Review and Assessment of Current Cadastral Data Models for 3D Cadastral Applications

Ali Aien, Abbas Rajabifard, Mohsen Kalantari and Ian Williamson

Abstract Three-dimensional (3D) cadastres are often described as the 3D digital representation of real property rights, restrictions, and responsibilities (legal objects). They can also contain physical counterparts (physical objects) of legal objects such as buildings and utility networks, on, above or under the surface. Implementation of 3D cadastres requires many elements such as existing 3D property registration laws, appropriate 3D data acquisition methods, 3D spatial database management systems, and functional 3D visualisation platforms. In addition, an appropriate 3D cadastral data model can also play a key role to ensure successful development of the 3D cadastre. Many jurisdictions have defined their own cadastral data models. However, none of them can fully support the requirements of 3D cadastres. This paper aims to explore the theories and concepts of the most common existing cadastral data models and investigate how they manage 3D legal and physical data. The result of this research can be used by cadastral data modellers to improve existing or develop new cadastral data models to support the requirements of 3D cadastres.

Keywords 3D cadastre · 3D cadastral data modelling · RRR · Legal Property Object · LADM

1 Introduction

Management of stratified land rights, restrictions and responsibilities (RRRs) is one of the most important challenges in the current land administration systems which are equipped with cadastres that are only able to maintain 2D spatial information.

Current cadastral systems are two-dimensional (2D) and land parcel based, that is, geometric and descriptive information is based on 2D land parcels, even if the properties have three dimensions. They cannot effectively represent the reality.

A. Aien (✉) · A. Rajabifard · M. Kalantari · I. Williamson
Department of Infrastructure Engineering, University of Melbourne, Melbourne, Australia
e-mail: aiena@unimelb.edu.au; ali_aien@yahoo.com

A. Abdul-Rahman (ed.), *Advances in 3D Geoinformation*,
Lecture Notes in Geoinformation and Cartography,
DOI 10.1007/978-3-319-25691-7_24

Current 2D cadastral systems are not able to manage and represent land ownership RRRs in a 3D context (Kalantari et al. 2008).

3D cadastres would overcome these problems. 3D cadastre should be capable of storing, manipulating, querying, analysis, updating, and supporting the visualisation of stratified land RRRs. There is not yet such a system in the world (Oosterom 2010; Godard 2004; Navratil 2009; Stoter and Oosterom 2006; Aien et al. 2013a).

There are several reasons why 3D cadastres have not been successfully implemented: legal, institutional, and technical aspects all play a role (Stoter 2004). Specific reasons include:

- Lack of legal support and mandate to register 3D properties (legal and institutional issues),
- Lack of specified guidelines and standards for surveyors to capture required 3D data, and a lack of data formats to integrate and exchange 3D data (legal, institutional and technical issues),
- Lack of available technologies for storing, manipulating, and visualising 3D objects (technical issues) and,
- Most importantly, lack of a comprehensive data model is one of the main obstacles to advancing implementation.

3D cadastral data model supports 3D cadastre's users to understand the structure or behaviour of the system and has a template that guides them to construct and implement the 3D cadaster (Aien 2013).

Many jurisdictions, organisations and software developers have built their own cadastral data models. The variation between these data models is the result of different attitudes towards cadastres (Aien et al. 2011). Six cadastral data models have been reviewed; however, only three (ArcGIS Parcel Data Model, ePlan, and LADM) have been discussed in detail in this paper (see Table 3 for the complete review). The aim of this review is to explore the advantages and deficiencies of these models in terms of supporting the requirements of 3D cadastre. Six cadastral data models are:

- The core cadastral data model (Henssen 1995)
- FGDC Cadastral Data Content Standard for the National Spatial Data Infrastructure (FGDC 1996)
- ArcGIS Parcel Data Model (Meyer 2004)
- The Legal Property Object Model (Kalantari et al. 2008)
- ePlan (ePlan 2010)
- ISO 19152, Land Administration Domain Model (LADM) (ISO19152 2012).

These data models are the most popular cadastral and land administration data models that were found in the literature and background research. They were assessed and compared based on selected criteria. The aim was to analyse how they manage stratified land ownership RRRs; meet 3D cadastre's requirements; and what data modelling techniques they use to support 3D data.

The remainder of the paper presents the assessment of data models in detail. Section 2 describes the selected criteria for assessment. Sections 3, 4, and 5 describe the above-mentioned data models respectively. Research conclusions and the summary of the models are presented in Sect. 6.

2 Assessment Criteria of Cadastral Data Models

The criteria were selected in a way to be able to assess the data models from different aspects and provide information on how they manage stratified RRRs. Table 1 summaries the criteria used for comparing the above-mentioned cadastral data models.

This assessment enables an understanding to be gained of important cadastral data models, their advantages and disadvantages for improving the existing or developing a new data model. Each data model is reviewed in the following sections.

Table 1 Criteria for comparing current cadastral data models

Criteria	Description
(a) Core objects	What are the core objects of the data model? (person, right, spatial unit, parcel)
(b) Basic spatial unit	What are the basic spatial units of the data model? (2D parcel, 3D parcel)
(c) Other forms of spatial units	Does the data model have other forms of spatial units? (text-based, point-based)
(d) Reference documents	What are the data sources? (survey plans, architectural plans, titles, deeds)
(e) Applications	For what applications can the data model be used? (registration, taxation, valuation, planning, etc.)
(f) Inclusion of other types of interests	Whether or not other types of interests are considered in the data model? (utility network right, biota right, mineral right)
(g) Temporal aspects	Whether or not temporal aspects of interests are considered? (time the right is created or terminated)
(h) Management and representation of stratified RRRs	How does the data model render stratified RRRs? (projection on the ground level, 3D primitives)
(i) Semantic-level	At what level does the data model support semantics? (class-level, attribute-level, geometry level)
(j) Physical objects	How does the data model support the physical counterparts of legal objects? (internally [in the model], externally [external databases])

3 ArcGIS Parcel Data Model

The purpose of the ArcGIS Parcel Data Model is to describe parcel information to support local government and private sector decision making (Fig. 1). Parcel managers and GIS professionals can use the model as a starting point for defining parcel information in the GIS environment and plan for migration strategies from current data designs to the new object environment (Meyer 2004).

(a) What are the core objects of the data model?

Core objects of the data model are: *Ownership*, *Encumbrances*, and *Separated Rights*.

- *Ownership Parcel*: a parcel is a unit of real property with rights and interests.
- *Encumbrances*: limitations on the rights and use of the land.
- *Separated Rights*: rights and interests in land ownership that can be disconnected from the primary or fee simple surface ownership.

(b) What are the basic spatial units of the data model?

Parcel is the only basic spatial unit of the data model.

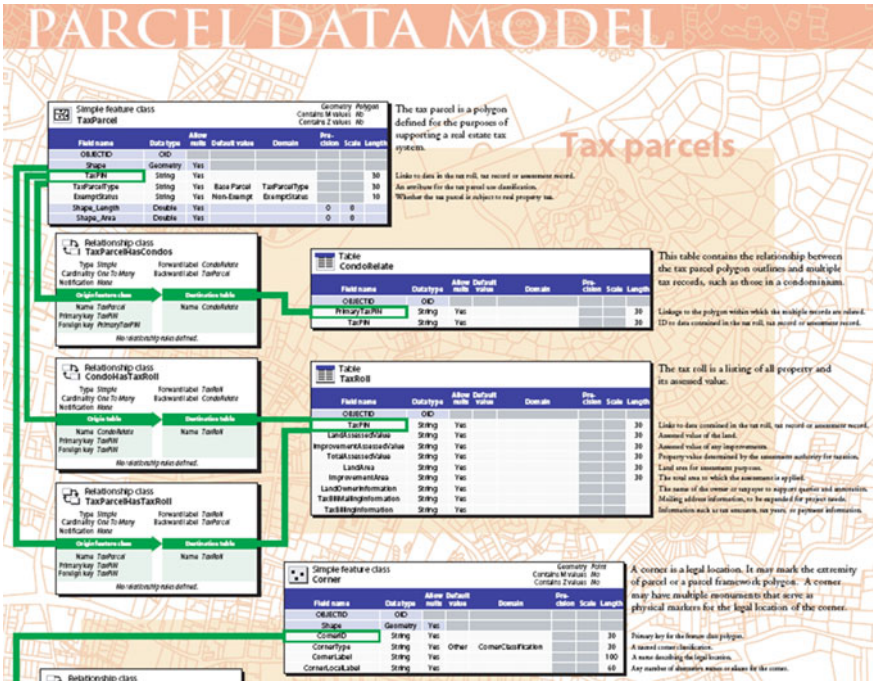

Fig. 1 Part of the ArcGIS Parcel Data Model (Meyer 2004)

(c) Does the data model have other forms of spatial units?

No other forms of spatial units are considered in the data model.

(d) What are the data sources (reference [legal] documents)?

All legal and authoritative documents such as deeds, survey plans, mortgages and lease contracts are used as a source of information.

(e) For what applications can the data model be used?

The data model can be used for development of parcel level management and can support parcel level functionality in the GIS environments.

(f) Does the data model have other types of interests (rights)?

Types of rights are mineral rights, oil rights, grazing right, and fishing rights.

(g) Does the data model consider temporal aspects of interests?

Temporal information (transaction date and time) is recorded in the data model.

(h) How does data model render stratified RRRs?

Many jurisdictions have condominiums or other structures that can form common interest areas and three-dimensional surfaces with different owners on different levels of the structures. A condominium is a separate system of ownership of individual units in a multiple-unit building. The units or buildings in the condominium are part of the ownership parcels with a vertical aspect and are called vertical parcels in the ArcGIS Parcel Data Model (Meyer 2004).

Figure 2 illustrates a vertical parcel that is a condominium building with condominium unit F that is on three separate floors. Unit F is connected by common elements, such as stairways and elevators. In the ArcGIS Parcel Data Model there are several ways to model or represent vertical parcels:

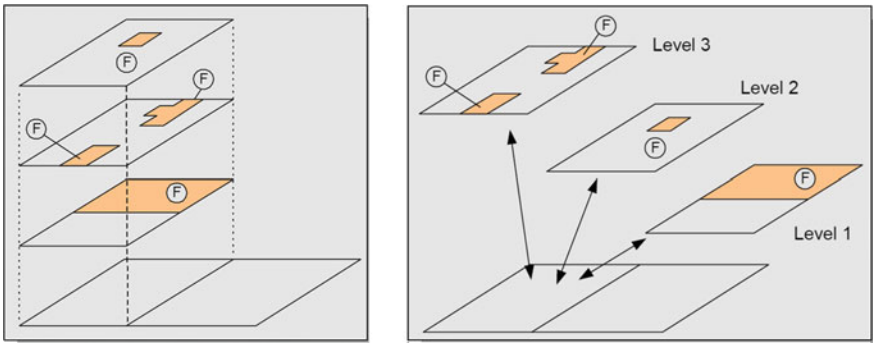

Fig. 2 Vertical parcels (*Left*) and a method of representing vertical points (*Right*) (Meyer et al. 2001)

- single outline polygon pointing to multiple parcel records,
- single outline polygon pointing to another series of polygons that represent the levels or floor, and
- single outline polygon that points to a three dimensional model of the building.

Stratified RRRs are projected on the polygons and they are not rendered with 3D primitives. Three-dimensional model of the building is not supported in the model.

(i) At what level does the data model support semantics?

Semantics are used to define the model's classes, attributes and parcel geometry.

(j) How does the data model support the physical counterparts of legal objects?

Land parcel is the representation of both legal and physical objects.

Overall, the ArcGIS Parcel Data Model is a general and flexible data model that helps users to manage land parcels using GIS technology. Vertical parcels (condominium) are supported in the data model; however, 3D primitives are not used to represent the vertical parcels.

4 ePLAN

The ePlan model was developed to model geometrical and textual information of Australian survey plans under the direction of the Intergovernmental Committee on Surveying and Mapping (ICSM). The ePlan model accommodates all of the survey geometry and administrative and titling data required to process a plan of subdivision from its initial preparation by the surveyor through to its lodgement with council for certification and subsequent registration (Kalantari et al. 2009).

The ePlan model has been classified into a number of packages (Fig. 3). They are Document, Surveyor, Survey, Parcel, Address, Geometry, Point, and Observation. 2D land parcels form the basis of ePlan. All administrative information is collected based on the land parcels, which are defined in the parcel package of the model (Kalantari et al. 2009).

(a) What are the core objects of the data model?

Core objects of the data model are: *Parcel*, *Document*, *Survey*, *Surveyor*, *Observation*, *Address*, *Point*, and *Geometry*.

- *Parcel*: The parcel element provides a basic unit to describe a spatial area.
- *Document*: Any other legal documents that define rights or ownership of land attached to the parcel.
- *Survey*: The survey element contains the survey components of the ePlan such administrative information, observation elements, and observation setup points.
- *Observation*: Observation elements.
- *Address*: Street address information for the parcel.

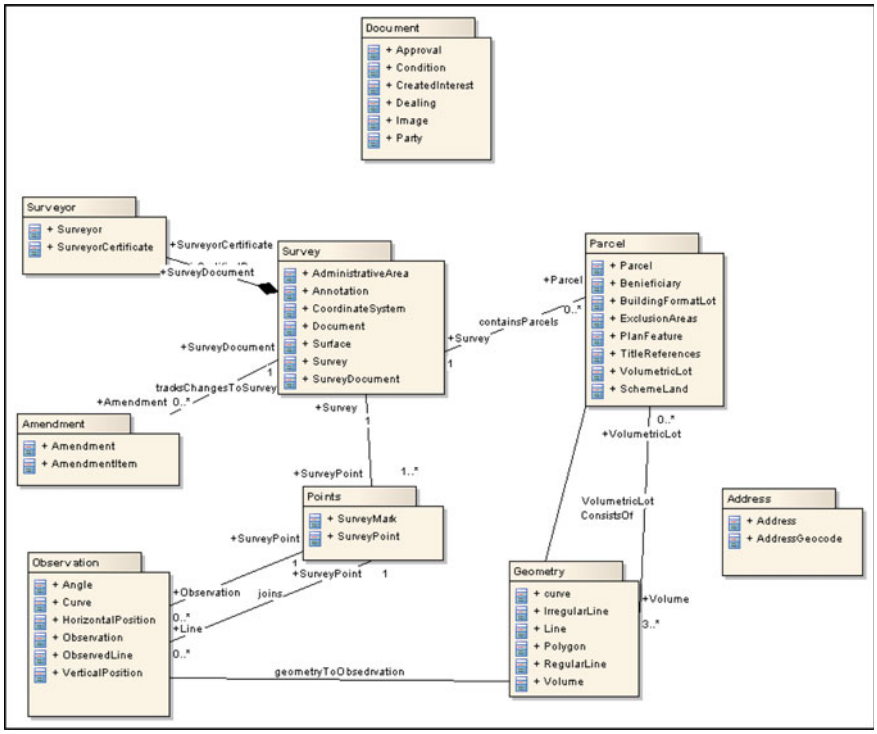

Fig. 3 ePlan model packages (ePlan 2010)

- *Surveyor:* information about the surveyor who participated in the survey.
- *Point*: Various administrative points such boundary points, traverse points, reference marks, and permanent survey marks.
- *Geometry*: Consists of *Curve*, *IrregularLine*, *Line*, *Polygon*, *RegularLine*, and *Volume* to represent geometry of the parcel.

(b) What are the basic spatial units of the data model?

Parcel is the only basic spatial unit of the data model. *BuildingFormatLot* and *VolumetricLot* are used to describe 3D legal objects.

(c) Does the data model have other forms of spatial units?

No other forms of spatial units are considered in the data model.

(d) What are the data sources (reference [legal] documents)?

Title, Approval, Dealing and any other legal documents that defines rights or ownership of land attached to the parcel are used as sources of information.

(e) For what applications can the data model be used?

They can be used to: eliminate the current reliance on hardcopy or PDF plans, improve the quality of plan data and associated documents, improve plan examination processing, reduce requisitions, and enhance the accuracy of the Digital Cadastral Database.

(f) Does the data model have other types of interests (rights)?

Primary parcels are based level parcels that form the continuous cadastral fabric. They consist of lots, roads, reserves, common property, crown parcels and staged lots. In ePlan, they are captured using the parcel element (ePlan 2010).

Secondary interests in cadastral survey plans provide benefits and/or pose restrictions on primary cadastral parcels. These include easements, restrictions and depth limitations (ePlan 2010).

(g) Does the data model consider temporal aspects of interests?

Temporal information such as transaction date, surveying date, and administrative date is recorded in the data model.

(h) How does data model render stratified RRRs?

Each Australian state and territory has modified the ePlan's national protocol specification (ePlan 2010) to cater for its requirements. For example, the Victorian ePlan version does not support volumetric lots and ePlan's 3D elements, such as *VolumetricLot* (3D parcel) and *VolumeGeom* (3D primitive), have been excluded from the Victorian ePlan model (ePlanVictoria 2010). In Victoria, stratified interests are represented as 2D parcels.

Queensland, in contrast, supports 3D parcels and defines the properties of a 3D coordinate geometry collection (ePlanQueensland 2010). Building Format Plan and Volumetric Format Plan are two types of 3D parcels (Fig. 4).

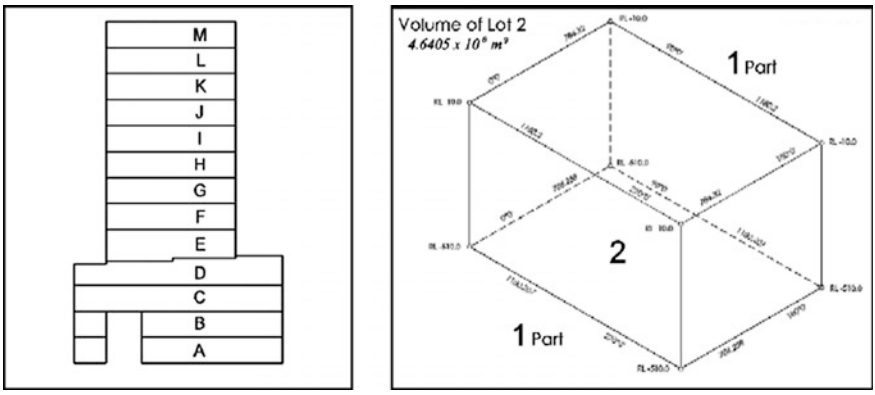

Fig. 4 Building format plan (*Left*) and volumetric format plan (*Right*) (DERM 2011)

In Queensland, if the format of the parcel is Building or Volumetric, it is mandatory to use building level number (*BuildingLevelNo*) and volumetric geometry (*VolumetricGeom*) to represent stratified interests (ePlanQueensland 2010).

(i) At what level does the data model support semantics?

Semantics are used to define the model's classes and attributes. However, the data model does not define the geometrical description of parcel.

(j) How does the data model support the physical counterparts of legal objects?

This ePlan does not support physical counterparts of legal object (parcel).

Overall, the current ePlan model has been exercised rigorously over the last several years in Australian jurisdictions. It has been designed to support 3D surveys, which include Volumetric and Strata (Building) surveys. These types of surveys can be prepared with the current protocol but have not been fully exercised (Cumerford 2010).

This ePlan is serving very well for 2D cadastre; however, having only *VolumetricLot* and *BuildingFormatLot* as attributes of ePlan's Parcel class (Fig. 4) to support Volumetric and Strata (Building) surveys, they are not enough to support the requirements of 3D cadastre (Aien 2012), which will be described in the next chapters.

5 LADM (ISO 19152)

The Land Administration Domain Model (LADM) is now the ISO standard and most recognisable data model in land administration discourse. This data model has been under development since the early 2000s. The LADM provides a conceptual description for a land administration system. The model aims to provide an extensible basis for the development and refinement of efficient and effective land administration systems and to enable involved parties, both within one country and between different countries, to communicate, based on the shared vocabulary implied by the model (ISO19152 2012).

(a) What are the core objects of the data model?

LADM has four basic classes (Fig. 5). They are *LA_Party*, *LA_RRR*, *LA_BAUnit*, and *LA_SpatialUnit* (ISO19152 2012).

- *LA_Party*: A person or organisation that plays a role in a rights transaction.
- *LA_RRR*: *Right* (action, activity or class of actions that a system participant may perform on or using an associated resource), *Restriction* (formal or informal obligation to refrain from doing something), *Responsibility* (formal or informal obligation to do something).
- *LA_BAUnit*: A Basic Administrative Unit is an administrative entity, subject to registration (by law), or recordation consisting of zero or more spatial units

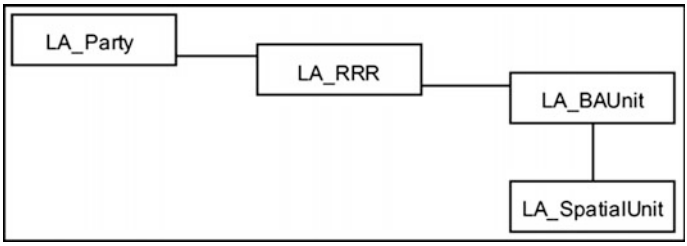

Fig. 5 Basic classes of LADM (ISO19152 2012)

against which (one or more) unique and homogeneous rights, responsibilities, or restrictions are associated to the whole entity, as included in a land administration system.

- *LA_SpatialUnit*: A single area (or multiple areas) of land and/or water, or a single volume (or multiple volumes) of space. Spatial units are structured in a way to support the creation and management of basic administrative units.

(b) What are the basic spatial units of the data model?

LA_SpatialUnit is the basic spatial unit of the data model. LADM's code lists for Spatial Unit Package represents all types of spatial units supported by LADM (Fig. 6).

(c) Does the data model have other forms of spatial units?

Yes, LADM's spatial component (*LA_SpatialUnit*) supports many ranges of spatial units such as *Sketch-based*, *Text-based*, *Point-based*, *Line-based*, *Polygon-based*, and *Topology-based* units. These spatial units are applicable in different land administration systems.

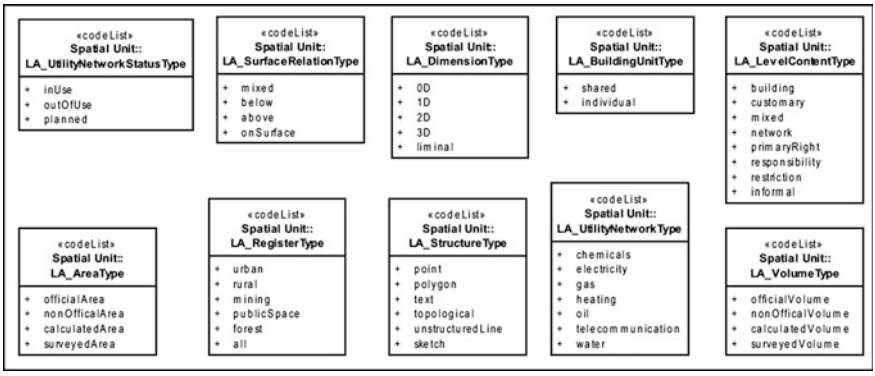

Fig. 6 Code lists for spatial unit package (ISO19152 2012)

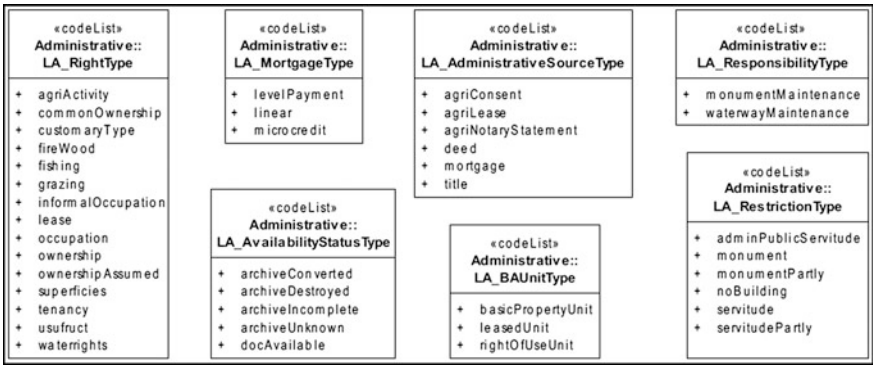

Fig. 7 Code lists for administrative package (ISO19152 2012)

(d) What are the data sources (reference [legal] documents)?

The data sources are all documents providing legal and/or administrative facts on which the land administration objects such as rights, restrictions, responsibility, basic administrative units, parties, or spatial units are based on. Deeds, titles, mortgages, agreements are examples of administrative or legal documents.

(e) For what applications can the data model be used?

The data model can be used for a number of land administration applications.

(f) Does the data model have other types of interests (rights)?

LADM's code lists for the administrative package that represents all types of interests supported by LADM (Fig. 7).

(g) Does the data model consider temporal aspects of interests?

Yes. LADM covers history and dynamic aspects. *Class VersionedObject* is introduced in the LADM to manage and maintain historical data in the database. History requires, that inserted and superseded data, are given a time-stamp. In this way, the contents of the database can be reconstructed, as they were at any historical moment. Most of LADM's classes are subclasses of *Class VersionedObject*.

(h) How does data model render stratified RRRs?

LADM has a solution to represent stratified interests and 3D parcels using Class *LA_BoundaryFace*. However, the LADM does not use solid geometry (*GM_Solid*) to represent 3D parcels. Pouliot et al. (2011) also suggests how solid representation can increase LADM's 3D functionalities. Solid geometry facilitates 3D representation, volumetric calculation, and 3D spatial analysis.

LADM uses Class *LA_BoundaryFaceString* to represent 2D *LA_SpatialUnit* such as land parcels, and Class *LA_BoundaryFace* to represent 3D *LA_SpatialUnit*

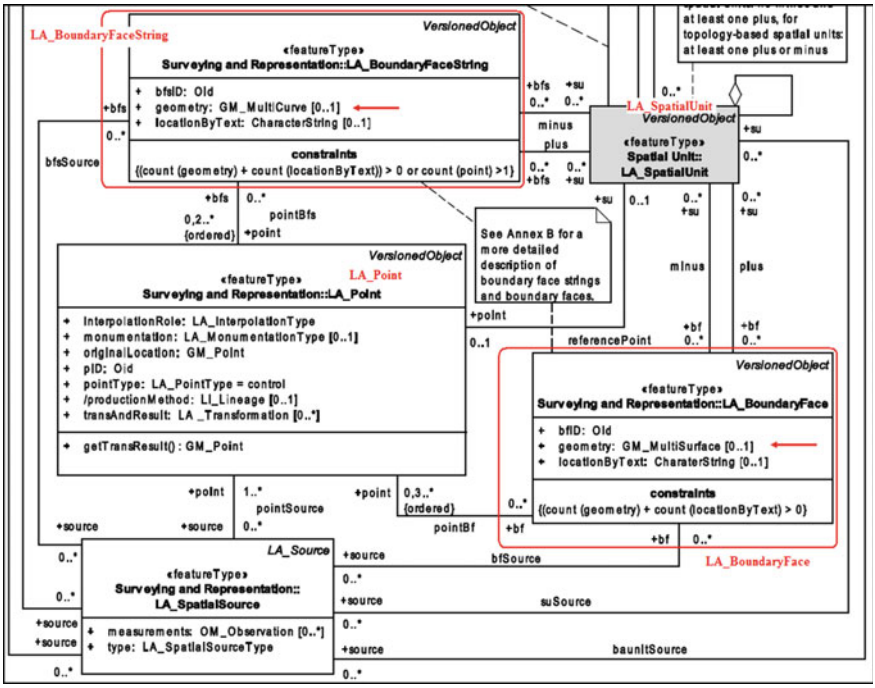

Fig. 8 Surveying and representation subpackage of LADM (ISO19152 2012)

such as 3D parcels (apartment units). These classes are defined by associating to Class *LA_Point* and Class *LA_SpatialSource* (survey documents).

LADM also utilises ISO 19107's *GM_MultiCurve* and *GM_MultiSurface* geometry objects to represent Classes *LA_BoundaryFaceString* and *LA_BoundaryFace* respectively. They are included as attributes of those classes (Fig. 8).

According to ISO 19107, *GM_MultiSurface* is an aggregate class containing instances of *GM_OrientableSurface*. *GM_OrientableSurface* consists of a surface and an orientation inherited from *GM_OrientablePrimitive*, which is a subclass of *GM_Primitive*. Figure 9 shows that *GM_MultiSurface* only returns accumulated area and perimeter of all *GM_Surfaces* contained in the *GM_MultiSurface* and does not return volume (ISO19107 2005).

In contrast, using *GM_Solid* and *GM_CompositeSolid* in 3D cadastral data models to construct and represent 3D objects would facilitate 3D spatial analytical methods (3D buffering, overlap, intersect, etc.), interoperability for 3D data (integration, data discovery), 3D computation, and 3D visualisation (Zlatanova and Lee 2008). Therefore, LADM's *LA_BoundaryFace* cannot return volume of the 3D objects according to ISO 19107 standard. Table 2 summarises LADM's representation objects, their geometry attributes and corresponding objects in ISO 19107.

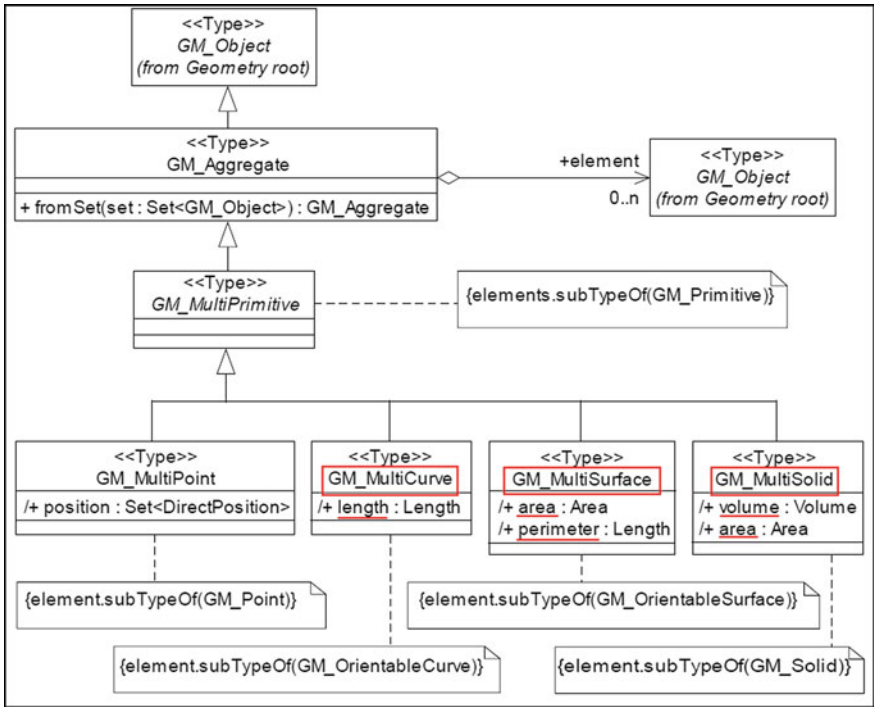

Fig. 9 *GM_MultiSurface* returns accumulated area of all *GM_Surfaces* contained in the *GM_MultiSurface* (ISO19107 2005)

Table 2 LADM's representation objects and their attributes

LADM's representation objects	Corresponding legal objects	LADM's geometry attributes	Corresponding attributes in ISO 19107
LA_BoundaryFaceString	2D parcel	GM_MultiCurve [0..1]	Returns: **length**
LA_ BoundaryFace	3D parcel	GM_MultiSurface [0..1]	Returns: **area** and **perimeter**, **No** volumetric attributes

(i) At what level does the data model support semantics?

Semantics are used to define the model's classes, attributes. However, LADM's 3D geometry representation class (*LA_BoundaryFace*) does not fully support semantics.

LA_BoundaryFace (semantic object), which is used to represent *LA_SpatialUnit* (semantic object) or its two specialisations *LA_LegalSpaceBuildingUnit* and *LA_LegalSpaceUtilityNetwork*, is not semantically enriched (Fig. 10). Semantically

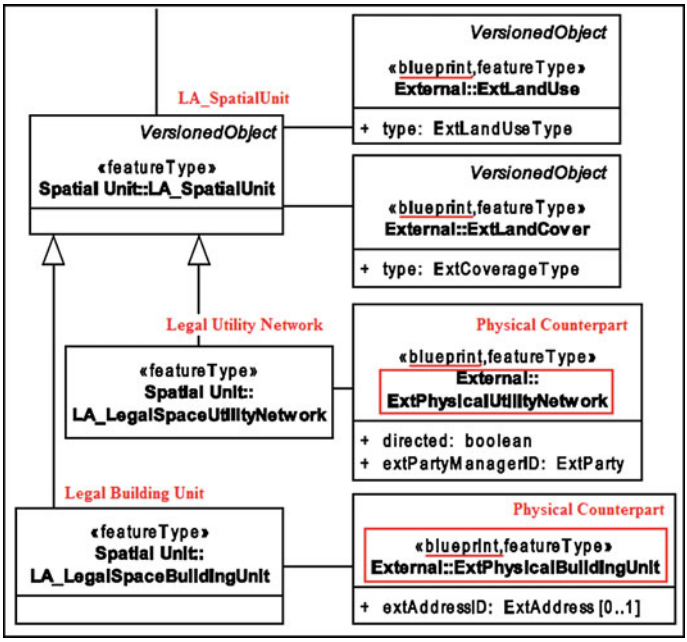

Fig. 10 External classes such as *ExtPhysicalUtilityNetwork* and *ExtPhysicalUtilityNetwork* in relation to LADM's *LA_SpatialUnit* class (ISO19152 2012)

enriched data means enriching the content/context of the data by categorising or classifying data in relationship to each other. In a level of semantics, for example, a 3D object can be defined as a residential unit or a car park using appropriate names and attributes in a 3D virtual city models. In more detailed and enriched level, various parts/structures of the unit or car park including its walls, floors and ceilings can be identified.

A *LA_LegalSpaceBuildingUnit* that is represented by *LA_BoundaryFace* is used to describe the extent or part of an administrative entity (*LA_BAUnit*) that is associated with one or more unique and homogenous right (*LA_Right*) such as an ownership right. In the case of apartment units, ownership rights are defined based on physical structures and bounded by walls, roofs, floors and ceilings. It must also define whether the surface boundaries are interior, median, or exterior boundaries. *LA_BoundaryFace* does not provide such semantics and it represents merely the bound shape of a spatial unit using surfaces regardless to their definitions.

(j) How does the data model support the physical counterparts of legal objects?

LADM makes a distinction between legal and physical objects by introducing external classes. However, it is not possible to explicitly model a physical object in LADM. Using < <blueprint > > stereotype in external classes (Fig. 10,

highlighted in red colours) indicates that the classes are outside the scope of the LADM (ISO19152 2012), which means that they are not directly created in the LADM.

As such, LADM's legal objects are connected using object identifiers to the physical objects, which are in the external databases. For example, *ExtPhysicalUtilityNetwork* is a class for the external registration of mapping data of utility networks and is associated to Class *LA_LegalSpaceUtilityNetwork* (Fig. 10).

Also, *ExtPhysicalBuildingUnit* is a class for the external registration of mapping data of building units. *ExtPhysicalBuildingUnit* is associated to class *LA_LegalSpaceBuildingUnit* (Fig. 10).

In this model, the legal and physical objects are kept in different sources and are manipulated by different data providers. Diversity in data providers would create inconsistency in the integration of datasets, including institutional, technical, social, legal, and policy heterogeneity (Mohammadi et al. 2010). As a result, legal models may not match with their corresponding physical models in this data models.

Overall, LADM can be used as a basis for land administration system developments. It enables communication between land administration parties, both within one country and between different countries, based on the shared vocabulary implied by the model. However, implementation of LADM is not obvious (Pouliot et al. 2011). It supports 3D representation of interest. But, semantics are not fully supported by the data model in terms of geometry representation.

6 Summary of the Models and Conclusions

In this paper, six popular and important cadastral data models were reviewed and assessed. Actually, a few more data models such as DM.01 (Steudler 2005), Hormonised Data Model (ICSM 2008), South Korean Cadastral Data Model (Lee and Koh 2007; Park et al. 2010) were investigated; however, only six of them were chosen because they were well documented and accessible to the researcher.

The aim of this paper was to understand how existing cadastral data models manage stratified land rights, restrictions, and responsibilities and their physical counterparts. Ten criteria were developed for the assessment purpose. They helped to explore each data model in detail. The results were summarised in Table 3.

Overall, it is concluded that although cadastral data models vary among jurisdictions, they rely on the basic building block of a 2D land-parcel. This trend is working satisfactorily for areas where no layered and stratified land rights exist. However, for 3D developments above and below ground, such as apartments, multi-story buildings, tunnels, and utilities, a 2D land parcel is no longer the most effective building block of cadastres; it is replaced by the 3D parcel. The 3D parcel is a volume of space on, above, or below the ground that defines and represents a particular array of rights, restrictions, or responsibilities (Aien et al. 2015).

Table 3 Specifications of the data models

Specification	Core cadastral Data Model	FGDC	ArcGIS parcel Data Model	Legal property Object Model	ePlan	LADM
Core objects	Person, right, parcel	Agent, Right and Interest, Parcel	Ownership, Encumbrances, Separated Rights	Person, Legal Property Object	Parcel, Document, Survey, Surveyor, Observation, Address, Point, Geometry	LA_Party, LA_RRR, LA_BAUnit, LA_SpatialUnit
Basic spatial unit	2D parcel	2D parcel	2D parcel	Legal Property Object	2D Parcel	LA_Spatial Parcel
Other forms of spatial units	N/A	N/A	Vertical parcels	Every object will be treated as a separate Legal Property Object	BuildingFormatLot, VolumetricLot	Sketch-based, Text-based, Point-based, Line-based
Reference documents	Transactions evidences, mortgages	Deed, aerial, photograph, agreement, mortgage, satellite image, survey notes	Deeds, survey plans, mortgages, lease contracts	All legal Document	Title, approval, dealing, any other legal documents	All documents providing legal and/or administrative facts
Applications	Valuation, taxation, security of land tenures, spatial or physical planning	Model cadastral information, Basis for automating the legal elements	Development of parcel level management, Support parcel level functionality in the GIS environments	Facilitates the land administration system to be more extensible and scalable in terms of new legislations and land-related laws	Eliminate the current reliance on hardcopy or PDF plans, Improve the quality of plan data, Improve plan examination processing	Land administration applications
Inclusion of other types of interests	N/A	Mineral rights, oil rights, grazing rights, fishing rights, development rights, floodplains	Mineral rights, oil rights, grazing rights, fishing rights	Biota rights, Mineral rights	N/A	Utility Network

(continued)

Table 3 (continued)

Specification	Core cadastral Data Model	FGDC	ArcGIS parcel Data Model	Legal property Object Model	ePlan	LADM
Temporal aspects	Yes	Yes	Yes	Yes	Yes	Yes
Management & representation of stratified RRR	2D parcel	2D Parcel	2D Parcel	2D Parcel	2D Parcel, VolumeGeom	LA_BoundaryFaceString (2D Parcel), LA_BoundaryFace (3D Parcel)
Semantic-level	Class and attribute description	Class and attribute description	Class and attribute description	Class and attribute description	Class and attribute description	Class and attribute description
Physical objects	N/A	N/A	N/A	N/A	N/A	External databases

Most of the cadastral data models such as the Core Cadastral Data Model, FGDC, and ArcGIS Parcel Data Model have been developed based on 2D land-parcels. ePlan and LADM support 3D parcels to model 3D RRRs. However, it has not been fully exercised in ePlan (Cumerford 2010). And, LADM does not use solid geometry (GM_Solid) to represent 3D parcels.

None of cadastral data models' geometrical representation is semantically enriched. Semantic enrichment reduces the ambiguities for geographic integration and geometrical inconsistencies (Kolbe 2009).

3D cadastres can be used by different customers within multiple applications, provided a common information model could extend over the different users and applications. A semantically enriched 3D cadastral data model would then enable collaboration in heterogeneous environments.

The cadastral data models do not integrate physical counterparts with 3D legal objects (3D parcels) (Aien et al. 2013b). The required level of detail of physical information is dependent on the application. For example, land registries may require a simplified overview of the physical models (walls, ceilings, and roofs), while very detailed information (windows, doors, stairs, and pipes between walls) may be required in property management. Using LADM's external classes would not allow the users to define the level of detail of required information for a specific application.

Acknowledgments The authors wish to acknowledge the support of the Australian Research Council Linkage Project (LP110200178) on Land and Property information in 3D, its industry partners and the members of the Centre for Spatial Data Infrastructures and Land Administration in the Department of Infrastructure Engineering, The University of Melbourne, in the preparation of this paper and the associated research. However, the views expressed in the paper are those of the authors and do not necessarily reflect those of these groups.

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