datasets of ZSLU as a part of urban development and land cadastre documentation.

GIS modeling of ZSLU also require appropriate spatial database (ZSLU SDB) with simple logical structure (Fig. 4).

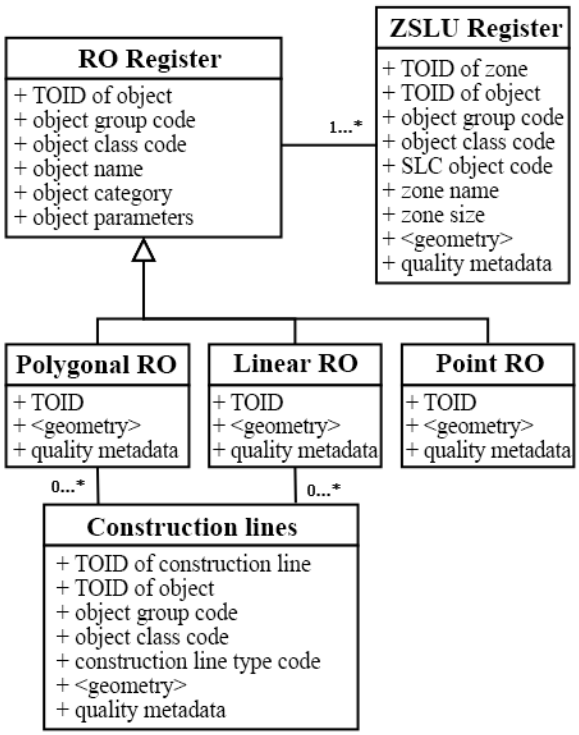

Fig. 4. UML-chart conceptual model of base geospatial data and RO ZSLU

Each spatial object of ZSLU SDB has an unique identification attribute *TOID in order to organize logical assosiations.* The main information resource of BHD ZSLU is the register of restricted objects *(RO Register), . Its subclasses are separated by type of spatial localization into : - polygons (land, buildings) - linestrings (line infrastructure facilities, rivers) - points (eg, single emission source).Each polygonal or linear RO can have constructions lines, which determs the size and boundaries of ZSLU. One or more ZSLU with different land use regulations can be established for each RO. health resorts protection buffer zones with various regimes.*

Note that all spatial objects need to have metadata about geospatial data quality, in particular the accuracy of the coordinates of RO boundaries, structural lines and ZSLU boundaries. This is a very important characteristic of ZSLU as it deals with the accuracy of the boundaries of legally valid objects of land cadastre.The accuracy requirements for the spatial location of the zone boundaries must be clearly defined by specific regulatory papers. This regulations should be followed strictly when modeling in GIS. Enlargement of the zone as compared to the standard could lead to expansion of restricted business activity areas in number and size. A reduction of ZSLU in size increases negative impact of RO on people, environment or product production and endangers safe use of restrictions object itself. ZSLU boundary-fitted coordinates validation accuracy of is a compromise between costs of appropriate quality data obtaining and practicability certainlevel of accuracy for specific types and categories of FBOs.

Infrastructure approach is a key principle of succes workflow management. Many publications regardless of the country emphasise three core figurative geospatial data "bird flu symptoms" : 1) funding shortage; 2) significant

dublication of work; 3) low data quality and inconsistency.Implementation of NSDI concepts allows to overcome this "dangerous disease". The base for it is coordinated co-production, use of geospatial data with common standards and production agreements, cooperation, and internet-based access to data.The Fig. 5 illustrates modern infrastructural approach to multi-purpose cadastre.

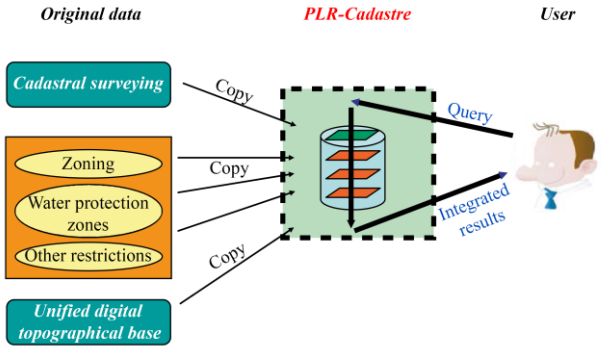

Fig. 5.Scheme of the formation and use of PLR-cadastre geospatial data based on infrastructural approach

Data producers provide copies of the original data to the cadastre system according to the nature of industry, their needs and responsibilities. They must stick to the following four principles of the framework concept of geospatial data integration [25]:

1) compliance to the legal and / or institutional independence of stakeholders;

2) use of standardized data modeling concept;

3) specification of nonlogical (spatial) relations between different types of objects is performed according to the geographical location of objects and spatial analysis;

4) use of consistent basic geospatial dataset (unified digital topographic base in unified coordinate system).

Each department or state institution keeps registers and geospatial databases according to its authority. They also provide access to metadata and data to all stakeholders. It conforms to the key principles of information systems development - the information should be recorded close to the source of the information to prevent its distortion and loss of relevance. This approach can assure efficient production, keeping geospatial data of high quality and up to date, development and registration hundred restriction objects in multi-purpose cadastre within Ukraine.

Conclusions

Special-use areas must be registered in modern multi-purpose cadastres.In Ukraine it requires creating an electronic registry for more than three hundred thousand restricted objects of different types and developing geospatial datasets of ZSLU for them.

Modeling of ZSLU for most types of restricted objects belongs to the classic problem of buffer analysis, that is why use of GIS is especially reasonable in this area.

Viable solution of this challenging issue is possible in case of infrastructured approach to geospatial data development, and target events activity coordination. The restricted objects' electronic (digital) registers should be developed and maintained up to date, for certain types of RO, based on a single normative database, unified digital topographic base and in compliance with standard procedure of geoinformation modeling of ZSLU and supplying of copies of datasets for restriction registration in SLC.

Other institutional and technological solutions leads to the inevitable dublication of activities, degradation of geospatial data quality and database refresh rate.

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Conceptual bases of geoinformation modeling restriction zones and their registration in the land and urban cadastre

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The principles of production and registration of geospatial data on the limitation of use of land in cadastral systems, formulated main priorities proposed conceptual database model for implementing GIS technology production and registration of geospatial data sets limits zones in the system SLC.