DEVELOPMENT OF A CADASTRAL DOMAIN MODEL

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ABSTRACT: This paper gives an overview of efforts being made in the development of a Cadastral Domain Model. Two models, both under development, are presented: the first one as a result of joint efforts between Delft University of Technology and the International Institute of GeoInformation Science and Earth Observation ITC, The Netherlands. The second model is a draft version of a Cadastral Data Model for ESRIs ArcGIS.

1. Introduction

Cadastral systems include a database containing spatially referenced land data, a set of procedures and techniques for systematic *collection, updating, processing and distribution* of data and a uniform spatial reference system. Theoretical and practical developments in Geo-Information and Communication Technology ICT such as the ubiquitous communication (Internet), data base management systems (DBMS), information system modelling standard UML (Unified Modelling Language; Booch, Rumbaugh, Jacobson, 1999). and positioning systems will improve the quality, cost effectiveness, performance and maintainability of cadastral systems. Further, users and industry have accepted the standardization efforts in the spatial area by the OpenGIS Consortium and the International Standards Organisation (e.g. the ISO T211 Geographic Information/Geomatics).

As a next step starting of development of standardization of the Cadastral Domain is felt as useful. Many countries experience the development of cadastral systems as complex, time consuming and expensive. Starting from scratch is even more complex then adapting and extending an existing system.

A standardized core cadastral domain model, covering land registration and cadastre in a broad sense, will serve at least three goals: 1. avoid reinventing and re-implementing the same functionality over and over again, but provide a extensible basis for efficient and effective cadastral system development based on a model driven architecture, 2. enable involved parties, both within one country and between different countries, to communicate based on the shared ontology implied by the model and 3. facilitate cadastre data exchange between in country organizations (ex: National Agency and Municipalities) and between countries.

In (Van Oosterom, Lemmen, 2003) an overview is given of the initiatives in this domain:

1. Land Title and Tenure SIG: first initiative of the OpenGIS Consortium (OGC) in 2000,

2. Several standardization initiatives and developments in Cadastral Organizations:

- Introduction of ISO Standards in Germany (Seifert, 2002),
- US National Integrated Land System (FGDC, 1999, Meyer, von *et al.,* 2001),
- Initiatives from Australia and New Zealand (LINZ, 2002, LandXML, 2002, ICSM 1999, 2002),
- Initiative from Sweden: The EULIS project (Ollén, 2002),

3. COST Research Activity Statement,

4. The International Federation of Surveyors, FIG (Greenway, 2002).

Further initiatives can be recognised in Europe: INSPIRE is “an initiative to support the availability of spatial information for the formulation, implementation and evaluation of Union policies”.

After the introduction to the subject, an overview of a data model as developed in the Netherlands by Delft University of Technology and the International Institute of Geo-Information Science and Earth Observation (ITC) is given in chapter 2. An earlier version of this model, combined with the concepts of FIGs ‘Cadastre 2014’ (Kaufmann, Steudler, 1998) has been used as input for a Workshop on Cadastral Data Modeling, held in The Netherlands in April 2003. Outcomes of this workshop have been the basis for the development of a Cadastral Model by ESRI. The draft version of ESRIs Cadastral Data Model for ArcGIS is presented in chapter 3. Conclusions are presented in chapter 4.

2. Generic Cadastral Domain Model (V3, Delft University-Itc)

The contents of this chapter are based on a paper by (Lemmen, van der Molen, van Oosterom, Ploeger, Quak, Stoter and Zevenbergen, 2003), presented at the 'Digital Earth' conference in Brno, Czech Republic, September 2003. The core of the cadastral domain model as depicted the UML Class Diagram in Figure 1 is the central part of the model as was already presented at the FIG working week in April 2003, Paris (Lemmen, Van Oosterom 2003). The relationship between real estate objects (e.g. parcels) and persons (sometimes called 'subjects') via rights is the foundation of a land administration. Besides rights, there can also be restrictions between real estate objects and persons. The figure shows that RightOrRestriction is an association class between the classes Person and RealEstateObject. Note that this an n-to-m relationship, with the conditions that every person should at least be associated with one RealEstateObject and vice versa every RealEstate object should be associated with at least one Person (indicated in the UML diagram with the multiplicity of '1..*' at both ends of the association).

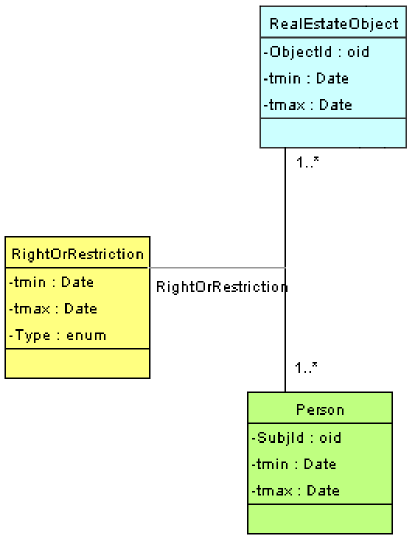

Figure 1 : Core of the Cadastral Domain Model

A UML class diagram describes the types of objects and the various kinds of structural relationships that exist among them like associations and subtypes. Furthermore the UML class diagrams show the attributes and operations of a class and the constraints that apply to the way objects are connected (Booch, Rumbaugh, Jacobson, 1999). The proposed UML class diagram for the cadastral domain contains both legal/administrative object classes like persons, rights and the geographic description of real estate objects. This means in principle that data could be maintained by different organizations, e.g. Municipality, Planning Authority, Private

Surveyor, Cadastre, Conveyancor and/or Land Registry. The model will most likely be implemented as a distributed set of (geo-) information systems, each supporting the maintenance activities and the information supply of parts of the dataset represented in this model (diagram), thereby using other parts of the model. This underlines the relevance of this model; different organizations have their own responsibilities in data maintenance and supply and have to communicate on the basis of standardized processes in so called value adding production chains based on data sharing.

One should not look at the whole model (all packages together as presented at the end of this section) at once as the colours are representing UML 'packages' or coherent parts of the model: green and yellow: legal/administrative aspects, green and blue: real estate object specializations, blue, pink and purple: geometric/topological aspects. It is likely that more packages will be developed. Besides being able to present/document the model in comprehensive parts, another advantage of using packages could be that it is possible to develop and maintain these packages in a more or less independent way. It is not the intention of the model that everything should be realized in one system. The true intention is that, if one needs the type of functionality covered by a certain package, then this package should be the foundation and thereby avoiding reinventing (re-implementing) the wheel and making meaningful communications with others possible. Furthermore basic packages could be implemented by software suppliers. In the following subsections the different packages will be described in more detail.

2.1. Specializations of RealEstateObject: object detail classes

A RealEstateObject is an abstract class, that is, there are no object instances of this object class. However, it has specialization classes (which have object instances), such as Parcel, ParcelComplex, PartOfParcel, VolumeProperty, RestrictionArea, ApartmentUnit, and NonGeoRealEstate. In a UML class diagram the specialization classes point to the more generic class with an open headed arrow. The specializations are mutual exclusive. The specializations of the RealEstateObject class are represented in the 'blue' package; see Figure 2. All these specialisations of RealEstateObjects have associations with one or more Persons via the RightOrRestriction association. The Parcels are also part of a two dimensional partioning of the surface (see section 2.4.), but not all these parts have this direct association with Persons. There are parts, called ServingParcels in our model, which only have direct associations with two or more (main) Parcels. This means that a ServingParcel serves a number of other Parcels; e.g. a joint facility, such as a path or playground. A straight line in the UML class diagram depicts this association. It could be considered as some kind of joint ownership via the (main) Parcels. In the UML class diagram Parcel and ServingParcel are both specializations of PartitionParcels, which all-together form the partition of the 2D domain. The PartitionParcel class, just as the RealEstateObject class, is an abstract class as there will never be instances of this class. Note that Parcel is based on multiple inheritance (from RealEstateObject and PartitionParcel, both abstract classes).

A ParcelComplex is an aggregation of Parcels. The fact that the multiplicity at the side ParcelComplex is 0..1 (in the association with Parcel) means that this is optional. A ParcelComplex situation might occur in a system where a set of Parcels - could be in one municipality or even in another administrative unit - has a legal/customary meaning, for instance being the object of one mortgage. A Parcel can be subdivided in two or more PartOfParcel's. This case could occur when 'preliminary' Parcels are created during a conveyance where the Parcel will be split and surveying is done afterwards. It could also be helpful to support planning processes, based on cadastral maps, where establishment of Parcels in the field is done later in time. Note that in the model a composite association is used, indication that the components (from the class PartOfParcel) have no meaning/right of existence without the aggregate class (Parcel), this in indicated with the closed diamond.

An ApartmentComplex is associated with one or more Parcel's. There can be at most one ApartmentComplex located on a Parcel. There can be two or more ApartmentUnit's in an ApartmentComplex. In case the multiplicity of a class in an association is one ('1'), then this is not explicitly shown in the UML class diagram as is the case at the site of the ApartmentComplex in the association between ApartmentUnit and ApartmentComplex. Note that an ApartmentUnit is intended in the general sense, not only unit for living purposes, but also for other purposes, e.g. commercial. In other words, all building units with legal/registration significance are included here.

Parcels are defined by ParcelBoundaries and have a geometric/topological description (Oosterom, van, Lemmen, 2001). The class ParcelBoundary always has two neighbour PartitionParcel's, where territorial ParcelBoundary's have one 'zero-Parcel' as neighbour, representing the external territory. There can be more then one ParcelBoundary between two neighbour PartitionParcels, depending on attributes and the geometric configuration. Exclaves and enclaves from territorial perspective can be managed in this approach. In general this approach implies that individual PartitionParcels, and therefore also the derived classes Parcel and ServingParcel, are not explicitly represented as 'closed polygons'. Attributes can be linked to individual boundaries; this allows for example classification of individual boundaries based on the administrative subdivision of the territory. In this way double, triple or multiple storage of the same boundary can be avoided, thus avoiding all kind of 'gap and overlap' problems, which don't have a meaning in reality. In most cadastral systems a restriction is associated to a complete RealEstateObject (Parcel) and this is also reflected in the presented model: a Person can have a (RightOr)Restriction on a RealEstateObject. There are also PublicRestrictions; see section 2.5. However, this may be inconvenient in some cases: one 'thing' may cause the restriction on many RealEstateObjects and in such a case this information has to be repeated many times, with all possibilities for inconsistencies. Further, a restriction might also cover/affect only a part of the RealEstateObject, but it is not (yet) registered which part this is.

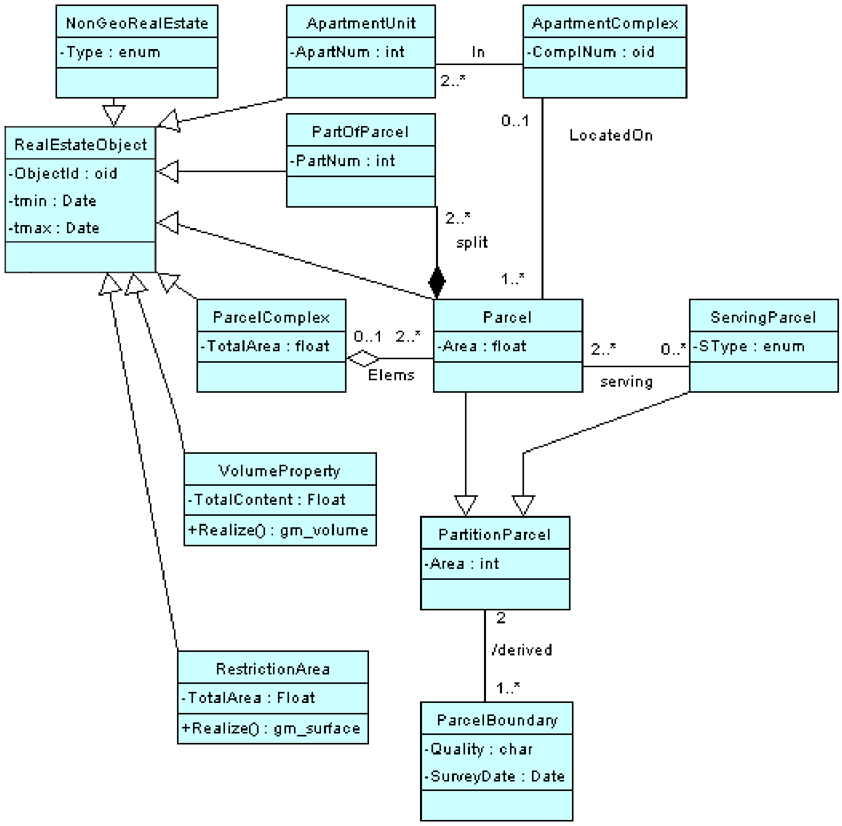

Figure 2 : The RealEstateObject package refined ('blue'part)

A better solution for this situation is to introduce a *new layer,* in addition to the planar partition of the PartitionParcels, with RestrictionAreas. This is comparable with and based on the 'Cadastre 2014' concept (Kaufmann and Steudler 1998, Kaul and Kaufman, 2003). These can be considered as a kind of RealEstateObjects 'overlapping' other RealEstateObjects, from which they 'carve out' a part of the associated rights. It is suggested to maintain only the 'positive' rights, that is not explicitly store (for one Person) that another Person has a part of the rights, in the cases where the 'positive' right holder is known (see also section 2.4.). This can be obtained via inspecting all rights associated with the RealEstateObject and the overlapping RestrictionArea's. Note that RestrictionArea's are modelled as closed polygons and obtain their coordnates from SurveyPoint's, (see section 2.3.) and there is no explicit topology between RestrictionArea, that is, they are allowed to overlap. It is expected that they will not often share common boundaries as Parcels do.

Because of the high pressure on the use of space, more and more situations occur which can best be modelled in three dimensions. Normally a (2D) Parcel represents the whole 3D column from the centre of the Earth, trough the surface out into the sky.

Explicit 3D VolumeProperties 'carve out' a part of this space in favour of another Person (the buyer of a 3D VolumeProperty). It is possible that one VolumeProperty overlaps with many Parcels (again this can be obtained via spatial overlay). In the same manner as suggested for RestrictionAreas, it is suggested only to register the 'positive' side of the registration without redundancy. VolumeProperties are modelled without external topology, but with internal topology by referencing several times to the same SurveyPoint, when this is shared between the different faces of a polyhedron. VolumeProperties should not overlap in 3D space. However, their projection in 2D space may overlap. It is expected that it will not happen often that VolumeProperties will share faces with other explicit VolumePropties (as is the case in 2D with the PartitionParcels). Might this assumption turn out to be wrong, then a 3D topological structured model should be introduced. More background and discussion on alternative 3D cadastral modelling can be found in (Lemmen, van der Molen, van Oosterom, Ploeger, Quak, Stoter and Zevenbergen, 2003).

The class NonGeoRealEstate can be useful in case where a (complete) geometric description of the RealEstateObject does not (yet) exist. E.g. in case where only one co-ordinate inside the RealEstateObject is observed, using Satellite Images or GPS. Or in case of a right to fish in a commonly held area (itself depicted as a ServingParcel), where the holder of the fishing right does not (or no longer) hold rights to a land parcel in the area.

2.2. Surveying Classes

Object classes related to surveying are presented in pink colour; see Figure 3. A cadastral survey is documented on a SurveyDocument, which is a (legal) source document made up in the field. Most importantly, this document contains signatures; in a full digital surrounding a field office may be required to support this under the condition that a kind of digital signatures have a legal support. Otherwise paper based documents should be considered as an integral part of the cadastral system. Files with terrestrial observations - distances, bearings, and referred geodetic control- on points are attributes of SurveyDocument: the Measurements. Both ParcelBoundary and SurveyPoint are associated with SurveyDocument. From the multiplicity it can be recognized that one SurveyDocument can be associated with several SurveyPoints. In case a SurveyPoint is observed at different moments in time there will be different SurveyDocuments. In case a SurveyPoint is observed from different positions during a measurement there is only one association with a SurveyDocument.

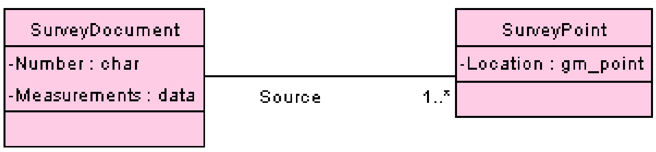

Figure 3 : The Survey Package, 'pink'

2.3. Geometry and Topology: imported OpenGIS classes

Object classes describing geometry and topology are presented in purple; see Figure 4. The Cadastral Domain Model is based on already accepted and available standards *on geometry and topology* published by ISO and OGC (ISO, 1999a, 1999b, OpenGIS Consortium 1998, 2000a, 2000b, 2000c and 2000d). *Geometry* is based on SurveyPoints (mostly after geo referencing, depending on data collection mode: tape, total station, GPS, etc) and is associated with the classes tp_node (topology node) and tp_edge (topology edge) to describe intermediate 'shapes' points between nodes, metrically based on SurveyPoints. The association between a ParcelBoundary and SurveyDocument is *derived* via the classes SurveyPoint, tp_node and tp_edge.

Parcels have a 2D geometric description. A Parcel corresponds one-to-one to the tp_face in a topological structure (as defined by ISO TC 211 and OpenGIS Consortium). A face is bounded by its edges in 2D. An edge is related one-to-one to a ParcelBoundary, which may contain non-geometric attributes. Every edge has exactly two end points, represented in tp_nodes. In addition, an edge may also have several intermediate points. Both intermediate points and nodes are associated with SurveyPoints. The topological primitives tp_face, tp_edge and tp_nodes, have all a method ('operation') called 'Realize' which can be used to obtain a full metric representation.

There are two additional geometry layers, which are not based on explicit topology structure, these can be found in respectively the classes RestrictionArea and VolumeProperty. As in the topology/geometry layer of PartionParcel, all coordinates are obtained from the SurveyPoints. There are also 'Realize' methods available within the RestrictionArea and VolumeProperty classes to return the complete and explicit geometry respectively gm_surface and gm_volume. A VolumeProperty is defined by at least 4 non-planar SurveyPoints; this would result in a tetrahedron, the simplest 3D volume object. The RestrictionArea is defined by 3 or more SurveyPoints, which all have to locate in the same horizontal plane (of the earth surface).

2.4. Legal/Administrative classes

Object classes presented in yellow cover the refinements in the Legal/Administrative side; see Figure 5. All updates associated to RightsOrRestrictions are based on LegalDocuments as source. In principle legal data will not be changed without provision of a LegalDocument. The essential data of a LegalDocument are associated with ('can be represented in') the classes RightOrRestriction, Mortgage or PublicRestriction. A single legal document may be the source of multiple instances of these classes and may even create of mix of these three types. In the other direction, a RightOrRestriction, Mortgage or PublicRestriction is always associated with exactly one LegalDocument as its source.

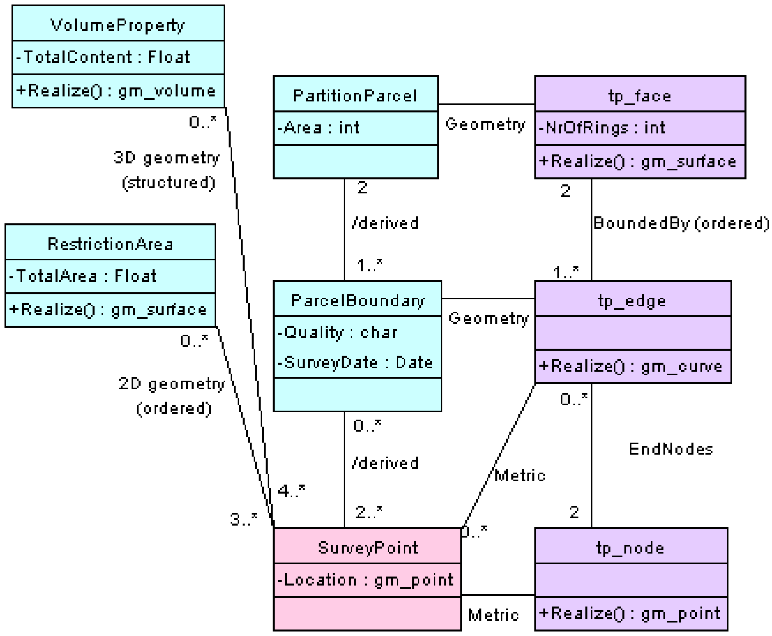

Figure 4 : The Geometry, Topology and some related packages, purple

Each jurisdiction has a different 'land tenure system', reflecting the social relationships regarding rights (and restrictions) to land in that area. The variety of rights is already quite large within most jurisdictions and the exact meaning of similar rights still differs considerably between jurisdictions. Usually one can distinguish between a number of categories of land rights.

a) Firstly there is the strongest right available in a jurisdiction, called e.g. ownership, freehold or property.

b) Secondly there are derived rights from the previous category where the holder of this derived right is allowed to use the land in its totality (often within the limits of a certain land use type, e.g. housing or animal farming).

c) Thirdly there are minor rights that allow the holder of it to some minor use of someone else his land, e.g. walking over it to the road. Such rights can be called servitude or easement, and also may include the right to prevent certain activities or construction at some nearby land, e.g. freedom of view.

d) Fourthly we have the so called security rights, whereby certain of the previously mentioned rights can be used as collateral, mainly through bank loans, e.g. mortgage, lien.

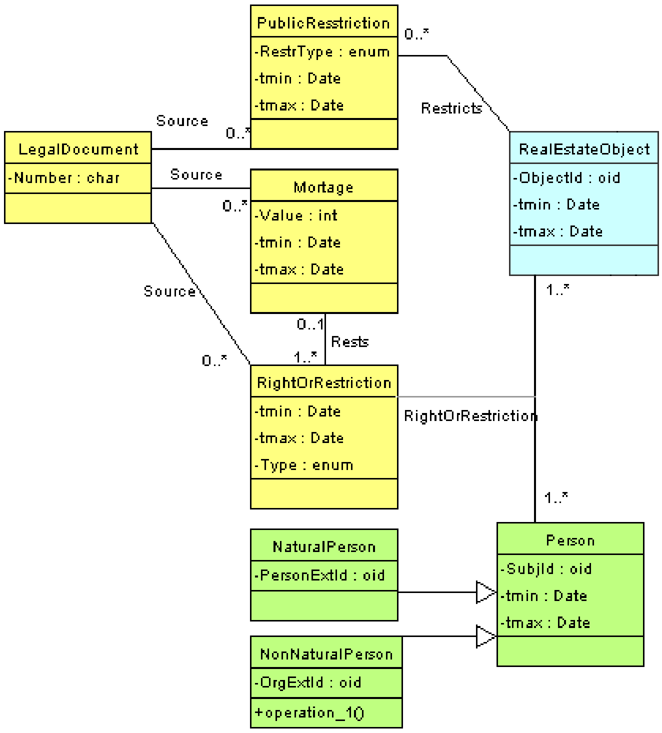

Figure 5 : The legal/administrative classes (yellow) and person classes (green)

Because property and ownership rights are based on (national) legislation, 'lookup tables' can support in this. E.g., the right of 'ownership' might be 'Norwegian Ownership', 'Swedish Ownership', etc. 'Customary Right' related to a region or 'Informal Right' can be included; from modelling perspective this is not an item for discussion. Of course, for the actual implementation in a given country or region, this is very important.

In addition to private law restrictions, many countries also have public law restrictions, which are usually imposed by a (local) government body. The 'holder' of the right is abstract (either "the government" or "society-at-large") and usually they are primarily seen as restrictions. Some of them apply to a specific RealEstateObject (or right therein) or a small group of them. E.g. most pre-emption rights, or the duty to pay a certain tax for improvements on the road, or the duty to repair damage or perform belated maintenance. Others have their own area of application, like whether there is soil pollution present, flood plains, (re) zoning of areas (esp. when urban development is made possible in a rural area). The abstract class 'Person' (that is again a class without object instances) has as specialisation classes NaturalPerson or NonNaturalPerson like organisations, companies, co-operations and other entities representing social structures. If a Person is a NaturalPerson it cannot be a

NonNaturalPerson and the other way around. That is, NaturalPerson and NonNaturalPerson are mutual exclusive.

Right (a subset based on the type attribute in RightOrRestriction) is compulsory association between RealEstateObject and Person, where this is not compulsory in case of restriction (the other subset in RightOrRestriction). For example, a restriction like encumbrance is only associated with the land: the RealEstateObject.

The class RightOrRestriction allows for the introduction of 'shares of rights' in case where a group of Persons holds a undivided part of a 'complete' right, e.g. in case of marriage.

2.5. History and dynamic aspects

There are two different approaches when modelling the result of dynamic systems (discrete changes in the state of the system), 'event' and/or 'state based' modelling:

- In event based modelling, transactions are modelled as a separate entity within the system (with their own identity and set of attributes). When the start state is known and all events are know it is possible to reconstruct every state in the past via traversing the whole chain of events. It is also possible to represent the current state, and not keep the start state (and go back in time via the 'reversal' of events).
- In state based modelling, only the states (that is the results) are modelled explicitly: every object gets (at least) two dates/times, which indicate the time interval during which this object is valid. Via the comparison of two succeeding states it is possible to reconstruct what happened as result of one specific event. It is very easy to obtain the state at a given moment in time, by just selecting the object based on their time interval (tmin-tmax).

In the model a hybrid approach is introduced, as both aspects of event and state based modelling can be found. The legal and survey documents can be considered as explicit representation of events (transactions). However, the effects of these events are kept in the states of the associated objects (which have tmin and tmax attributes). New inserted instances get a tmin, equal to the check-in/transaction time and a tmax equal to the maximal (integer) value. A deleted instance gets a tmax equal to its check-in/transaction time. In case of update of one or more attributes, a new instance will be created (as copy from the old instance with its new values for updated attributes) with a tmin equal to check-in/transaction time and a tmax equal to a maximum value. The old instance gets a tmax equal to check-in/transaction time. This allows to query for the spatial representation of cadastral objects at any moment t back in time or to query for all updates between a moment $t1$ and $t2$ in the past. Apart from check-in/transaction times the real dates of observation in the field can be included to manage history.

Note that nearly every object inherits these tmin and tmax attributes via either RealEstateObject, RightOrRestriction or Person. It would have been possible to introduce a new object (TemporalObject with tmin and tmax) from which in turn these three mentioned classes would inherit their temporal attributes (mainly because of legality this was not done). In addition to the event and state modelling, it is also possible that the ‘parent/child’ associations between cadastral objects are modelled (lineage), e.g. in case of sub-division of a cadastral parcel. However, as these associations can also be derived from a spatio-temporal overlay, it was decided to not further complicate the model with the explicit parent-child relationships.

Besides the data modelling aspect of the dynamic processes within the Cadastral Domain, one could question how are the functions and processes related to each other? Focus of the work until now has been on the UML class diagram, that is, the structural aspect. The UML class diagram should further be completed by diagrams covering other aspects, e.g. via state (use case, sequence, collaboration, state or activity) diagrams. Figure 6 shows a state diagram of the splitting of a parcel. Activity diagrams show how processes are related to the information (data) and how one ‘flows’ from on to the other. In all the other mentioned types of UML diagrams, actors or organizations play an important role and this may be quite dependent on that (national) set-up. The introduction of different ‘stages’ of a parcel (one-point, image, surveyed), a right (start, landhold, freehold) and a person could further reflect the dynamic nature of the system.

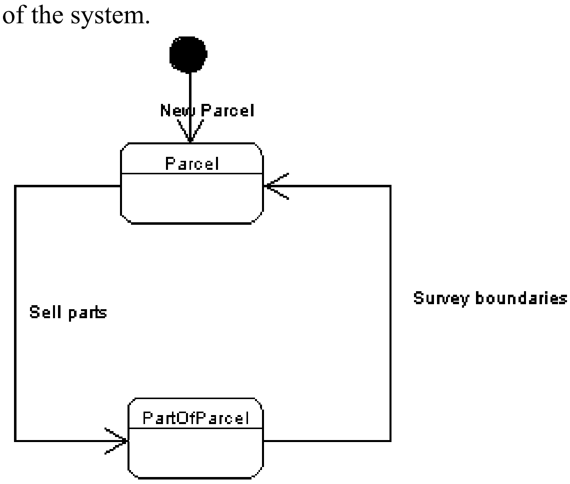

Figure 6 : (by: Wilco Quak) State diagram of splitting a PartionParcel. If a part of a parcel is sold, the parcel is split into several PartOfParcels, which become regular parcels again only when their boundary is surveyed.

2.6. Further developments

As indicated in the beginning of this section, the presented third version of the Core Cadastral Domain Model (see Figure 7) is just a proposal and a potential start for the final standardized model. Many more things have to be done (and perhaps modelled in additional packages or refinements). Potential further developments could be:

- GeodeticReferencePoints, could be a specialization of SurveyPoint. This will make SurveyPoint an abstract class with CadastralSurveyPoints and

GeodeticReferencePoints as its specializations. Further specialization could be CadastralCentroidPoint, in case only one point of a Parcel or NonGeoRealEstate is observed, see Jackson 2002.

- Higher level administrative units (aggregations: sections, municipalities,...) and the relationship to the lower level units. If possible redundant storage of the geometric and topological data should be avoided.
- Land consolidation/reform, urban development, urban and rural cadastres.
- Three dimensional alternatives/extensions, see (Lemmen, van der Molen, van Oosterom, Ploeger, Quak, Stoter and Zevenbergen, 2003) for a first approach.
- Links to external registrations could include:

1. Persons (e.g. via fiscal person identifier, or other approved identifiers)
2. Companies/organizations (e.g. chamber of commerce)
3. Addresses and zip codes, related to objects *and* subjects
4. Buildings or more general, topographic data, in relation to core cadastral data.

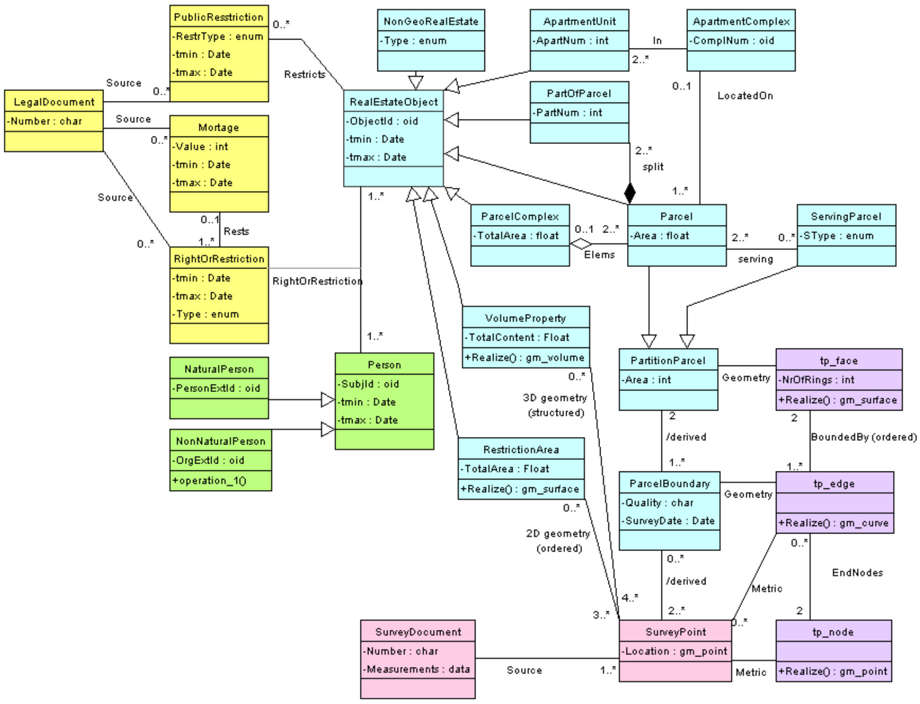

Figure 7 : the ‘complete’ cadastral core model, version 3.0

3. ESRI ArcGIS Cadastral Data Model: Initial Draft

3.1. ESRIs approach in data modeling

With the ArcGIS platform, the ESRI vision is to build many industry-specific data models. ESRI is providing models for several domains like agriculture, topographic mapping, biodiversity/conservation, defence, energy utilities, environmental regulated facilities, forestry, geology, historic preservation, hydrograpic/navigation, marine, petroleum, pipeline, system architecture, telecommunications, urban, water utilities, water resources.

Basic goals are to simplify the process of implementing projects and to promote standards within our user communities. These models support ESRI's goal to support many different vertical industries with one GIS platform; to build and maintain ArcGIS and a set of relatively thin data model extensions for each of the industries and scientific disciplines that ESRI serves. Read about the goals and process in the Introduction to ArcGIS Data Models (http://support.esri.com/index.cfm?fa=downloads.dataModels.intro.) The goal for the ArcGIS Data Models is to provide a practical template for implementing GIS projects. While most users will find the open data models a great starting point for work on their specific data model, they will also find related models useful in the development of their system. Beyond the benefits to a specific organization, this common starting point results in the creation of data model design templates that simplify the integration of similar data sets at the local, state/provincial, national, and global levels. There are compelling reasons for ESRI to pursue the ambitious task of getting many organizations in more than a dozen industries to build these data models. It is basically the opportunity to simultaneously make a successful GIS implementation more accessible to average organizations with limited budgets, along with the power to bring consistency and synergy between similar systems. In the long term we believe that common data models are key to making better decisions based on available geographic information. But these efforts are not designed to create formal standards. Rather, they are designed to provide immediate and long-term benefits to people working on real GIS projects while supporting existing standards.

ESRI's general process for creating a model involves bringing together a consortium made up of users and business partners. In each domain, the ESRI Industry Manager is responsible for organizing the group. ESRI is actively looking for individuals who are interested in contributing to additional modelling projects. In each case there is typically an industry expert that serves as a catalyst to drive the group and take overall responsibility for the development of the model. Each user community also requires a contact in the ESRI development organization to assist with technology transfer and model review activities. A successful group will have strong representation from the user and business partner communities, often with different experiences and ideas, which works together to develop the essential model for their industry. What has worked well in the past is a core group that works to define a first pass at the scope and content of the model. We call this a "Draft Data Model" that is intended for people working on projects as a starting point for implementation. It is then useful to get together a larger group to review the model and provide input. From that point forward we expect that ESRI, business partners, and end users will use the data models on their projects and provide feedback through ongoing discussions and a series of database design review meetings. After a year or so of project development, a book and CD will be developed to capture important characteristics of the models for specific industries, along with practical advice on how to implement your own project, along with lessons learned in the form of Case Studies.

3.2. Workshop on Cadastral Data Modelling

On March 17 and 18 2003 a Workshop on this subject has been held ITC. This Workshop has been organised by the ITC and the Netherlands Cadastre, in close co-operation with ESRI, provider of ArcINFO and ArcGIS software. About 30 experts in this field, from cadastral organisations, universities and commercial companies, participated in this workshop. The idea was to define cadastre building blocks and to develop a concept for a generic cadastral data model, to be implemented in ESRIs products later. After a series of presentations on the subject break out sessions were organised to discuss legal, technical (surveying) and administrative subjects in the context of data modelling. Basis for those discussions has been the Cadastre 2014 Model, partly presented in figure 8 and an earlier version of the proposal for a Cadastral Data Model developed by Delft University of Technology and ITC as is presented in chapter 2 of this paper.

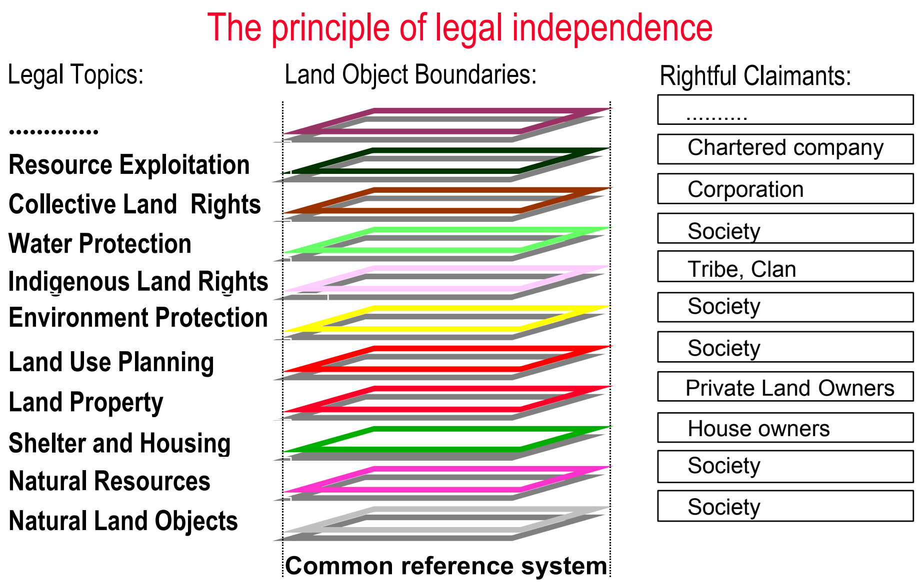

Figure 8 : The layer structure of the Cadastre 2014 model (Kaufmann, Steudler, 1998)

3.3. Conclusions of the Workshop in Enschede

During the workshop there was agreement that:

- the approach should be object oriented,
- all object classes and attributes should be defined, there should be the flexibility to include in implementation only those objects which will be maintained, attributes could be value, area's, land use, geographic description, person name, dates (check in, observation, birth, acceptance, transaction, etc), type, share, interest, transaction, conveyor, geodetic control point, etc.,
- identifications should be free of semantics, there is a need for 'identification' providers, e.g. for parcels, area's, names, rights, restrictions, taxation, mortgage, land use, survey and document,
- there could be a collaborating systems, system boundaries based on legislation,
- a spatial representation of (public) restrictions on land has to be included in the model, this means in other words that the parcel should not be 'overloaded', in principle public restrictions don't result in subdivisions of parcels,
- GIS technology makes the layer concept available for Cadastre, the layers of the Cadastre 2014 Model map well to GIS layers, each layer has associations with non-spatial tables, the layer set up has to be flexible, geometry can be based on ISO geometry and ISO topology,
- There is no need to specify whether geometry from base layers should be reused, the model should be flexible enough to leave this to the market place to decide,
- A 3D subclass of RealEstateObject is a vertical parcel, this could have references to documents/images/3D Models and to 3D geometry,
- A PartOfParcel is a FutureParcel,
- Surveying needs to be worked out: 'TerrainBoundary' can be included in the model,
- data maintained by different organisations (e.g. cadastre and land registry) have to be integrated in the model,
- maintenance of historical data should be possible, to be supported by a robust version management system,
- implementation of the model could start at the data publication function, followed by attention to the transaction function on rights on land.

3.4. ESRI's Cadastral Data Model (draft version)

ESRI's approach is based on the principles of Cadastre 2014 (Kaufmann, Steudler, 1998) and on the results of the Workshop Cadastral Data Modeling in April 2003. The principle of legal independence is a key item in Cadastre 2014. The principle stipulates that: legal land objects, being subject to the same law and underlying a unique adjudication procedure, have to be arranged in one individual data layer; and for every adjudicative process defined by a certain law, a special data layer for the legal land objects underlying this process has to be created. Cadastre 2014 is therefore based on a data model organized according to the legislation for the different legal land objects in a particular country or district. The Cadastre 2014 is documenting all of these different categories of legal land objects, adjudicated to different rightful claimants, independently, but in a common reference system. This approach fits to the approach as presented in chapter 2 of this paper.

For ArcGIS ESRI prefers to implement a structure where the Rights and RealEstateObjects are combined. This will work better for implementation and is probably more consistent with the Cadastre 2014 vision.

A draft version is presented in Figure 9. Three types of Land Objects are included: legal, informal and administrative. In the model presented in chapter 2 of this paper the distinction between 'legal' and 'informal' is not made in an explicit way, but are considered as different types of 'Rights'. Administrative Land Objects are integrated in the planar partition as presented in chapter 2. Administrative Objects are managed by Government Agencies, Administrative Objects can represent public rights and are for this reason managed independently from individual rights. The relationship between Legal Objects and people is via 'Rightful Claimants'.

Land Objects are closed polygons, but in ESRIs approach the Survey components still have to be worked out further. Further area's that need more work are vertical parcels (3D approach), other types of Administrative Land Objects and Buildings. Expected implications are on workflow, cadastral mapping and integration with registries.

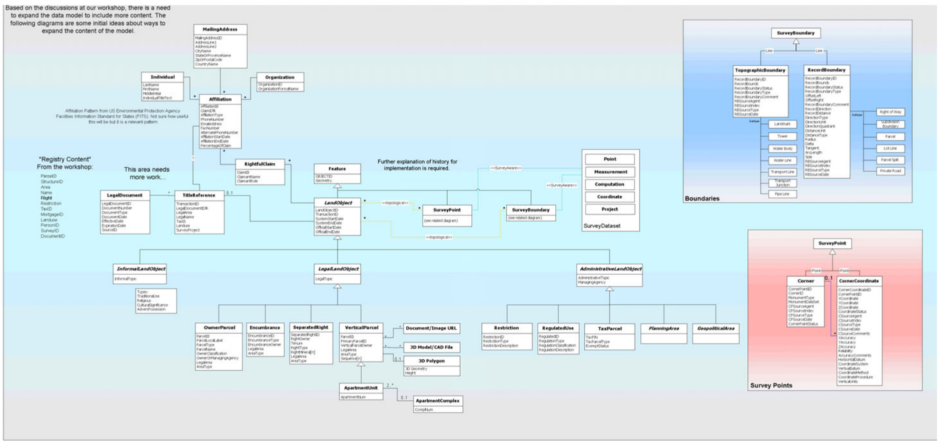

Figure 9 : ArcGIS Cadastral Data Model (draft version), see also: support.esri.com/datamodels

4. Conclusion

In this paper two efforts in standardization of the cadastral domain have been presented. Both approaches are based on input from experts in the field. A substantial overlap can be recognized. Efforts should be made to further combine the best of two on short term. One principal discussion is required on the integration of the RightOrrestriction class in the ESRI model.

Implementation by a market GIS leader as ESRI will strongly support further standardization in the Cadastral Domain as a basis for local cadastral systems and as a basis for (international) data exchange.

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www.oicrf.org, the library on Cadastre and Land Management, use as keyword 'WCDM'
support.esri.com/datamodels

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