Initial Design of an LADM-based 3D Cadastre –Case Study from Korea

Dong-Hoon JEONG, Bong-Bae JANG, Ji-Yeong LEE, So-Il HONG, Republic of Korea, Peter VAN OOSTEROM, Kees DE ZEEUW, Jantien STOTER, Christiaan LEMMEN and Jaap ZEVENBERGEN, The Netherlands

Key words: 3D Cadastre, LADM, Korea, Standards, cadastral modeling

SUMMARY

Korea and The Netherlands have started a 3 year cooperation covering joint research, capacity building and international advisory in the domain of cadastre and land administration with a special focus on 3D developments. At the Korean side the Korea Cadastral Survey Corporation and the University of Seoul are involved, while at the Netherlands side the Kadaster, Delft University of Technology, and the University of Twente (ITC) are involved. These partners have been active during the last decade in a range of cadastre, 3D GIS, and related investigations, pilots, tests, etc.

The Republic of Korea has also formulated a policy of a 3D NSDI (National Spatial Data Infrastructure), which forms the context for further cadastre developments. Similarly, in the last two to three years in the Netherlands a national 3D pilot has been conducted resulting among others in the inclusion of 3D in model of the BGT (base register for large scale topography). These are excellent environments to design 3D cadastral solutions as the 3D cadastral parcels (3D legal spaces) are often related to (planned) physical objects; such as buildings, tunnels, pipelines and other constructions. For reference (and consistency) purposes the 3D legal objects and their 3D physical counterparts should be associated. This implies at least two aspects: 1. the 3D physical object descriptions (topographic objects) should exists, which is not obvious as in most countries the large scale topographic base map is still 2D, and 2. the topographic objects should be usable and reference-able even when the data is maintained by other organizations. The Land Administration Domain Model (LADM, ISO 19152) supports SDI implementations as the information infrastructure requires in the model (and the system that maintains data within the model): unique id's for all objects, full database history (versioning), and blueprints of external classes. This besides the fact the standard provides the semantics of land administration data to other users within the SDI.

After completing the first step the Korean 3D Cadastre Pilot Project, with focus on describing use cases and collecting 3D data for selected cases to populate the prototype systems to gain experience and support, the second step must now further provide a 3D cadastre application model (together with a legal and systemic alignment strategy). In the context of the reform of the Korean cadastre we (further) investigate the potential use of the ISO LADM standard, for both 2D and 3D representation. This paper presents our plans for the design of an LADM-based 3D extension to the cadastral registration in Korea. Note that in Annex D9 of the ISO LADM, 2012, there is already a very first version of a Korean country profile.

Initial Design of an LADM-based 3D Cadastre – Case Study from Korea

Dong-Hoon JEONG, Bong-Bae JANG, Ji-Yeong LEE, So-Il HONG, Republic of Korea, Peter VAN OOSTEROM, Kees DE ZEEUW, Jantien STOTER, Christiaan LEMMEN and Jaap ZEVENBERGEN, The Netherlands

1. INTRODUCTION

The 3D cadastre system in Korea is under development with the overall aim of implementing comprehensive land administration and management practices including management of resources on the surface and above ground as well as below ground at the national level. The increasing value of land and development of architecture- and construction-related technology has led to a growing demand for multi-dimensional land use methods.

The Cadastre Reform Project started in this year in Korea. This comprehensive reform includes the implementation of a 3D cadastre and a review of the approach for registration for the underground space and facilities (Lemmen, 2012). The 3D cadastre will be implemented nation-wide. Since 2009, the Korean Cadastral Survey Corporation (KCSC) has carried out research projects involving 8 different regions in Seoul (Jeong et al, 2011). Using multidimensional cadastral land survey data, these projects succeeded in registering the 3D dimensions of these property areas in the cadastral system. In 2011 KCSC completed a pilot project related to the establishment of an underground mall in close cooperation with the Seoul metropolitan government (Seoul Government, 2009, 2011a and 2011b).

A co-operation between Korea and The Netherlands started in April 2012 in Amsterdam with the signing of a Memorandum of Understanding for sharing knowledge and experience in cadastre and the land administration domain. At the Korean side the Korea Cadastral Survey Corporation (KCSC) and the University of Seoul, Department of Geo-informatics are involved, while at the Netherlands side the Kadaster, Delft University of Technology, and the University of Twente (ITC) are involved. A joint research and development (R&D) project related to the realization of 3D cadastre is the main focus of this international co-operation. Further main activities are organizing events, and capability building to support the application of appropriate information and data communication technology, GIS and remote sensing with regard to input and output of land related information and 3D cadastral systems.

The Land Administration Domain Model (LADM) is in stage of final approval and is expected to be available by the end of 2012. The development of the standard started in 2008 with the submission of a New Working Item Proposal by the International Federation of Surveyors (FIG) to ISO TC211 on Geographic information/Geomatics. The development of a 3D cadastre can be based on the conceptual model of the LADM.

In this paper, we wish to seek the 3D cadastre implementation direction that aligns the implementation of this international standard with the results of research and the pilot projects in Korea. In section 2 the National Spatial Data Infrastructure (SDI) of Korea is briefly introduced. And the status of legal development and the institutional improvement to achieve a 3D cadastre is discussed in this section. Section 3 introduces the Land Administration Domain Model, with a focus on 3D cadastral functionality and requirement related to working within an information infrastructure (or to be more specific an SDI). Section 4 proposes alignment between LADM and the development of a 3D cadastre in Korea based on the experiences and functional requirements derived from the comprehensive pilot project. The paper ends with conclusions.

2. CURRENT STATUS OF THE 3D CADASTRE IN KOREA

2.1 Cadastre in the Spatial Data Infrastructure (SDI)

Article 12 of the Korean National Spatial Data Infrastructure Law describes the SDI management. According to this Article, the Minister of Land, Transport and Maritime Affairs is in charge for selecting the SDI components and for the construction of databases for utilization in society. The current SDI datasets consist of coastlines, administrative boundaries, road and railroad boundaries, river boundaries, cadastre, buildings, aerial photographs, a Digital Elevation Model (DEM) and Geodetic Control Points (GCPs).

The Korean government is building the SDI since 2001 and integrating the information scattered over many organizations. Spatial datasets for preservation purposes, with data on forest, national cultural heritage (most famous Korean temples, statues and national treasures), coast information, etc., are under construction. Further, the government plans to maximize the utilization of the National Spatial Information Integrated System (NSIIS) through development and dissemination of applications. The NSIIS provides the spatial information in the form of an OpenAPI rather than raw data, and also supports mash-up and mobile services. Figure 1 shows how the Korea Land Information System (KLIS) is connected to the NSIIS. Venture companies which develop mobile applications by utilizing the OpenAPI are able to generate new businesses at a lower cost.

The government is embedding various types of spatial information (including SDI) into the National Spatial Information Open Platform (NSIOP) to service via the 3D Web environment named Vworld (see Figure 2). A pilot version of the NSIOP service was launched in January 2012, and seamless cadastral maps and zoning districts with national coverage are accessible since July 2012. Other 2D data concern data on infrastructure such as roads, water, telecommunications, electricity, drawings, use districts, forest areas, river basins, spatial planning, environmental impact assessment, and land cover classification. Recently created are the 3D data like 3D geo-referenced images, topography (DEM), and building models (see Figure 2). The yellow line in this figure is the ‘2D cadastral boundary’; the representation of those boundaries will be changed to 3D in the near future.

2.2 Results of the3D cadastre pilot project

As an output of the pilot project (Jeong et al, 2011; Seoul Government, 2009, 2011a and 2011b), the Seoul government has delivered the ‘Task guideline for the condominium leasehold right’, which has been implemented in this year. The objective of this guideline is to clarify ownership- and use rights for a systematic and efficient management of the underground public facilities–based on accurate surveying of their 3D location. This guideline urges to fill in the registration form as shown in Figure 3 with location map, detailed drawing, cross-sectional view and stereoscopic view when establishing condominium leasehold right. Until last year, there were no appropriate criteria about reference frame or authorities to manage this kind of rights. Different organizations used different types of drawings to establish condominium leasehold right. And for the underground space, Seoul government made a 'underground space registration form' and recommends it to affiliated organizations such as the Subway Corporation and urban developers to use it.

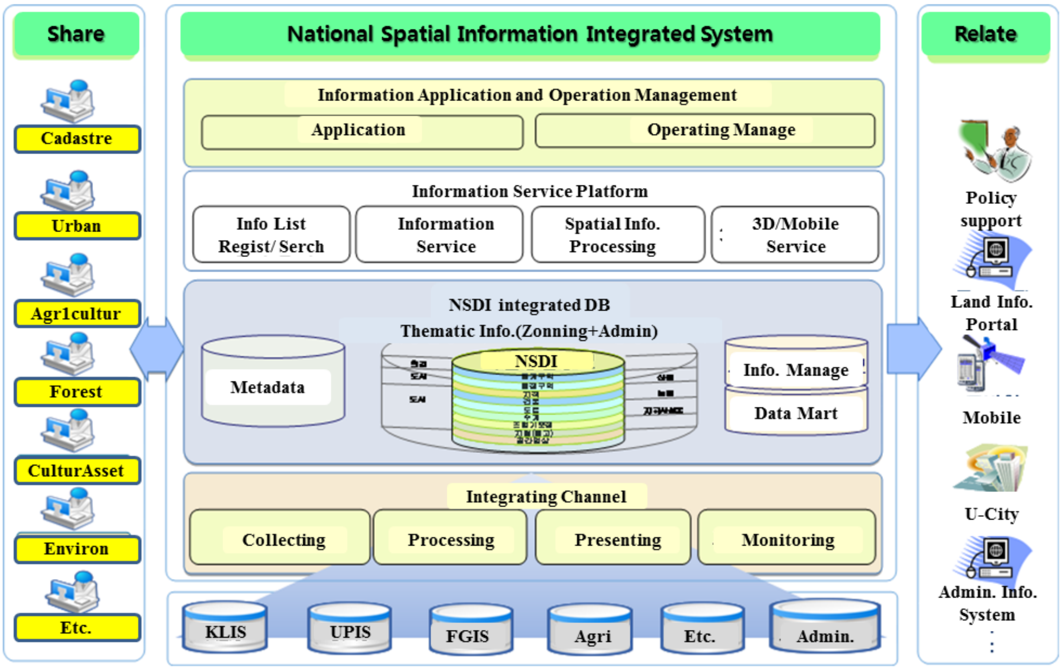


Figure 1. Functionality of National Spatial Information Integrated System of Korea

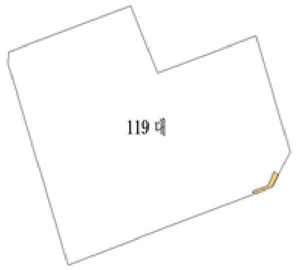
Figure 2. 3D Web service of the National Spatial Information Open Platform named “Vworld”

<앞면>

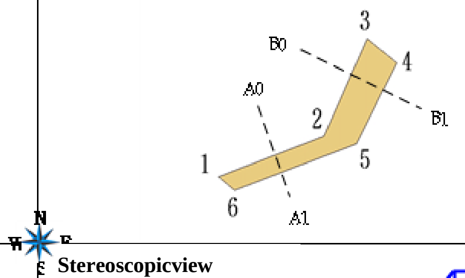
ID	11680-10800-1-0119-0000	구분지상권 도면(개별)			Use	대	번호	1
Addres	서울특별시 강남구 논현동	Parcel No.	119		Area	2986.9㎡	장번호	2

Purpose	Setup Area		Setup Scope				Period	지료	지급 방법	ManageOrg._
	평면(㎡)	입체(㎡)	방위	기준	상	하				
연결통로	7.77	59.28	남동측	평균해수면	49.1	41.5	도시철도시설물 존속시까지	무상		토지소유자, 도시철도공사

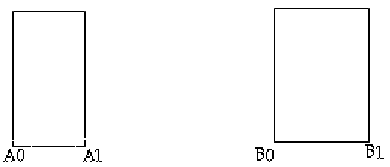
Location map



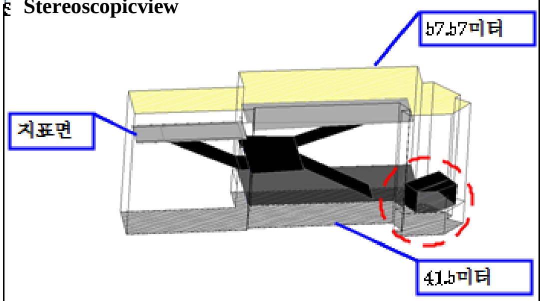
Detaieddrawing



Sectionalview



Stereoscopicview



<뒷면>

Point No.	Coordinate						
	부 호	1	2	3	4	5	6
	X	54642673	546428.25	546431.92	54643102	546427.97	54642621
	Y	20362125	203625.20	203626.81	203627.91	203626.40	20362186
	Z 상	49.1	49.1	49.1	49.1	49.1	49.1
	Z 하	41.5	41.5	41.5	41.5	41.5	41.5
	부 호						
	X						
	Y						
	Z 상						
	Z 하						
	부 호						
	X						
	Y						
	Z 상						
	Z 하						

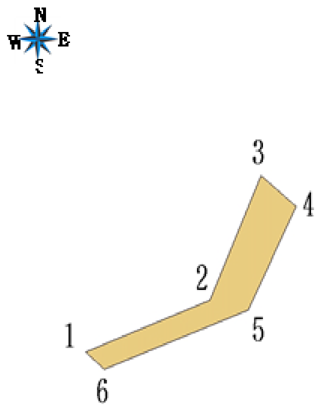


Figure 3. Condominium leasehold right registration form

With this guideline, Seoul Government expects to manage underground shopping centers more efficiently. The registration form is composed of a general section to state items for the whole shopping center and individual sections with items for each shop. Seoul added the underground shopping center information collected from the Uljiro Station during the pilot project to the 'Real Estate Portal of Seoul' (http://land.seoul.go.kr) shown in Figures 4 and 5, with attributes like address, name, toilets, exit gate number etc.

Figure 4. Underground shopping center in the Real Estate Portal of Seoul

Figure 5. Information of each shop in the Real Estate Portal of Seoul

Newly developed products through the pilot project such as the 'Condominium leasehold right registration form' and the '3D cadastral surveying workers manual' are recommended to be applied to the nationwide cadastre reform project based on the Cadastre Reform Project Law.

2.3 In the context of the Cadastral Reform Project Law

The cadastre reform project is a long-term national project which will run until the year 2030 and will involve approximately 38 million land parcels being resurveyed. The project will comprise three different approaches. Firstly, in areas with frequent boundary complaints and disputes between neighbors, KCSC will readjust the boundaries in their entirety through cadastral resurvey. This accounts for 15% of all land parcels. The second approach concerns 13% of all land parcels, namely those undergoing urban development or rural redevelopment: existing cadastral data associated with the area will gradually be improved by creating new cadastral maps after completion of the project. This is called 'cadastral confirmation surveying'. Lastly, the remaining 72% of land parcels will gradually be surveyed by superimposing cadastral maps and high-resolution aerial photographs so that the maps can be matched with ground boundaries based on the global coordinates system. This is a conversion from the Tokyo Coordinate System to the International Terrain Reference Frame (ITRF).

3D spatial data will be constructed as a part of the reform project aiming at the establishment of the Korean 3D cadastre. New cadastral registration items are defined in the enforcing rules (No.14, Article 13) of the Cadastral Reform Project Law. According to the rules, a person who is in charge of registration could record a condominium leasehold right of a parcel. Then it can be displayed with constructions laying above/underground in 3D and combined with the status of the rights. According to Article 10 of the law, the collection of parcel information (i.e. items of the new cadastre registration book) could be conducted in parallel to the cadastral resurvey. Article 4 of the enforcing rules defines the 'formation sheet to collect parcel information'. In this sheet, the relevant part for the establishment of 3D cadastre is the 'status of underground facility', with a set of attributes: the related parcel number, facility name, condominium leasehold right (purpose, area, scope, period), classification (railway, managing facility, connection path, shop, permission), etc.

When this comprehensive land administration, including management of resources on the surface, above and below ground at national level, is available, it is expected that KCSC is even better able to take advantage of this comprehensive set of information on land, for example to minimize land boundary disputes. Standardization for the registration of facilities installed in 3D space is required as part of the reform such as official surveying method of underground constructions and the establishment of condominium leasehold right.

3. 3D CADASTRE ASPECTS IN THE LADM

In the context of cadastral reform Korea wants to examine in which way the LADM and its basic classes spatial unit, party, *RRR* (right, restriction and responsibility) and basic administrative unit (ISO, 2012) can be implemented. In this chapter the focus is on the spatial unit package and the surveying and representation package of LADM; this is where the 3D aspects in LADM occur; see ISO (2012). Further, specific attention is paid to aspects relevant for information infrastructure (or NSDI) based implementation in LADM; this is a very important aspect for Korea. In case of 3D parcels, there is in many cases a natural tendency to relate this 3D cadastral object to the 3D real world object (or planned object); e.g. building complex, tunnel, pipeline, etc. The 3D NSDI of Korea is providing an excellent framework to realize this referencing between 3D cadastral and 3D real-world (topographic) objects.

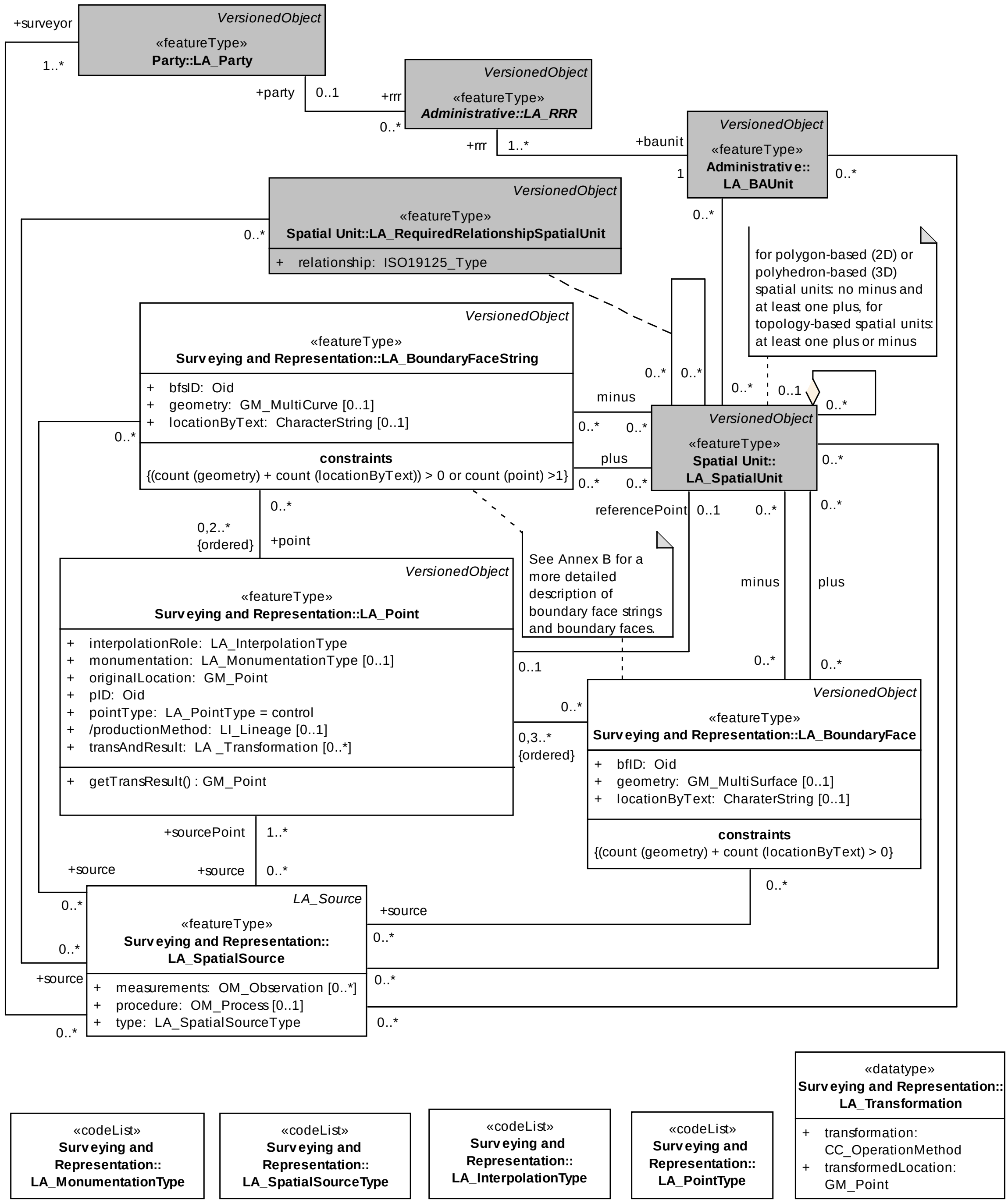


Figure 6. LADM Surveying and Representation Package with associations to basic classes

3.1 3D Aspects in the Land Administration Domain Model

In order to support rights, restriction or responsibility (RRRs related to 3D spatial units), which can be held by parties, there is a need for a legal basis (of course). Specific 3D RRR types can be included in a code list (if needed and different from the '2D'types). LADM also supports mixed representation of 2D spatial units and 3D spatial units in a territory and basedon thisalsogradually transition from 2D representations to 3D representations. It shouldbenotedthat the LADM only covers the ‘legal space’. That is, the spacethat is relevant for the registration and cadastre (‘legal boundingbox’ of the object), which is usuallylargerthan the physicalextent of the physicalobjectitself.

The Spatial Unit Package contains a.o. the classes LA_Spatial Unit and its specializations LA_Legal Space Network and LA_Legal Space Building Unit. A spatial unit is a point (or multi-point), a line (or multi-line), representing a single area (or multiple areas) of land (or water) or, more specifically, a single volume of space (or multiple volumes of space). This is where the 3D functionality comes in. Single areas (volumes) are the general case and multiple areas (volumes) the exception. Spatial units support the creation and management of basic administrative units. Those are administrative entities, subject to registration[1] (by law), consisting of zero or more spatial units against which (one or more) unique and homogeneous rights (e.g. ownership right or land use right), responsibilities or restrictions are associated to the whole entity, as included in a land administration system. The Spatial Unit Package has a Surveying and Spatial Representation Subpackage; see Figure 6, with classes such as: LA_Point, LA_BoundayFace, LA_BoundaryFaceString and LA_SpatialSource.

LA_BoundaryFaceStringis a boundary, that is, a set of points thatrepresents the limit of an entity (ISO 19107:2003, definition 4.4). A boundary face string is a boundaryforming part of the outside of a spatial unit. Boundary face stringsareused to represent the boundaries of spatial units via line strings in 2D. This 2D representationimplies in a 2D land administration system a 2D boundary, or in a 3D land administration system a series of verticalboundaryfaces. In that case an unboundedvolume is assumed, surrounded by boundaryfaces, whichintersect the earth’ssurface (such as traditionallydepicted on the 2D cadastral map). LA_BoundaryFace is a boundary face, that is, a face that is used in the 3-dimensional representation of a boundary of a spatial unit. Boundaryfacesareusedwhen the impliedvertical and unboundedfaces of a boundary face stringare not sufficient to describe 3D spatial units. Boundaryfacesclosevolumes in height (e.g. everyapartmentfloor), or in depth (e.g. an undergroundparking garage), or in all otherdirections to form a boundedvolume. 2D and 3D representations of spatial units useLA_BoundaryFaceStrings and LA_BoundaryFaces as keyconcepts (see Figure 7). In manycountries, a 2D representation is interpreted as a 3D prismaticvolume, with no upper and lowerbound. Using this interpretation, 2D and 3D representations can be unified.

[1] or recordation (by informal right, or customary right, or another social tenure relationship)

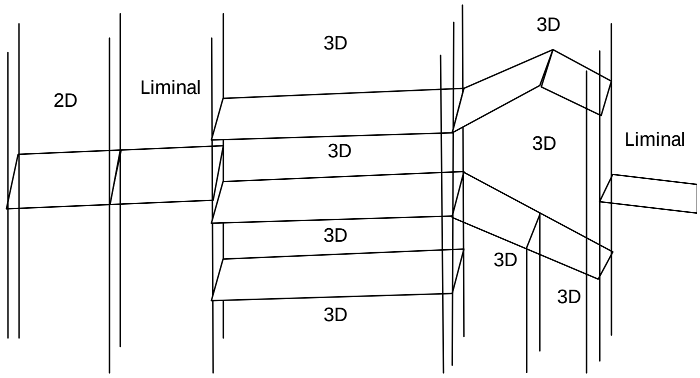


Figure 7. Side view showing the mixed use of boundary face strings (two parcels on the left) and boundary faces (other parcels) to define both bounded and unbounded 3D volumes (from ISO/TC211, 2012)

3.2 The Land Administration Domain Model and Spatial Data Infrastructure

Spatial data sets are most useful in the support of areas like decision making, management of space, performance of government or business processes, when they are integrated in governmental information infrastructures and architectures (Van Oosterom et al, 2009). The basic idea behind data infrastructures is that it provides for tools giving easy access to distributed databases to people who need those data for their own decision making processes (Van der Molen, 2005). Although data infrastructures have a substantial component of information technology, the most fundamental asset is the data itself, because without data there is nothing to have access to, to be shared or to be integrated. Last decade it was understood that the development of data infrastructures not only provided easy access to distributed databases, but also gave good opportunities for re-thinking the role of information supply for the performance of governments. Based on this starting point, the 'Streamlining Key Data' Programme of the Netherlands' government took the lead in the development and implementation of a strategy for restructuring government information in such a way that an electronic government evolves that (Van Duivenbode, 2003):

- inconveniences the public and the business community with request for data only when this is absolutely necessary;
- offers them a rapid and good service;
- cannot be misled;
- instills the public and the industrial community with confidence;
- is provided at a cost that is not higher than strictly necessary.

This implies availability of well-maintained links between spatial data sets and other 'basic' or 'key' data sets, e.g. on addresses, persons, companies, buildings or land rights. Integrated inter-organizational value chains and business process management with a reduction in administrative overhead can be realized based on good co-operation. In general, solving the problems in society requires more information than provided by one single data set. It is evident that this type of data provision is complex in case data is stored at a variety of locations and in data models specific to their applications (Van Oosterom et al 2009).

LA has important relationships with other key registers in the (spatial) information infrastructure, some of which are spatial, e.g. topography or buildings (and as argued earlier, even more so in case of large scale and 3D data), while others contain administrative information, like names of persons, addresses or names of companies. It is therefore important to have unambiguous definitions of the contents of these key registers in order to avoid overlap and to enable re-use of information. Further, due to continuous updating of these independent, but related, key registers care has to be taken to maintain consistency, not only within one database, but also between databases. By re-using basic standards (for geometry, temporal aspects, metadata, observations and measurements from the field), at least the semantics of these fundamental parts of the model are well defined and can be shared. What is needed in addition to this is domain specific standardization to capture the semantics of the land administration domain on top of this agreed foundation (Van Oosterom et al 2009). In this way information about land rights can be accessible from SDI. The SDI can provide a platform for access to many other data sets; see for example Williamson et al (2010).

The construction of external databases with party data, address data, taxation data, land use data, land cover data, valuation data, physical utility network data, and archive data, is outside the scope of the LADM. However, the LADM provides stereotype classes (‘blueprints’) for these data sets, which indicate what data set elements the LADM expects from these external sources, if available. This is a very relevant aspect in the context of a (developing) SDI concept (see Figure 8). Taken from Annex K of the ISO LADM - Land Administration Domain Model (ISO, 2012) associations between a. LA_LegalSpaceBuildingUnit (a specialization of LA_SpatialUnit) and the external class ExtPhysicalBuildingUnit and b. LA_LegalSpaceUtilityNetwork (again a specialization of LA_SpatialUnit) and the external class ExtPhysicalUtilityNetwork are explicitly modelled. In addition to these modelling activities, it is also the intention to investigate the visualization of (invisible) cadastral volume units. In order to be able to refer to object instance level (possible maintained by different parts/systems within the SDI), there must be unique object identifiers for all relevant object classes. Within the LADM a generic data-type is available for that purpose: LA_VersionedObject (and nearly all classes inherit from this top level class).

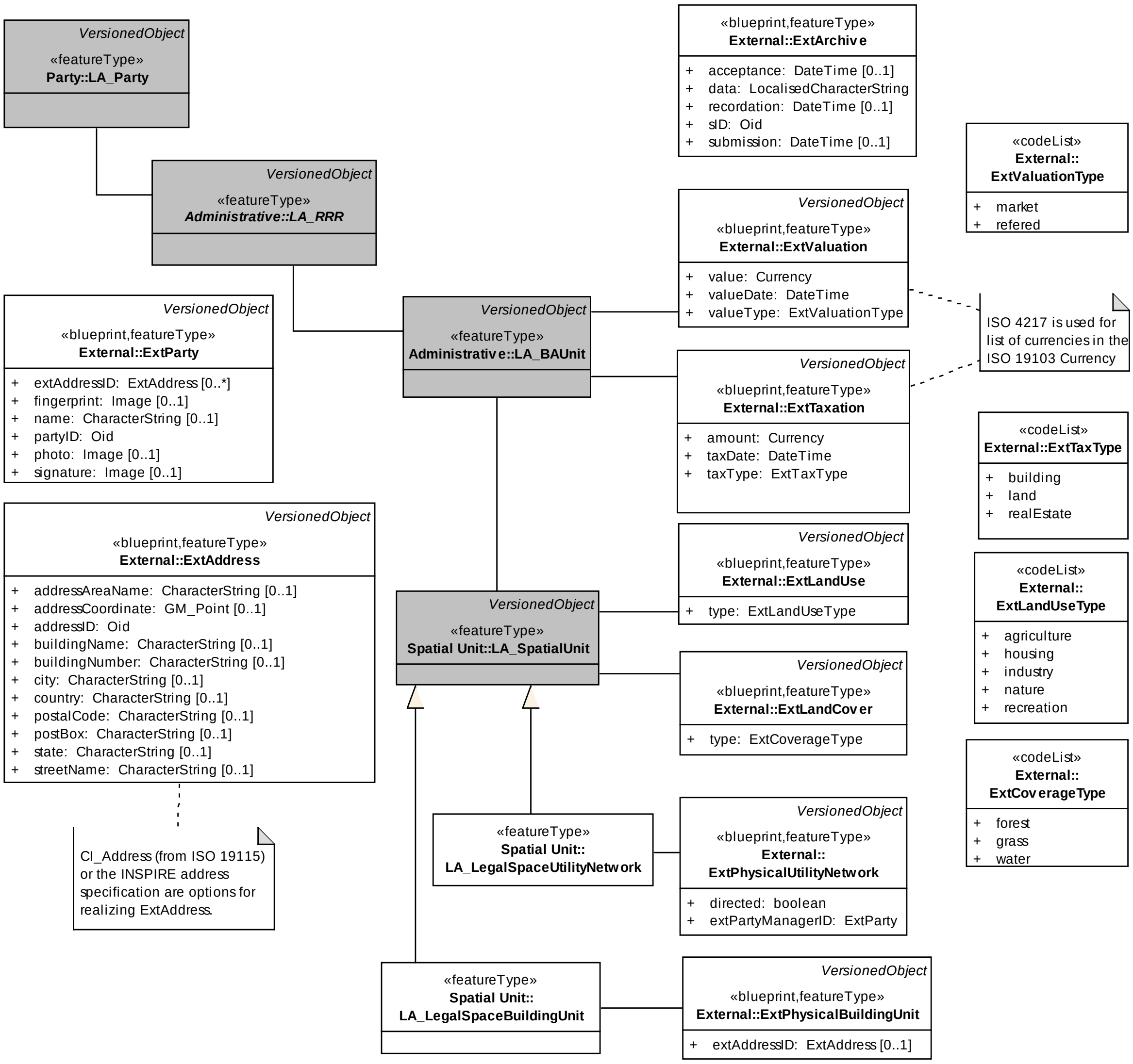


Figure 8. External LADM classes

The need for 3D representation is identified. The next dimension is time: there is a need to include time to reconstruct history, to be integratable in SDI, to manage events in maintenance processes and to reflect reality in case of temporal rights. Spatial units with different accuracies, dimensions and representations should be possible to include. This implies a range of spatial units should be possible. One more reason to include the temporal dimension (3D + time) is the need for information assurance within SDI: both current and historic versions are always accessible. Although the related objects, for example persons in case of a LAS, are not the primary purpose of the registration, the whole LA production process (both update and delivery of LA information) does depend on the availability and quality of the data at the remote server. Information assurance is needed to make sure that the primary process of the LA organization is not harmed by disturbances elsewhere and vice versa (e.g. one cannot simply update the LAS when this creates ‘dangling references’; at least the reference should then be pointing to the old version). This is the first and main reason to include temporal (database history) support in an SDI setting. In addition, remote (or distributed) systems or users may not only be interested in the current state of objects, but they may need a historic version of these objects e.g. for taxation or valuation purposes. So even if the organization responsible for the maintenance of the objects is not interested in history, the distributed use may require this (as a kind of 'temporal availability assurance'). The total set of goals (goals can be distributed over organizations) has to be considered. In conclusion, an LA domain model needs the temporal dimension especially in an SDI context. The conceptual model of the LADM provides the required temporal support. The LADM covers both event based modeling, and state based modeling.

In event based modelling, transactions are modelled as separate entities within the system. The event is represented by an instance of LA_Source. In state based modelling, all states (or versions) are modelled explicitly: every object is assigned (at least) two dates/times which indicate the time interval during which the object is recorded in the system as actual version. It is straightforward to obtain the state at a given moment in time, by selecting the object based on a time interval (tmin-tmax).

4 EXAMINING THE CONTENTS OF A 3D CADASTRE IN KOREA

4.1 Framework of 3D Cadastre

Understanding various preconditions and essential contents is crucial for the purpose of introducing the re-conceptualization of the cadastre to a 3D cadastre. Figure 9 shows the framework for applications of 3D cadastre. The system consists of four fundamental elements including 'Definition of 3D Cadastre', 'Subjects of 3D Cadastre', 'Objects of 3D Cadastre' and 'Forms of 3D cadastre', which are interrelated with each other.

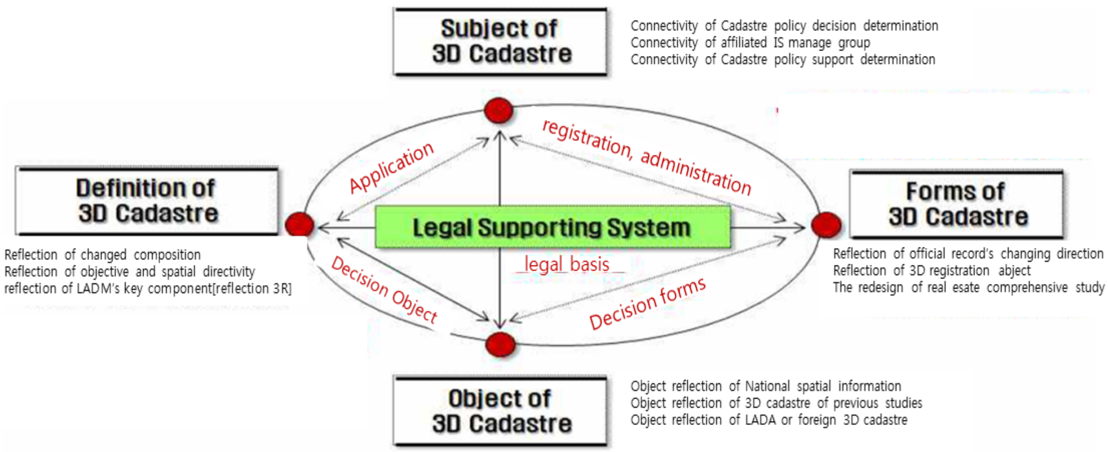


Figure 9. Framework for application of 3D cadastre

In order to re-define the cadastre in Korea, the re-definition should reflect the historical changes of 3D cadastre components, and be compatible to the LADM basic classes, especially RRR (rights, restrictions, and responsibilities). Based on the definition of 3D cadastre, the objects of 3D cadastre will be defined. The objects of 3D cadastre include 3D parcels, 3D right spaces and 3D physical facility objects. The objects should reflect spatial objects related to parcels dealt with by public sectors in Korea, as well the objects of LADM or foreign 3D cadastres. The subjects of 3D cadastre mean horizontal and hierarchical organizational structures which are linked to cadastre administration organizations in the public sectors as the center of the organization's network. The public corporations or the circles of horizontal and organizational structure are mentioned as the subjects of 3D cadastre. Moreover, cadastral surveying companies and associations can be considered as the subject of 3D cadastre too. Therefore, subject of 3D cadastre means interrelated partnerships between government organizations and private stokeholder. The form of 3D cadastre means legal registration forms for “the efficient management of space and for the protection of the property right of people”.

4.2 Alignment with LADM

As mentioned before the next generation cadastral system will be realized through the ongoing cadastral reform project. The functional requirements for the new system are available in LADM:

- the newly developed cadastral (spatial) system should be linked with the existing cadastral administrative system, and moreover linked and utilized with other relevant land administrative systems. The 3D cadastral system should not only cover positional information (x,y,z) about registration objects but also rights information such as ownership, surface rights, servitude, leasehold interest on real property and so on. Moreover, the system has to include a lot of useful functions to provide the services immediately to the general public as well as experts. This is possible in LADM with its party package, administrative package and spatial unit package (with a surveying and representation sub-package). (Sub)packages facilitate the maintenance of different data sets by different organizations. The complete model may therefore be implemented through a distributed set of (geo-) information systems, each supporting data maintenance activities and the provision of elements of the model (and this might function especially very well in the context of an SDI or information infrastructure setting). The model may also be implemented by one or more maintenance organizations, operating at national, regional or local level. This underlines the relevance of the model: different organizations have their own responsibilities in data maintenance and supply, but may communicate on the basis of standardized administrative and technical update processes,
- it should be based on international spatial standards and national spatial data infrastructures. Also this requirement can be fulfilled with LADM; LADM is based on re-use of existing standards:
    - ISO 4217:2008, *Codes for the representation of currencies and funds*
    - ISO 8601:2004, *Data elements and interchange formats — Information interchange — Representation of dates and times*
    - ISO/IEC 13240:2001, *Information technology — Document description and processing languages — Interchange Standard for Multimedia Interactive Documents (ISMID)*
    - ISO 14825:2011, *Intelligent transport systems — Geographic Data Files (GDF) — GDF5.0*
    - ISO/TS 19103:2005, *Geographic Information — Conceptual schema language*
    - ISO 19105:2000, *Geographic Information — Conformance and testing*
    - ISO 19107:2003, *Geographic Information — Spatial schema*

- ISO 19108:2002, *Geographic Information — Temporal schema*
  - ISO 19111:2007, *Geographic Information — Spatial referencing by coordinates*
  - ISO 19115:2003, *Geographic information — Metadata*
- 3D spatial information should be registered, managed, and utilized. This aspect is already highlighted in section 3.1 of this paper (and all geometric information has its origin in a LA_SpatialSource object; e.g. the data or document resulting from a survey),
- the system should have 'well defined' interfaces which can provide the link to the information that users want to refer to (anywhere, anytime). Also this requirement is covered in LADM. The construction of external databases with party data, address data, taxation data, land use data, land cover data, valuation data, physical utility network data, and archive data, is outside the scope of the LADM. However, the LADM provides stereotype classes ('blueprints') for these data sets, see section 3.2. Database history (versioning) is supported in LADM (external object referencing, including 'deleted' objects or versions and information assurance) and object identification. This is the basis for SDI implementation and integration of the new cadastral system with NSIIS and NSIOP,
- stable and effective object identification. In order to specify the relationships between objects, object identifiers should be defined and the complex object ID consists of parcel ID, rights ID and object ID as seen in Figure 10.For example, the administrative region codes are assigned by 5 digit values representing the administrative region, which a parcel and physical objects are located in. Also the rights code can be assigned according to the types of 3D cadastre rights invested in parcels or physical objects. The rights code and object code refer to a code list defined individually as digital numbers about rights and physical objects. The object number allows objects to be identified uniquely. All this is implementable with LADM, see section 3.1,

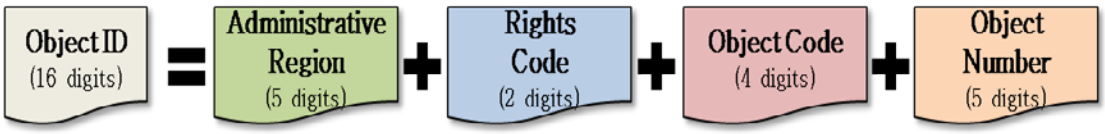


Figure 10. Composition of Object ID

- building's registration is already required and regulated in Korea, but the present cadastral system does not register that information (and does also not refer to this).LADM allows the inclusion of references from the cadastre (in case of an LA_LegalSpaceBuildingUnit) to the corresponding building unit in the 'external' building registration, which is especially relevant in the 3D setting (apartment complexes, etc.). The referencing is realized to better document the legal aspects of buildings via LA_LegalSpaceBuildingUnitwith a reference to the external stereotype class ('blueprint'): ExtPhysicalBuildingUnit (note that similar links could be used between LA_LegalSpaceUtilityNetwork and ExtPhysicalUtilityNetwork and they are again especially relevant in the case of 3D representations),
- inclusion of control points. This is possible with LADM, it contains a comprehensive survey functionality; see figure 6 and Annex A, and

- visualization functionality (dynamic) has to be provided by a system created based on the LADM designed database with careful attention for 3D display and interaction, see Annex A for good examples.

4.3 Design of the next generation cadastral domain model

An object oriented approach is required based on model driven architectures. This is possible with the UML standard, representing the current operating databases in Korea Land Information System (KLIS) and Local Administration System (LAS), combined with the LADM. Currently, the Korea cadastral information system is managed by legacy systems (as in many countries): KLIS and LAS, but those cannot satisfy various demands anymore from a modern society. In particular, users demand various services-not only 2D information but 3D spatial rights and physical objects. The current system reached its limits. The existing cadastral data model does not satisfy for demanding services form spatial information industries. An improved new model is required allowing flexible registration of buildings, spatial rights of surface and subsurface. The building's registration is already suggested from relevant regulations, but in the present cadastral system this information is not registered (or referred to). In addition registration of the spatial rights linked to the register of real estate is not supported by cadastral system and law, so the extension to the LADM is needed to register various rights.

In the ISO 19152 Final Draft International Standard a Korean Country profile is included, see Figure 11. In this country profile there is already an initial integration of KLIS and LAS via LA_Party (KR_OwnerInformation) and spatial units (KR_Parcel) through RRRs (KR_Price). Further included are spatial source (KR_SpatialSource), map sheet (KR_CadastralMapSheet) and control points (KR_ControlPoint). This is the main alignment with LADM. This has to be extended to 3D now.Further research should confirm in which way the existing 2D parcels can be linked to 3D parcels (for example using LA_BoundaryFace, and LA_Level).

'3D Superficies' has to be introduced as a specialization of LA_SpatialUnit. The '2D Parcel' describes parcels in the current planar approach. The '3D Superficies' represents a vertical range of parcels. It is divided into the upper and lower part. '3D Physical objects' should be possible to represent; this is outside the scope of LADM but can be easily integrated within the SDI via external references.

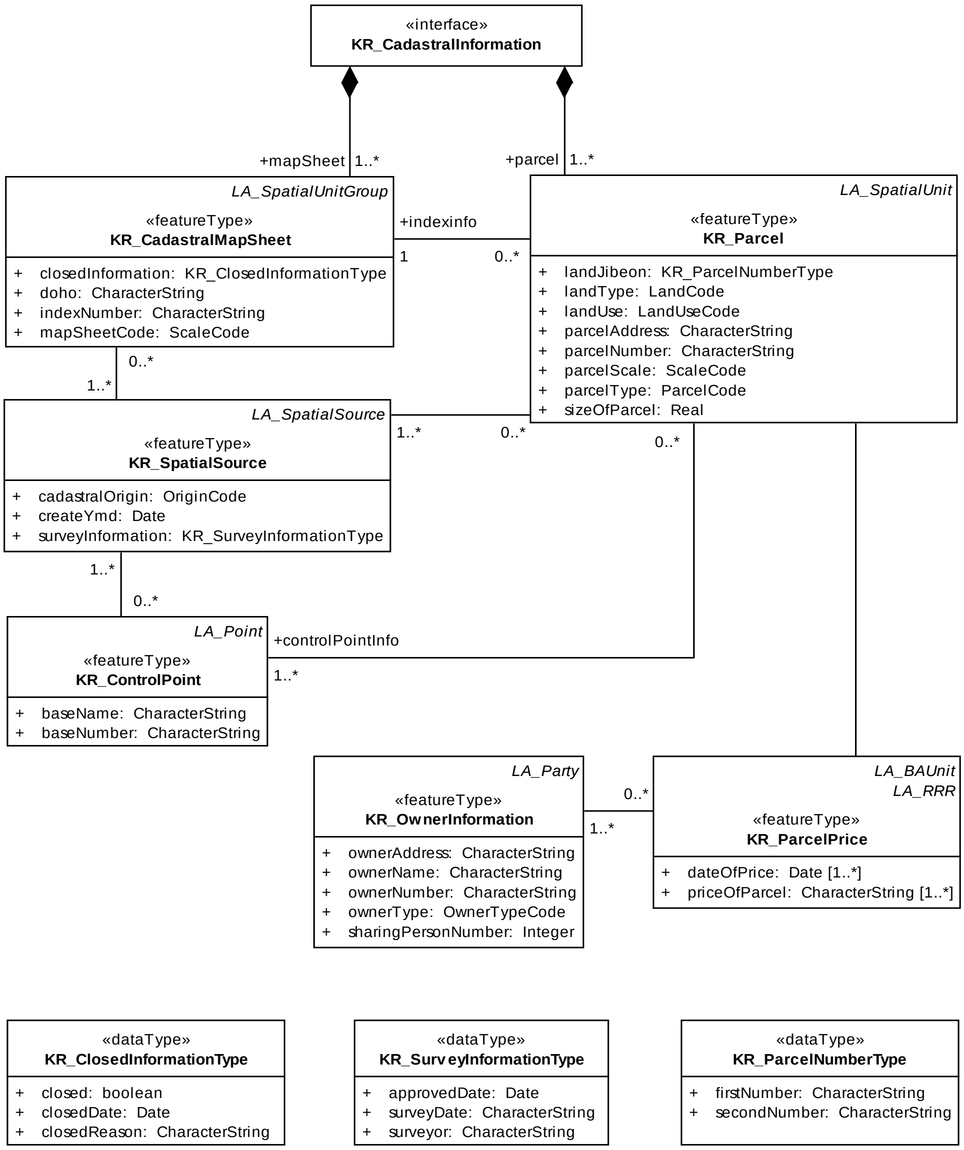


Figure 11. ISO FDIS, Korean Country Profile from Annex D, Figure D.9 of ISO (2012). This was created by the ISO LADM editors together with Young-Ho Lee in consultation with Taik-jin Kim

Attention has to be given to '3D Right space' which involves '3D Limited superficies', '3D Apartment right', '3D Joint ownership', '3D Right of long lease', 'Compensation space', and '2D zone under line' features. The '3D Limited superficies' is a subclass of '3D Superficies'. 'Compensation space' consists of a 2D and 3D compensation space. The integrated compensation space feature is required to represent both total and individual compensation space. 'Total 2D compensation space' feature has composition relationship with each of '2D compensation space' features and the 'Total 3D compensation space' feature consists of one or more '3D compensation space'. A first draft of the link between the new cadastral system and the existing administrative system is presented here in Figure 12. Spatial units are already represented as 3D parcels. Superficies are included (total, individual and colligation).

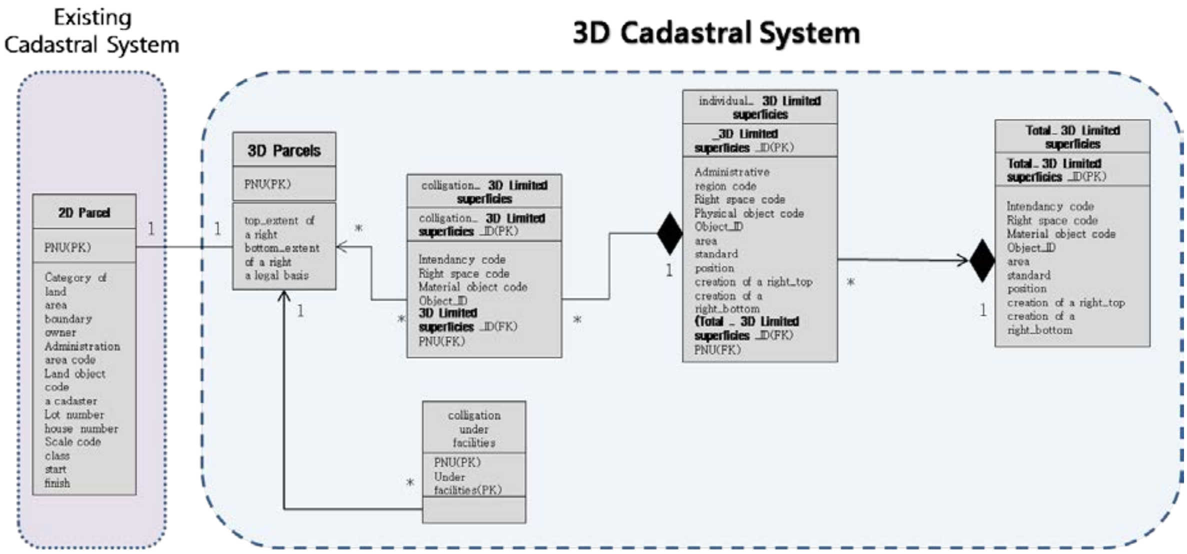


Figure 12. Database schema design of 3D limited superficies and parcel

5. CONCLUSIONS

KCSC will adapt a flexible 3D cadastre development strategy with a design based on the LADM and with a connection to the existing system. Further research is needed to define the integration of some specific classes. Korea has excellent information and communications infrastructures to build the 3D cadastral system based on information technology skills (enabling the effective realization of the SDI). In the case of a 3D cadastre there is even more tendency to refer to external registration (buildings, utility networks, etc.) compared to the traditional 2D cadastre. Therefore, application and possibilities of the 3D cadastre are very high in Korea. In order to build 3D cadastral system legislation of the related laws and regulations for legal guarantees in the 3D cadastre, interagency agreement for data sharing, strong commitment of the highest policy-makers for establishment of the 3D cadastral system and the system developed with international standards is required. The co-operation between Korea and the Netherlands brings together the expertise to develop a 3D cadastre that will meet the high expectations.

ACKNOWLEDGEMENTS

The research of Dong-HoonJeong and Ji-Yeong Lee is a part of the 2012 SIRI (Spatial Information Research Institute of KCSC) research for 3D cadastre standardization. The research of Jantien Stoter and Peter van Oosterom is supported by the Dutch Technology Foundation STW, which is part of the Netherlands Organisation for Scientific Research (NWO) and partly funded by the Ministry of Economic Affairs, Agriculture and Innovation (Project codes: 11300 and 11185).

REFERENCES

ISO TC211 (2012). Geographic information - Land Administration Domain Model (LADM), ISO/FDIS 19152 (Final Draft International Standard), August 2012. Lysaker, Norway. See LADM Wiki of Delft University: http://wiki.tudelft.nl/bin/view/Research/ISO19152/WebHome.

ISO/TC211 (2003). 19107, Geographic information—Spatial Schema. Lysaker, Norway.

Jang, Bong-Bae and Cho, Jung-Gan (2011). Current State of the 3-D Geospatial Data in South Korea and a Case Study on the Building 3-D Cadastre, 11th SEASC & 13th ISC, 22-24 June 2011. Kuala Lumpur, Malaysia.

Jeong, Dong-hoon; Kim, Taik-jin; Nam, Dae-hyun; Li, Hyo-sang and Cho, Han-keon (2011). A Review of 3D Cadastre Pilot Project and the Policy of 3D NSDI in the Republic of Korea. In: Proceedings of the 2nd International Workshop on 3D Cadastres. Delft, The Netherlands.

Lemmen, Ch., Van Oosterom, P., Thompson, R., Hespanha, J., Uitermark, H. (2010). The modelling of spatial units (parcels) in the Land Administration Domain Model (LADM), FIG Conference 2010. Sydney, Australia, FIG.

Lemmen, Christiaan (2012). Resurveying 38 Million Parcels of Land: GIM international interviews Young-Ho Kim, President of the Korea Cadastral Survey Corporation (KCSC). In: GIM international, the global magazine for geomatics, 26 (2012)9 pp. 14-19.

Seoul Government (2009). 3D cadastre basis creation business completion report, Seoul, Korea.

Seoul Government (2011a). 3D Cadastre basis creation 3 step business completion report.Seoul, Korea.

Seoul Governement (2011b). 3D cadastre demonstration complex completion report, Seoul, Korea (2011).

Park, Soyoung; Lee, Jiyeong and Li, Hyo-Sang (2009). 3D Cadastre Data Model in Korea: based on case studies in Seoul. In: The Journal of GIS Association of Korea, Vol. 17, No. 4, pp. 469-481, December 2009.

Spatial Information Research Institute (2012). System Design of Cadastral Spatial Information of the Next Generation Based on International Standards. In: Korea Cadastral Survey Corporation, Seoul, Korea.

Stoter, Jantien; Ploeger, Hendrik; Louwman, Wim; Van Oosterom, Peter and Wünsch, Barbara (2011). Registration of 3D Situations in Land Administration in the Netherlands. In: Proceedings of the 2nd International Workshop on 3D Cadastres, Delft, The Netherlands.

Van der Molen, P. (2005). Authentic Registers and Good Governance, FIG Working Week, Cairo, Egypt.

Van Duivenbode, H. and De Vries, M. (2003). Upstream! A chronicle of the Streamlining Key Data Programme, The Hague, The Netherlands.

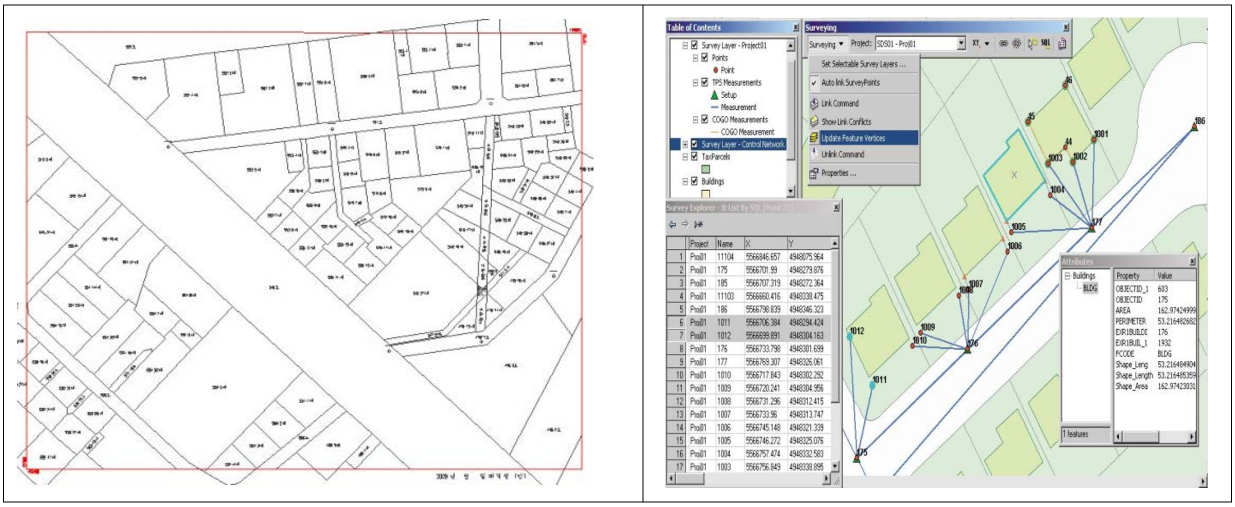
Van der Molen, P. (2005). Authentic Registers and Good Governance, FIG Working Week, Cairo, Egypt.

Van Oosterom, P.J.M., Groothedde, A., Lemmen, C.H.J., Van der Molen, P, and Uitermark, H.T. (2009). Land administration as a cornerstone in the global spatial information infrastructure, In: International Journal of Spatial Data Infrastructures Research 4: pp. 298-331.

Williamson, I.P., Enemark, S., Wallace, J. and Rajabifard, A. (2010). Land administration for sustainable development, Redlands, California, U.S.A., ESRI Press.

ANNEX A - Further requirements

The figure A.1 below shows the current and next generation contents of cadastral information services that are able to serve the system.



(a) the current contents of cadastral information services

(b) the next generation contents of cadastral information services

Figure A.1. Cadastral information services: current and future

The current cadastral information (a) provides only simple contents such as parcel boundaries, parcel numbers, land categories, and neat line information. Furthermore island maps are used in the 2D cadastral system. This is related to the original data acquisition (plane tables). However, building's information on the parcel and physical objects with space rights must be registered in the next generation cadastral system (b). Especially in order to improve spatial positioning accuracy, a system environment is required that allows control about how the graphic information is registered by cadastral control points. The next generation cadastral information services were implemented by the ArcGIS environment. It is very important to follow the same cadastral surveying procedures and cadastral mapping methods on a national scale by national control points. It should be noted that LADM provides a comprehensive functionality in support of cadastral surveying via classes LA_Point, LA_BoundaryFaceString and code tables LA_MonumentationType, LA_SpatialSourceType, LA_InterpolationType and LA_PointType.

In figure A.2, the cadastral surveying data collected by field survey can be seen in the GIS environment, and the quality of spatial location data also can be verified by the GIS. Thereby cadastral surveyors and government employees can support in reduction of disputes regarding parcel boundaries because they will be able to measure quality of the positioning accuracy in advance. However, the 2D cadastral system has limits on spatial information services, and it is hard to serve required functions on a professional level for decision making support.

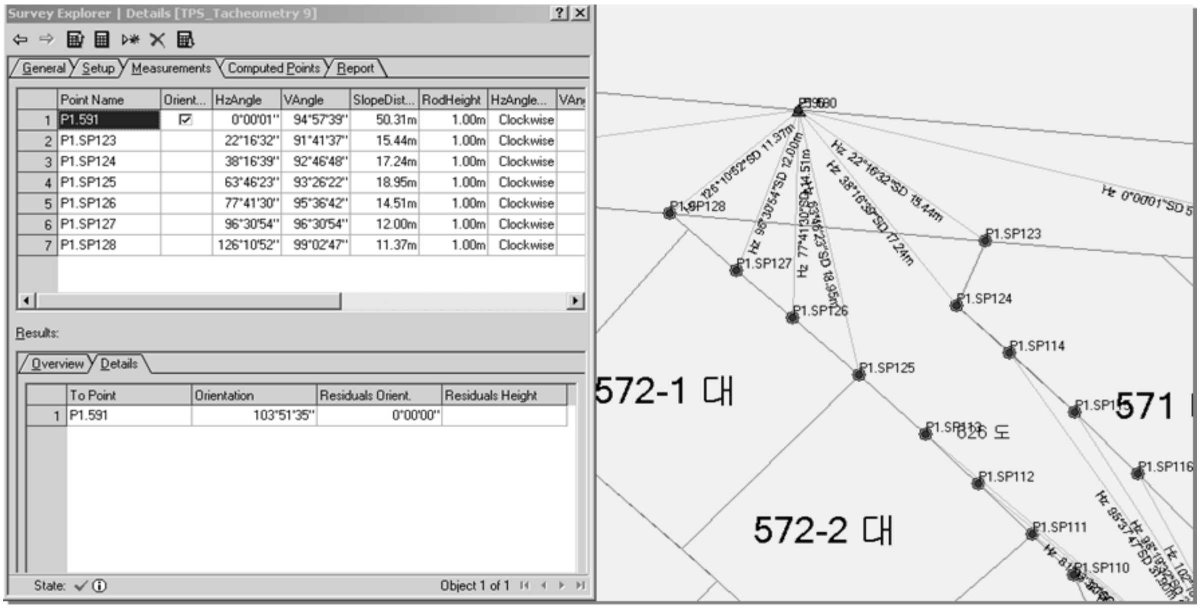
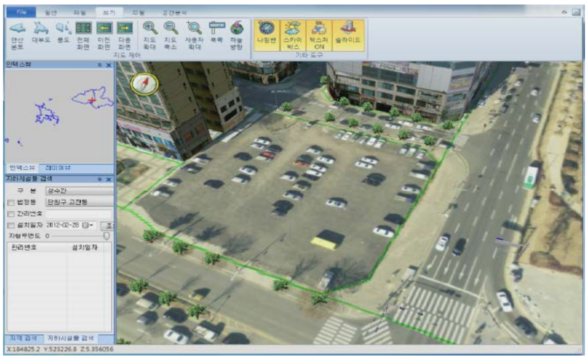
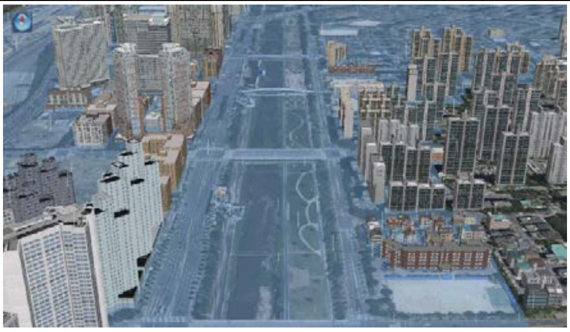


Figure A.2.Management and representation methods of the cadastral surveying raw data by GIS

Figure A.3 shows an example of the 3D cadastral information system for expert use. For example, 3D cadastral administrative management system, flight simulation, flood simulation, 3D buffer, urban planning, road building simulation, viewing right analysis, and LiDAR scanning data management system. The system not only satisfies user's requirements.

Currently, there are some local autonomous entities which have and hold their own 3D cadastral administrative management system to support experts' decision making and to offer prompt administrative services for the citizens. However, the system may not conform to international standards. Besides, the Korean government officially does not recognize the system and in addition the information of the right is not included.

	
3D cadastral administrative management system	Flight simulation



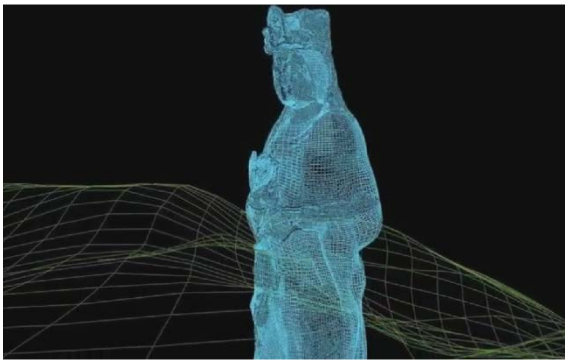
Flood simulation

3D Buffer

Urban planning

Road building simulation

Viewing right analysis



LiDAR scanning data management system

Figure A.3. Example of the 3D information system

BIOGRAPHICAL NOTES

Dong-hoon Jeong holds a PhD in Geo-informatic engineering from Inha University, Republic of Korea. From 2004 until 2007 he worked in the Korea Institute of Construction Technology as a postdoctoral researcher. Since 2007 he works at the Cadastre Research Institute of the Korea Cadastre Survey Corporation as the principal researcher. In 2009, he led the 3D cadastre pilot project team and now is also involved in that project during 3 years.

Bong-Bae Jang graduated with an MSc in Geo-Information Management from International Institute of Geo-Information Science and Earth Observation, ITC, The Netherlands, in 2008. He has been working as a professor since 2011 in the Cadastral Training Institute of the Korea Cadastral Survey Corporation, and he is professional engineer both in cadastral survey and geodetic surveying.

Ji-Yeong Lee is Associate Professor in the Department of Geo-informatics, University of Seoul, South Korea. He holds a PhD from the Ohio State University, USA. He is involved in the project "Development of 3D Indoor Spatial Awareness Technology for Ubiquitous Environment". He has been Assistant Professor of Geography and Earth Sciences at the University of North Carolina (2004–2007) and Minnesota State University, USA (2001–2004).

So-Il Hong is currently serving as head of the Overseas Projects Department of the Korea Cadastral Survey Corporation (KCSC). She holds a PhD from Korea University, Seoul, Korea, and a Master's degree in Russian and East European Studies from Yale University, USA. Prior to her work at KCSC, she was a Senior Coordinator at the Asian Institute of Policy Studies and a Senior Researcher and Policy Advisor to the Minister of Unification.

Peter van Oosterom holds a PhD from Leiden University, The Netherlands. He is professor at the Delft University of Technology and head of the section 'GIS Technology' since 2000. He is the chair of the FIG working group on '3D-Cadastres' (2010–2014). From 1985 until 1995 he worked at the TNO-FEL laboratory in The Hague, The Netherlands as a computer scientist. From 1995 until 2000 he was senior information manager at the Dutch Cadastre.

Kees de Zeeuw is director of Kadaster International, the international branch of the Cadastre. Land Registry and Mapping Agency (Kadaster) of the Netherlands. He holds an MSc from Wageningen University, The Netherlands. He was responsible at Kadaster for product and process innovation (2007 – 2010). He has an academic background in environmental and geo-information sciences working at Wageningen University and Research Centre.

Jantien Stoter holds a PhD on 3D Cadastre from Delft University of Technology, The Netherlands. She fulfils a dual position: one as Associate Professor at Section GIS technology at OTB and one as Consultant Product and Process Innovation at the Kadaster. From both employers she is posted to Geonovum. From 2004 till 2009 she worked at the International Institute for Geo-Information Science and Earth Observation, ITC, Enschede, The Netherlands.

Christiaan Lemmen holds a PhD from Delft University of Technology, The Netherlands. He is international consultant at Kadaster International and Assistant Professor at Twente University (Faculty ITC), The Netherlands. He is chair of the Working Group 7.1 'Pro Poor Land Management' of FIG Commission 7, and contributing editor of GIM International. He is director of the FIG International Bureau of Land Records and Cadastre, OICRF.

Jaap Zevenbergen is professor in land administration systems at the University of Twente, faculty ITC in Enschede, The Netherlands. He holds a PhD from Delft University of Technology, The Netherlands. He has published several articles and numerous papers about land administration and land registration. He is a co-chair of FIG Commission 7 Working Group 2: Land Administration, Natural Disasters and Climate Change.

CONTACTS

Dr. Dong-hoon Jeong
Korea Cadastral Survey Corporation, Spatial Information Research Institute
27-8, Kugjegeumyung-ro 8-gil, Youngdungpo-gu
Seoul
REPUBLIC OF KOREA
E-mail: gisjeong@daum.net

Bong-Bae Jang, MSc
Korea Cadastral Survey Corporation, Cadastral Training Institute
#624, Unhak-dong, Cheoin-gu, Yongin-si,Gyeonggi-do
Seoul
REPUBLIC OF KOREA
E-mail: bbjang@kcsc.or.kr

Dr. Ji-Yeong Lee
The University of Seoul, Department of Geoinformatics
163, Seoulsiripdaero-gil, Dongdaemun-gu
Seoul
REPUBLIC OF KOREA
E-mail: jlee@uos.ac.kr

Dr. So-Il Hong
Korea Cadastral Survey Corporation, Department of Oversees Business
#45, Yeoeuido-dong, Yeongdeungpo-gu
Seoul
REPUBLIC OF KOREA
E-mail: soilhong@kcsc.or.kr

Prof. Dr. Ir. Peter van Oosterom
Delft University of Technology, OTB, Section GIS-technology
P.O. Box 5030
2600 GA Delft
THE NETHERLANDS
E-mail: P.J.M.vanOosterom@tudelft.nl

Kees de Zeeuw, MSc
Netherlands Cadastre, Land Registry and Mapping Agency
P.O. Box 9046
7300 GH Apeldoorn
THE NETHERLANDS
E-mail: kees.dezeeuw@kadaster.nl

Dr. Jantien Stoter
Delft University of Technology, OTB, Section GIS-technology
P.O. Box 5030
2600 GA Delft
THE NETHERLANDS
E-mail: J.E.Stoter@tudelft.nl

Dr. Christiaan Lemmen
Netherlands Cadastre, Land Registry and Mapping Agency
PO Box 9046
7300 GH Apeldoorn
THE NETHERLANDS
E-mail: Chrit.Lemmen@kadaster.nl

Prof. Mr. Dr. Ir. Jaap Zevenbergen
University of Twente, Faculty of Geo-Information Science and Earth Observation (ITC)
P.O. Box 217
7500 AE Enschede,
THE NETHERLANDS
E-mail: Zevenbergen@itc.nl