**Strata Title in LandInfra from a Land Administration Perspective**

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**Abstract** Strata title, or condominium, is a form of ownership, concerning apartments in multi-level buildings. Stairways, roof, heating system, etc., and the concerned land parcel constitutes common property, which is managed by an association of apartment owners. A Strata Title Scheme specifies the individual units (also called lots) in very much the same way as a cadastral survey specifies cadastral parcels with identifier, boundary, and area. In addition, the Scheme locates the units to their respective floors and assigns to each unit a share in the common property.

An OGC Land and Infrastructure Conceptual Model (for short: LandInfra) for land parcels and the built environment is in preparation. The intention is to cover the content of LandXML and additionally support modern survey equipment. Therefore, LandInfra among others includes the packages Survey, and Land Parcels, respectively. This paper is concerned only with the modelling that reflects the strata title scheme. Concepts in related standards are compared, namely ISO 19152:2012 Geographic information - Land Administration Domain Model (LADM), CityGML with three proposals for Application Domain Extensions, and the buildingSMART standard IFC.

Based on the comparison, the modelling by Volkan Cagdas (2013) is considered the most relevant source of inspiration for LandInfra. His research presents a CityGML ADE with an articulated modelling of physical and legal aspects of building units as suggested by the LADM standard, and in addition specifies how to accommodate for LandXML needs.

1. **Introduction**

Strata title, or sectional title (in South Africa), or condominium (in most of North America and Europe), is a form of ownership, namely to apartments in multi-level buildings. In some jurisdictions, e.g. the USA, the condominium term is also used for detached housing schemes, but this is ignored here. Stairways, roof, heating system, etc., and the land parcel on which the building rests, constitute common property, which is managed by an association of apartment owners. Membership of this association is compulsory for apartment owners, and the associations' purpose is confined to management of the common property.

A Strata Title Scheme specifies the individual units (also called lots) in very much the same way as a cadastral survey specifies cadastral parcels with identifier, boundary, and area. In addition, the scheme locates the units to their respective floors and assigns to each unit a share in the common property. Finally, bylaws of the owner association must be lodged in the land registry, whether they are considered part of the strata title scheme or not.

In one of the LandXML jurisdictions, New South Wales, Australia, the establishment of a Strata Title Scheme presupposes two types of documents:

* Schedule of Unit Entitlements [which] breaks down for each unit, or ‘Lot’, what their ‘weighting’ is compared to other lots, and
* Plan Drawing Sheets must be provided and contain details on the exact geographical location of the building. It shows how the building sits in relation to the land parcel’s boundary. A floor plan must also be provided and is used to define the new strata units. ([Source](http://premiumstrata.com.au/common-questions/strata-title-strata-scheme-strata-plan-difference/))

Even if we in Denmark talk of condominiums, we also have to prepare a Condominium Registration Sheet (Ejerlejlighedsfortegnelse) for each of the condominium units with their corresponding share (~= weight) in common property, as well as Condominium maps (Ejerlejlighedskort), showing condominium location, boundaries and area, and the footprint of the building on the cadastral parcel. A condominium unit (in Denmark) may consist of separate lots, e.g. an apartment on 2nd floor and a garage on the ground.

As LandInfra is supposed to contain LandXML functionality, the information content of the mentioned two documents has to be represented in the LandInfra scheme. (For New South Wales, two other document types are mentioned, addressing Encroachments and Easements, respectively. As these issues are not specific for the strata/ condominium issue, they are not addressed here). LandXML includes among others the class Parcel with the following four attributes: Parcel+buildingLevelNo, Parcel+buildingNo, Parcel+liabilityApportionment, and Parcel+lotEntitlements. ([LandXML - 1.2 Documentation. 2008](http://www.landxml.org/schema/LandXML-1.2/LandXML-1.2%20Documentation.zip%22%20%5Ct%20%22_blank)). In ePlan they are grouped into two classes: Parcel::BuildingFormatLot, and Parcel::SchemeLand ([Intergovernmental Committee on Surveying and Mapping (2011) ePlan Protocol LandXML Mapping. Version: 2.1.2. Version Date: 12/08/2011](https://icsm.govspace.gov.au/files/2011/09/ePlan-Protocol-LandXML-Mapping-v2.1.pdf)), cf. Figure 1 below.



Figure 1. ePlan Model Diagram.

Section containing BuildingFormatLot and SchemeLand. [(Source)](http://icsm.govspace.gov.au/files/2010/11/ePlan-Model-Diagram.jpg)

The purpose of this note is to identify, if possible, whether and how the strata title needs, including the LandXML rendering of these, may be met by related standards, and more specifically, how it might be represented in LandInfra. No ambition is made to comply with UML formalism at this stage. Drawing on recent research, the following sections present the strata title/ condominium related parts of the three standards: ISO 19152:2012 Geographic information - Land Administration Domain Model (LADM for short), CityGML, and the buildingSMART standard IFC.

CityGML is outlined firstly, as this standard is frequently referred to in research which addresses the two other standards. As we shall see, CityGML may be extended through Application Domain Extensions. After presenting LADM and research which relates LADM with LandXML, three of such extensions are presented, and finally the potential of IFC is indicated. A Discussion section seeks to weigh pro et con, before the paper closes with a Conclusion.

1. **CityGML**

The CityGML data model enables the representation of the same city object in different degrees of resolution through the notion of level-of-detail (LoD). Five levels are specified: LoD0 the coarsest level is the digital terrain model. LoD1 provides a block model, without any roof structures. LoD2 is the block model with roof structures, texture and larger building installations. LoD3 provides detailed architectural models. Finally, LoD4 enriches LoD3 by adding interior structure objects (OGC, 2012, pp.12–13).

Of CityGML's modules, the Building module is central for the present purpose. The main class of the Building module is AbstractBuilding, which is either a BuildingPart or a Building. The former is used to model a structural part of a building. However, if a building consists of only one (homogeneous) part, the latter class is used. The BuildingPart and Building classes inherit the attributes of AbstractBuilding, among others the class of the building, its function, and the number and individual heights of the storys above and below ground. A building may have zero or more building installation objects such as chimneys, stairs, antennas, or balconies which are represented by the BuildingInstallation class. Moreover, a Building or BuildingPart consist of Rooms which also may have BuildingFurniture and IntBuildingInstallations. The BuildingFurniture refers to a movable part of a room, such as a chair or table, whereas an IntBuildingInstallation is used to model an object inside a building and permanently attached to the building structure, e.g. interior stairs, railings, radiators and pipes (OGC, 2012, pp. 67–82).

Although CityGML can be used to represent indoor space in LoD 4, it is not an appropriate data model to manage indoor space facilities (Y. Kim, et al., 2014, 247). CityGML may need to define detailed classes to describe facilities in indoor space, because the CityGML data model is focusing mostly on urban space. Therefore, the CityGML Building Model needs to be expanded to deal with additional classes used for indoor facility management applications.

Concluding, CityGML classes cover the physical features of a building and it’s interior. Managerial or other functional aspects request an alternative view of the building, which thus has to be added. This applies also for the legal boundaries between the individual property (condominium) units on one hand, and staircases and other common property on the other. However, the representation of legal extents can be implemented using CityGML’s extension mechanism called Application Domain Extension (ADE), cf. (Rönsdorf, et al, 2014).

1. **LADM**

The LADM is a conceptual model, and not a data product specification. The data model provides a standardized global vocabulary for land administration (Lemmen, et al, 2015). The standard covers basic information-related components of land administration (including those over water and land, and elements above and below the surface of the earth). The focus of the standard is on that part of land administration that is interested in rights, responsibilities and restrictions affecting land (or water), and the geometrical (geospatial) components thereof. It is based on the conceptual framework of ‘Cadastre 2014’ of the International Federation of Surveyors (FIG), while the geospatial aspects follow the ISO/TC 211 conceptual model (LADM, page vi). Both LADM and CityGML are compatible with ISO19107 which ensures an overlap of allowed geometry types (Rönsdorf, et al 2014).

The conceptual schema of LADM is structured into four packages with names and relations as follows:

1. Party Package: parties (people and organizations);
2. Administrative Package: basic administrative units, rights, responsibilities, and restrictions (ownership rights);
3. Spatial Unit Package: spatial units (parcels, and the legal space of buildings and utility networks); including
4. the Surveying and Representation Subpackage: spatial sources (surveying), and spatial representations (geometry and topology);

LADM's Spatial Unit has two sub-classes, LA\_LegalSpaceBuildingUnit and LA\_LegalSpaceUtilityNetwork, which represent the legal boundary of a building unit and a utility network, respectively. Following Kean Huat Soon, et al. 2014, the LA\_SpatialUnit and LA\_LegalSpaceBuildingUnit concepts from the LADM are equivalent classes with the Parcel and BuildingFormatLot classes from the ePlan model respectively. Both Spatial Unit and Parcel play the same role to make the connection between the spatial and non-spatial attributes of a property unit. However, the BuildingFormatLot class of the ePlan model does not contain the spatial element (i.e. geometry) of a parcel, as the BuildingFormatLot class is only described by two attributes: BuildingNo and BuildingLevelNo.

In previous research, LADM was formalized in Web Ontology Language (OWL) (Soon, 2013). With the intention to use the LADM OWL ontology for automated integration of land administration information, the LADM OWL ontology was augmented with a new concept Physical Space Building Unit (see Figure 8). In addition, as a physical building sometimes can have more than one legal boundary, for example through strata subdivision, a relation is defined as hasLegalSpace between Physical Space Building Unit and Legal Space Building Unit. The Physical Space Building Unit is considered as an equivalent class with the Abstract Building class from the Building module of CityGML (Soon et al, 2014, 324, 332, 333).



The framework of Soon et al attempts to integrate not only the semantic models inherent in the schemas, but also the geometries from CityGML and LandXML. This may be realized using the ExternalReference of CityGML and the DocFileRef elements of LandXML to transmit the URIs of concepts in the LADM OWL ontology. Telling in the present context is that the research pointed towards the need of relating LADMs Legal Space Building Unit with CityGMLs AbstractBuilding class, among other motivated with reference to strata subdivision.

1. **CityGML Application Domain Extensions which account for functional or legal partitioning of buildings**

A number of Application Domain Extensions (ADEs) have been developed for CityGML, including a Utility Network ADE ([citygmlwiki](http://www.citygmlwiki.org/index.php/CityGML-ADEs%22%20%5Ct%20%22_blank); [Zeis, 2012](http://geospatial.blogs.com/geospatial/2012/05/standards-based-intelligent-modeling-of-urban-multi-utility-networks.html)). As the focus here is on the modelling of functional or legal partitioning of buildings, only three recent efforts are presented, namely A Turkish case study, suggesting an ADE for immovable property taxation ([Cagdas, 2013](http://www.sciencedirect.com/science/article/pii/S0303243412001511)), an Indoor ADE to Manage Indoor Facilities ([Kim et al, 2014](http://link.springer.com/chapter/10.1007/978-3-319-00515-7_15)), and a LADM ADE for integration of LADM and CityGML ([Rönsdorf et al, 2014](http://www.gdmc.nl/3DCadastres/literature/3Dcad_2014_32.pdf%22%20%5Ct%20%22_blank)).

**An ADE for immovable property taxation**

Immovable property is specified in Turkish Civil Law as a cadastral parcel and a condominium unit. Turkish Condominium Ownership Law provides further details, most of which are covered sufficiently for the present purpose by the Introduction section. As in Denmark, a condominium unit may include, e.g. coal cellars and garages. These complementary parts of condominium units are called Annexes by Turkish law.

CityGML includes the BuildingPart class to represent the structural parts of buildings, but does not have a class to identify the legal parts (i.e., condominium units, joint facilities, and annexes) of buildings required for taxation purposes. This requirement is addressed in the developed ADE with a new abstract class, BuildingUsePart, which is an extension of the abstract Site and has CondominiumUnit, JointFacility, and Annex as concrete classes. The CondominiumUnit has the following attributes: number of condominium unit, number of floor where the condominium unit is located, area of condominium unit, ownership fraction of condominium unit, and tax value of condominium unit, as assessed by municipalities.

The abstract Site has Abstract Building as an extension, which is composed of one or more BuildingUseParts. The ADE includes specification of classes CadastralParcel and PropertyUnit, and a number of enumeration lists, but these and their relations are bypassed here.

**Indoor ADE for indoor space and indoor facility management applications**

CityGML Indoor ADE incudes two feature models based on CityGML Building Module, namely Indoor Space Feature Model and Indoor Facility Feature Model. The Indoor Space Feature Model represents space features like reading rooms, meeting rooms, and office rooms. The context is subway stations and public government buildings, and authors note the need for a feature class representing story for managing floors. Moreover, the feature model needs to represent the rooms as a set feature by combining the rooms in indoor space.

To meet this request, an extension of CityGML Building Package is proposed in terms of an Indoor Space Feature Model. Based on CityGML Building Model, the added feature classes are Indoor::InteriorBuildingObject and Indoor::Storey. Indoor::InteriorBuildingObject is a feature class to represent indoor space and indoor facilities in the space of the building like meeting rooms, office rooms, or parking lots. It is added not only distinguishing between outdoor space and indoor space, but also representing the rooms and facilities as a set feature. Indoor::Storey describes the indoor spaces representing a particular level of the building, and the class can be used to manage each floor.

The Indoor Facility Feature Model describes indoor facility features such as disaster facility, convenience facility, and mobile facility. For example, the ADE extends CityGML's IntBuildingInstallation with the feature class Indoor::MobileFacility, comprising stairs, elevators, etc.

As mentioned, the context motivation the Indoor ADE was subway stations and public government buildings, and not immobile property related issues. However, the feature classes Indoor::InteriorBuildingObject and Indoor::Storey both appear very relevant. Whether CityGML's IntBuildingInstallation would be relevant for modelling the common property of condominium units seems less certain.

**LADM ADE for integration of LADM and CityGML**

For integrating the Land Administration Domain Model with CityGML, the following feature classes are found particularly relevant (LADM classes are prefixed LA\_. LA\_SpatialUnitGroup is not mentioned, as it is not addressed in the present discussion):

* LA\_SpatialUnit: base class for spatial representations. LADM explicitly allows volumetric spatial representations in 3D.
* LA\_LegalSpaceBuildingUnit: A specialisation of LA\_SpatialUnit to link legal spaces to physical ones. This is useful to describe legal spaces within a building which coincide with the physical space of the building or parts of it. [as is the case for strata title]
* LA\_BAUnit: An administrative unit that can be represented by spatial units.
* LA\_RRR is used to describe Right, Restriction, Responsibility to give meaning to a BAUnit which is represented by a spatial unit. (Rönsdorf et al, 2014, 315)

The LA\_BAUnit compares to what Cadgas describes as a PropertyUnit. The LADM standard mentions a LA\_BAUnitType, which could be used to distinguish PropertyUnits consisting of a single land parcel, of more land parcels, of land parcel and building owned according to a strata scheme, of an individually owned building on a leased land parcel, and several more, depending on the legal provisions and practice of the jurisdiction concerned.

In developing the LADM ADE, rather than having a direct counterpart for LA\_BAUnit, the paper suggests ‘to directly create an instantiable object class with a semantic definition such as Parcel. Instances of this class can be linked to suitable instances of LA\_RRR qualifying the right associated with the Parcel. The Parcel can be represented by one or more SpatialUnits. LA\_SpatialUnit is implemented as the class LegalSpace which can have MultiSurface representations in different LoDs. A planimetric representation (i.e. a floorplan polygon with a given height) in LoD0 and a blockrepresentation (extruded and heighted block) in LoD1 appear to be useful in practise.’ (Rönsdorf et al, 2014, 318)

By avoiding a counterpart for LA\_BAUnit, authors seem to miss an opportunity to distinguish the different property types, mentioned above. As the LADM standard establishes that LA\_Parcel is an alias for LA\_SpatialUnit (5.5.1, p 10), it might be confusing to introduce a LADM ADE::Parcel as a quasi-counterpart for LA\_BAUnit. The statement that ‘a floorplan polygon with a given height in LoD0 and a blockrepresentation in LoD1 appear to be useful in practise’ seems not founded in the paper. The relevance of a given height (above some vertical datum?) has to be compared with the practice in most countries to indicate height by floor number. The paper informs that ‘the vertical separation of buildings into storeys is not covered by CityGML and can currently only be implemented by ADE’ (p. 316).

As regards the relationship between physical and legal representations, the paper notes that ‘the boundary of legal spaces may defined by or mered to any physical feature, all features with a physical representation in CityGML might be of relevance to express this relationship’ and next ‘suggest to model features with legal and physical representations independently and allow to establish an n:n relationships between these. Whilst the relationship between a LegalSpace and a Building is the most obvious one to be useful, relationships between LegalSpace and any \_CityObject should be allowed.’ (Rönsdorf et al, 2014, 316, 320)

Allowing for relationships might be useful, but in the present context it draws attention from ‘the relationship between a LegalSpace and a Building’ which indeed is the relationship most obviously needed. However, like storeys, the relationship between LegalSpace and Building is not specified in the LADM ADE.

**buildingSMART standard IFC**

buildingSMART International has published the Industry Foundation Classes IFC which represent an open specification for Building Information Modeling (BIM) data that is exchanged and shared among the various participants in a building construction or facility management project. ([Industry Foundation Classes IFC4 Official Release, 2013](http://www.buildingsmart-tech.org/ifc/IFC4/final/html/index.htm)). BIM is a computable representation of all the physical and functional characteristics of a building (Isikdag and Zlatanova, 2009).

We are looking for a way of modelling the legal distinction between individually and commonly owned parts of a building. This view of the building is basically motivated by a *functional* concern. Facility management has a similar view of the building, motivated by e.g. security or maintenance. As we shall see, IFC provides for functional views of a building and its parts. The following are quotes from the [Core schemas](http://www.buildingsmart-tech.org/ifc/IFC4/final/html/index.htm) of the IFC4. Numbers are retained for ease of reference with the source.

Inheritance listing of function-related classes originates with 5.1.3.5 IfcGroup, which is a generalization of any arbitrary group. A further specification is obtained through 5.4.3.53 IfcSystem, which is an organized combination of related parts within an Architecture, Engineering, and Construction product, composed for a common purpose or function or to provide a service. A system is essentially a functionally related aggregation of products. Finally, 5.4.3.57 IfcZone is a group of spaces, partial spaces or other zones. IfcZone is a mere grouping of instances of IfcSpace, it cannot define an own geometric representation and placement. If the need for own geometric representation occurs, IfcSpatialZone may be applied. 5.4.3.51 IfcSpatialZone is a non-hierarchical and potentially overlapping decomposition of the project under some functional consideration. A spatial zone might have its independent placement and shape representation.

An example from Denmark may illustrate the need of IfcSpatialZone: Roofs in Denmark are mostly inclined. The area of condominium units on roof storeys are measured in a plane 1.5 meter above finished floor ([CIR nr 177 af 25/08/1977 35, 4](https://www.retsinformation.dk/Forms/R0710.aspx?id=55012)). While most condominium units have legal boundaries, which compares to construction details, e.g. outer surface of walls, boundaries of roof units have faint relations with the construction. The normal condominium units may thus inherit geometric information through instances of IfcSpace (grouped into an IfcZone by using the objectified relationship IfcRelAssignsToGroup), while the roof storey units carry their own geometry through IfcSpatialZone.

The 5.4.3.45 IfcSpace is, in similar way as IfcZone, part of an inheritance hierarcy, with origin in IfcProduct and next IfcSpatialElement and including IfcBuildingStorey, but details are not rendered here.

1. **Discussion**

The research reviewed demonstrates a recent interest in standards, which accommodate LandXML needs and includes specifications which allow for recording of strata title ownership. Table 1 below renders for each of the five investigated papers their contribution towards LandXML needs, Combined physical and legal representations of building units, and Geometrical representation of space, respectively.

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| --- |
|  |
|  | LandXML+buildingLevelNo+buildingNo | LandXML+liabilityAppm.t+lotEntitlements | Physical and legal representationsof building units combined  | Geometrical representation of space |
| Soon et al, 2014 |  ? | ? | hasLegalSpace relates physical and legal building units | Through Extern.lReference |
| Cagdas, 2013 | floorNumberbuildingNumber | Ownership-Fraction | BuildingUsePart relating \_AbstractBuilding and CondominiumUnit, etc | Implicit, extending CityGML |
| Kim et al, 2014 | Indoor::Storey ~ | ? | Indoor::InteriorBuildingObject | Implicit, extending CityGML |
| Rönsdorf et al, 2014 |  ¬ ? | ? | relationship between LegalSpace and \_CityObject | MultiSurface rep. in CityGML |
| IFC 4, 2013 | IfcBuildingStorey ~ | ? | IfcZone grouping of instances of IfcSpace and IfcSpatialZone | ~ |

Table 1: Summary of research compliance with LandXML and strata title recording needs.
Legend:  ? : Not specified.   ~ : Not specified, but likely to be covered.  ¬ : Not covered

As for LandXML needs, Cagdas, 2013, stands out by covering LandXML needs concerning floorNumber, buildingNumbe, and ownershipFraction. The storey-related classes of Kim et al and IFC 4 provides for floor-related information, and no doubt, the building number can be accommodated for, hence the ~ in the table. Soon et al is not specific as to LandXML needs, hence the ?-sign. The ADE by Rönsdorf et al offers a 'floorplan polygon with a given height', but this does not directly compare with LandXML's need for identification and numbering of floors, hence a ¬-sign.

Soon et al, Cagdas, and Rönsdorf et al are all directly addressing the modelling of legal space in buildings.  Cagdas and Soon et al, in different ways present a modelling which combines physical and legal aspects of building units as suggested by the LADM standard's LA\_LegalSpaceBuildingUnit. Rönsdorf et al choose to model legal and physical representations independently.

The Indoor ADE of Kim et al provides for a modelling of interior building objects, which possibly could be developed to cover also land administration needs. The benefit of joining others, who are also interested in the development and implementation of an Indoor ADE, has to be weighed against the arguably less complex task of developing an CityGML ADE for the land administration community, as initiated by Rönsdorf et al.

buildingSmart International has set among its development goals the ability to map IFC alignment models to LandInfra and LandXML ([source](http://www.buildingsmart-tech.org/infrastructure/projects/alignment)). The specifications of IFC 4 in terms of IfcZone and IfcSpace compares to the LADM standard's classes LA\_BAUnit and LA\_SpatialUnit, cf. the presentation of these classes in the context of the review of the LADM ADE. The wish of being able to map IFC models to LandInfra provides a strong argument for maintaining both classes in LandInfra, and also in a further developed LADM ADE. In fact, as far as the above classes are concerned, the 14-116 OGC Draft LandInfra Conceptual Model allows for the intended mapping.

As to the geometrical representation of space, only the modelling by Rönsdorf et al is specific. However, this should not be considered critical from a cadastral / land administration point of view. Geometrical representation of space is indeed useful, but among others Danish experience attests that nominal and ordinal schemes of localization have priority relative to metric schemes. Nominal schemes are realized as names of landmarks, places, streets, and roads, while ordinal schemes are realized as house numbers and storey numbering. The 14-116 OGC Draft LandInfra Conceptual Model fits this need perfectly by containing geometrical representation issues within the class BoundingElement.

Summarizing this section, Cagdas, 2013 seems to have presented the most relevant source of inspiration for LandInfra, as his modelling combine physical and legal aspects of building units as suggested by the LADM standard, and in addition as the only author specifies an accommodation of LandXML needs.

#### Conclusion

The need of recording strata title / condominium information, as expressed by LandXML, was confirmed with Danish evidence. Analysis of five resent investigations of how to reconcile this need with available standards was performed. Cagdas (2013) presents a CityGML ADE with an articulated modelling of physical and legal aspects of building units, and in addition specifies how to accommodate for LandXML needs. Therefore, the modelling of this research is considered the most relevant source of inspiration for LandInfra. Three of the five investigations were developments of CityGML ADEs. The apparent attention towards CityGML might motivate a further development of the LADM ADE, initiated by Rönsdorf et al (2014).

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