Survey Review

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/ysre20

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To cite this article: Mehmet Alkan, Hicret Gürsoy Sürmeneli & Zeynel Abidin Polat (2021) Design and development 3D RRR model for Turkish cadastral system using international standards, Survey Review, 53:379, 312-324, DOI: 10.1080/00396265.2020.1758386

To link to this article: https://doi.org/10.1080/00396265.2020.1758386

Published online: 12 May 2020.

Design and development 3D RRR model for Turkish cadastral system using international standards

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The concepts of three-dimensional cadastre (3D) and property ownership led to increased interest in land use management and research towards the end of the 90s. Within the scope of these studies, international standards and definitions have been realised. In Turkey, there are some academic studies available. However, there are not many studies conducted on an institutional basis. Turkey cadastre carried out by the General Directorate of Land Registry, and Cadastre (GDLRC) are kept. In this context, a 3D RRR (Right, Restriction and Responsibility) for Turkey-based cadastral data model design and development is essential in terms of not constitute a base for the study. The fact that these studies are in the context of LADM and ISO standards and OGC is very important in terms of the fact that the cadastral system is related to international standards.

Keywords: Land registry, 3D cadastre, 3D RRR, LADM, International standards, Land administration

1. Introduction

From the late 1990s onwards, 3D cadastral work has been continuing in scientific and institutional terms all over the world. These studies are carried out within the framework of international standards and in the context of cadastre 2014 and 2034 declarations (Stoter 2004, Aien 2013, Alkan *et al.* 2018). A lot of cadastral system attention because more and more situations occur for which standard 2D registration appears to be problematic. Although most legal systems provide the possibility to create property rights with 3D boundaries, the primary registration entity is mostly still a 2D parcel. For that reason, multi-level property situations are not projected on the plane, which cannot be used in the 3D data model and data schemas. Thus, within the scope of Cadastre 2034 vision, it was aimed to provide essential services expected from the cadastre such as knowing all rights, restrictions and responsibilities (RRR) related to the real estates with these components, access to property and positional content and to direct the future cadastre with the developed policies, models and standards (Stoter *et al.* 2004, Aien 2013).

Several studies on national and international 3D cadastral studies and developments have been carried out (Benhamu and Doytsher 2003, Onsrud 2003, Stoter and Ploeger 2003, Stoter and Salzmann 2003, Stoter and Van Oosterom 2005, Stoter and Van Oosterom 2006, Paulsson 2007, Döner *et al.* 2010, Eriksson and Janssan 2010, Karki *et al.* 2010, Pouliot *et al.* 2010, Aien *et al.* 2011, Döner *et al.* 2011, Guo *et al.* 2011, Rahman *et al.* 2011, Van Oosterom 2018). These studies have been performed a detailed analysis of various complex 3D right configurations and developed for several prototypes. Until now, 3D cadastral studies focused on studying the optimal legal, technical and cadastral frameworks for 3D cadastral data model and implementations.

In Turkey, cadastre comprises of two parts which are land registry and spatial information with update situation. The land registry that represents the legal relationship between people and real properties, and the spatial information (cadastral maps) that besides geometry data and annotations, contain land-use components visualised by topographic symbols with 2D (Döner *et al.* 2010, Alkan and Polat 2017, Polat *et al.* 2017). Land Registry and Cadastre in Turkey have encountered numerous problems in previous years, such as storing data in multiple places, data storage in analogue form, the discrepancy in records concerning the actual situation, poor performance of search and update of data, and lack of a standard format for data exchange. However, in this period, it has made significant progress by solving many of these problems. Especially in many places, analogue cadastral maps have been converted to digital form by General Directorate of Land Registry and Cadastre (GDLRC). Digital maps are provided in the shared database of the GDLRC. Also, the cadastral system and cadastral data have been improved with many projects. Initiatives projects are developed for providing integration to vision on the future of cadastres. These are namely, Turkey

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Received 14 July 2019; accepted 15 April 2020
DOI 10.1080/00396265.2020.1758386

National Spatial Data Infrastructure (TUCBS) and as an information system the Land Registry and Cadastre Information System (TAKBIS in Turkish) (Alkan *et al.* 2018, Gursoy Surmeneli and Alkan 2018). The target of TAKBIS project is to create the Turkish Land Registry and Cadastre Information System across the country. The title deeds and cadastre services will be conducted as standard and electronic way, and right, secure and updated data will be submitted to the Local Governments, the public institutions and organisations by analysing the title deed and cadastre services within the scope of the Geographical Information System (GIS) and the Land Information System (LIS) (GDLRC 2015, Polat and Alkan 2018). TUCBS is an e-government project aiming at establishing the infrastructure for Geographical Information System following the technological developments at the national level (Turkish National Geographic Information System-TUCBS). Besides being created a web portal by public institutions and organisations to provide the geographic information they are responsible for on a shared infrastructure, creating the content standards in the manner that geographic data can meet the needs of all user institutions and be determining the standards of geographic data interchange.

An official cadastre has not been developed to date due to legal differences. Such as technical and economic impossibilities in every country all over the world. Various categorisations and definitions have been made for the cadastre taking into consideration criteria such as priority purposes, types of registered rights, techniques used for collecting data (FIG 1995). However, the definitions of cadastre conflicts with existing surveying systems. For this reason, the physical world is four dimensions. These are horizontal (x), (y), vertical (z) and time (t) dimensions.

In Turkey, today's cadastral systems are defined as two-dimensional and parcel-based. It is not possible to accurately model the physical world with the existing cadastral systems today. Regarding reality in existing systems, it reveals the lack of height and time dimension (Alkan and Polat 2017, Gursoy Surmeneli and Alkan 2018). Due to limited land resources, above and under of the earth must be planned and managed together. Because of this, the need for cadastral data is increasing. As a result of this need, demand has emerged, which is a three and 4-dimensional cadastre that represents the real world. Institutions and academicians have intensively studied the concept of three-dimensional immovable property in the last decade (Stoter and Van Oosterom 2006, Van Oosterom *et al.* 2011, Paasch *et al.* 2013, Van Oosterom 2013, Paulsson and Paasch 2013, Kitsakis *et al.* 2016). As a result of the studies, different topics have come up within the context of 3D cadastre. These are listed in the five main headings in FIG publication (Van Oosterom 2018).

In this paper, our motivation is to design and develop 3D Right, Restriction and Responsibility (RRR) cadastral data model for Turkey based on the international standards with the Land Administration Domain Model (LADM) within ISO 19152. Also, to contribute to the development of the land registry with LADM. It is one of the components of TUCBS project. Furthermore, this paper presents a first stage basic model of the Turkey 3D cadastre to propose an international-based profile, which is the current cadastral registration and the corresponding legal requirements.

2. Methodology

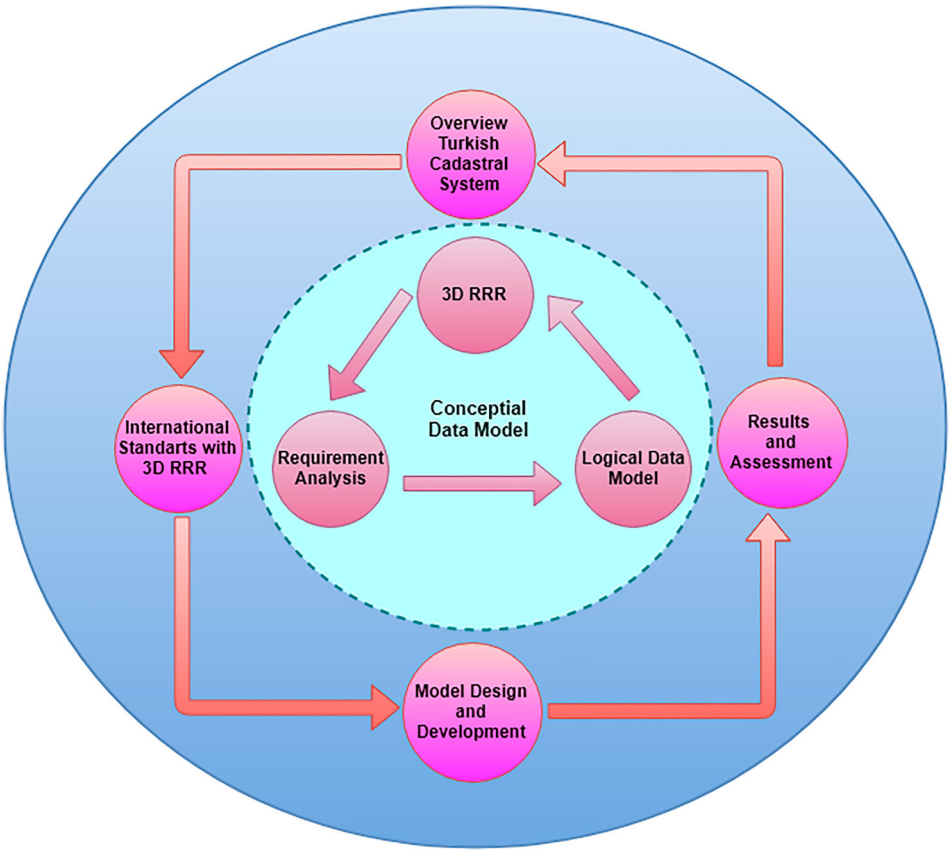
This paper explores how existing Turkish cadastral data models address 3D RRR problems and proposes a conceptual 3D cadastral data model as a solution capable of the 3D data that is integrating 3D RRR attributes with their corresponding 3D legal objects. The 3D RRR model represents 3D legal objects and connects legal and physical objects. In this regard, the 3D RRR data model is equipped with the concepts of the Turkish cadastral system database. The first facilitates the modelling of all existing interests as legal objects. In order to develop an experimental 3D RRR data model for Turkish cadastral systems, which is a methodology called design and development approach, as shown in Fig. 1. In the scope of the methodology, first of all, 3D RRRs in Turkish cadastral system were determined. In order to determine how the identified 3D RRR will be recorded in the cadastral system following international standards, the needs requirement analysis was conducted. Thus, the logical data model of the aimed model was created. As a result, the product, the conceptual data model, was developed based on LADM. Throughout this design approach, Unified Modeling Language (UML) diagrams, along with textual and graphical descriptions, were used for the representation of all activities, processes, classes, attributes and associations. The key to address this complexity, as well as a constant change in data. That is to work with standards and conceptual data models. The conceptual data models have been defined and identified in section four.

In this study, the first step of the Turkish 3D RRR cadastral system design approach was a review of existing standards, models and tools used in both disciplines with related International standards. The next steps are design and development 3D RRR based cadastral system for Turkey based on the requirement analysis and exploration of the discussion, conclusion and suggestion parts.

3. Turkish cadastral system based on 3D RRR data model design

Traditional cadastral systems have begun by dividing the land surface by two-dimensional (2D) boundaries. For this reason, 2D parcels constitute the basic unit in the current cadastral maps (Stoter 2002, Steudler 2004). Nowadays in Turkey, cadastre system based on 2D plots which are consists of two basic units, including land registration and cadastral mapping (Döner and Bıyık 2007, 2013, Gursoy Surmeneli and Alkan 2018). In this context, the land registry records are formed by the title deed and the registry directorate and the maps by the cadastral directorates and officially registered. A two-dimensional graphic representation of most rights and restrictions is possible. The rights and restrictions regarding the third dimension are recorded as textual (annotated to the title deed) however, although the presentation of the presentation is shown as right (e.g. right of passage) as a restriction (usually in large engineering projects: Metro route, pipelines, etc.) not shown in the cadastral maps (Öztürk 2007).

Although land parcels are represented as 2D, the use of parcels is volumetric. The use of 3D plots of volume parcels is provided by the real rights determined in the Civil Code. As a consequence, as stated by Döner *et al.* (2010), legally, the property is already three-dimensional (3D). However, in cadastre, the spatial registration of the



1 The methodology of the study

property is reduced to two dimensions. In time, the question of whether the traditional cadastral registration based on 2D parcels is sufficient to register all the conditions that emerged in the modern world (Rajabifard 2014) and the necessity of a 3D approach for the cadastre (Döner and Bıyık 2007, Döner *et al.* 2010).

Several studies have been conducted in academic and institutional level for 3D cadastre in Turkey. The studies conducted at the academic level are summarised below: Aydin (2008), 3D cadastre in terms of Turkey's have explored the integration of 3D geographic information system. In this context, typical applications are given for the problems experienced in the recording of underground and surface structures (such as underground markets, underground pedestrian roads, and car parks) as a 3D object.

Döner and Bıyık (2007) tried to describe 2D parcels in 3D studies by using elevation information. Thus, they argued that the integration of 3D objects such as tunnels, pipelines and cables with cadastral maps is possible. Aydin (2008), in his study, mentioned the problems of showing the underground spaces used for various purposes (e.g. parking lot, warehouse) in the cadastre in 3D. He proposed the use of a conceptual model with legal and technical details to solve these problems.

Gursoy Surmeneli and Alkan (2018) studies need to determine the scope and content of the three-dimensional cadastre that can be applied in Turkey and examining opportunities and constraints. In this context, they have carried out the current situation analysis in terms of legal, institutional and technical aspects. Bilgin (2015) mentioned the importance of 3-dimensional cadastre in the study. Coruhlu *et al.* (2015) examined the registration of the independent sections in the floor ownership register, within the scope of the 3D cadastral structure. In this context, they have benefited from a variety of existing applications and workflow schemes in order to examine the current registration procedure technically. Coruhlu *et al.* (2016) determine the property assets folded as 3-dimensional objects of cultural heritage in Turkey and examined the record to the log. The technical and legal situations necessary for the recording of these structures were determined, and explanations were made on various examples.

3D cadastral work under various institutional levels outside of the academic studies and projects are carried out in Turkey. These studies and projects are in the order of three-dimensional urban models and cadastre project, Turkish Land Registry and Cadastre Information System (TAKBIS in Turkish), Land Registry and Cadastre Modernization Project (TKMP in Turkish), Turkey's National Geographic Information System Project (TUCBS in Turkish). The characteristic feature of all these projects is to contribute to the TUCBS project in the context of National Spatial Data Infrastructure (UKVA in Turkish). TUCBS is an e-government project which is aiming at establishing the infrastructure for Geographical Information System. Also, TUCBS following the technological developments at the national level and being created a web portal by public institutions and organisations to provide geographic information. These are responsible for the common infrastructure, creating the content standards in the manner that geographic data can meet the needs of all user institutions and determining the standards of geographic data interchange. It was conducted under the responsibility of the General Directorate of Land Registry and Cadastre.

TUCBS Conceptual Model comprises of the principles and principles, reference model, scale-resolution and generalisation approaches, general detail model, detail catalogue, application scheme rules, geometry, topology, geographic object identification and temporal management, metadata, data quality and data sharing components. In this context, AD (Address), Building (Building), TK (Land Registry), IB (Administrative Unit), UL (Transportation), HI (Hydrography), AR (Land Cover) in the process of determining TUCBS standards based on conceptual model components UML implementation schemes, detail catalogs and GML based application schemes are produced in detail classes of OR (Orthophoto), TO (Topography) and JD (Geodesy). In determining the conceptual data models of TUCBS data themes, the basic schemes of ISO / TC211 standards and other internationally accepted INSPIRE initiatives are adopted (Aydinoglu and Bovkir 2017).

4. International studies with 3D RRR cadastre

In time, the question of whether the traditional cadastral registration based on 2D parcels is sufficient to register all the conditions that emerged in the modern world (Rajabifard 2014) and the necessity of a 3D approach for the cadastre (Döner and Bıyık 2007, Döner *et al.* 2010). Within this scope, studies have been carried out in FIG. In the Cadastre 2014 vision, which is one of these studies, it is recommended that the cadastre should be considered and registered in 3 dimensions by emphasising that the ideal cadastral system should show the entire legal status of the land including public rights, responsibilities and restrictions. Lemmen and Van Oosterom (2013) explain three specialisation classes of right, restriction and responsibility:

> A "right" is an action, activity or class of actions that a system participant may perform on or using an associated resource. Examples are ownership right, tenancy right, possession, customary right or an informal right. A "restriction" is a formal or informal entitlement to refrain from doing something; e.g. it is not allowed to build within 200 meters of a fuel station, or servitude or a mortgage as a restriction to the ownership right. A "responsibility" is a formal or informal obligation to do something; e.g. the responsibility to clean a ditch, to keep a snow-free pavement or to remove icicles from the roof during winter or to maintain a monument.

Land-use changes have occurred depending on the population. Since land is scarce, in many countries there has been a vertical use on land (above and below ground). Therefore, many countries have experienced problems with the registration of overlapping property units. In traditional cadastral systems, the property structure is formed by using 2-dimensional boundaries. Therefore, in many cadastral systems, the 2-dimensional cadastral parcel is the basic unit for registration. Therefore, cadastres had to develop solutions to register 3D property units and rights, restrictions and responsibilities on these units (Döner *et al.* 2010, Gursoy Surmeneli and Alkan 2018). Many countries conduct legal, institutional and technical studies in order to register 3D property units and create the required 3D cadastre.

Within the scope of the study, when the legal structures of some countries are analysed within the scope of 3D cadastre, there are regulations in Australia (Aien 2013) and Canada (Stoter and Van Oosterom 2006) which contain detailed explanations on how to measure and register a parcel in 3D. The Netherlands changed the Law on Civil Law and Cadastre in 2007, thus redefining the ownership of land and paved the way for the registration of 3D objects determined by the law independently from the parcel (Wakker *et al.* 2003). In the Netherlands and Switzerland, there is a separate Line cadastre for the recording of underground networks (Wakker *et al.* 2003, Steudler 2015). In Norway, the registration of underground structures is not mandatory and is made optional (Herdlevær 2018). In Switzerland, studies have been carried out to convert the existing cadastral database into a 3D state. For the Swiss Cadastre, a comprehensive plan covering the transition to 3D cadastre was prepared (Steudler 2015). Thus, it is seen that many legal regulations and practices have been made in the cadastral systems available for transition to 3D cadastre in many countries.

4.1. International standards

4.1.1. *Land administration domain model (LADM)*

The three-dimensional cadastre is a cadastre that provides information on the rights, responsibilities and restrictions on registration and not only on the parcel but also the 3D possessive units (Stoter 2004). In this context, the Basic Model of Land Administration constitutes a basic class in order to define the rights, responsibilities and constraints concerning the 3rd dimension of the real estate. With this class structure, the management of the rights, responsibilities and restrictions that may occur on the spatial unit will be ensured.

The main starting point of the LADM is to establish a common ontology for rights, responsibilities and restrictions affecting the land administration and its geometric components. Thus, it will enable communication between related parties within a country or between different countries (Van Oosterom *et al.* 2006, Lemmen *et al.* 2015). The LADM is developed in line with the Cadastre 2014 vision and complies with international ISO and OGC standards (Lemmen *et al.* 2009, 2011, Tjia and Coetzee 2013). Besides, it has been conducted in the studies showing the compatibility of LADM with INSPIRE (Alkan and Polat 2017).

LADM has three main packages and one sub-package. These are LA_Party (Party package), LA_AdministrativePackage (Management package) and LA_SpatialUnitPackage (Spatial Unit package) and LA_Surveying AndRepresentation (Fig. 2).

It also supports the time component of the Land Administration Basic Model. The most important feature of the model is a flexible model and can be expanded within specified standards. It is possible to associate with external classes such as Valuation, Address, and the Landcover as required by the model feature.

4.1.2. *Infrastructure for spatial information in Europe (INSPIRE)*

Infrastructure for Spatial Information in Europe (INSPIRE: Infrastructure for Spatial Information in the

European Community) is an initiative initiated by the European Commission in 2001 together with the member states of the European Union (Akıncı and Cömert 2009, Mataracı *et al.* 2009, Aydınoglu 2010). The formation aims to identify, evaluate, monitor and implement the European Union (EU) policies, and to define the general framework. Within the framework of determination of the framework, the harmonisation of the spatial data between the member states of the European Union and ensuring access to reliable and current spatial data is determined as the basic principle. In this context, the studies carried out in line with environmental policies, including agriculture, transportation and other sectors, at the local, regional and national level, facilitate the access of the citizens and the corporate environment to the spatial data.

The INSPIRE directives 34 include the spatial data theme. Data themes such as land registry, administrative unit, address, building, land cover, land use are examples of these data themes (EC 2007). The data structure of the cadastral plots is simple, extensible and flexible. In this case, data providers contribute to the most appropriate and practical publication of their data (Aydınoglu and Bovkir 2017).

According to Lemmmen *et al.* (2015), the focus of the LADM is on that part of land administration that is interested in rights, responsibilities and restrictions affecting land (or cadastral parcels), and the geometrical components thereof. On the other hand, cadastral parcels are part of Annex I of INSPIRE Directive are as a result of this considered as reference data (Psomadaki *et al.* 2016). The data specifications related to cadastral parcels in INSPIRE have been developed in parallel with LADM (Sladić *et al.* 2014, Lemmen *et al.* 2015). However, the data specifications related to cadastral parcels focus only on the geometrical scope of cadastral parcels while information about rights, restrictions and responsibilities are outside its scope (Psomadaki *et al.* 2016).

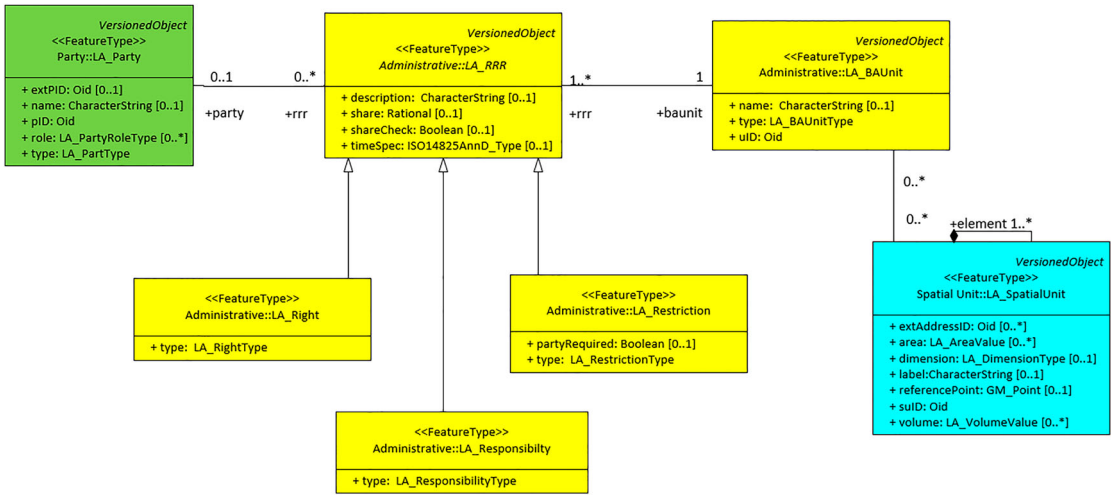
Turkey is a candidate country to join the EU. In terms of land management in order to ensure coordination between Turkey and the EU must take into account the INSPIRE directive. In this context, considering the INSPIRE standards, a national parcel based geographic database design is planned. The study conducted under the name of TUCBS aims to produce usable and interoperable geographic data models which use data themes such as Address, Building, Land Registry / Cadastre, Administrative Unit and Transportation (Coruhlu *et al.* 2015). Thus, LADM and INSPIRE standards-based Turkey model provided to be understood in the international platform.

4.1.3. *OGC standards*

OGC (Open Geospatial Consortium) is a non-profit industry association and consists of members working in order to ensure the interoperability of technologies within positional knowledge and to improve it (Ekin and Cabuk 2011). OGC conducts parallel works with ISO / TC211 committee. OGC within its structure, ISO / TC211 and data standards are similar and compatible (Aydınoglu 2010, OGC 2012, ISO/TC211 2012, Özçelik 2013) (Fig. 4). The vision of OGC is to provide a network, application or platform that can be used by anyone carrying out activities with geographical information or location information. Its mission is to make the spatial interface and technical coding standards available to all users (Ekin and Cabuk 2011). In line with its vision and mission, OGC produces direct sector-oriented standards for geographic information sharing and interoperability in different software and hardware platforms. ISO / TC 211 identifies high-level and non-direct data models for geographic information producers and users. In this context, the Geo-Marking Language (GML-Geography Markup Language) developed by OGC is a language that enables the modelling, storage and sharing of the geometry and attributes information of geographic objects according to the XML schema structure (Aydınoglu 2007).

The TUCBS data model aims to establish a common data standard that different users and sectors need to share. In this context, there should be a relationship between data groups and models in a different hierarchy. The institutional level is the lowest level of data. With this approach, TUCBS standards produced from the predictions of ISO, OGC and INSPIRE standards at international level; TAKBIS, KBIS etc. forms the basis for data exchange in applications in different sectors (NEN 2005, Aydınoglu and Yomralıoglu 2010, ÇŞB 2012).

According to the ISO 19109 Code of Practice Scheme accepted by OGC, implementation schemes for TUCBS data themes will be produced. The model designed in this study is associated with TUCBS cadastral



2 LADM core classes (Lemmen *et al.* 2015)

parcel themes. Therefore, the designed model is also related to OGC standards. ISO / TC211 Geographical Information standards and OGC standards play a leading role in the GIS sector (Figs. 3 and 4).

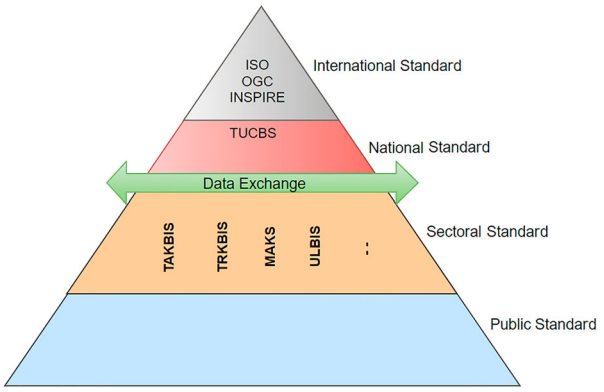
5. Design and development 3D RRR based cadastral system for Turkey

In Turkey, studies carried out so far within the scope of 3D cadastre (Alkan 2005, Ayazlı 2006, Öztürk 2007, Döner *et al.* 2010, Aydınoglu and Inan 2014) modelling of cadastral data to a certain standard and the necessity of representing the real world. The cadastral data registered in this context is significant for the modelling, analysis and questioning using international standards. Another common point of the study is the reshaping of the cadastral system within the framework of ISO 19152 Land Administration Basic Model (LADM), which is an international standard. This study aims to contribute to the TUCBS project by modelling the land rights, restrictions and responsibilities for the Turkish Cadastre System using the OGC, INSPIRE and ISO 19152, Land Administration Domain Model (LADM). Within this scope; the three-dimensional rights, responsibilities and restrictions which are a component of the Turkish cadastral system were analysed under ISO 19152, LADM. The data types and characteristics to be used within the scope of the model are determined.

5.1. Requirement analysis

The study was carried out using the following process steps.

1. Land management and cadastre system in Turkey was discussed. In the Turkish cadastral system, the rights defined in the Civil Code are represented with the 3rd dimension. International standards and literature review were conducted to determine the rights representing the 3rd dimension and how these rights were recorded in the title.
2. The subject of ISO 19152 Land Administration Basic Model (LADM), OGC and INSPIRE Cadastral Plots of data contact, which has an essential role in the land management system, has been examined. Based on the



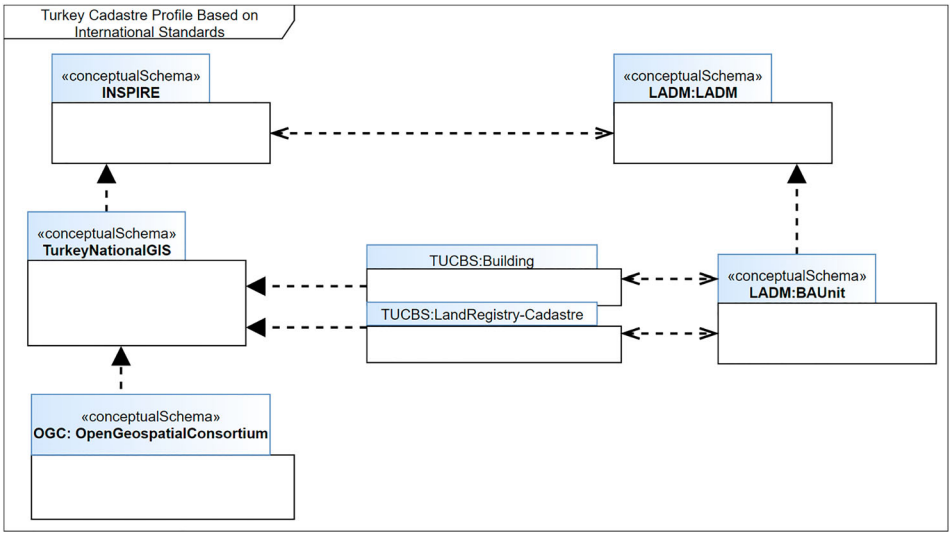
4 Data hierarchy between standards (ÇSB 2012)

LADM standards in developing 3D RRR data model, since the rights representing the dimension are best defined and accepted as an ISO standard in the land management system.

3. Afterwards, these data types and data dictionary were used (Table 1).
4. The attributes, which are determined under the Civil Law and representing the 3rd dimension, are classified under rights, restriction and responsibility classes (Table 2).
5. LADM used in Turkey from 3D rights, restrictions and responsibilities that represented a conceptual model design is made.

3D RRR data model design is designed to be compatible with the developed TUCBS projects in Turkey. The TUCBS data model is considered a primary /standard data model, allowing different users and sectors to share data with a common standard. TUCBS standards, which are produced according to ISO, OGC and INSPIRE standards at the international level, constitute the basis for data exchange of other projects. The model that we have developed for this purpose contributes to the representation of 3-dimensional rights, restrictions and responsibilities in line with the TUCBS project.

Table 1 shows the comparative representation of the data and classes to be used in the model based on LADM.



3 The general 3D RRR cadastre profile based on international standards for Turkey

Table 2 shows the attributes, data types, descriptions and attributes used in the model.

5.2. Overview of the database schema

The TR_RRR package is based on the LADM. TR_RRR is an abstract class in which the rights, restrictions and responsibilities set out in the Civil Code are represented to represent the 3rd dimension. The TR_RRR package has three sub-classes TR_Restriction, TR_Responsibility and TR_Right.

Figure 6 shows the TR_Right class. Freehold rights according to civil law, including applicable in Turkey and limited real rights are divided into two classes. The right to property: According to Article 35 of the Constitution of the Republic of Turkey; A limited right is the right that restricts the freeholder's right to property and provides one or both of the rights to use and access to goods. As such, the owner of the right provides direct control on the goods, but this control is not kept as broad as the property in terms of ownership, but it is divided into three subcategories, namely easement, mortgage and real estate. Information regarding the real estate that is mortgage is provided with the RealEstateID attribute. The information of the debtor and the creditor can be queried with the attributes PayerID and PayeeID. According to the civil law, the amount of mortgage that is not certain or can be changed, an individual mortgage degree is placed and maintains its order regardless of the changes that will occur after the registration. According to this statement, the attribute of the Degree and Sum are in the mortgage class.

The easement right is a type of right that gives the right holder the right to use and benefit from that real estate. The type of easement right can be one of the rights types specified in the RightType code list. Information about the real estate established in the easement can be queried with the RealEstateID, Share and Area attribute. The information of the real estate's owner can be determined by the PersonalID, the information of the person requesting the easement to be established by the RequestonerID attributes. General information about the right of the easement can be found in the description attribute. Since there may be no or more than one rights type related to a real estate, the relationship type 0 .. * (0-many) is determined (Figs. 5 and 6).

Figure 7 shows the TR_Restriction class. The TR_Restriction class consists of four subclasses. These are TR_RightAndLiability, TR_Mortgage, TR_Annotations, and TR_Representation. Thanks to this class, it is the class in which the restrictions on the real property are registered land registry, and the information is determined. The representations are recorded in the land registry with the subject which are a transaction, the page number of the land registry and the document number. The RealEstateID, Share and Area related to real estate are included in the TR_Representations class. The Representation CodeList shows that what types of representations might be. Since there may be no or more than one representation related to a real estate, the type of relationship is determined as 0 .. * (0-many).

The TR_Mortgage class is the class of information required for the collateral of immovable property for a possible debt. The class of annotation is the part of the disclosure of rights on an immovable. It is the class in the declaration class that contains information about any situation related to immovables. The mortgage is both a type of right and restriction. Some rights and restrictions may overlap such as the mortgage. If the mortgage expires, the information in the relevant line is overwritten, and the date and document number are written. As a mortgage can be established on a real estate, the type of relationship is selected as 0..1 (0-one).

TR_RightsAndLiability class is the section where the rights such as easement rights, usufruct rights, right of passage, and right of ownership are registered to the land registry (Alkan 2005). The attributes required for registration to the land registry (such as date, document number, transaction description) are defined in the classes. Type of Right and Liability are in the Restrictions CodeList. 0 .. * (0-many) relationship type is selected for Rights and Liability.

TR_Annotation class is the part of the restrictions for any real estate. The annotation process is registered in the area of the land registry as in the representations process. Annotation types can be listed in Annotation CodeList. Relationship type is defined as 0 .. * (0-many).

In Fig. 8, the TR_Representation class is represented. In this class that contains the attributes necessary for the fulfilment of responsibilities such as tax and maintenance on an immovable. There may be at least one or more types of responsibility on an immovable. Therefore, the relationship type is determined as 1 .. * (one to many).

6. Discussion

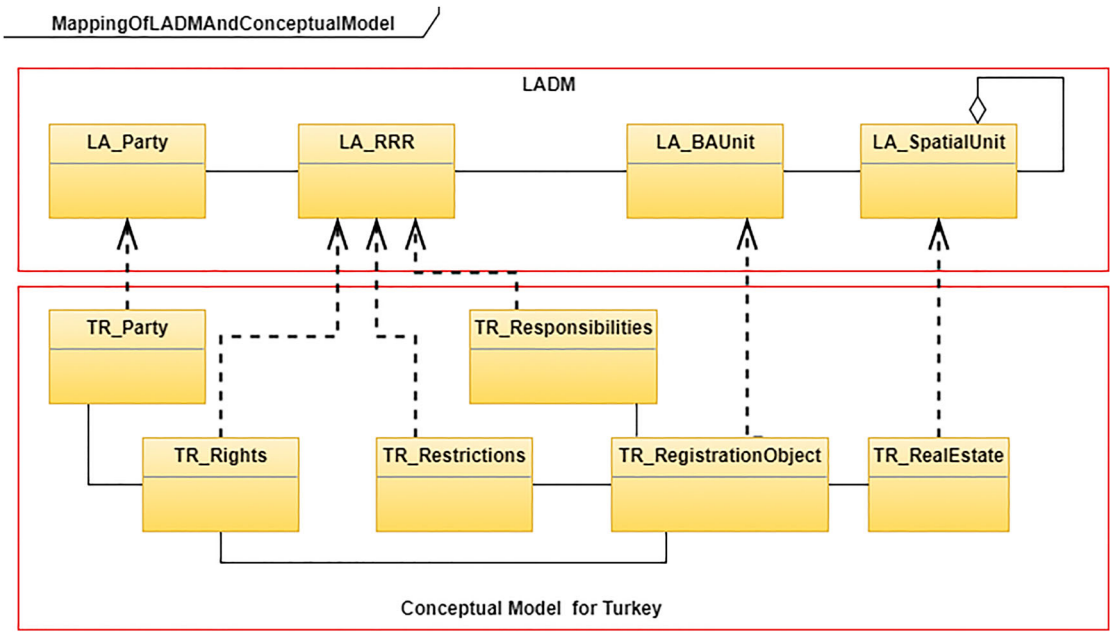
With the development of modern technology, the 2D cadastre no longer responds adequately to the property needs. In this context, international standards (LADM, cadastre

Table 1 Comparison of 3D RRR used in Turkish land registration system with LADM

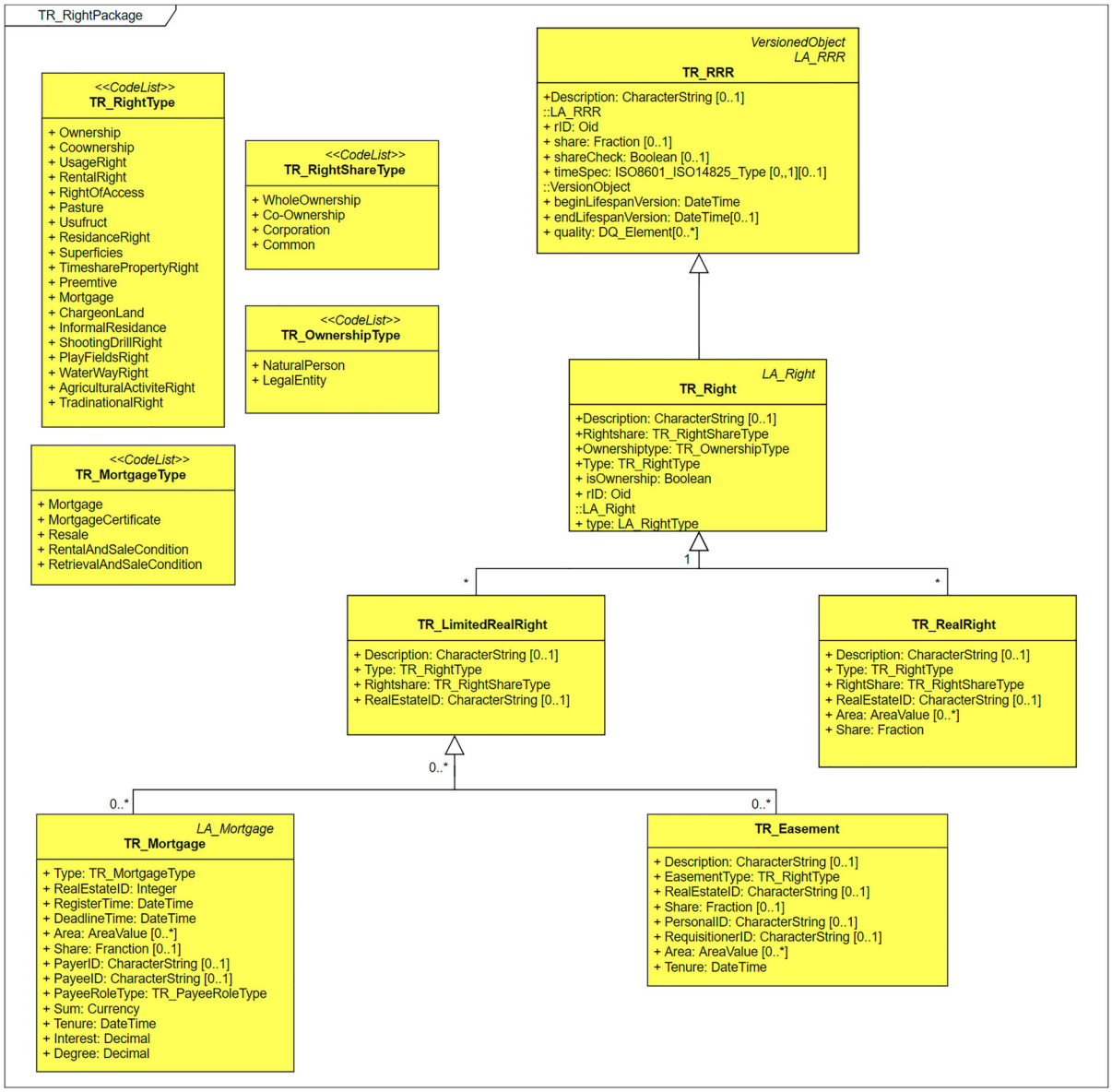
Turkey conceptual data model	LADM	Turkey profile class
Undefined	LA_RRR	TR_RRR
Right	LA_Right	TR_Right
LimitedRealRight	LA_Right	TR_LimitedRealRight
RealRight	LA_Right	TR_RealRight
Mortgage	LA_Mortgage	TR_Mortgage
Easement	LA_Right	TR_Easement
RightofLandChanges	LA_Right	TR_RightofLandChanges
Restriction	LA_Restriction	TR_Restriction
RightAndLiability	LA_Restriction	TR_RightAndLiability
Annotations	LA_Restriction	TR_Annotations
Representation	LA_Restriction	TR_Representation
Responsibility	LA_Responsibility	TR_Responsibility

Table 2 3D RRR modelling of the data used in the Turkish land registry system detail

Attribute	Detail	Class	Value type
Type	Specifies the RRR use on the real estate	Right, Restriction and sub-classes, Responsibility	RightType, RestrictionType, MortgageType, AnnotationType, RepserentationType, RightShareType, OwnershipType, ResponsibilityType
RealEstate	Specifies an identifier to the real estate	Right, Restriction and sub-classes, Responsibility	ID
Description	A description of the RRR	Right, Restriction and sub-classes, Responsibility	CharacterString
RegisterTime	Specifies the date of the transaction	Right, Restriction and sub-classes, Responsibility	DateTime
DeadLineTime	Specifies the deadline of the transaction	Right, Restriction and sub-classes, Responsibility	DateTime
DocumentNumber	Specifies the page number in the daybook in which the transaction was registered	RightAndLiability, Mortgage, Annotations, Representation	Integer
ClaimantName	The name of the claimant	RightAndLiability, Mortgage, Annotations, Representation	CharacterString
ClaimantSurname	The surname of the claimant	RightAndLiability, Mortgage, Annotations, Representation	CharacterString
ClaimantVillage	Claimant's villige	RightAndLiability, Mortgage, Annotations, Representation	CharacterString
Payer	People with debts on real estate	Mortgage	ID
Payee	Payment to the person	Mortgage	ID
Sum	Total dept	Mortgage	Currency
Tenure	Payment period	Mortgage	DateTime
LandRegisterPage Number	Specifies the land registry page number of relevent procedure on the title	RightAndLiability, Mortgage, Annotations, Representation	CharacterString
Detail	Subject of the procedure	RightAndLiability, Mortgage, Annotations, Representation	CharacterString
Rightshare	Specifies the share type of right	Right	RightShareType
Area	The area of used RRR on real estate	Right, Restriction and sub-classes, Responsibility	AreaValue
Ownershiptype	Specifies the ownership type	Right	OwnershipType
NumberOfPapers	Specifies the number of transactions	RightAndLiability, Mortgage, Annotations, Representation	Integer



5 Turkish conceptual model based on the LADM database schema



6 TR_Right class

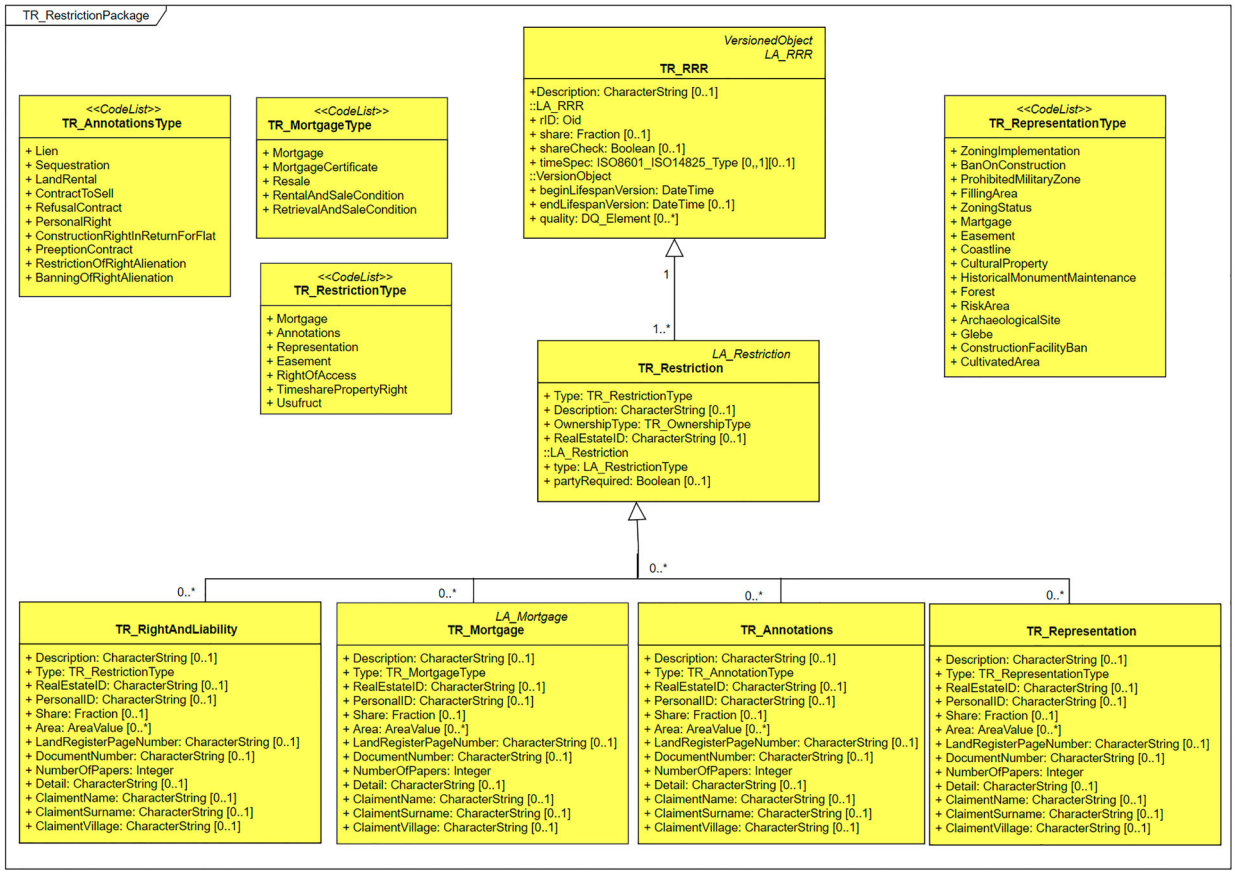
2014 and 2034 vision) have been defined in order to develop 3D cadastre. In line with these standards, many studies have been carried out in many countries. It is observed that in the context of an insufficient number of scientific studies on 3D cadastre in Turkey. When our study examines it, these studies are considered to be insufficient new cadastral models based on international standards for Turkey. In the institutional context, there is no adequate study of the 3D Cadastre made by GDLRC. Also, TUCBS studies conducted by the Ministry of Environment and Urbanization General Directorate of Geographical Information Systems do not yet have a data structure and model study in the context of 3D cadastre. Currently, the studies on the standardisation and improvement of the existing cadastral system are continuing.

The main objective of this study is to contribute to the country profile of the 3D cadastre by matching the title of the land registry module with the LADM, which is a submodule of the TUCBS data theme. The existing land registration system in turkey was discussed in the study. 3D rights, restrictions and responsibilities following the legal regulations in the title system have been determined with which attributes. After determining the required data and data types, 3D rights, restriction and responsibilities are modelled according to international standards based on LADM.

TUCBS is currently accepted and validated for INSPIRE data themes has been initiated for all European countries. These projects were designed as a comprehensive model that includes primary and thematic geographic data themes that meet user requirements for various sectors. In this perspective, it is assumed that the needs of TUCBS.TK (TUCBS Land Registry) cadastre data contact expropriation, real estate valuation, taxation, land consolidation, agriculture and forestry can be used together with the land registry data model and other geographic data themes.

7. Conclusion

ISO 19152 LADM is an important step in terms of standardisation and communication of cadastre and land management systems. With the use of OGC and



7 TR_Restriction class

INSPIRE standards, which are based on positional data management as well as ISO standards, the management of temporal data and 3D data/rights/boundaries will be significantly facilitated. In this study, it is assumed that LADM and INSPIRE cadastral parcels are considered as a suitable template for analysing data requirements and international standards to design a model that will meet the requirements in the land registry and cadastre data. The data model is compatible with the data content of INSPIRE cadastral parcels, including the geographical part of the cadastral data. Within the scope of the study, RRR package, classes, subclasses, properties, relations and methodology of LADM model elements were analysed and adapted to our model. However, only exceptional and specific elements for the Turkish land administration system are presented as a significant contribution to the LADM. In this context, different types of RRRs are added to the LADM for Turkey.

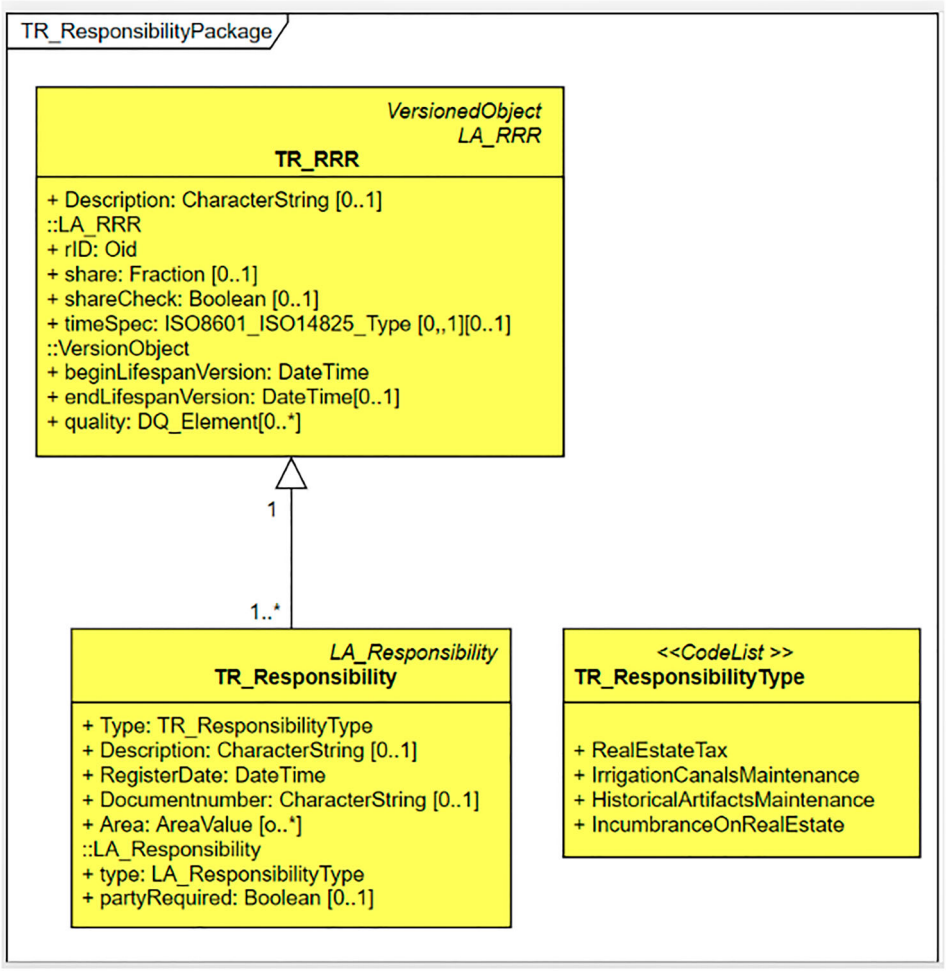
The operation flow is as follows. In the first place, the Turkish cadastral system was analysed and how the right/restriction/responsibilities representing the 3D were represented in the land registry system were analysed. In the second step, data and data types set up following INSPIRE and LADM standards. In the 3rd step, the data model was developed to be compatible with TUCBS.TK and LADM. Finally, UML drawings of RRR's packages were made following LADM.

The advantages and disadvantages of this study can be listed as follows. Firstly, to be held in Turkey in the future will contribute to academic studies related to 3D cadastre. Secondly, it will contribute to the cadastral studies which are carried out institutionally (such as TUCBS). International contributions are the introduction of the national profile of the Turkish cadastral system in the process of 3D cadastral transformation. Besides, different RRRs in the Turkish cadastral system are presented as a contribution to the LADM. The disadvantages are that the study remains only as a conceptual model.

As a result, three-dimensional representation RRR based on LADM a conceptual model design that was made. Thus, it is determined that the existing Turkish cadastral system and data organisation are compatible with a data model based on LADM. Besides, the model is designed to be compatible with the developed TUCBS projects in Turkey. It will accelerate the establishment of spatial data infrastructure in Turkey by the designed model are improved. Thus, a controlled and rapid transition to information systems will be provided. At the same time, the use of LADM will not only provide interoperability but will also provide an international experience to provide better service to both end-users and the enterprise, provide timely, more accurate data that is not valid for the current system.

8. Suggestions

This paper is deal with the development of a conceptual data model that deals with the registration and management of 3D objects and RRRs related to cadastre system. The current registration system does not store geometry and attributes of RRRs on 3D real property in a single system whereas there is an excellent opportunity to adopt LADM basic classes in enhancing registration and visualisation of real property and RRRs. For that



8 TR_Representation class

reason, the conceptual data model for the management of 3D RRRs in the cadastral system is proposed. The model was built based on a simple implementation of LADM basic classes by conforming to the national law on title deed for 3D RRRs related to cadastral registration systems. However, considering the scope of 3D RRRs evolution framework, it needs to be enhanced by the following:

- Introduction of 3D-based Public Law Regulations,
- Revision of cadastral survey and record procedures,
- Data recording to include 3D characteristics of real property,
- Moreover, 3D visualisation of RRRs on real estate as well as the transition of current 2D real property to 3D.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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