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CONCEPTUAL MODELING OF THE STRUCTURE OF A GEOINFORMATION SYSTEM FOR FORMATION OF LAND PLOTS IN STATE AND MUNICIPAL OWNERSHIP OF SETTLEMENTS

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Abstract. The article deals with the issues of automation of land cadastral information processing based on the modern international standards for management and processing of geospatial information. Object-relational databases together with the GIS provide powerful opportunities for collection, systematization, processing, analysis of various data, as well as storage and visualization of spatial information. According to the results of the analysis of the current legislative provision and processing of the existing data based on the international standards of the ISO 19110 series, the research developed a conceptual scheme of the geospatial database for the formation of state and municipal land plots within settlements. The research provides a model for checking the topology of the geospatial database of the system of automated formation of state and municipal land plots within settlements according to the structure and requirements of the international standard "ISO 19107:2019 Geographic information. Spatial schema". The developed conceptual model and topology verification model are the basis for physical data modeling and allow ensuring the principle of interoperability in the Spatial Data Infrastructure.

Keywords: Land Use Plan, GIS, conceptual model, formation of land plots, state and municipal ownership, urban planning reports.

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1. Introduction

The geo-informational approach is most widely used in land assessment, land cadastre management, management of urbanized territories (urban GIS), and in many other areas.

The tasks of forming land plots arise at different stages of spatial planning of territories and land use. During the development of the Comprehensive plans for the spatial development of the territory of the territorial community, general plans of settlements, detailed plans of the territory, the issue of forming land plots of municipal ownership of the territorial community may arise. Land management projects regarding the arrangement of territories for urban planning needs resolve the issue of the formation of land plots of state and municipal ownership, both within the boundaries of settlements and outside them. However, solving the issues of collection, systematization and analysis of input materials, making project management decisions during the formation of land plots of state and municipal ownership within settlements is connected with a large information capacity and the complex nature of the accumulation of various information. The use of a geo-informational approach in the process of forming state and municipal land plots allows accumulating and processing the necessary information of large volumes, form a data bank, quickly receive and correct information, and form different kinds of documentation.

Automation of the process of formation of land plots of state and municipal ownership with the use of geo-information support involves formalization of knowledge about the subject area; creation of an up-to-date digital cartographic base; development of databases to solve issues of fast and high-quality management of electronic data, their input and use; development of methods and technologies of automated formation of land plots in state and municipal ownership.

The formation of land plots of state and municipal ownership primarily consists in the identification of the land plot in spatial-coordinate and legal terms. When

forming the geospatial base of the system of automated formation of land plots, there is a need to introduce attributive spatial-coordinate and legal characteristics of land plots. The collected attributive information about the land use through systematization, structuring, formalization, automated search and visualization allows making project management decisions regarding the formation of land plots that are already classified as state or municipal property according to the existing legal provisions, or are proposed to be classified as state or municipal property according to the documentation of spatial planning of territories and prospective land use.

The basis of the legal support for the development of a modern system of production, supply, and use of the geospatial data in Ukraine was created by the adoption of the Law of Ukraine "On the National Infrastructure of Geospatial Data" (Verkhovna rada Ukrainy, 2020) and the Resolution of the Cabinet of Ministers "On Approval of the Procedure for the Operation of the National Infrastructure of Geospatial Data" (Kabinet Ministriv Ukrainy, 2021a).

The methodology and information environment of the National Infrastructure of Geospatial Data is used for the informational interaction of management subjects at different hierarchical levels in the process of territorial-spatial planning, maintaining the land cadastre, and ensuring the publication and access to the geospatial data in the network of geoportals.

2. Analysis of research

Currently, the automation of managerial decision-making in the field of land management is carried out through the development of information, geo-information, and land registration systems. The scientific research is conducted in the direction of the development of mathematical and informational models and methodological bases for the creation of the above systems based on the concept of the geospatial data infrastructure, systems for the classification and identification of geospatial objects, development of the Ukrainian software and GIS technologies. These issues are covered in detail in the works of Karpinskyi and Liashchenko (2001).

A significant contribution to the automation of the management of land resources of settlements was the scientific research by Liashchenko (2003). It summarized the methodological approaches, models and methods of formation and use of geo-informational resources of urban cadastral systems as a component of geospatial data infrastructure; determined directions for the formation of a national system of standards in the field of geographic information based on the harmonization of international standards of the ISO 19100 series; expanded the models of abstract classes, which provide support for object-oriented models of objects of the basic set of geospatial data and objects of cadastral accounting of the land and urban cadastre in databases.

The issue of the use of remote sensing data for the creation of up-to-date planning and cartographic materials for the automation and geo-informational support in land management and cadastre projects was considered in the works of Barladin and Yaroshuk (2006), Barladin et al. (2010), Barladin and Mykolenko (2011).

Foreign scientists also pay considerable attention to these issues.

The works that deal with the concept of land resource management using GIS technologies have been known for a quite long time. For example, the work (van Oosterom & Lemmen, 2001) describes the experience of creating a cadastre database of the Netherlands with support for topological relationships, historical data, geodetic and cartographic attributes, and flexible access to data. The studies in the recent years have largely been devoted to the implementation of the Land Administration Domain Model (LADM). The LADM should bridge the gap between land policy and information management capabilities and be adaptable to local situations (Lemmen et al., 2015). The model should cover the main data-related components of land management (legal/administrative, cartographic and topographical), and it should satisfy a variety of user requirements. The domain model in its implementation can be distributed among different organizations with different tasks and responsibilities. The study (Lemmen et al., 2015) provides a concept for implementing the LADM using UML diagrams.

In each country, the land management system must be adapted to the local features of land management processes and regulatory documents. In particular, the work (Govedarica et al., 2021) describes the experience of the development and implementation of cadastral information systems based on the LADM in Serbia, Montenegro, and the Republika Srpska. It summarized four phases of the development and implementation: conceptual modeling and development of the LADM-based country profiles in these regions; definition of real estate cadastre business processes; database implementation and data migration; implementation of the country profile in the form of a technical solution used in cadastre offices and on the Internet. The study (Akakba & Filali, 2017) deals with the development of a database based on the object-relational modeling with the information on the cadastral plans and the Land Use Plan in the territory of Algeria. This approach makes it possible to produce a wide range of spatial, structured and standardized information, facilitating the preparation of documentation, the formation of reports, the assessment of spatial-temporal changes, etc.

In addition, the works of the recent years have paid considerable attention to the implementation of the three-dimensional cadastre. The study (Barzegar et al., 2021) explores three-dimensional digital approaches to facilitate the management of rights, restrictions and responsibilities (RRR) in cities. The development of effective spatial analysis mechanisms can unlock the value of 3D RRR data, which will subsequently improve decision-making in complex urban environments.

3. Methodology and theoretical framework

The research involved the analysis of a significant array of regulatory and legal materials, in particular, the Land Code of Ukraine, Laws of Ukraine ("On the National Infrastructure of Geospatial Data"; "On Public Electronic Registers"; "On Amendments to Some Legislative Acts of Ukraine Regarding the Demarcation of State and Municipal Property"), resolutions of the Cabinet of Ministers of Ukraine ("On Approval of the Procedure for the Development, Updating, Amendment and Approval of Urban Planning Documentation"; "On urban cadastre"; "On Approval of the Procedure for Maintaining the State Land Cadastre"; "On Approval of the Procedure for the Functioning of the National Infrastructure of Geospatial Data"), state standards of Ukraine (State Standard of Ukraine ISO19101:2009 Geographic information. Reference model (ISO 19101:2002, IDT); State Standard of Ukraine 8774:2018 Geographical information. Rules for modeling geospatial data; State Standard of Ukraine ISO 19103:2017 (ISO 19103:2015, IDT) Geographic information. Conceptual schema language), as well as international standards of the ISO19100 series "Geographic Information/Geomatics" (given below).

4. The results of the research

Based on the existing approaches in the field of automation of land management processes (Liashchenko, 2003; Lahodniuk, 2008), in order to solve the set tasks, the research proposes a system of automated formation of land plots of state and municipal ownership, which includes a standard GIS, DBMS, technical and software tools for entering attributive and normative data, the formation of consolidated information and lists of land plots of state and municipal ownership with an indication of landowners and land users (form of ownership, a type of property right, plots with existing restrictions (encumbrances) (Figure 1).

The GIS provides display of electronic maps of settlements, input of cartographic data, execution of spatial queries, calculation of areas, coordinates of angles of rotation of geometric objects, and other necessary calculations for the formation of the operational data.

The geospatial database of the system of automated formation of land plots contains cartographic, normative, and statistical information, which is systematized in the process of collecting input data and analyzed in the course of making project management decisions. The operational information is created in the process of forming land plots of various forms of ownership and carrying out relevant calculations.

The functional interaction between the GIS and DBMS should ensure the input and compatibility of cartographic and attributive data, the formation of lists of land plots of various forms of ownership with planning and cartographic support.

The initial stage of creating a system of automated formation of land plots in state and municipal ownership is the creation of an up-to-date, high-quality digital cartographic base.

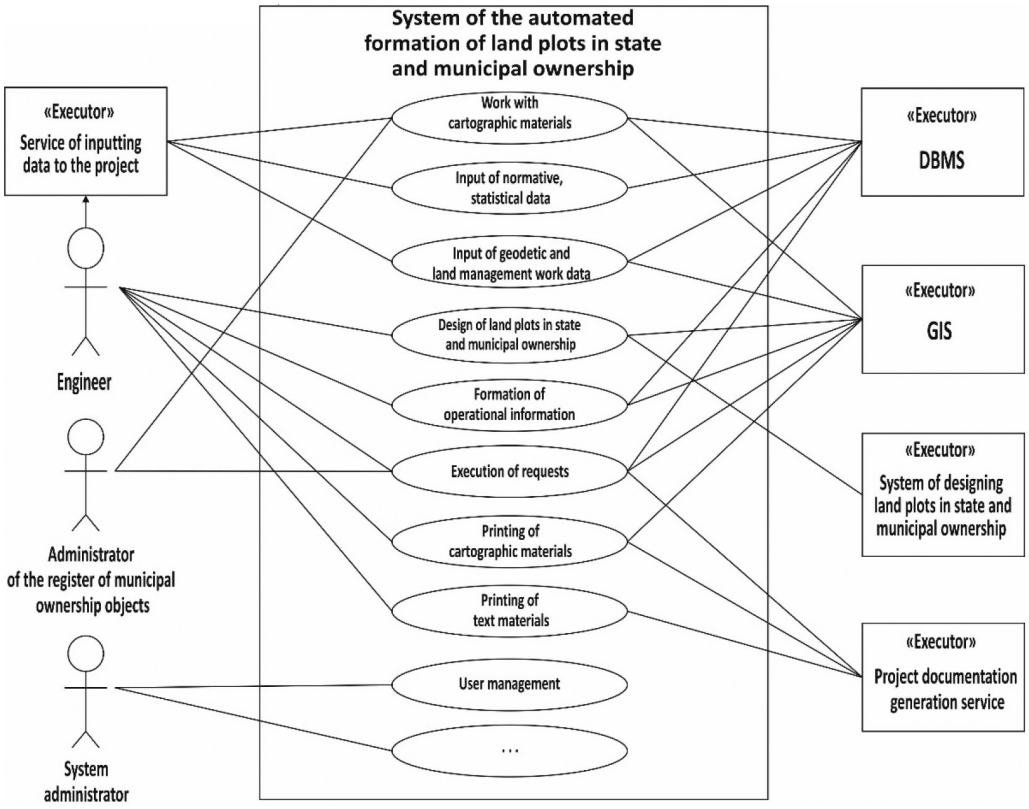

Figure 1. UML-diagram of the structure of the system of automated formation of land plots in state and municipal ownership

Currently, the development of earth remote sensing technologies makes it possible to widely use ultra-high and high-resolution space photographs and aerial photographs in topography, cartography, urban planning, land management, forestry, and other fields. The use of remote sensing is especially efficient for updating planning and cartographic materials and maintaining electronic cartographic information in an up-to-date condition (Barladin et al., 2010; Barladin & Mykolenko, 2011).

Space photographs with high spatial resolution (50–60 cm) – QuikBird (USA), WordView-2 (USA) and GeoEye or aerial photographs can be used as an operational source of obtaining up-to-date map information. Solving the problems of forming state and municipal land plots within settlements involves the use of a large-scale cartographic basis. The ratio of the resolution of aerospace survey materials and maps that can be created based on the research materials (Aristov, 2008) is analyzed in Table 1.

Table 1. The ratio of the resolution of the materials of aerospace photography and the maps developed on their basis (according to M. Aristov, 2008)

Spatial resolution category	Image resolution		The scale of the developed maps	Type of photography
Super high	0.1–2 m	0.1 m	1:1000; 1:2000	Aerial photography
		0.1–0.5 m	1:2000; 1:5000	Aerial photography
		0.5–1.0 m	1:5000; 1:10000	Aerial and space photography (QuikBird, WordView-2, GeoEye)

The research by Dorozhynskyi and Pochkin (2009) confirms that modern aerial imaging systems and photogrammetric technologies meet the requirements of land management work for cartographic materials. However, space systems, even of ultra-high resolution, cannot yet fully meet the requirements of land cadastral work in Ukraine. Although there are other opinions. The studies by Barladin and Yaroshuk (2006), Bazarnova et al. (2006) prove the possibility of using QuikBird high-spatial resolution space images to create urban GIS. The work by Hermonova et al. (2006) showed the possibility of using space images to demarcate state and municipal property at the level of city blocks.

During the formation of state and municipal land plots in settlements, cartographic materials (cadastral plans) are produced with a scale of 1:500–1:2000 (Kabinet Ministriv Ukrainy, 2021b). Therefore, during the development of the digital cartographic basis for the system of automated formation of land plots, it is necessary to use aerial photography materials to ensure the necessary accuracy of work performance.

The development of the system for the automated formation of state and municipal land plots begins with the creation of a digital cartographic basis of the territory of the settlement in the form of models and geospatial databases based on the formation of a multi-purpose basic set of spatial data and its integration with various sections of attributive data. The geoportals of local self-government bodies (territorial communities) provide users with access to detailed sets of basic geospatial data with scales of 1:2000 and 1:500 and thematic geospatial data and metadata about geospatial objects located in the territory of districts, cities, towns or villages, the holders of which are local self-government bodies (Karpinskyi et al., 2023).

The development of cartographic models and geospatial databases for the system of automated formation of land plots in state and municipal ownership should be based on international standards of the ISO-19100 series "Geographic information/Geomatics" (Table 2). The set of ISO 19100 standards is based on general standards and concepts of modern information technologies and develops them in accordance with the features of geospatial data and their use in the applied systems:

- standards defining the standardization infrastructure in the field of geospatial information: ISO 19101:2002 Geographic information. Reference model; ISO/TS 19101-2:2008 Geographic information. Reference model. Part 2. Image; ISO/TS 19103:2005 Geographic information. Conceptual schema language; ISO/TS 19104:2008 Geographic information. Terminology; ISO 19105:2000 Geographic information. Conformance and testing;
- data modeling standards: ISO 19107:2019 Geographic information. Spatial schema; ISO 19108:2002 Geographic information. Temporal schema; ISO 19109:2005 Geographic information. Rules for application schema; ISO 19111:2019 Geographic information. Referencing by coordinates; ISO 19112:2019 Geographic information. Spatial referencing by geographical identifiers; ISO 19123:2005 Geographic information. Schema for coverage geometry and functions; ISO 19137:2007 Geographic information. Core profile of the spatial schema;
- standards on metadata and data administration: ISO 19115:2003 Geographic information. Metadata. ISO/TS 19127:2005 Geographic information. Geodetic codes and parameters;
- standards for geographic information services: ISO 19116:2004 Geographic information. Positioning services; ISO 19117:2005 Geographic information. Portrayal;
- geographic information coding standards: ISO 19118:2011 Geographic information. Encoding. ISO 19136:2007 Geographic information. Geography Markup Language (GML). ISO/TS 19139:2007 Geographic information. Metadata. XML schema implementation.

During the development of the digital cartographic basis of a settlement with a scale of 1:500–1:2000 for the formation of land plots in state and municipal ownership,

Table 2. Development of the system for the automated formation of land plots in state and municipal ownership in accordance with international standards of the ISO 19100 series "Geographic information/Geomatics"

The system for the automated formation of land plots in state and municipal ownership / International standards ISO	Digital cartographic base of the settlement	Spatial-coordinate identification of the land plot	Topological compatibility check	Legal identification of the land plot	Development of databases of land plots registers	Preparation and printing of cartographic materials	Information interaction of process and data management subjects
ISO 19101:2002	+	+	+		+		+
ISO/TS 19101-2:2008	+	+					
ISO/TS 19103:2005							
ISO/TS 19104:2008	+	+	+	+	+		+
ISO 19105:2000	+	+	+	+	+		+
ISO 19107:2019	+	+	+				
ISO 19108:2002	+	+	+	+	+		
ISO 19109:2005	+	+	+	+	+		
ISO 19111:2019		+	+				+
ISO 19112:2019		+	+				
ISO 19115:2003							+
ISO 19116:2004							+
ISO 19117:2005						+	
ISO 19118:2011							+
ISO 19123:2005	+						
ISO/TS 19127:2005	+	+	+				
ISO 19136:2007							+
ISO 19137:2007	+	+	+				
ISO/TS 19139:2007							+

in accordance with the Law of Ukraine "On the National Infrastructure of Geospatial Data" (Verkhovna rada Ukrainy, 2020), executive state bodies and local self-government bodies, legal entities under public law, and subjects of natural monopolies are obliged to publish the following geospatial data and metadata on the Internet:

- reference systems of coordinates and heights;
- the state border of Ukraine;
- administrative-territorial units, including their borders;
- territorial communities, including the boundaries of their territories;
- hydrographic objects and hydro-technical structures;
- settlements, including their street and road network;
- buildings and structures;
- highways;
- railways;
- engineering communications;
- airports, sea and river ports;
- land cover and soils;
- land plots and cadastral zoning;
- registers of streets and addresses of objects;
- geographical names;
- nature conservation areas and facilities;
- world heritage sites, their territories and buffer zones, cultural heritage sites;
- types of land use;
- territorial zones, regulatory zones, land use restrictions and inventory units;
- digital terrain model (with a scale accuracy of 1:2000 for the territory of populated areas);
- orthophoto plans.

The thematic set for the formation of land plots in state and municipal ownership is formed by expanding the attribute data of certain objects of the basic sets of the national infrastructure of geospatial data and developing coordinate and attribute descriptions of new geospatial objects that have coordinate-spatial and topological compatibility with certain objects from basic sets of geospatial data (Karpinskyi & Liashchenko, 2001). The thematic sets of geospatial data include all types of geospatial data that are developed based on the basic geospatial data or as independent data sets and meet the requirements of the standards for geographic information and metadata, placed in the information environment of the infrastructure in compliance with the principles and rules of access and use of geo-information resources. Such sets can be developed by state and local self-government bodies, enterprises and citizens (Karpinskyi et al., 2023).

At the stage of conceptual modeling, a certain set of attributes is formed, which will ensure the functionality of the future system.

To form state and municipal land plots, the following set of attributes must be included in the thematic set of the geospatial data for the "Land plots" object: cadastral number of the land plot; the area of the land plot; address or location of the land plot; type of intended purpose of the land plot (code of the type of intended purpose), category of land; ownership; coordinates and description of land plot boundaries; the owner/user of the land plot, the composition of the land; documents certifying the right to the land plot.

The data for the geospatial object "Buildings and structures" includes: registration number of the building or structure; address or location; intended purpose; ownership; area; technical condition; architectural and historical-cultural value; coordinates and description of the boundaries of the building or structure; owner/user of a building or structure.

The database of geospatial and attributive data of the system for the automated formation of land plots in state and municipal ownership is intended for recording the results of the design of land plots.

The database contains the following basic information:

Register of state-owned land plots (R_STATE_LAND).

Register of land plots in municipal ownership (R_MUNICIPAL_LAND).

Register of land plots jointly owned by territorial communities and the state (R_COMMON_LAND).

Register of privately owned land plots (R_PRIVATE_LAND).

Register of owners/users of land plots or buildings and structures located on them (except for privately owned land plots) (R_HOLDER_REALTY).

Register of regime-forming objects (R_REG_OBJ).

Register of land use restrictions (R_RESTRICTION_LAND).

Classifiers and codifiers of the subject area of formation of land plots in state and municipal ownership (C_SUB_AREA) (Figure 2).

In order to develop the geo-information system for the automated formation of land plots in state and municipal ownership at the design stage, with the use of UML modeling tools, we worked out a conceptual database diagram and a catalog of geo-data objects, which reflect the structure of the geodatabase of the automated system for the formation of land plots in state and municipal ownership within settlements (Figure 3).

"Register of state-owned land plots":

R_STATE_LAND {#R_Sl_Id, Cad_Num, Parcel_A, #Adr_Id, #Parcel_Category, #Parcel_Purpose, Parcel_Border,

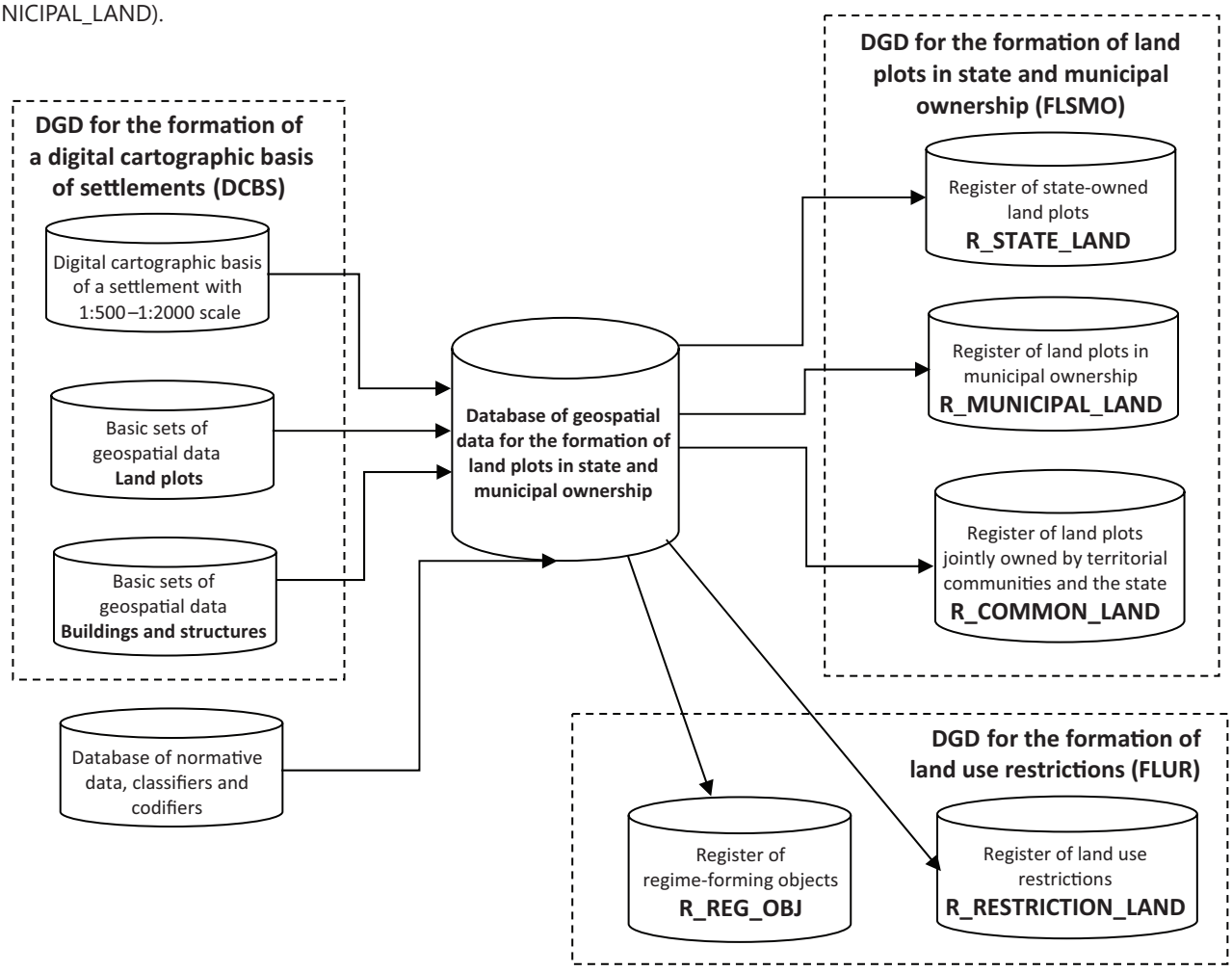

Figure 2. Structural-logical model of the geospatial database for the formation of land plots in state and municipal ownership within settlements

Part_SP, #Holder_Id, #Title_Parcel_Id, #Title_Real_Num, #Title_Real_Id},

where #R_Sl_Id – unique identifier of the land plot on the cartographic basis; Cad_Num – cadastral number of the land plot; Parcel_A – the area of the land plot; #Adr_Id – identifier of the address or location of the land plot; #Parcel_Category – land category code by main purpose #Parcel_Purpose – code of the type of the intended purpose of the land plot; Parcel_Border – coordinates and description of the land plot boundaries; Part_Sp – a share of state ownership of the land plot or building and structure; #Holder_Id – unique identifier of the owner/user of the land plot; #Title_Parcel_Id – identifier of the document certifying the right to use the land plot; #Title_Real_Num – extract number from the register of property rights for buildings and structures; #Title_Real_Id – identifier of the document certifying the right to operational management or economic management of buildings and structures located on the land plot.

"Register of land plots in municipal ownership":

R_MUNICIPAL_LAND {#R_Ml_Id, Cad_Num, Parcel_A, #Adr_Id, #Parcel_Category, #Parcel_Purpose, Parcel_Border, Part_Mp, #Holder_Id, #Title_Parcel_Id, #Title_Real_Num, #Title_Real_Id},

where #R_Ml_Id – unique identifier of the land plot on the cartographic basis; Cad_Num – cadastral number of the land plot; Parcel_A – the area of the land plot; #Adr_Id – identifier of the address or location of the land plot; #Parcel_Category – land category code by main purpose; #Parcel_Purpose – code of the type of the intended purpose of the land plot; Parcel_Border – coordinates and description of the land plot boundaries; Part_Mp – a share of municipal ownership of the land plot or building and structure; #Holder_Id – unique identifier of the owner/user of the land plot; #Title_Parcel_Id – identifier of the document certifying the right to use the land plot; #Title_Real_Num – extract number from the register of property rights for buildings and structures; #Title_Real_Id – identifier of the document certifying the right to operational management or economic management of buildings and structures located on the land plot.

"Register of land plots jointly owned by territorial communities and the state":

R_COMMON_LAND {#R_Cl_Id, Cad_Num, Parcel_A, #Adr_Id, #Parcel_Category, #Parcel_Purpose, Parcel_Border, Part_Sp, Part_Mp, #Holder_Id, #Title_Parcel_Id, #Title_Real_Num, #Title_Real_Id},

where #R_Cl_Id – unique identifier of the land plot on the cartographic basis; Cad_Num – cadastral number of the land plot; Parcel_A – the area of the land plot; #Adr_

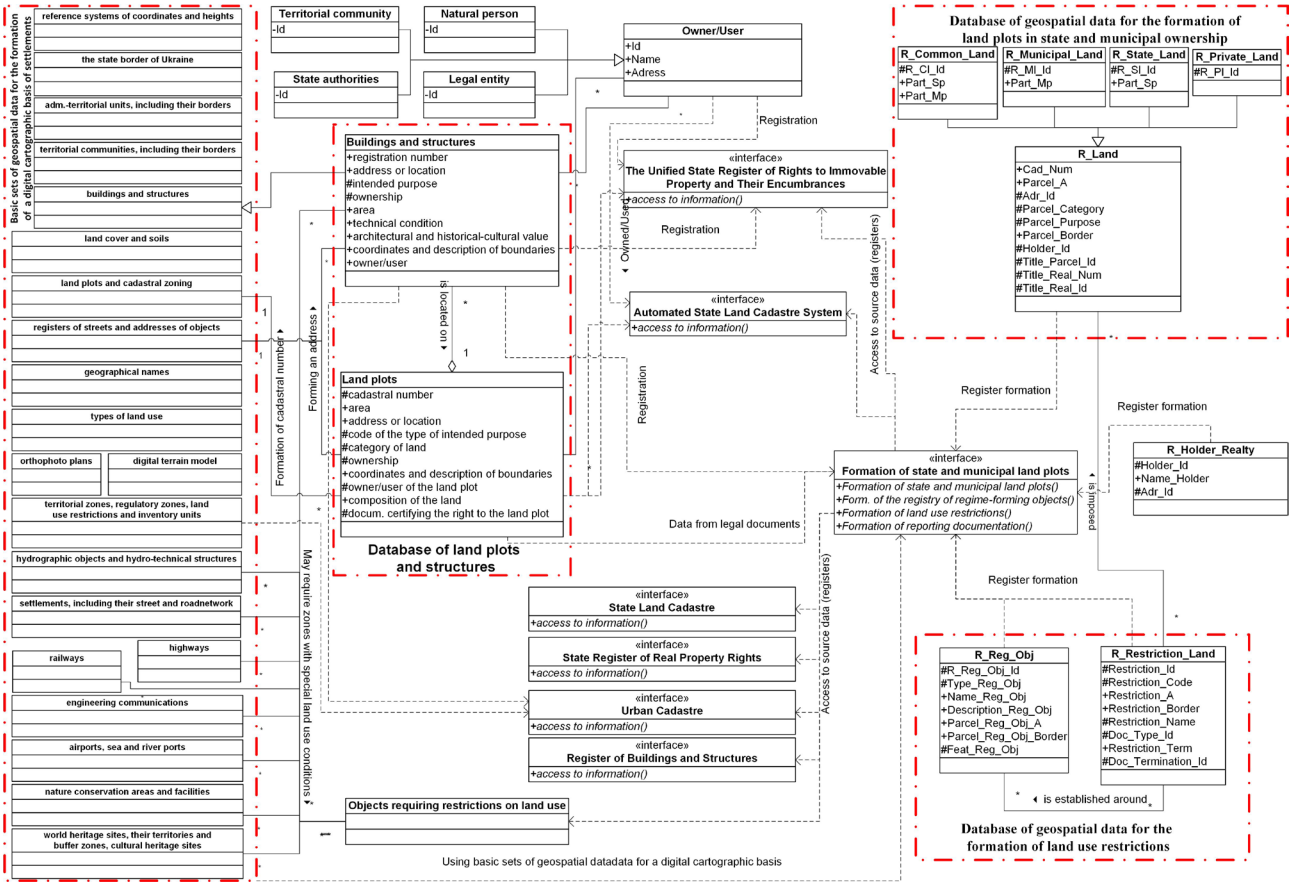

Figure 3. Conceptual model of the geospatial database for the formation of land plots in state and municipal ownership within settlements

Id – identifier of the address or location of the land plot; #Parcel_Category – land category code by main purpose; #Parcel_Purpose – code of the type of the intended purpose of the land plot; Parcel_Border – coordinates and description of the land plot boundaries; Part_Sp – a share of state ownership of the land plot or building and structure; Part_Mp – a share of municipal ownership of the land plot or building and structure; #Holder_Id – unique identifier of the owner/user of the land plot; #Title_Parcel_Id – identifier of the document certifying the right to use the land plot; #Title_Real_Num – extract number from the register of property rights for buildings and structures; #Title_Real_Id – identifier of the document certifying the right to operational management or economic management of buildings and structures located on the land plot.

"Register of privately owned land plots":

R_PRIVATE_LAND {#R_Pl_Id, Cad_Num, Parcel_A, #Adr_Id, #Parcel_Category, #Parcel_Purpose, Parcel_Border, #Holder_Id, #Title_Parcel_Id},

where #R_Pl_Id – unique identifier of the land plot on the cartographic basis; Cad_Num – cadastral number of the land plot; Parcel_A – the area of the land plot; #Adr_Id – identifier of the address or location of the land plot; #Parcel_Category – land category code by main purpose; #Parcel_Purpose – code of the type of the intended purpose of the land plot; Parcel_Border – coordinates and description of the land plot boundaries; #Holder_Id – unique identifier of the owner of the land plot; #Title_Parcel_Id – identifier of the document certifying the right of ownership/use of the land plot.

"Register of owners/users of land plots or buildings and structures located on them":

R_HOLDER_REALTY {#Holder_Id, Name_Holder, #Adr_Id},

where #Holder_Id – unique identifier of the owner / user; Name_Holder – name/surname, first name, patronymic name; #Adr_Id – registration address identifier.

"Register of regime-forming objects":

R_REG_OBJ {#R_Reg_Obj_Id, #Type_Reg_Obj, Name_Reg_Obj, Description_Reg_Obj, Parcel_Reg_Obj_A, Parcel_Reg_Obj_Border, #Feat_Reg_Obj},

where #R_Reg_Obj_Id – unique identifier of the regime-forming object; #Type_Reg_Obj – classification code of the type of regime-forming object; Name_Reg_Obj – name of the regime-forming object; Description_ Reg_Obj – description of the regime-forming object; Parcel_Reg_Obj_A – the area of the land plot of the regime-forming object; Parcel_Reg_Obj_Border – coordinates and description of the land plot boundaries of the regime-forming object; #Feat_Reg_Obj – classification code of the characteristics of the regime-forming object that determine the establishment of land use restrictions.

"Register of land use restrictions"

R_RESTRICTION_LAND {#RESTRICTION_Id, #RESTRICTION_Code, RESTRICTION_A, RESTRICTION_Border, #RESTRICTION_Name, #Doc_Type_Id, RESTRICTION_Term, #Doc_Termination_Id},

where #RESTRICTION_Id – unique identifier of the land use restriction; #RESTRICTION_Code – classification code of the type of land use restriction; RESTRICTION_A – the area of the land plot, which is subject to land use restrictions; RESTRICTION_Border – coordinates and description of land use restrictions; #RESTRICTION_Name – classification code of the content of land use restrictions; #Doc_Type_Id – identifier of the document on the basis of which land use restrictions are established; RESTRICTION_Term – validity period of land use restrictions; #Doc_Termination_Id – identifier of the document on the basis of which restrictions on land use were terminated.

The classifiers and codifiers of the subject area of the automated system for the formation of land plots in state and municipal ownership (C_SUB_AREA) include:

- the classifier of the intended purpose of land plots (Kabinet Ministriv Ukrainy, 2012);
- the land category classifier (Kabinet Ministriv Ukrainy, 2012);
- the classifier of types of documents certifying the right to own/use land plots (Kabinet Ministriv Ukrainy, 2012);
- the classifier of types of documents certifying the right to operational management or economic management of buildings and structures located on land plots (Ministerstvo yustytsii Ukrainy, 2012);
- the address classifier of the settlement (Kabinet Ministriv Ukrainy, 2011);
- the classifier of types of regime-forming objects;
- the classifier of the characteristics of regime-forming objects that determine the establishment of land use restrictions;
- the classifier of restrictions on the use of land and land plots (Kabinet Ministriv Ukrainy, 2012);
- the classifier of the content of restrictions on land use and the regime of land use in them;
- the classifier of types of documents on the basis of which land use restrictions are established (Kabinet Ministriv Ukrainy, 2012);
- the classifier of types of documents on the basis of which restrictions on land use are terminated.

From the given classifiers, it is necessary to develop a classifier of types of regime-forming objects, a classifier of the characteristics of regime-forming objects that determine the establishment of land use restrictions, a classifier of the content of restrictions on land use and the regime of land use in them, and a classifier of types of documents on the basis of which restrictions on land use are terminated.

The database of the automated system for the formation of land plots in state and municipal ownership is intended for the accumulation of cartographic and attributive data regarding the existing condition of land use in the settlement, normative data and legal documents for the formation of land plots in state and municipal

ownership and operational data of project management decisions. To ensure the implementation of the set tasks, it consists of a set of tables of the relational database, which establish the corresponding main and auxiliary relations for object models.

The attributive information of the database of the automated system is formed based on the data of the basic registers, which include the State Land Cadastre, the State Register of Real Property Rights, and the Register of Buildings and Structures (Verkhovna rada Ukrainy, 2021). In addition, information can come from a number of other industry registers and cadastres, namely, the Urban Cadastre, the Unified Register of State-Owned Objects, the State Register of Immovable Monuments of Ukraine, the State Cadastre of Territories and Objects of the Nature Reserve Fund, and the Register of Objects that have a harmful effect on the natural environment (Figure 4).

To automate data entry and processing, the following sections should also be included in the database:

- a reference set of land purpose, land categories;
- a reference set of types of documents certifying the right of ownership/use of land plots or the right of ownership of buildings and structures;
- a reference set of types of documents certifying the right to operational management or economic management of buildings and structures located on land plots;
- a reference set of characteristics of regime-forming objects that determine the establishment of land use restrictions;
- a reference set of types of regime-forming objects;
- a reference set of types of restrictions on the use of land and land plots;
- a reference set of the content of land use restrictions and their land use regime;
- a reference set of types of documents on the basis of which land use restrictions are established;
- a reference set of types of documents on the basis of which restrictions on land use are terminated.

During the formation of land plots in state and municipal ownership within settlements, the establishment of the boundaries of land plots must take place within the elements of the planning structure, taking into account the approved red lines established by the general plan and they must agree with the cadastral zoning of the territory. When forming land plots, it is necessary to ensure their topological compatibility.

According to "ISO 19107:2019 Geographic information. Spatial schema" (International Organization for Standardization, 2019c), the geometry of a land plot as a spatial object is quantitatively described by the following spatial characteristics: dimension, position, size, shape, and orientation. The geometry of a spatial object changes when geographic information is transferred from one geodetic system or coordinate system to another. Topology deals with the characteristics of geometric spatial objects that do not change during continuous elastic deformation of space, for example, during the transition of geographic data from one coordinate system to another.

The model for verifying the topology of the geospatial database for the system of automated formation of land plots in state and municipal ownership within settlements

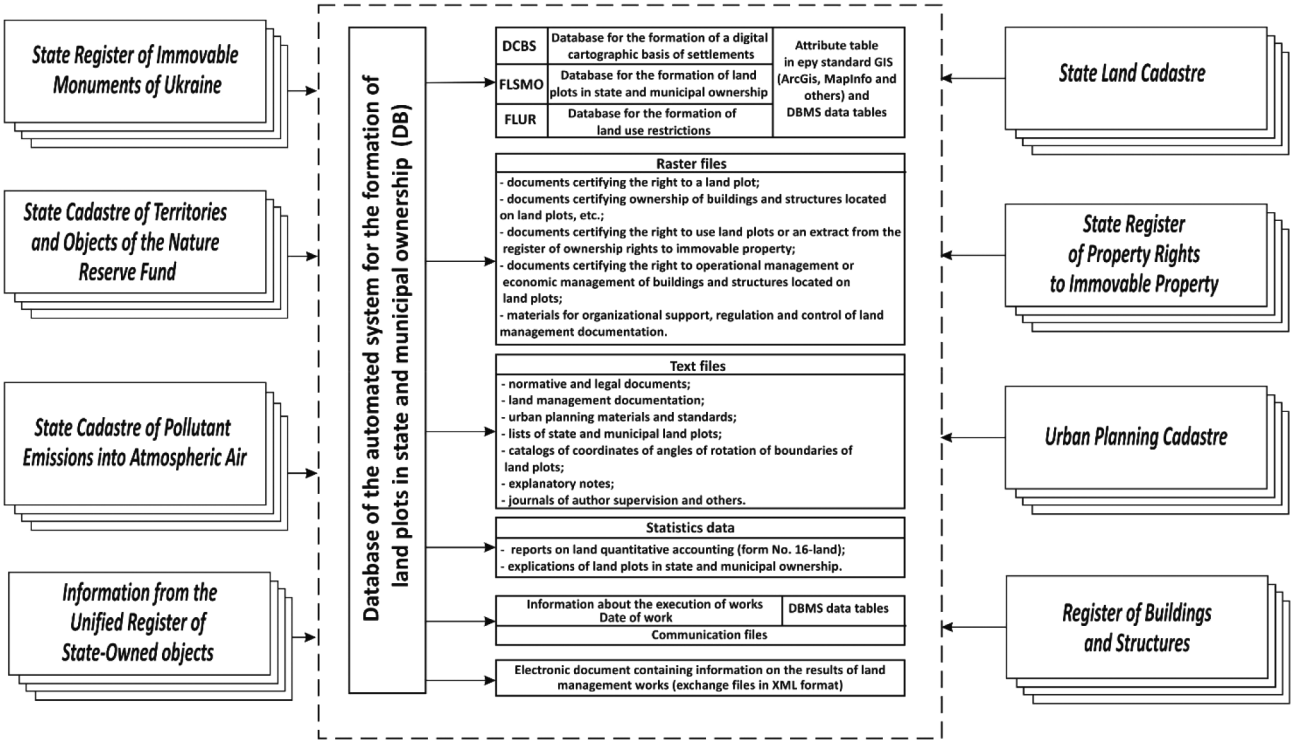

Figure 4. Generalized scheme of information interaction in the formation of the geospatial database for the formation of state and municipal land plots within the boundaries of settlements

is shown in Figure 5. Checking the topological compatibility of state and municipal land plots within settlements is carried out in the following directions:

- verification of the correctness of the geometric shape of the site through the correspondence of the spatial object to the geometric primitive according to the geospatial data sets "ISO 19107:2019 Geographical information. Spatial schema" (International Organization for Standardization, 2019c) and "ISO 19137:2007 Geographic information. Core profile of the spatial schema" (International Organization for Standardization, 2007);
- verification of the absence of common points is performed by searching for nodes along the common boundary between adjacent geometric primitives of spatial objects according to the geospatial data sets "ISO 19107:2019 Geographic information. Spatial schema" (International Organization for Standardization, 2019c), "ISO 19111:2019 Geographic information. Referencing by coordinates" (International Organization for Standardization, 2019a), and "ISO 19137:2007 Geographic information. Core profile of the spatial schema" (International Organization for Standardization, 2007);
- verification of the overlap of areas is performed according to the geospatial data sets "ISO 19107:2019 Geographical information. Spatial schema" (International Organization for Standardization, 2019c), "ISO 19111:2019 Geographic information. Referencing by coordinates" (International Organization for Standardization, 2019a), and "ISO 19137:2007 Geographic information. Core profile of the spatial schema" (International Organization for Standardization, 2007) via:
  - the search for duplicate geometric primitives;
  - geometric primitives forming inclusions in other spatial objects;
- incorrect geographic location of the site is performed by checking the inclusion of a geometric primitive to a specific geographic spatial object according to the geospatial data sets "ISO 19111:2019 Geographic information. Referencing by coordinates" (International Organization for Standardization, 2019a) and "ISO 19112:2019 Geographic information. Spatial referencing by geographic identifiers" (International Organization for Standardization, 2019b);
- the intersection of the borders of land plots with solid contours is performed by checking the intersection of edges of geometric primitives with geometric primitives of other classes of spatial objects according to the geospatial data sets "ISO 19107:2019 Geographic information. Spatial schema" (International Organization for Standardization, 2019c) and "ISO 19137:2007 Geographic information. Core profile of the spatial schema" (International Organization for Standardization, 2007);
- the intersection of the boundaries of plots with cadastral units is performed according to the geospatial data sets "ISO 19107:2019 Geographic information. Spatial schema" (International Organization for Standardization, 2019c), "ISO 19108:2002 Geographic information. Temporal schema" (International Organization for Standardization, 2002), "ISO 19112:2019 Geographic information. Spatial referencing by geographic identifiers" (International Organization for Standardization, 2019b), and "ISO 19137:2007 Geographic information. Core profile of the spatial schema" (International Organization for Standardization, 2007) by checking the intersection of edges of geometric primitives with the boundary of a geometric primitive of the:
  - spatial object "cadastral zone";
  - spatial object "cadastral block";
  - spatial object "land plot";
- the incorrect number of the inventory cadastral unit or its absence is performed through the verification of the:
  - plots with an incorrect code in the Classification of objects of the administrative-territorial system of Ukraine;
  - plots with an incorrect cadastral zone code;
  - plots with an incorrect cadastral block code;
  - plots with a repeated cadastral number;
  - plots with an incorrect cadastral number;
- the intersection of the boundaries of the plots with the planning elements of the territorial structure of the settlement is performed according to the geospatial data sets "ISO 19107:2019 Geographical information. Spatial schema" (International Organization for Standardization, 2019c), "ISO 19111:2019 Geographic information. Referencing by coordinates" (International Organization for Standardization, 2019a), "ISO 19112:2019 Geographic information. Spatial referencing by geographic identifiers" (International Organization for Standardization, 2019b), "ISO 19137:2007 Geographic information. Core profile of the spatial schema" (International Organization for Standardization, 2007), and "ISO 19108:2002 Geographic information. Temporal schema" (International Organization for Standardization, 2002) by checking the intersection of edges of geometric primitives with the boundary of a geometric primitive of the:
  - spatial object "functional zone";
  - spatial object "red line";
  - spatial object "restricted land use".

The proposed automated system provides formation of:

- planning and cartographic materials for the entire territory of the design object, as well as for individual land plots in state and municipal ownership;
- catalogs of the coordinates of the angles of rotation of the boundaries of land plots of various forms of ownership;
- lists of land plots in state and municipal ownership by users and other parameters included in the attribute data of the automated system database;

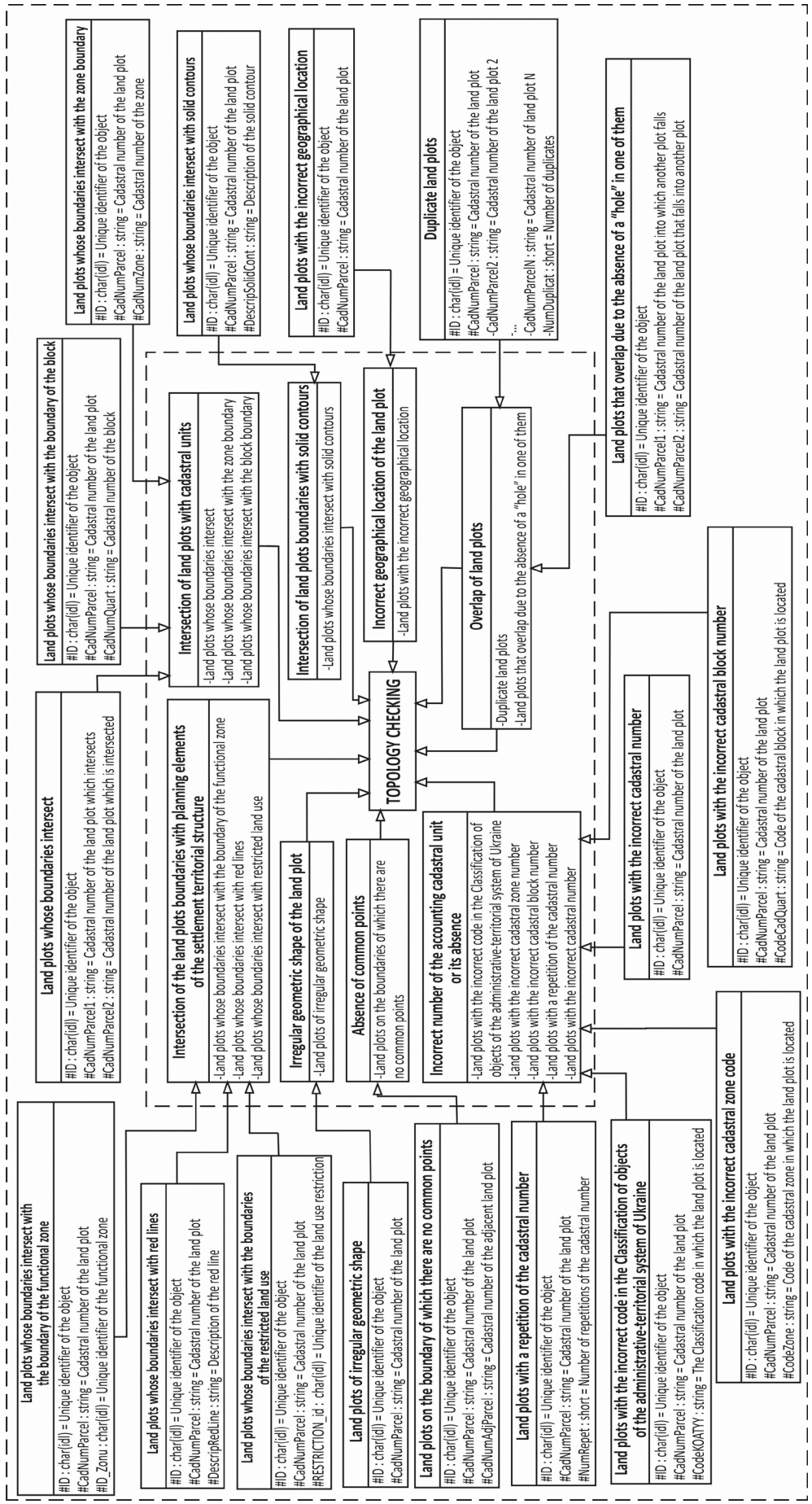

Figure 5. Model for verifying the topology of the geospatial database for the formation of state and municipal land plots within settlements

- explications of state, municipal, and private lands, and other necessary explications within the scope of the project;
- formation of other necessary planning, cartographic, and textual materials within land management documentation.

5. Conclusions

Based on the analysis of the current legislative provisions and processing of the existing data with the use of the international standards of the ISO 19110 series, a conceptual scheme of the geospatial database for the formation of state and municipal land plots within settlements was developed. Performing work on the formation of state and municipal land plots using geo-information technologies allows increasing the dynamism of systematization and analysis of incoming information, the quality of making project management decisions and ensuring their validity, implementing the automation of data use in the management of formed land plots. The research developed a model for verifying the topology of the geospatial database for the system of automated formation of state and municipal land plots within settlements according to the structure and requirements of the international standard "ISO 19107:2019 Geographic information. Spatial schema". The use of the orthophoto plans in the system of automated formation of land plots in state and municipal ownership allows monitoring the dynamics of land use of the territory, spatial coordinate changes of the boundaries of land plots and regime-forming objects when forming land use restrictions. The obtained data make it possible to continuously update planning and cartographic materials, make changes to the spatial and attribute information regarding newly formed land plots, and to adjust the list of regime-forming objects and the configuration of the established land use restrictions.

The developed conceptual model and topology verification model are the basis for physical data modeling and allow ensuring the organization of the principle of interoperability in the Spatial Data Infrastructure. The proposed automated approach will allow for geo-information interaction between local self-government bodies, state authorities, and project organizations during the formation of land plots and subsequently during the management of state and municipal lands. Such a system can be a component of the city GIS; serve as information support during the management of the territorial resources of the settlement, the creation of Comprehensive plans for the spatial development of the territory of the territorial community, general plans of settlements, detailed plans; interact with state and municipal land registers and ensure their constant updating and revising of spatial information.

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