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CHALLENGES AND PERSPECTIVES OF IMPLEMENTING A MULTIDIMENSIONAL CADASTRE IN THE REPUBLIC OF SRPSKA

Abstract:

This study analyzes the need to transform the traditional two-dimensional cadastre in the Republic of Srpska into a multidimensional system (3D/4D). The research aims to examine the compliance of the current real estate records with the international standard ISO 19152 (LADM) and to identify the key prerequisites for introducing the third and fourth dimensions into the cadastral register. The methodology includes an analysis of national legislation, a comparative review of international experiences, and an assessment of the current state in this field. The results indicate that the existing system in the Republic of Srpska provides a foundation for modernization but requires integration with contemporary standards to enable more efficient management of complex properties.

Keywords: 3D and 4D cadastre, ISO19152 (LADM), standards, Republic of Srpska Legislation

ИЗАЗОВИ И ПРАВЦИ РАЗВОЈА ВИШЕДИМЕНЗИОНАЛНОГ КАТАСТРА У РЕПУБЛИЦИ СРПСКОЈ

Сажетак:

У овом раду анализира се потреба за трансформацијом традиционалног дводимензионалног катастра у Републици Српској у вишедимензионални систем (3Д/4Д). Циљ истраживања је испитати усклађеност тренутне евиденције непокретности са међународним стандардом ИСО 19152 (ЛАДМ) те идентификовати кључне претпоставке за увођење треће и четврте димензије у катастарски регистар. Методологија обухвата анализу домаће легислативе, компаративни преглед међународних искустава и анализу тренутног стања у овој области. Резултати указују на то да постојећи систем у Републици Српској посједује основу за модернизацију, али захтијева интеграцију са савременим стандардима ради ефикаснијег управљања сложеним објектима.

Кључне ријечи: 3Д и 4Д катастар, ИСО 19152 (ЛАДМ), стандарди, легислатива Републике Српске

1. INTRODUCTION

Technological advancement, together with political, economic, ecological, and social factors, has transformed the perception of the world over the past fifteen years. This transformation has had profound effects on state systems and their administration. In the context of land management, this concerns issues of tenure security and the registration of property rights, aiming to reduce poverty and achieve sustainable development of land and real estate markets. There is a need to reorganize cadastre and real estate management systems to keep pace with global developments such as urbanization, demographic changes, social inequalities, digital transformation, unstable global economies, anthropogenic environmental damage, and similar challenges.

Given that geodesy in all its branches strives to be multidimensional and focused on 3D geoinformation, the introduction of the third and fourth dimensions into property management and cadastral systems is a logical necessity. Furthermore, the demand for 3D and 4D cadastre arises from the high population density in urban centers, the construction of complex buildings, the expansion of structures above and below ground level, and the need to resolve property rights in all spatial domains.

Many researchers globally and regionally have addressed this topic, both in terms of developing models for their own countries and in seeking appropriate universal solutions applicable to most cadastral systems. The International Federation of Surveyors (FIG) has established a dedicated Working Group to address this issue, organizing surveys and conferences to enable researchers worldwide to exchange ideas and reach common solutions to certain challenges. Among the most influential researchers contributing significantly to this field are P. V. Oosterom, H. Ploeger, J. Stoter, R. Thompson, and C. Lemmen, as well as regional experts such as M. Govedarica, A. Radulović, D. Sladić, N. Vučić, M. Roić, N. Višnjevac, and many others who have actively participated in research for several years.

This paper will present the historical development of the concept of 3D and 4D cadastre, the standards used in their implementation, the evolution of the cadastral system in the Republic of Srpska, and the possibilities for extending the basic model to incorporate third and fourth dimensions. Additionally, examples will be provided where the use of the third dimension is essential for accurately and precisely representing spatial and property-right relationships.

2. STUDY AREA

The area of research is the entity of the Republic of Srpska (Figure 1). In the Republic of Srpska, there exist multiple property data registries that aim to be integrated into a unified system—the real estate cadastre. The registries currently used in the Republic of Srpska include: the land cadastre based on surveys in the polyhedral projection, the land cadastre based on surveys in the Gauss-Krüger projection, the real estate cadastre, the cadastre of properties with established user-possession rights, the inventory cadastre, the land registry, the registry of deposited contracts for the purchase of residential buildings and apartments, the registry of deposited contracts for the sale of commercial buildings, business premises, and garages, and, finally, the real estate cadastre [1].

The real estate cadastre represents a unified registry of geodetic-technical and property-legal data under the authority of the Republic administration for geodetic and property affairs of the Republic of Srpska. According to the Law on Survey and Cadastre of the Republic of Srpska, it is defined as the primary and public register of real estate and property rights thereon. As such, it comprises both spatial and legal components. For the purposes of this law, real estate is defined as land, aboveground and underground construction objects, and specific parts of buildings that constitute a construction unit [2].

Given the highly complex nature of property registries in the Republic of Srpska, it is evident that the introduction of the third and fourth dimensions represents a significant challenge for the responsible institutions.

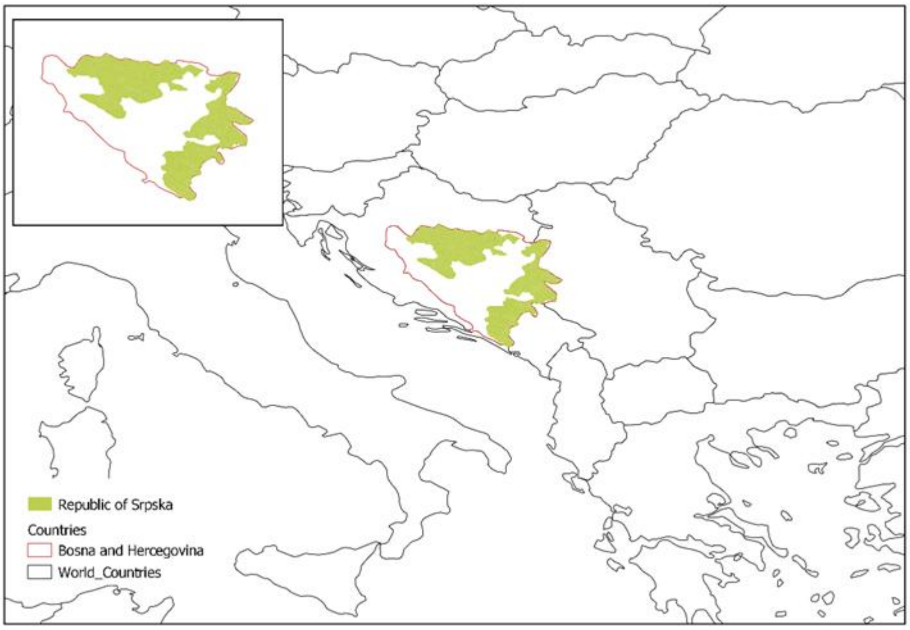

Figure 1. Study area (created by author).

3. MATERIALS AND METHODS

The need for a multidimensional cadastre is the result of intensive changes in architectural, spatial, and ownership structures. In order to assess the necessity of such a system in the Republic of Srpska, an analysis of existing 3D and 4D cadastral systems worldwide was conducted. Furthermore, relevant standards in this field were examined, and the current legal framework governing the regulation of land administration and registration systems was reviewed.

3.1. THE NEED FOR A 3D CADASTRE

At the FIG Congress in April 2002 in Washington, it was concluded that there was a need to establish a special working group tasked with investigating 3D cadastral registration issues at the international level. The FIG Working Group on 3D Cadastres consisted of subcommissions 3 and 7 (FIG Joint Commission 3 and 7 Working Group on 3D Cadastres) and included three sections addressing the legal, institutional, and technical aspects of 3D cadastres [3].

According to the FIG Statement on the Cadastre, a cadastre is defined as an up-to-date information system, typically parcel-based, containing records of interests in real property (rights, restrictions, and responsibilities). Parcels are defined by formal or informal boundaries and are owned by individuals or groups (families, corporations, or other social entities) [4].

The Bathurst Declaration highlighted that a large number of administrative systems are unable to cope with the increasing complexity of rights, restrictions, and responsibilities associated with parcels, and that modernization of these systems is necessary, including the consideration of spatial extensions [5].

The need for a 3D cadastre arises in parallel with political, economic, ecological, and social changes, as well as the rapid advancement of technology. Recent research in geodesy focuses on 3D geoinformation, tools for data acquisition, data management, optimization, web-based sharing, standardization of 3D data, modeling and visualization, and the development of a sustainable real estate market [6], [7], [8], [9], [10].

As the development of smart cities progresses, surveyors and Geographic Information Systems (GIS) engineers need to develop services and tools that enable more transparent, secure, attractive, and cost-efficient management of geospatial data. This approach leads to the concept of a multi-dimensional and multi-purpose land information system. Such systems include extensions of the 3D cadastre, adding a temporal dimension and levels of detail, ultimately evolving toward a 5D cadastre. While 3D allows for spatial modeling of objects, 4D tracks changes over time, and 5D adds a fifth dimension—different Levels of Detail (LoD), enabling the same objects to be represented in simplified or highly detailed architectural forms. This additional dimension facilitates efficient visualization and analysis of large urban areas and allows customization of displays to meet diverse user needs, from urban planning to asset management and urban regeneration. In short, 5D integrates spatial, temporal, and scalable information into a single system, enabling precise, flexible, and dynamic management of land and infrastructure [11].

The concept of 3D property registration has been explored since the late 1990s. Although the idea emerged relatively early, in most countries the legal aspects of 3D properties and their integration into 3D models were not thoroughly defined or examined. The application of artificial intelligence in 3D cadastres enables automated processing and updating of three-dimensional data for above- and below-ground structures. Using machine learning, deep learning, and computer vision, objects, floors, and underground structures can be efficiently recognized from LiDAR, photogrammetric, and other geospatial data. AI thus contributes to more accurate modeling of property rights in vertical space, improves data quality, and facilitates the implementation of modern, interoperable 3D cadastres [12].

From the perspective of a 3D cadastre, three models are distinguished [13], [14]:

- Cadastre with 3D links – an extension of the 2D model with external 3D representations for complex 3D situations.
- Hybrid model – a combination of 2D and 3D approaches, providing a 3D visualization of the object, while the legal status is linked to a 2D parcel.
- Full 3D cadastre – the entire space is divided into 3D parcels defined as parts of 3D space, enabling registration of 3D rights.

Several countries are currently implementing full 3D cadastres. The following table presents an overview of states, their registration methods, representations, and types of cadastral parcels.

Table 1. Overview of countries and methods for registration and representation of cadastral parcels [15]

Country	Existing 3D Objects (Registered or Not)	3D Cadastral Objects (Registered)	Representation of 3D Objects on the Cadastral Plan
Australia (State of Queensland)	3D easements, 3D roads, airspaces, 3D variable boundaries, water bodies, underground spaces, easement restrictions, mining rights, restrictions (above or below certain heights), apartments and co-ownership; tunnels, utilities (network and individual infrastructure), commercial spaces; parking lots, bridges, sports facilities	3D easements, 3D roads, airspaces, 3D variable boundaries, water bodies, underground spaces, easement restrictions, mining rights, restrictions (above or below certain heights), apartments and co-ownership; tunnels, utilities (network and individual infrastructure), commercial spaces; parking lots, bridges, sports facilities	2D base with 3D isometry; different plan types for 2D, 3D buildings, and volumetric objects; different numbering for 3D; 3D plans for volumetric objects require linking to vertical geodetic control network; any mathematically definable 3D geometry is allowed
Australia (State of Victoria)	Apartments and their additions, common property, underground and airspace restrictions	Apartments and their additions, common property, underground and airspace restrictions	2D
Canada (Province of Quebec)	Apartments and commercial spaces; underground infrastructure such as tunnels and subways; utility and mining cadastres	Mandatory: Apartments and commercial spaces; underground infrastructure such as tunnels and subways; mining objects. Optional: Utility cadastre	2D plans with text referring to the corresponding PC plan (PC plans show vertical profiles with floor-level parcelation; heights

			and volumes are included)
China	Apartments; commercial spaces; underground infrastructure	Apartments; commercial spaces	2D
Netherlands	Apartments, offices, commercial spaces, infrastructure objects, tunnels, and bridges	Complex buildings in Delft	2D (some in 3D)
Sweden	Apartments, offices, commercial spaces, infrastructure objects, tunnels, and other underground objects	No restrictions on registration of rights	2D[3]
Croatia	Apartments, commercial spaces, communal infrastructure with associated objects, transport infrastructure, dams, hydroelectric plants, culverts, and bridges	Apartments, commercial spaces	2.5D
Greece	Horizontal strata ownership, vertical ownership, mines, easements for utility networks, infrastructure, and communal installations	Horizontal strata ownership, vertical ownership, mines, easements for utility networks, communal installations	2D[2]

Within the framework of the FIG and its Working Group on 3D Cadastres, a global survey was conducted in 2010 to assess the state of 3D cadastres worldwide and activities in this field. The survey covered the status of cadastral systems in 2010 as well as development plans up to 2014. The results and analyses were presented during the FIG Working Week 2011 and at the 3D Cadastre Workshop held in 2014.

Based on the survey results and subsequent workshops, several conclusions were drawn: 3D property rights often need to be projected onto a 2D plane and registered within the boundaries of a 2D parcel. In most surveyed countries, except Canada and Australia, there were no explicit regulations for registering rights to space above or below the ground. No clear definition of a 3D parcel existed, and such registrations were not standardized. Descriptions of 3D property could typically be found on cadastral maps or accompanying documentation. For buildings, floor-level plans were commonly used, showing property boundaries for each floor [16].

Significant progress was anticipated by 2014.

A follow-up survey was conducted in 2014, expanding the questionnaire to include new sections on:

- Extensions of 3D cadastral information;
- Statistical information;
- Review and evaluation.

Certain questions from the previous survey were clarified and expanded in the 2014 version. Most countries indicated that they did not expect major changes in 3D cadastre status by 2018, though some anticipated improvements in cadastral database development as a key prerequisite for implementing 3D property registration) [17].

The third survey (3rd FIG 3D Cadastres Questionnaire), conducted in 2018, aimed to assess the current status and future plans up to 2022. Some countries that had participated in earlier surveys did not respond, considering the changes since the previous survey to be minimal. Analysis of the survey results indicates continuous progress, particularly in the development of 3D modeling technologies and the modernization of legal frameworks. The focus remained on apartment registration, while future objectives increasingly emphasized the alignment of legal definitions with 3D volumetric property registration) [18].

Compared to the third survey, the fourth survey (2022) retained the core structure for result comparability but introduced several innovations. Questions were clarified for more precise interpretation. New questions addressed LADM (ISO 19152) implementation and national profiles, BIM usage in 3D parcel registration, operational or prototype systems reusing BIM data, development of 3D city models and digital twins, and bitemporal registration of objects (distinguishing real-world valid time from database system time).

This shift indicates a movement from primarily descriptive monitoring toward deeper examination of interoperability, standardization, and practical implementation of 3D land administration systems.

The main priorities for 2026 are:

- Legal aspects: Linking legislation to 3D land administration.
- Organizational aspects: Training and capacity building for 3D land administration, as well as developing guidelines and procedures for working with 3D data.
- Technical aspects: System interoperability, application of modern VR/AR technologies, and specialized support for precise collection and processing of 3D data [19].

3.2. THE NEED FOR A 4D CADASTRE

The relationship between humans and land is inherently time-dependent [20]. When discussing a 4D cadastre, the temporal dimension is considered from several perspectives: the history of property ownership, changes in shape and size of land parcels, the costs of establishing and maintaining cadastral systems over time, and the relationship between time and cadastral value. Rights, responsibilities, and restrictions also inherently possess a temporal aspect [21].

Several countries are actively addressing these issues, including Australia, the Netherlands, Turkey, Hungary, China, Indonesia, Argentina, and Croatia. Researchers have illustrated the application of 4D cadastre concepts for land disputes, natural hazards such as earthquakes, and the monitoring of land parcelation and land use over time [22], [23], [24].

The need to incorporate time as the fourth dimension can be categorized as follows [25]:

- Monitoring the development of cities and villages over time;
- Statistical analysis of changes in land use;
- Planning purposes;
- Archival history;
- Monitoring of cultural heritage.

To efficiently manage the life cycle of real property, a model requires a unique identifier for each property along with temporal information about its creation and deletion. Deletion of a property does not imply its permanent removal from the database; rather, its thematic relevance is lost while historical information is retained. In other cases, modifications may occur without deletion, preserving multiple versions of the same property. This approach supports the temporal dimension independently of spatial dimensions, typically implemented through separate versioning attributes or a temporal range [26].

Time has always played an important role in cadastral systems; however, it has never been integrated with the spatial dimension (2D or 3D) and has traditionally been treated as a separate segment. The separation of temporal and spatial data creates challenges when determining relevant aspects, such as identifying the legal right-holder at a specific moment. Currently, time is not incorporated into topological-geometry data types but is represented as a separate attribute [25].

Examples of spatio-temporal cadastral applications for defining movable properties and their rights, responsibilities, and restrictions include [25]:

- Grazing rights: location changes over the seasons (2D + time);
- Fishing rights: shifts and modifications in rights (3D + time).

The integration of time and space into a unified 4D data type offers significant advantages for 4D cadastres (Figure 2) [27]:

- Optimized 4D querying: more efficient database searches;
- Improved parent-child visibility: easier tracing of hierarchical relationships between parcels;
- 4D analyses: e.g., overlapping scenarios in land consolidation, where historical and current parcel states can be observed simultaneously, or tracking movement rights across datasets with spatio-temporal overlap;

- 4D partitioning (3D + time without overlaps or gaps) as a foundation for 4D cadastre, enabling 4D geometry and topology.

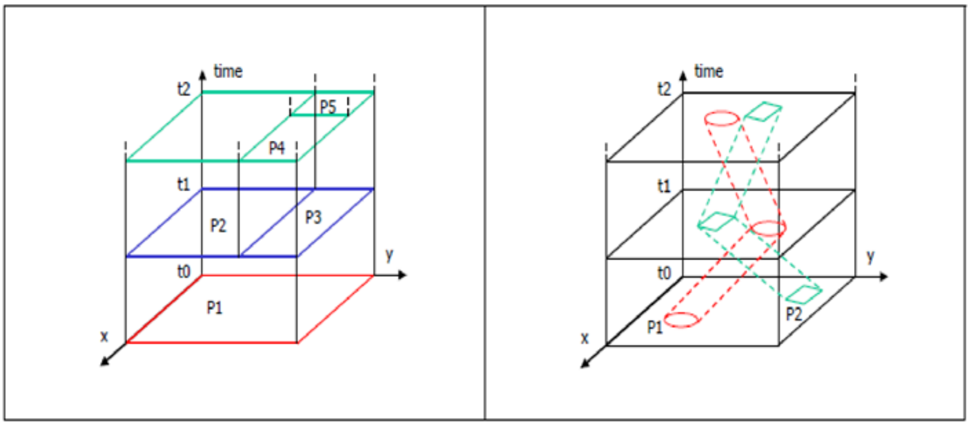

Figure 2. Integration of Space and Time in a 4D Cadastre [27]

3.3. STANDARDS IN THE FIELD OF CADASTRE

Standardization is an activity present in all areas of work and business, aimed at increasing efficiency through unification and simplification. The primary goal of standardization is the systematic effort to eliminate differences between individual objects and concepts used for the same purpose [28].

International standards and directives in the field of cadastre represent a crucial factor for the development and implementation of cadastral systems, both in terms of security and process rationalization, by providing services and methods that correspond to actual needs.

The most important standards in the field of cadastre include:

- OGC standards;
- ISO 19000 series;
- LADM – ISO 19152 standard;
- INSPIRE directive.

The following section provides a brief description of each of the above standards.

3.1.1. OGC Standards

The Open Geospatial Consortium (OGC) is an international, non-profit organization that brings together over 500 companies, government agencies, research institutions, and universities with the goal of making geospatial data easily accessible and interoperable. Geospatial information and its processing encompass GIS, remote sensing, surveying and mapping, navigation, location-based services, access to spatial databases, sensor web technologies, and other spatial technologies and information sources [29].

OGC has defined more than fifty standards. For the collection, modeling, storage, and visualization of cadastral data, the most relevant standards include: CityGML, Geography Markup Language (GML), Keyhole Markup Language (KML), LandInfra/InfraGML, GeoPackage, Web Feature Service (WFS), as well as the new generation of OGC API standards [30].

For 3D cadastral applications, CityGML and KML are particularly important, as they enable standardized exchange and storage of complex 3D models, while 3D Tiles and Indexed 3D Scene Layers (i3s) are increasingly used for efficient visualization and web-based distribution of 3D data.

In the development of OGC standards, CityGML 3.0 (conceptual model, 2021) holds particular significance for 3D cadastre. Its conceptual model is structured into 17 modules, with key enhancements compared to version 2.0 including the introduction of four new modules—Dynamizer, Versioning, PointCloud, and Construction—as well as revisions to the building and transportation modules. The architecture was redefined with the introduction of abstract classes Space and SpaceBoundary, separating object semantics from geometric type. Additionally, LoD were optimized to range from LoD 0 to 3, with the previous LoD 4 (interior details) integrated into the other levels, allowing a unified representation of both interior and exterior elements of a building [31].

3.1.2. ISO 19000

The International Organization for Standardization (ISO) is an independent, non-governmental international organization that brings together 175 national standardization bodies. Each body represents the leading standardization organization in its respective country, with only one member per country. ISO was founded in London in 1947 and initially comprised 67 technical committees. The first standard was published in 1951 as ISO/R 1:1951 – Standard Reference Temperature for Industrial Length Measurements. To date, ISO has published 26,201 standards covering all aspects of technology and industry [32].

ISO/TC 211 – Geographic Information/Geomatics is the technical committee responsible for digital geographic information. Its primary objective is to establish a set of standards related to objects and phenomena that are directly or indirectly associated with locations on Earth. These standards specify methods for processing, analyzing, accessing, representing, and exchanging spatial data at local, regional, and global levels. They also provide a framework for the development of applications related to geographic data. To date, 105 standards have been developed in this field [33].

Key standards for cadastre include ISO 19101 (2014) for interoperability concepts; ISO 19103 (2024) for conceptual schema language using Unified Modeling Language (UML); ISO 19107 (2019) for spatial data and operations; ISO 19108 (2002) for temporal characteristics; ISO 19109 (2025) for application schema rules; ISO 19111 (2019) for coordinate referencing; ISO 19115 (2014) for metadata; ISO 19136 (2020/2015) for GML; and ISO 19156 (2011) for observations and measurements. The ISO 19152 series (LADM) defines a data model for land administration, with Part 1 (2024) providing a generic conceptual model and Parts 2–5 (2025) extending it to land registration, marine georegulation, valuation, and spatial planning.

3.1.3. ISO 19152 Geographic information – Land Administration Domain Model

ISO 19152 defines a data model for land administration, known as the Land Administration Domain Model (LADM). This refers to LADM Edition I, which represents the original version of the standard with core concepts for 2D cadastre and the description of rights, responsibilities, and restrictions. LADM is a descriptive, not prescriptive standard, intended to describe existing systems rather than change them. The standard has two main objectives [34]:

- To prevent redundant data implementations by providing a core model that can be adapted for the needs of individual countries or regions.
- To enable system interoperability through the addition of attributes, classes, and operations according to national requirements.

When designing LADM, four key principles were followed: covering the most common land administration models, based on the Cadastre 2014 concept (FIG), creating a simple and practical model, and following the ISO/TC 211 conceptual model for geospatial data [35].

LADM covers the main components of land administration, including space above and below the ground, water areas, as well as rights, restrictions, and responsibilities. Core classes include [36]:

- LA_Party – individuals and organizations;
- LA_RRR – rights, restrictions, and responsibilities;
- LA_BAUnit – spatial units (parcels, parts of buildings, utility lines);
- LA_SpatialUnit – geometry and topology, including 2D representations.

For 3D cadastre purposes, the key class is LA_SpatialUnit, whose instances may be surfaces or volumes, described using text, points, lines, surfaces, or 3D volumes [36]. The subclass LA_LegalSpaceBuildingUnit relates to the legal aspects within buildings. LADM Edition I allows combining 2D and spatial representations and supports basic topological structures, while more advanced 3D and temporal concepts are not included in the original edition.

The temporal dimension in LADM Edition I is not integrated into the core model; it is treated separately through records of changes and transactions, limiting the ability to track historical and future changes in space.

In LADM Edition I, the temporal dimension is represented through two approaches [36], [37]:

- Event-based modeling – Transactions are modeled as separate entities with their own identifiers and attributes. Each event is represented as an instance in LA_Source, which allows reconstruction of the sequence of changes over time.
- Result-based modeling – Each object is assigned at least two timestamps, representing the period during which the object exists in the current version. This is implemented in the abstract class VersionedObject, which links changes throughout the history of all classes and subclasses, enabling temporal reconstruction of the database content.

The development of LADM has continued from 2012 to the present, with a revised version being developed between 2017 and 2025, where each part represents a separate international standard. The following types of standards exist [38]:

- ISO 19152-1:2024 Geographic information – Land Administration Domain Model (LADM) – Part 1: Generic conceptual model
- ISO 19152-2:2024 Geographic information – Land Administration Domain Model (LADM) – Part 2: Land registration
- ISO 19152-3:2024 Geographic information – Land Administration Domain Model (LADM) – Part 3: Marine georegulation
- ISO 19152-4:2024 Geographic information – Land Administration Domain Model (LADM) – Part 4: Valuation information
- ISO 19152-5:2024 Geographic information – Land Administration Domain Model (LADM) – Part 5: Spatial plan information

This model introduces a new term with a more detailed meaning: "georegulation," which is defined as the activity involving the determination of geographic spaces and the establishment of control over them through regulation [39].

The extended LADM is based on six main classes, all of which inherit from VersionedObject and are associated with LA_Source. The first four main classes – LA_Party, LA_RRR, LA_BAUnit, and LA_SpatialUnit – were described in ISO 19152:2012. Two new classes introduced in this version are: VM_ValuationUnit – valuation unit and SP_PlanUnit – plan unit [40].

The international standard ISO 19152-1:2024 in the context of land administration focuses on several aspects: provides terminology for land administration/georegulation, based on various national and international systems; allows the integration of land administration information from different sources in a coherent way; provides a content model that is independent of encoding; enables a common description of various formal and informal practices and procedures across different jurisdictions; provides a basis for national and regional profiles [41].

In LADM I, the class LA_SpatialUnit models basic spatial units (parcels), while in LADM II it is extended with new subclasses and more precise support for 3D legal spaces and specific elements (e.g., legal spaces in buildings and infrastructure), enabling more detailed and flexible modeling of complex spatial situations [42].

In LADM I, the Surveying and Representation subpackage contains only basic classes (LA_Point, LA_BoundaryFaceString, LA_BoundaryFace, and LA_SpatialSource), whereas in LADM II, it is extended with new classes for observation types and data sources (LA_SurveySource and LA_DesignSource), providing more detailed geodetic surveying models and linking them to data sources. LA_SurveySource is a subclass of LA_SpatialSource and represents data derived from surveying – e.g., finalized survey reports, measurement logs, field sketches, GNSS/TPS data, or other documents resulting from field measurements).LA_DesignSource is also a subclass of LA_SpatialSource, but represents data originating from design documentation, e.g., technical projects, plans, or BIM models – data not collected in the field but generated during the design process [42].

All classes from the six packages now inherit from VersionedObject, which means that [38]:

- Changes in valuation (land, building prices) can be versioned and tracked over time.
- Changes in spatial plans and planned parcels can be versioned and tracked historically.

Associations via LA_Party and LA_SpatialUnit allow versioning in new packages to be integrated with existing registers, so that changes in valuation and spatial plans can be linked with changes in cadastral units and rights.

LADM Edition II introduces a bi-temporal model that allows tracking of data across two temporal dimensions: system versioning and real-world time. Temporal attributes such as *beginRealWorldLifespanVersion*, *endRealWorldLifespanVersion*, and acceptance record changes in rights, ownership, valuation, and spatial plans as they occur in the real world, while versioning through VersionedObject tracks changes within the system itself [38], [40].

This integration of space and time creates a 4D cadastre, enabling historical tracking and planning in urban and infrastructure contexts. The first five parts of LADM Edition II have now been published as ISO standards [38], [40].

3.1.4. INfrastructure for SPatial InfoRmation in Europe (INSPIRE)

The Infrastructure for Spatial Information in Europe (INSPIRE) was developed in 2007 and has since been implemented in several versions. The primary objective of the INSPIRE Directive is to harmonize spatial data sets to ensure their use across applications throughout Europe. Achieving this goal requires the definition of core concepts for the 34 themes covered by INSPIRE. These themes are organized into three annexes. Annex I contains the foundational data themes from which other themes are derived. It includes: coordinate reference systems, geographic grid systems, geographic names, administrative units, cadastral parcels, addresses, transportation networks, hydrography, and protected sites. In contrast, the Buildings theme, which is key for 3D modeling, is defined in Annex III, with its own data specification. This specification, like that for parcels, was revised in line with the 2024 modernization process [43].

For each data theme, a specification defines a UML data model, which serves as the basis for defining national data profiles to ensure compliance with the INSPIRE Directive. According to the latest technical guidelines (2024), efforts are underway to simplify these models (simplified schemas) to facilitate practical implementation and migration to modern formats such as GeoJSON. It is also important to note that the previous Public Sector Information (PSI) Directive has been updated by the Open Data Directive (2019/1024), which identifies “high-value” datasets, among which geospatial data are critical for reuse in public and private sectors.

Although the initial specifications were defined in 2013 and 2014, INSPIRE is currently undergoing a modernization process) [44]. A key milestone was Implementing Regulation (EU) 2023/138 on high-value datasets, which mandates that member states make cadastral parcel and building data fully available for free, in machine-readable format, and via API services. Concurrently, technical implementation is evolving toward OGC API standards and simpler formats such as GeoJSON, overcoming the complexity of earlier GML/XML schemas and facilitating integration with modern systems like digital twins.

According to the Data Specification for Buildings (D2.8.I.6), buildings can be represented through basic or extended profiles, allowing 2D, 2.5D, or 3D representation. While INSPIRE initially relied on the four LoD from older CityGML versions, modern practice increasingly adopts CityGML 3.0, offering more flexible modeling and better separation of geometry and semantics [45].

The 3D building profile includes extensions for representing detailed building components such as walls, roofs, windows, doors, internal room layouts, and different textures based on materials.

To achieve full efficiency, ISO standards must be aligned with the INSPIRE Directive. Since LADM and INSPIRE have developed in parallel, a high degree of conceptual alignment has been achieved. However, differences remain: INSPIRE primarily focuses on environmental protection, while LADM is a multi-purpose system supporting legal security, taxation, and planning.

Today, with the development of LADM Edition II, this standard further extends INSPIRE’s capabilities, particularly in aligning ownership rights over 3D objects and integration with BIM technology, enabling more precise management of complex urban spaces that the initial INSPIRE profile did not fully encompass.

3.4. LEGAL FRAMEWORK FOR THE CADASTRE OF REAL ESTATE IN REPUBLIC OF SRPSKA

A high-quality legal framework enables sustainable land management and the regulation of changes occurring on it. Republic of Srpska has enacted a series of laws that define the procedures for managing and maintaining land. The cadastre of real estate, representing a unified registry of real estate and property rights, is regulated by the Law on Survey and Cadastre (“Official Gazette of Republic of Srpska”, Nos. 6/12, 110/16, 62/18, 90/23; hereinafter referred to as “the Law”) [2]. This law governs administrative and professional activities related to: surveying in Republic of Srpska, cadastre of real estate, cadastre of utilities, basic geodetic works, address registry, topographic-cartographic activities, the geoinformation system of the Republic administration for geodetic and property affairs, geospatial data infrastructure in Republic of Srpska, and geodetic works in engineering-technical fields.

From this Law, subordinate regulations (bylaws, regulations, decisions, and rulings) are derived.

3.5. ALIGMENT OF REPUBLIC OF SRPSKA WITH THE LADM STANDARD

The real estate cadastre model in Republic of Srpska has been developed in accordance with the ISO 19152:2012 (LADM) standard and extended with additional classes and attributes to comply with national legal regulations (Law on Survey and Cadastre). The existing relational data model was based on the standard cadastral concept [46].

The basic classes of the LADM model for the Republic of Srpska are illustrated in Table 2.

Table 2. Explanations of Core Classes[47]

Class Name	Description
LA_SpatialUnitGroup	RS_CadastralMunicipality, cadastral municipality
RS_Parcel	Parcels, derived from the cadastral municipality
RS_PartOfParcel	Part of a parcel; a parcel may consist of multiple land uses
RS_Building	Buildings
RS_PartOfBuilding	Part of a building
LA_Party	Individuals
RS_Owner	Organizations
LA_RRR	Rights, restrictions, and responsibilities
RS_OwnershipParcel	Rights over parcels
RS_OwnershipBuilding	Rights over buildings
RS_OwnershipPartOfBuilding	Rights over parts of buildings
LA_BAUnit	Encompasses all rights, restrictions, and responsibilities of one or more parties over a set of spatial units, such that the sum of ownership shares equals 1

The **Property Sheet** consists of four separate sheets, each designated by a different letter. **A Sheet** contains information about parcels, **B Sheet** contains data on ownership of parcels, **V Sheet** contains data on buildings and special parts of buildings, as well as ownership information, **G Sheet** contains information about encumbrances on spatial units defined in the A and V sheets.

The **G Sheet corresponds to the former C Sheet**, while the **V Sheet consolidates data from A1 and B1 Sheets**, which, according to the **Rulebook on Surveying and Cadastre**, is used in Republic of Srpska. Modeling of these sheets is implemented through the creation of **interfaces ASheet, BSheet, VSheet, and GSheet** respectively [48].

The **A Sheet** contains data on parcels and parts of parcels (different land uses within the same parcel). A parcel may consist of one or more parts, depending on whether multiple uses exist on its surface. Core parcel data include **parcel number, cadastral municipality, and property sheet number**. One property sheet may include multiple cadastral parcels within a single cadastral municipality. The **B Sheet** contains information on rights over parcels defined in the A Sheet. Rights are described by **type of right** (ownership, right of use, holder), **share in the right**, and **right-holder information** (name, organization, personal ID, registration number, address). The **V Sheet** contains data on buildings and special parts of buildings along with information on rights associated with them. Each building is identified by **parcel number, sub-parcel number, and building number**, while rights over the building are defined by **right-holder, type of right, and share in the right (fraction) (professor Lukić)**. The **G Sheet** contains information on **other real rights and restrictions** on real estate. In addition to identifying the property, it records the **type of restriction** (mortgage, easement, usufruct, etc.) and a textual description of the restriction [47]. In the Republic of Srpska, the LADM profile was delivered to the Geodetic Authority as part of the documentation for the development of a Cadastral Information Systems (CIS) [49].

The development of LADM-based country profiles in the region, specifically in Serbia, Montenegro, Croatia, and the Republic of Srpska, reflects a shared transition toward interoperable digital systems based on the ISO 19152 standard [50], [51], [52]. These countries face common historical challenges, such as the existence of multiple, often disconnected land records and registers, which lead to data redundancy and inconsistencies [46]. While Croatia, as an EU member state, focuses on integrating these records to align with the INSPIRE directive, its profile is specifically adapted to address issues like building legality and old cadastral surveys [53], [54], [55].This modernization, which also includes research by Radulović et al. on 3D utility cadastre, aims to overcome traditional administrative barriers and provide a solid foundation for managing complex spatial rights across the region [56].

4. RESULTS

The current Law on Survey and Cadastre in Republic of Srpska does not address the issue of a 3D Cadastre. However, the Law on Real Rights defines strata ownership, which regulates the legal aspects of buildings and their special parts. The outdated system, the problem of dual records, insufficient financial resources, and a lack of trained and qualified personnel are among the challenges faced by the Republic administration for geodetic and property affairs. Consequently, the implementation of a 3D Cadastre has not yet been prioritized as a primary issue requiring immediate solutions. The two-dimensional representation constitutes a limited structure that does not allow manipulation of the space above or below the ground surface.
In Figure 3, three objects in Derventa Municipality, Cadastral Municipality Derventa 1 are shown. On the left is the cadastral representation, and on the right is the actual condition. Parcels 892/2 and 1338/2 in reality do not intersect with object 1338/3, but are located above it. In the absence of a third dimension, this cannot be represented on the digital cadastral plan.

Figure 3. Cadastral parcel no. 1338/3 (created by author).

Another challenge concerns the representation of **infrastructure objects** located on roadways. For example, a **pedestrian overpass** in **Banja Luka, Cadastral Municipality Banja Luka 5** is not represented on the digital cadastral plan (Figure 4). The parcels on which the overpass is constructed are owned by the **City of Banja Luka – Land Fund**, while the portion of the overpass above the roadway is part of parcel **2486/1**, owned by the **Public and Unclassified Roads**, and is not represented on the digital plan.

Figure 4. Pedestrian bridge in the city of Banja Luka (created by author).

The passage, assigned for use by the **University of Banja Luka**, is not depicted on the plan. Figure 5 shows the location where the underground passage should be. On the digital cadastral plan, only the roadway **2251/4** above the passage is displayed, owned by the **Public and Unclassified Roads**, while the entrance and exit of the passage are part of parcels **1706** and **1623/4**, owned by **Akvana** and the **University of Banja Luka**. Relying solely on cadastral data would provide no indication of the passage's existence.

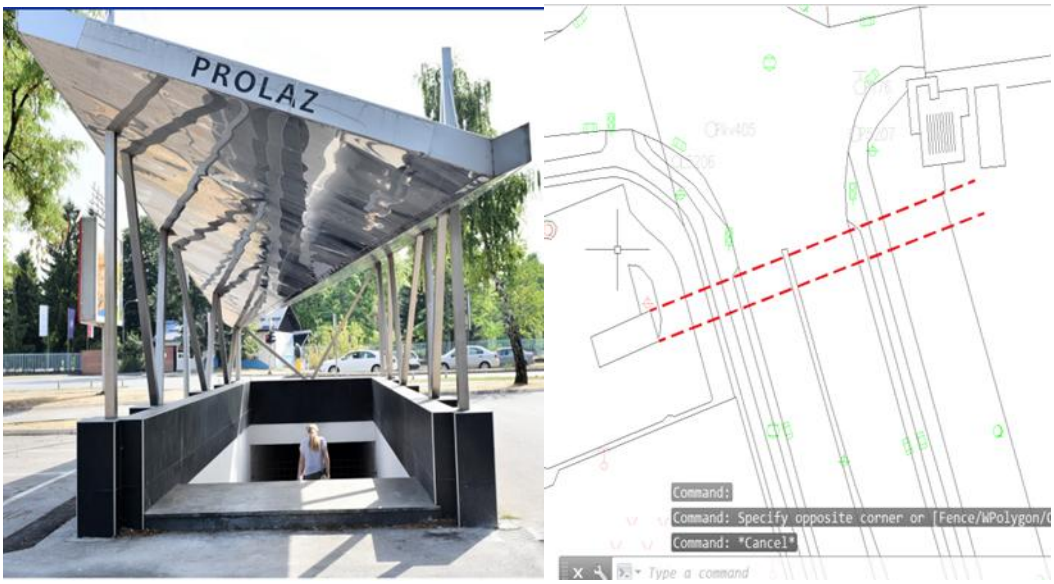

Figure 5. An underpass located beneath the surface of parcel 2251/4 (created by author).

Another example concerns parcel no. 1632/2, Cadastral Municipality Banja Luka 6, City of Banja Luka, which is owned by G.P. Krajina a.d. Banja Luka, with parts of the parcel registered as a construction site and garage. Commercial spaces located beneath the garage are not recorded in the cadastre and are not represented on the digital cadastral plan (Figure 6).

Figure 6. Cadastral parcel no. 1338/3 (created by author).

The development of a 3D Cadastre should be based on the ISO 19152 standard described in previous chapters, as it provides guidelines for the representation of 3D models and the registration of 3D rights. In Republic of Srpska, the process of forming a 2D cadastre is still ongoing; however, this should not prevent the inclusion of 3D data and 3D models in cases where it is feasible. Current technology enables the collection of 3D building data in CityGML format. Additionally, there are examples of using BIM for modeling objects applied in the cadastre. BIM and CityGML data can be linked to the basic model to generate 3D representations—for example, by creating a connection between the BHRS_Building class from the basic national model and AbstractBuilding from the CityGML conceptual model. The base model can also be extended with the BHRS_BoundaryFace class. This integration is further supported by the new LADM Edition II (ISO 19152:2024), which emphasizes interoperability between legal spaces and physical objects, ensuring that the

BHRS_BoundaryFace class accurately defines the spatial extent of 3D rights, even in complex urban environments.

The next dimension to consider is time. As previously emphasized, including time is essential for observing past changes and for predicting future situations. In the Cadastre of Republic of Srpska, all changes must be recorded with the date and time of modification to allow reconstruction of events regarding geometric representation, rights, and restrictions. Furthermore, most municipalities in Republic of Srpska now have digital plans, which can be overlaid with orthophotos from different periods to obtain data on spatial changes of real estate.

It is important to emphasize that any changes related to the formation of 3D and 4D Cadastre models must be accompanied by appropriate legal acts.

The main challenge lies in the integration of time and 3D information into a single 4D dataset, which would serve as the basis for forming a 4D Cadastre, as described in previous chapters. For instance, using a 4D Cadastre, it would be possible to obtain information about the extension of a building through a simple query.

5. CONCLUSION

The significance of developing a multi-dimensional cadastre for the growth and development of a country, its administrative system, public awareness, and adaptation to technological advancements is clearly demonstrated in this study. Despite the visible shortcomings in its current system, Republic of Srpska can be considered a strong candidate for achieving this goal.

An important step toward this objective is the introduction of standardization in the field of 3D cadastre, which would provide guidelines and facilitate work at the national level.

By observing examples from neighboring countries with similar cadastral systems that are actively developing technologies for the integration of 3D data models, it can be concluded that these approaches are also applicable in Republic of Srpska. Numerous researchers in neighboring Serbia and Croatia are working on the development of 3D cadastral models that could be implemented within existing systems.

On a global scale, many questions in this area remain unresolved. Issues such as the lack of harmonization among cadastral systems and the ongoing efforts to establish a unified, improved system applicable across multiple countries highlight the continuing challenges and opportunities in the development of multi-dimensional cadastral frameworks.

Ultimately, the transition toward a 4D cadastre in the Republic of Srpska should not be viewed merely as a technical upgrade, but as a strategic necessity. By aligning national legislation with the latest LADM Edition II standards and embracing interoperable formats like CityGML and BIM, the cadastre can evolve into a dynamic spatial infrastructure capable of supporting sustainable urban development and transparent land administration for future generations.

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