Further Progress in the Development of the Core Cadastral Domain Model 1)

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SUMMARY

In this paper we present the latest version of the FIG Core Cadastral Domain Model (CCDM). Important changes and extensions to the model are presented; most of them are the result of an international workshop devoted to standardisation in the cadastral domain. Also the relation with the FIG guidelines from Cadastre 2014 is discussed. Important extensions in this version of the model can be found in the legal and administrative part of model with new classes such as Appurtenance, Encumbrance, Obligation, MoneyProvider, Conveyor, Surveyor, and AdminParcelSet. In addition, several attributes have been added to existing classes such as useCode, taxAmount, salePrize, interest, ranking, timeSpec, computedArea, legalArea, etc. Further both the LegalDocument and the SurveyDocument are now modelled as specialisation of the abstract SourceDocument, which has several Date attributes: submission, registration and acceptance. More classes (attributes and relationships) will make the model look more complex, however the model now also captures more domain knowledge in a formal manner.

One should not look at all the classes at the same time, but one should only look at the relevant classes in a certain context. That is, one 'layer' at a time; e.g. ownership of an ApartmentUnit, restriction on a Parcel, public RestrictionArea crossing several parcels, ownership of a 3D VolumeProperty, and so on. Further, not all classes need to be used in every country. There is a kernel set of classes, which will be present in every country (including RealEstateObject, Person and RightRestrictionResponsibility). However, if more functionality is needed (e.g. 3D VolumeProperty), then the model specifies how this should be done in order to understand each other and being able to communicate. It has always been the intention of the FIG core cadastral model to be compliant with both OGC and ISO TC211 standards (including the geometry and topology). In this version we have putted the 'dot on the i' to make sure that this is indeed for 100% the case. Finally, it is shown how the UML class diagram can be converted into XML/GML schemas. This is the exact structure as will be used in the actual exchange.

1) This paper has been presented earlier:
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1. INTRODUCTION

One of the big problems in the cadastral domain is the lack of a shared set of concepts and terminology. International standardisation of these concepts (that is, the development of an ontology) could possibly resolve many of these communication problems. There are several motivations behind these standardisation efforts, such as meaningful exchange of information between organisations, or efficient component-based system development through applying standardised models. It should be emphasised that a cadastral system entails land registration, the 'administrative/legal component', and (geo referenced) cadastral mapping, the 'spatial component'. Together, these components facilitate land administration and a land registry/cadastral system provides the environment in which this process takes place. Data are initially collected, maintained and, probably the most relevant issue in standardisation: disseminated in a distributed environment, which in principle means that data could be maintained by different organisations, such as municipalities or other planning authorities, private surveyors, conveyancers and land registrars — depending on the local traditions. Standardisation of the cadastral domain is in the initial phase and many non-co-ordinated initiatives can be identified.

Standardisation of the cadastral domain is relevant because computerised cadastral systems can support a customer and market-driven organisation with changing demands and requirements. Customers want to have an efficient on line information service that links to the database(s) of cadastral organisations. The application software to support cadastral processes is extending continuously in many countries because of changing requirements. In the future the volume of cross border information exchanges are expected to increase, particularly within the European Union. The more remote that the data user is from the data source, the more important it becomes to ensure that the data are well defined — for the obvious reason that remote users are likely to have much reduced local knowledge to assist them in interpretation. Trying to make the meaning of the data explicit is therefore an important step in facilitating meaningful exchanges of information across greater distances. The concepts used have to be well defined and structured (that is, related to one other), and this entails development of a cadastral domain ontology. One potential way to express parts of this ontology is UML (Unified Modelling Language) class diagrams.

Cadastral data that are accessible in a computerised environment can (significantly) increase the demand for cadastral data in the cadastral market. Standardisation definitively contributes to efficient development and renewal of cadastral systems, also in developing countries. Many land registry or cadastre organisations implemented their computerised systems between 10 and 20 years ago. These systems are now outdated, and their maintenance is complex and expensive. The organisations are now increasingly confronted with rapid developments in the technology: there is a *technology push* driven by developments in the Internet, (geo-)databases, modelling standards, open systems, GIS; and a *market pull* driven by an increasing demand for enhanced user requirements, e-governance, sustainable development, electronic conveyancing, and integration of public data and systems. A great deal of effort is being devoted to the development of viable strategies for the modernisation of the ICT systems of land registry and cadastral organisations. Standardisation in the cadastral domain would help (geo-)ICT vendors, as it would allow them to invest their efforts in the development of a (generic) system, based on the concepts as described in UML class diagrams, instead of focusing on a single cadastral organisation. This would stimulate the availability of generic (object-oriented) standard software from multiple (geo-)ICT vendors from which the cadastral organisations can make a selection. This will provide them with the fundament of new systems (in ways that are largely compatible with the concepts used in other countries), without developing everything from scratch: only local modification and extensions would need to be developed.

Whilst access to data, its collection, maintaining and updating should be facilitated at a local level, the overall land information infrastructure should be recognised as belonging to a uniform national service so as to promote sharing within and between countries. A Core Cadastral Domain Model (CCDM) in which classes and associations between classes representing objects, attributes and operations are derived from different tenure systems could, in the opinion of the workshop organisers, definitively contribute to the efficient fulfilment of local cadastral needs. To summarise, a standardised CCDM model will serve at least two important goals: it will avoid re-inventing and re-implementing the same functionality over and over again, instead it will provide an extensible basis for efficient and effective cadastral system development, *and* it will enable stakeholders, both within one country and between different countries, to engage in meaningful communication based on the shared ontology implied by the model.

The development of the CCDM has its history. In 2000 a first, non-successful, proposal was made to create 'Land title and tenure SIG' within OGC (not successful). During the FIG Congress in April 2002, held Washington, US, a proposal was by Lemmen/ van Oosterom to develop a CCDM (Oosterom, van, 2002a) a first version of this model was presented at a OGC meeting, organised in Noordwijk, the Netherlands, September 2002 and at a COST Workshop in Delft, the Netherlands in November 2002 (Oosterom, van, 2002b) . The second version of the Model, based on expert reviews has been presented at a workshop on Cadastral Data Modelling at the International Institute for Geo-Information Science and Earth Observation, ITC, in Enschede, the Netherlands in March 2003 (see www.oicrf.org) and during the FIG working week, Paris, April 2003. Several publications have been made in GIM International 2002-2003. The OGC announced in March 2003 the 'Property and Land Information Initiative' (LPI Initiative).

A third, comprehensive, version of the Model (multi-purpose cadastre, 3D extensions, refinements and by more authors, domain specialists) has been presented at Digital Earth, September 2003, at the second Cadastral Congress in Kraków, Poland in September 2003 (Lemmen et al, 2003b) and at the EULIS Seminar on 'Land Information Systems and the

Real Estate Industry', Lund, Sweden, April 2004. During an Expert Group Meeting on Secure Land Tenure, Nairobi Kenya (see www.fig.net), November 2004 it came clear that customary tenure should be included. This was worked out in the fourth version of the model, presented during the second workshop on standardisation of the cadastral domain, held in the Aula of the University of Bamberg, Germany, 9-10 December 2004 (Oosterom, van et al, 2004). In the paper presented in Bamberg there has been attention to the system boundary and some other suggestions for further improvement have been included in the conclusions.

A report of this workshop in Bamberg is given in section 2 of this paper, some relevant observations, needs and requirements for the development of the CCDM are highlighted. Section 3 discusses the relation between Cadastre 2014 (guidelines and model) and the CCDM. In Section 4 the boundary of the CCDM (within a Geo-Information Infrastructure) is described. The new version of the model is given en Section 5. The paper is concluded with Section 6, which also describes important future work.

2. WORKSHOP ON STANDARDISATION IN THE CADASTRAL DOMAIN, BAMBERG, GERMANY, DECEMBER 2004

Within the scope of the European COST Action G9 'Modelling Real Property Transactions' and jointly with FIG Commission 7 'Cadastre and Land Management', a workshop on 'Standardisation in the cadastral domain' was held in the Aula of the University of Bamberg, Germany on 9 and 10 December 2004.

As indicated above standardisation of the cadastral domain serves several purposes. In order to develop this, the workshop brought together representatives from different communities and disciplines involved in the cadastral domain: legal specialists, surveyors, ICT-specialists, etc. from different organisations (land registry and cadastral organisations, standardisation institutes, industry and academia). An initial model has been developed based on the results of a first workshop (Lemmen et al., 2003b) and was used as a reference for further development. However, the workshop was limited to this specific model alone and also included:

(1) efforts at the national level that do not (directly) aim at an international standard
(2) work that goes beyond the current scope of the core cadastral model and addresses for instance process modelling

The specific goals for this workshop were:

- further developing the administrative/legal aspects of the model: rights of persons to lands, customary and so called 'informal rights', 3D aspects, legal and survey based source documents
- further formalising the model (semantics ontology, knowledge engineering)
- testing the current model in different countries (evaluation)

- involving the geo-ICT industry and standardisation institutes (support for implementations of the model)

Of great importance for the implementation of interoperable cadastral and land information data could be the Land Information Initiative of the Open Geospatial Consortium (OGC).

The workshop brought together 61 experts from different communities and disciplines from 19 countries and involved in the cadastral domain: legal specialists, surveyors, ICT-specialists, etc. from different organisations. During presentation and discussion sessions 20 papers have been presented with keynotes from Prof. Andrew Frank, Austria and Juerg Kaufmann, Switzerland. Those papers and related presentations have been published on the web. The Scientific Committee has made reviews of the extended abstract, which were used to select the papers for the workshop.

In his Bamberg paper **Frank** (2004) observes that one of the original functions of cadastre is the equitable taxation of land. The base for taxation is the assessed value, computed from historical assessments. Land transactions are a good opportunity for taxation under many legislations. Further he discusses pre-emption rights and certification in case of ownership transfer. During the workshop sessions in Bamberg the taxation issue has been discussed, there was agreement that this area should be represented in the Core Cadastral Domain Model (CCDM), and also awareness that this will increase the complexity of the model. Frank's remarks on pre-emption and certification concern the transaction processes; however certificates could be registered after a transaction. Several speakers in Bamberg referred the relevance of modelling transaction processes in relation to the CCDM, there was agreement on this during the workshops.

Heß and Schlieder (2004) observe that reference models, often called core models are developed in various application domains. Until now, no computational support exists for the task of verifying the conformity between such core models and their domain models. The approach developed at Bamberg University uses Semantic Web technologies to examine whether or not a domain model is a derivation of a core model. This ontology-based conformity verification supports an iterative modelling process in which core or domain models are modified. Inference services as provided by ontology's can be used to analyse the relationships between core and domain models They conclude that their approach reveals problems in the conformity verification with the CCDM as it actually is .The CCDM must be refined in close cooperation with experts for the national cadastral systems who in the other way round must be willing to modify their national model in order to achieve conformity. It is important to discuss core and national cadastral models on the same level of abstraction. There will always be problems in the conformity verification and the subsequent use of the models in various applications if some of the models are close to the implementation level representing directly the underlying databases and other models are more on the conceptual level abstracting from the concrete implementation. But even if core and the national cadastral models are in an early stage, the core model with national models which conformity was shown by the conformity verification represent a promising approach to standardisation in the cadastral domain. Our results permit to expect concrete applications on the basis of conforming models. The core model can be the basis of a core software application which is only adapted to the local requirements expressed in the domain models. Furthermore, data could be exchanged between organisations and institutions of different countries with the help of the core model representing the minimum common data of all domain models. The next step would be to realise software in of these application areas.

Ottens (2004) observes that because of the social nature of the cadastral system designing is not as straightforward as with technical systems. In social sciences research is done to social systems and knowledge regarding these systems might be used in shaping the socio-technical cadastral system. The distinction we make between social and technical elements seems very useful in analysing the cadastral system. Problematic issues in modelling and designing can be identified beforehand. Neither Cadastre 2014 nor the (Lemmen at al, 2003b) model do take sufficient notion of the socio-technical nature of the cadastral system.

Heß and de Vries (2004) recommend to include address for search as an abstract class selection purposes. Further they recommend providing more classes for groups of attributes in core and national cadastral models. These complex data types group as 'attribute classes' the attributes that belong together. Candidates are for example: Address, PersonName, OrganisationName, PostalAddress, LocationAddress, ParcelNumber etc. They state that harmonisation of attribute values would improve query translation.

Bjornsson (2004) concludes that implementing Cadastre 2014 represents just the beginning (note: cadastre 2014 is being implemented by ESRI, see Kaufmann, 2004b). Current GIS technology provides a variety of options for implementing a robust land records management system; as it should. A core cadastre data model should be the foundation of a system built upon industry standards and interoperable information technology. While the model needs to be flexible, adaptable, and extensible (Lemmen, et.al.), *as represented in the Cadastre 2014 Data Model*, there are other technical issues to be addressed as land administrators approach the design and implementation of such a model. Regardless of the GIS or database product chosen, whether open source or commercial, the design and implementation must follow a data modelling process, and support such land records functions as rule-based topology, multi-user access with version management, and interoperability of data and other systems. Note: the Cadastre 2014 approach is included in the CCDM. It is questionable if the Cadastre 2014 approach really can be implemented in a distributed environment, see....below

Very interesting in the paper of **Le Roux** (2004) is his reference to the MISMO Commercial Mortgage Data Standards Initiative and gives insight into what the e-commerce impact to a public agency may be, the data exchange standards of the U.S. Mortgage Industry Standards Maintenance Organization (MISMO) are briefly reviewed. MISMO is developing a commercial mortgage origination data standard that provides both the content and format for borrowers and originators to transfer critical data to lenders. The data standard will use XML Schema to define the structure and format for moving data between parties involved in a mortgage origination transaction. These parties typically include the borrower, the lender, third-party report providers, due diligence providers, rating agencies, and, if appropriate, investors. As is the case with the FIG Commission 7 Standardised Core Cadastral Content

Standard, MISMO expects that users of the standard may have additional data requirements, and that some of additional data will be incremental to the standard. This MISMO standard is thus designed to be extensible, so that each participant can supplement the standard with its own unique requirements. It is also anticipated that not all the data in the standard would be applicable for all loans, and, therefore, there may be more data defined than would actually be used in originating a particular loan. Further he asks attention for attribute values.

Louis Hecht (2004), representing the Open Geospatial GIS Consortium, asks attention for the UML to GML Application Schema Process. A first effort in this direction in relation to the CCDM is presented further on in this paper. Hecht concludes that the union of FIG and OGC to address web delivery of cadastral information is an ideal combination: OGC benefits from working with a highly precise and complex need that has been defined by a well coordinated community (FIG), and FIG benefits by leveraging the state of the art standards that OGC has already created. It is anticipated that both the Model and the OGC specifications will be improved by this coordination. The OGC has always concentrated on its piece of the overall software world – software interfaces. OGC relies on dejure, (legal) bodies such as the International Standards Organisation and expert community groups such as FIG to determine the user requirements for services and data content, and then use these requirements as the 'use cases' for which we engineer software interfaces. The Cadastre Model is especially important to us because it represents a very well defined, highly precise and demanding set of requirements. OGC looks forward to working with FIG and others to realise common and mutual objectives for connecting information processes and content within the Cadastre community.

Astke, Mulholland and Nyarady (2004) refer to the Cadastral Data content Standard developed by the US Federal Geographic Data Committee (FGDC). As Le Roux they also observe the need for a more comprehensive list of attributes, e.g. date of submission, registered date, in relation to source documents (note: also date of exception could be included here). They give detailed and very complete examples of attribute to be included based on the FGDC standard. As others they ask attention for processes to be included.

Tiainen (2004) introduces quality labels for cadastral information and for information services. The semantic approach with ontology explication enables quality labelling of information, if we consider the OGC approach more closely. Properties and property values of data entities also reflect quality if the semantic explication displays an adequate high-level of objectivity. A common understanding of reliability for the property/value aggregations needs to be achieved as a prerequisite, and equally advanced ontology explication or qualitative methods are needed. The simple aim is to *measure the quality against user needs*. He gives detailed examples of quality labels.

Zevenbergen (2004) observes that the class for the legal relations shown in the core model used in (Lemmen et al, 2003b) is RightOrRestriction. However, current literature on cadastral and land administration issues is often talking about three R's: Rights, Restrictions and Responsibilities. A restriction means that you have to allow someone to do something or that you have to refrain from doing something yourself. Restrictions can both be within private

law, especially in the form of servitudes, as within public law, through zoning and other planning restrictions as well as environmental limitations.
Responsibilities mean that one has to actively do something. Not all legal systems allow such mandated activities as property rights (rights *in rem*), and this will also effect the question if they can (and have to be) registered. Obviously their impact can be substantial and their registration makes sense. This proposal is worked out below.

Paasch (2004) introduced a Legal Cadastral Domain Model. There is a need for a legal cadastre model, which focuses on the right of ownership (to a property) in relation to appurtenances (benefits) and encumbrances (burdens) reducing the extent of the ownership. This presentation will focus on the modelling of real property rights, or to be more exact rights of ownership and granted rights, and including official and private regulations imposed on real property. A better understanding of the legal and logical aspects of property rights might increase the possibilities of producing standards towards the cadastral domain. His approach is very useful and has been used in modelling the 'legal administrative' side of the CCDM below.

Wallace and Williamson (2004b) state that the use of the land registration system to manage more bureaucratic controls, permits, licences and regulations is widely used in Australia with substantial negative and unforeseen consequences. In 1999, they foreshadowed co-option of the land registration system as part of the regulatory framework of government and warned that this was inappropriate. Land registration is now used, or is capable of being used, to provide building and planning officialdom with opportunities for enforcement of "controls" over standards relating to chemical hazards; wiring and electricity installations; cable capacity; business compliance; domestic safety standards; plumbing, heating, building permits and certificates; registration of plumbers, builders and electricians and other bureaucratic edifices (Wallace, 1999). This option of loading public regulation management into a Torrens type register appears especially attractive to those who require certificates or installations in premises to be evidenced at the time of sale as a means of enforcement of regulations which would otherwise more likely than not be avoided.
Given the improved capacity of cadastres developed in the intervening five years, the point at which a cadastral model should assist this process of cluttering the register and the cadastre to assist day-to-day enforcement of restrictions and regulations affecting land is a real issue. Governments are making more regulations, not less. Some of the more open-ended or multi-faceted restrictions and responsibilities (RRs) are problematic in the context of cadastral modelling. A key question is then how or why new RRRs might be incorporated into a cadastral fabric when they are remote from physical objects or even spatial identification. One possible approach suggests answers are available from increased technical precision and/or administrative competencies. These problems associated with emerging RRs are emphasised particularly by management of the marine environment where the marine cadastre is only just developing. In the marine context especially there is a clash between cadastral certainty and rigidity (seen in its focus on defined parcels, or on realisable spatial definitions) and management needs, technical capacities and fuzzy, natural and other kinds of boundaries (Wallace and Williamson, 2004a).

Kaufmann (2004a) gives in his keynote paper an assessment of the Core Cadastral Domain Model. Both the Cadastre 2014 approach and the CCDM approach are FIG initiatives. Both approaches, although originally developed independent from each other have very much in common. The Cadastre 2014 is recognised worldwide, the principles behind it have been translated to many languages. In a separate paragraph below the relation between both approaches is further assessed.

van Oosterom, Lemmen, van der Molen (2004) present a series of remarks and observations on the Cadastral Domain Model as published at 'Digital Earth' in Brno 2003, see Lemmen, et al (2003b). A substantial part of those remarks and observations is based on the presentations and discussions of the Expert Group Meeting on secure land tenure (new legal frameworks and tools), held in the Nairobi, Kenya, 11-12 November 2004, see www.fig.net. Earlier versions of the CCDM, have been developed on the basis of experiences in Europe, the Nairobi meeting provides input from developing countries. The requirements resulting from this input is analysed with respect to the impact on the CCDM. Further there is attention to the system boundary, see also below.

Stubkjær (2004) pays a lot of attention to actors in cadastral processes. In general there have been a lot of attention to cadastral processes in the Bamberg workshop, there needs to be more attention to this, the authors agree on this. Stubkjær concludes that standardisation of the cadastral domain supports the meaningful exchange of information between organisations and parties, in their dealing with rights in land and other real estate. Standardisation is here conceived in the proactive sense, as a kind of legislation or regulation, which is imposed on actors and their future activities within the cadastral domain. Regulation needs to be legitimised. The Parliamentary process is essential in the legitimating of general prescripts, while the legitimating of standards appears to be a more open issue. Nebulous references to 'user needs' may be found. The relevance of a Cadastral System in its totality is established, not with reference to user requirements, but rather with reference to the historical fact that such infrastructure is needed to enable a market in real estate. His paper suggests that rational requirement analysis provides the legitimacy in cases, where users are not able themselves to specify the requirements. The approach draws upon recent developments in software engineering methodology, in an effort to state user needs in a way, which is specific enough to allow for empirical testing, and which facilitates a subsequent systems analysis.

Ljunggren (2004) states that the public sector is not taking full advantage of IT. The public sector is busy in maintaining existing processes, systems and legal framework, so it is protecting its business, avoiding big changes. IT is used to support existing processes and not as tool to change these processes and move the business forward. In this field the public sector is far behind the private sector e.g. the industry and the financial sector. As a first step systems should be built on a national basis covering the whole sector for land administration, users should not have to turn to a number of systems for getting a complete picture. Co-operation between ministries has been a driving force for building a Common Cadastral Dataset. Standards are important! In the next step it is important to exchange data between systems within Europe in such a way that data can be 'understood' by the customer. Coming that far a lot has been achieved; but doing business concerning land in the same way

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throughout Europe, using similar processes, is the ultimate and may be unreachable step. However for the citizen it would be of great interest as the transaction costs will be much lower.
The Real Property Register, includes in Ljunggrens opinion: an Address Register, a Building Register, a Co-ordinate Register, a Plan Register, a Property Assessment Register, a Sales Price Register, an Owner Associations Register and a Housing Credit Guaranties Register.

Steudler (2004) concludes that the introduction of the new data-modelling concept for the description of cadastral surveying data in 1993 also triggered the development of SDI in Switzerland. The data-modelling concept with INTERLIS (a data description language) has initiated the definition of more than 100 other spatial data domains since 1995, enabling the use of the same data exchange mechanisms as in cadastral surveying. In 1998, a new agency has been established to foster the coordination, acquisition, and use of spatial data within the federal administration. COSIG promotes the INTERLIS concept for the definition and handling of all spatial data. This concept is also at the core of the new eGovernment initiative, which attempts to bring digital spatial data closer to the users. INTERLIS has become the accepted approach within the Swiss geodata community for the modelling and exchange of data.

Hespanha, van Oosterom, Zevenbergen and **Paiva Dias** (2004) follow recent worldwide developments and initiatives by FIG (Cadastre 2014) and UN, an object oriented, conceptual model for the Cadastral Domain, adapted to Portuguese Cadastre and related Real Estate Register is presented, based on a previously proposed CCDM standard. After a brief description of present Cadastral and Land Registration situation in Portugal, UML (Unified Modelling Language) literate modelling was used to describe the top-level classes by using a structured mix of UML Class Diagrams and natural text. Important contributions of this paper are the evaluation of the FIG core cadastral model *by applying* it to Portugal. It turns out that a limited number of the classes of the core model are currently not needed (but some of them might be used in the future) and that other classes were added specifically for the situation in Portugal. Most of them are related to aggregations and partitions of parcels. In relation to this many cases are discussed in (UNECE, 2004).

Iván, Mihály, Szabó and Weninger (2004) note that during the last ten years there were many successful and unsuccessful developments in the Hungarian Cadastral Domain. The base of them is the National Standard of Digital Base Map (Cadastral Map), which was accepted by the Hungarian Standardisation Body in 1996. The standard defines a relational database scheme based on CEN pre-standards. A new cadastral base map instruction system (called DAT) has been developed by the Institute of Geodesy, Cartography and Remote Sensing (FÖMI), which has been operative since 1997. In the National Cadastral Program of Hungary, new cadastral maps (databases) have been created for 500 thousand hectares (5% of the whole territory of the country), based on the standard and instruction system. They outline the former developments, describes the legal circumstances that belong to cadastre and land registry. The main characteristics of the above-mentioned standard are described. The new, DAT based cadastral data model is presented. The similarities and differences are stated between the Hungarian model and the CCDM.

Finally **Vaskovich** (2004) notes that land privatisation is at the moment regarded as the main tool for land distribution in Belarus. Obviously, the process has to function smoothly and effortlessly from the user's point of view. She addresses the land privatisation process in Belarus with aim to identify its drawbacks and pitfalls. Land privatisation is overcomplicated as well as time-consuming and not adapted to the user's needs process. There is an urgent need for simplification and, thereby, making the property market active and efficiently functioning. She further analyses modelling of the privatisation process and the developed models with application to further formalisation of the core cadastral domain model. In particular, two types of modelling, namely static and dynamic, or process modelling, are employed and two respective models in UML notion are used as basis for this analysis. The paper employs the 'Literate Modelling' approach when the diagrams alternate with explanatory text.

In Bamberg it was concluded that common steps in workflows have to be identified, where the legal situation in different countries has to be modelled. A single standard model might not be possible but a core model based on common concepts should be achievable; there should be common concepts, this allows talking across boundaries. From the performed test in and between different countries it was concluded that no system is alike. The Core Cadastral Domain Model is the least common denominator. Additions are needed to the core model. The Core Cadastral Domain Model issues are under scientific debate now, further activities have to be identified in international context, together with ICT industry, OGC, academia, COST, EULIS, professionals and with a strong focus to and involvement of users. The Core Cadastral Domain Model might be part of a big machinery with interfaces, data exchange and interoperability. The Geo-ICT industry will be driven by the market; if needed the models will be developed. Semantic aspects require further attention.

From European prospective, it can be expected that financial institutes like banks, mortgages and security and other users could be the drivers for development of a Core Cadastral Domain model, but who takes the lead role? Search for an authority that will drive development of Core Cadastral Domain model further, e.g. the FIG with its network. A co-ordinating group is needed who can further identify the driving force. The 'model boundaries' (what should not be included, what should be included) require further investigations; rights, restrictions, responsibilities related to land should be included and an extension of fiscal rights and responsibilities. It is of utmost importance to better communicate the Core Cadastral Domain Model.

3. THE RELATION BETWEEN CADASTRE 2014 AND THE CCDM

Kaufmann (2004a), in his paper on the assessment of the CCDM from 'Cadastre 2014' perspective, notes that in Cadastre 2014 the legal land object is in the centre. All legal land objects are handled in the same manner. Further he notes that cadastral surveying is not explicitly treated in Cadastre 2014. He concludes that the basic considerations made in the context of the core cadastral model and those behind Cadastre 2014 do not differ much.

Standardisation is crucial for both approaches. But beyond, the ontology needs to be harmonised.

Kaufmann further concludes that the core cadastral domain model initiative, trying to model existing occurrences of cadastres, is confronted in every step with new questions. The development of the core cadastral domain model shows that with every step more elements of Cadastre 2014 are included. A trend in direction of Cadastre 2014 can be identified. Cadastre 2014 is a totally new approach to cadastre. Including all legal land objects of a certain jurisdiction and according to its laws and handling them according to the proven and successful principles of the traditional cadastre, is a new approach made possible by the development of ICT. This new approach makes it necessary to throw overboard some traditional practises as the parcel-centric approach. Thinking in land objects is the future in modern cadastral systems. The nature and fundamental truths of the cadastre are remaining the same, but its content is changing significantly. These differences have nothing to do with the modelling; they are in the field of the ontology. The ontology discussion, initiated by the standardisation efforts, has to be continued.

In principle we agree with this 'non parcel based' approach (for every possible real estate object), but we recognise that many cadastral systems are still parcel based, it should be possible to include those situations in the CCDM. Recently a PhD thesis with proposal for a Parcel Based Land Information System, with a focus to Nepal and Bhutan, was defended at Delft University, The Netherlands (Tuladhar, 2004). In the paper (van Oosterom et al, 2004) in Bamberg 'PointParcels' and 'SpagettiParcel' have been included to cover situations where geometric data are missing or are under production. Also other specialisations of the real estate object, with own geometry, have been introduced over time in the CCDM: RestrictionArea, VolumeProperty, and ApartmentUnit/Complex. These can all be considered to be 'non parcel based' (in the traditional 2D planar partition sense). Fourie et al (2002) recognises the need for a *'range' of spatial units*, including, but going beyond, cadastral parcels, which simultaneously allows land management/administration to continue across the range of organisations, but which facilitates increased inter-operability over time between organisations. According to them a research challenge is to identify what the characteristics of those spatial units should be and to work out which spatial units or common identifiers will facilitate and encourage this interoperability. Further they propose further research on the required accuracy of co-ordinates and the use of simple sketch plans. They see those issues (amongst others) as critical for developing a way forward to also implement aspects of FIGs Cadastre 2014. In our approach with the CCDM we try to find solutions in relation to this. Using different accuracies can imply that polygon overlays come to incorrect results, this could imply a need for explicit relations between objects.

From a review of the model by UN HABITAT (Dr Clarissa Augustinus) we know that it is really important that CCDM can deal with both unregistered land tenures and less accurate spatial units; note: the point- and spaghetti parcels (allowing 'inconsistencies', including lacking geometric data) are already included (Oosterom, van, 2004) and reference to source documents can be made. While it is extremely important that less accurate parcels are included in the information system, it is equally important that the land tenures to be included are not necessarily registered rights. Figure 1 shows us the kind of land tenures that UN-HABITAT is supporting for informal settlements and we expect that a land administration system can be designed in such a way as to accommodate most if not all of these land tenure types. As said: it is really important that the CCDM can deal with both unregistered land tenures and less accurate spatial units.

We have the intention to further analyse the 'range of spatial units' and 'land tenures for informal settlements' and its impact to the classes and relationships in the CCDM. We are not sure if all those spatial units and land tenures can be included in Cadastre 2014 without extensions to this approach. One example can already be identified below in relation to nomadic behaviour within a certain region/time pattern nomadic behaviour within a certain region/time pattern. Other examples can be found in (van Oosterom, 2004). The Sketch Plan approach, as mentioned by Fourie et al (2004) fits well to SurveyDocument in the CCDM.

Further it can be noticed that the CCDM includes an orientation to land objects which covers most of the cases identified in (UNECE 2004), it covers 3D cadastre, links to source documents (providing evidence, as said: sketch plans can be included here. The CCDM includes accepted standards for nodes, faces and edges. But the core is the object-right-subject relationship as a 'start' for specialisations. In fact such specialisations are required in all object oriented approaches, also in the 2014 approach in our opinion.

In general we look for a complete alignment with the Cadastre 2014. We are very open for discussions here. Further we should better highlight and communicate the layer based structure of the CCDM.

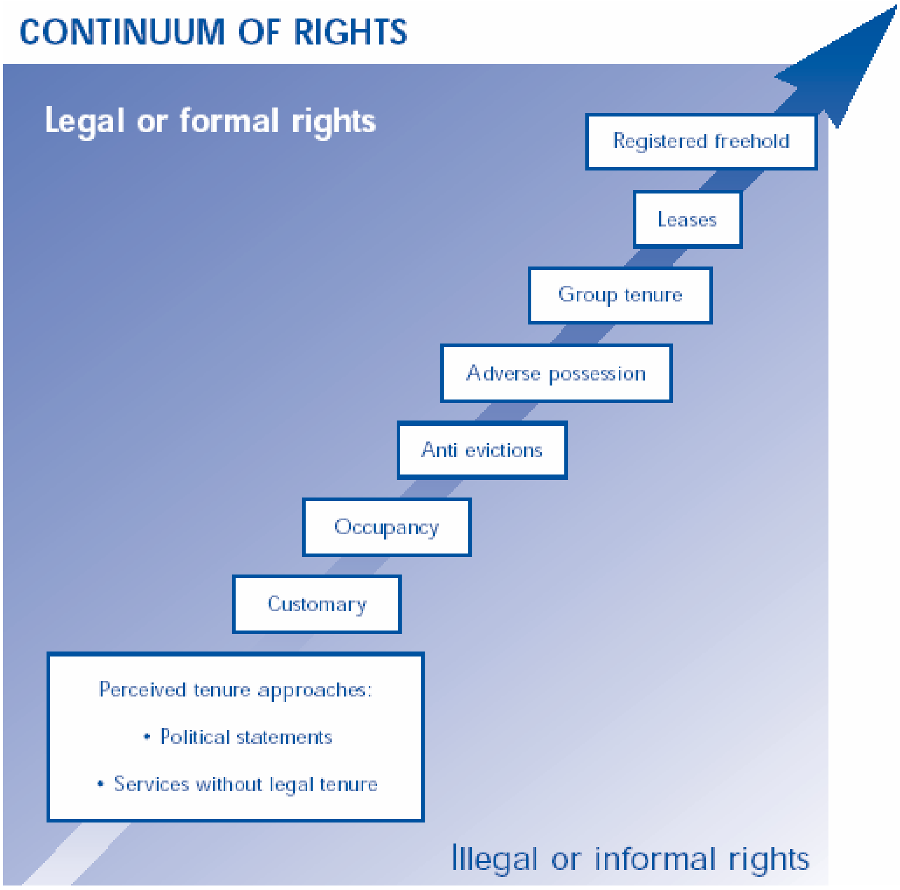

Figure 1: Continuum of rights (UN Habitat, kindly provided by Dr Clarissa Augustinus)

In short one could state that FIG guidelines in Cadastre 2014 give an excellent start for implementing a cadastral model. However, it is a generic, or abstract, set of guidelines, which must be further refined into a more specific model. This is the aim of the FIG Core Cadastral Domain Model. One could compare these two levels with the abstract and the implementation level of specification within Open Geospatial Consortium (OGC). The abstract level contains the most important knowledge, but this can be implemented in several different manners, which can all claim to be compliant (but the systems won't support automated interoperability). The FIG core cadastral domain model goes now one step further and specifies an implementation level of the model, which means that different systems adhering to the core cadastral model will be interoperable.

The terminology is one more relevant aspect in this discussion. It could be so that the Core Cadastral Domain Model is in fact a model for the Land Administration Domain. It tries to cover many situations in the relationship between people and land, not all of them are needed in all cases (see Hespanha et al, 2004). The same can be recognised in relation to other standards, GML3 is an example here. In any case: there is a need for a clear system boundary.

4. BOUNDARY OF THE SYSTEM

The current 'Brno 2003' version of the model is organised into several packages. 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 is that it is possible to develop and maintain these packages in a more or less independent way. Domain experts from different countries could further develop each package. It is not the intention of the developers of the model that everything should be realised 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. The principles of Cadastre 2014 (Kaufmann, Steudler, 1998) are integrated in our approach.

It is very tempting to keep on adding more packages as (new) object classes are often related to classes in the current model (and this becomes more true when the model keeps on growing by adding more and more packages). Further, the result of comparing cadastral models depends a lot a the equal scope of the two models; e.g. in one cadastral model includes a person registration (with all attributes and related classes to persons) and the other model just refers to a person (in another registration), then the two models may look different, but the intentions is the same. Only the system boundary of the involved models is different. However, the boundary of the cadastral domain model is quite arbitrary in a certain sense. Perhaps, also (some of the) current packages of the model should be considered as separate models outside the core cadastral model. It is therefore proposed to try to get some consensus on the model boundary by considering the current cadastral registration practice in different countries of the world.

We propose everything (all packages except the imported ISO TC211 model for geometry and topology) in the Brno version of the core cadastral model ('2003' version) to be indeed part within the boundary of the model. Next an attempt to list classes or packages of classes that are related to the core cadastral model, but of which we propose that these are outside the core cadastral domain model:

1. spatial (coordinate) reference system;
2. ortho photos, satellite imagery, and Lidar (height model);
3. topography (planimetry);
4. geology, geo-technical and soil information;
5. (dangerous) pipelines and cable registration;
6. address registration (incl. postal codes);

7. building registration, both (3D) geometry and attributes (permits);
8. natural person registration;
9. non-natural person (company, institution) registration;
10. polluted area registration;
11. mining right registration;
12. cultural history, (religious) monuments registration;
13. fishing/hunting/grazing right registration;
14. ship- and airplane (and car) registration;
15. …

Again it is stressed that it is very difficult define the scope of the core cadastral model as nearly all topics mentioned above are (sometimes strongly) related to the classes in the core cadastral model. The first four topics listed above are or can be used in the cadastral system for reference purposes (or support of data entry; e.g. of the RealEstateObjects). Other topics have a strong relationship in the sense that these (physical) objects may result in legal objects ('counterparts') in the cadastral registration. For example, the presence of cables or pipelines can also result in a restriction area (2D or 3D) in the cadastral registration. However, it is not the cable or pipeline itself that is represented in the cadastral system, it is the legal aspect of the this. Though strongly related, these are different aspects (compare this to a wall, fence or hedge in the terrain and the 'virtual' parcel boundary).

The fact that these 'external' objects (or packages) are so closely related also implies that it is likely that some form of interoperability is needed. When the cables or pipelines are updated then both the physical and legal representations should be updated consistently (within a given amount of reasonable time). This requires some semantic agreement between the 'shared' concepts (or at least the interfaces and object identifiers). In other words these different, but related domain models need to be harmonised. As it is within one domain (such as the cadastral world) already difficult to agree on the used concepts and their semantics, it will be even more difficult when we are dealing with other domains. However, we can not avoid this if a meaningful interoperable geo-information infrastructure has to be realised. Some vendors (e.g. ESRI) are quite active in developing domain models and it can be expected that the will try to avoid overlap (and especially when this is inconsistent) between the different models: agriculture, topographic mapping, biodiversity/conservation, defence, energy utilities, environmental regulated facilities, forestry, geology, historic preservation, hydrotropic/navigation, marine, petroleum, pipeline, system architecture, telecommunications, urban, water utilities, water resources. It seams appropriate that also a more neural organisation plays a coordinating role in this harmonisation process; FIG, OGC, ISO, CEN,….

In several countries of the world we see attempts to harmonise a number of domain model within one country; e.g. Australia (ICSM, 2002), Germany, The Netherlands. But this is not sufficient, as the models should also be harmonised internationally. One could raise the question: 'What is the best order for harmonising: first within a specific domains (at an international level) and then harmonise these different domains, or first within a specific country (including all relevant domains) and then harmonise these different country models?'. Anyhow, it will be an iterative process as our insight and knowledge will keep on refining (and both approaches will probably be applied).

An extremely important aspect of the future Geo-Information Infrastructure (GII), in which (related) objects can be obtained from another side (instead of copied), it that of '*information assurance*'. Though the related objects, e.g. persons in case of a cadastral system, are not the primary purpose of the registration, the whole cadastral 'production process' (both update and delivery of cadastral information) does depend on the availability and quality of the data at the remote server. Some kind of 'information assurance' is needed to make sure that the primary process of the cadastral organisation is not harmed by disturbances elsewhere. In addition, remote (or distribute) systems/users might not only be interested at the current state of the objects, but they may need an historic version of these object; e.g. for taxation or valuation purposes. So even if the organisation responsible for the maintenance of the objects is not interested in history, the distributed use may require this (as a kind of 'temporal availability assurance').

Finally, a fundamental question is: 'How to maintain consistency between two related distributed systems in case of updates?'. Assume that System A refers to object X in System B (via object id B.X_id), now the data in System B is updated and object 'X_id' is removed. As long as System A is not updated the reference to object X should probably be interpreted as the last version of this object available. Note that the temporal aspect is getting again a role in and between the systems! The true solution is of course also updating system A and removing the reference to object X (at least at the 'current' time). How this should be operationalised will be mainly depend on the actual situation and involved systems. It might help to send 'warning/update messages' between systems, based on a subscription model of the distributed users/systems.

5. THE NEW VERSION MODEL

The most fundamental unit of the new cadastral model could be a *3D spatio-temporal parcel (actually four dimensions) with possible fuzzy boundaries*. The temporal aspect is due to the requirements that certain RealEstateObjects have a dynamic aspect, that is, time is involved. This can then be used to represent dynamic/ temporal situations such as:

1. long lease (or ownership limited in time)
2. nomadic behaviour within a certain region/time pattern
3. time-sharing of certain property (mon-fri: X, sat-sun: Y)
4. fishing/hunting right in certain region during certain seasons

It should be noted that this very general version of the model (based on 3D spatio-temporal parcels with fuzzy boundaries) contains all other models as specialisations. If there are no point or spaghetti parcels the model becomes sharp again (special case of fuzzy). When one thus not consider the temporal aspect, the result is a pure geometric parcel. When one is not interested in the 3D situation, everything is projected on the 2D surface and we are more or less back at the traditional model. The temporal aspect of the model can be found in the attribute 'timeSpec' in the RRR class. So, this is not includes as an attribute of RealEstateObject. As a result of the FIG Cadastre 2014 guidelines the Apartments are now independent of the Parcels. This also means that the ApartmentComplex does have it's own geometry.

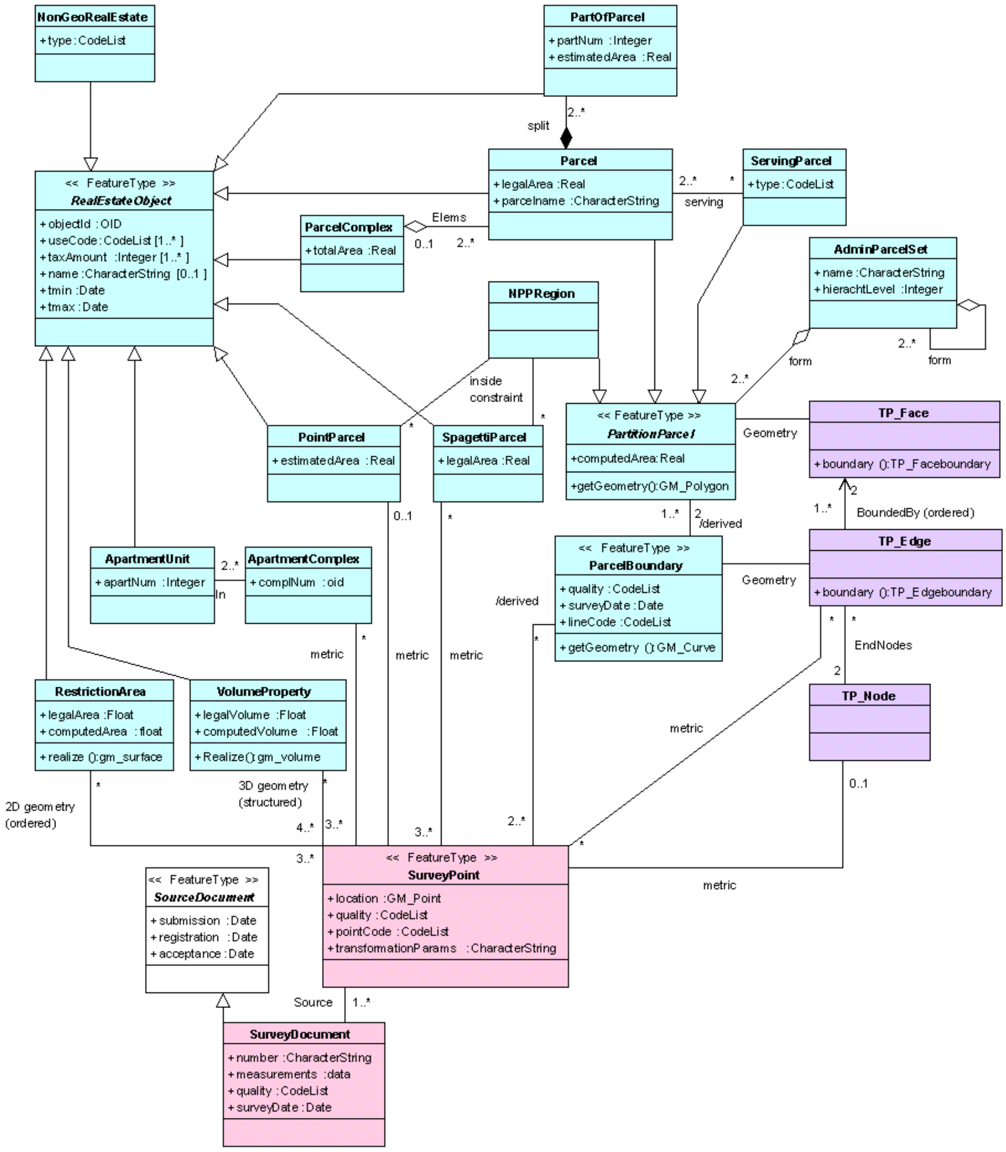

Figure 2: The geographic side of the new version of the model

5.1 Legal/administrative classes

Object classes presented in yellow cover the refinements in the Legal/Administrative side; see Figure 3. Compared to the earlier versions of the model extensive rethinking was undertaken here. Several papers presented in Bamberg contributed to this. For the legal side especially Paasch 2004 and Zevenbergen 2004, and for the person side Lemmen e.a. 2004. Of course the discussion before, during and after the workshop also contributed to these refinements.

The first refinement is the extension of the class RightOrRestrction to explicitly include Responsibilities as well. In current thinking and literature on cadastral and land administration issues usually the three R's of Rights, Restrictions and Responsibilities are used. A restriction means that you have to allow someone to do something or that you have to refrain from doing something yourself. Restrictions can both be within private law, especially in the form of servitudes, as within public law, through zoning and other planning restrictions as well as environmental limitations.

Responsibilities mean that one has to actively do something. Not all legal systems allow such mandated activities as property rights (rights in rem), and this will also effect the question if they can (and have to be) registered. Obviously their impact can be substantial and their registration makes sense.

In the model we make a clear distinction between the private law and the public law RRR's. The public law RRR's have a direct relation to the RealEstateObject. In addition to the Restrictions, the model now also encompasses Advantages which can be seen as a public law right. An example can be the right to build a house on a certain parcel. Therefore we now use the class PublicRestrictionOrAdvantage, with specialisations Advantage and Regulation.

The private law side has also been extended. Here we have the class RRR (for rights, restrictions and responsibilities) which is presented as an association class of the association between Person and RealEstateObject. The fact that RRR is presented as an association class does not mean that the class is of a lower importance within the (core) model than the other two classes. Therefore the suggestions in (Zevenbergen 2004) to put RRR in between RealEsateObject and Person, and have each of those relate to RRR, and not directly between the two (as is also used in (Paasch 2004)), is not taken over.

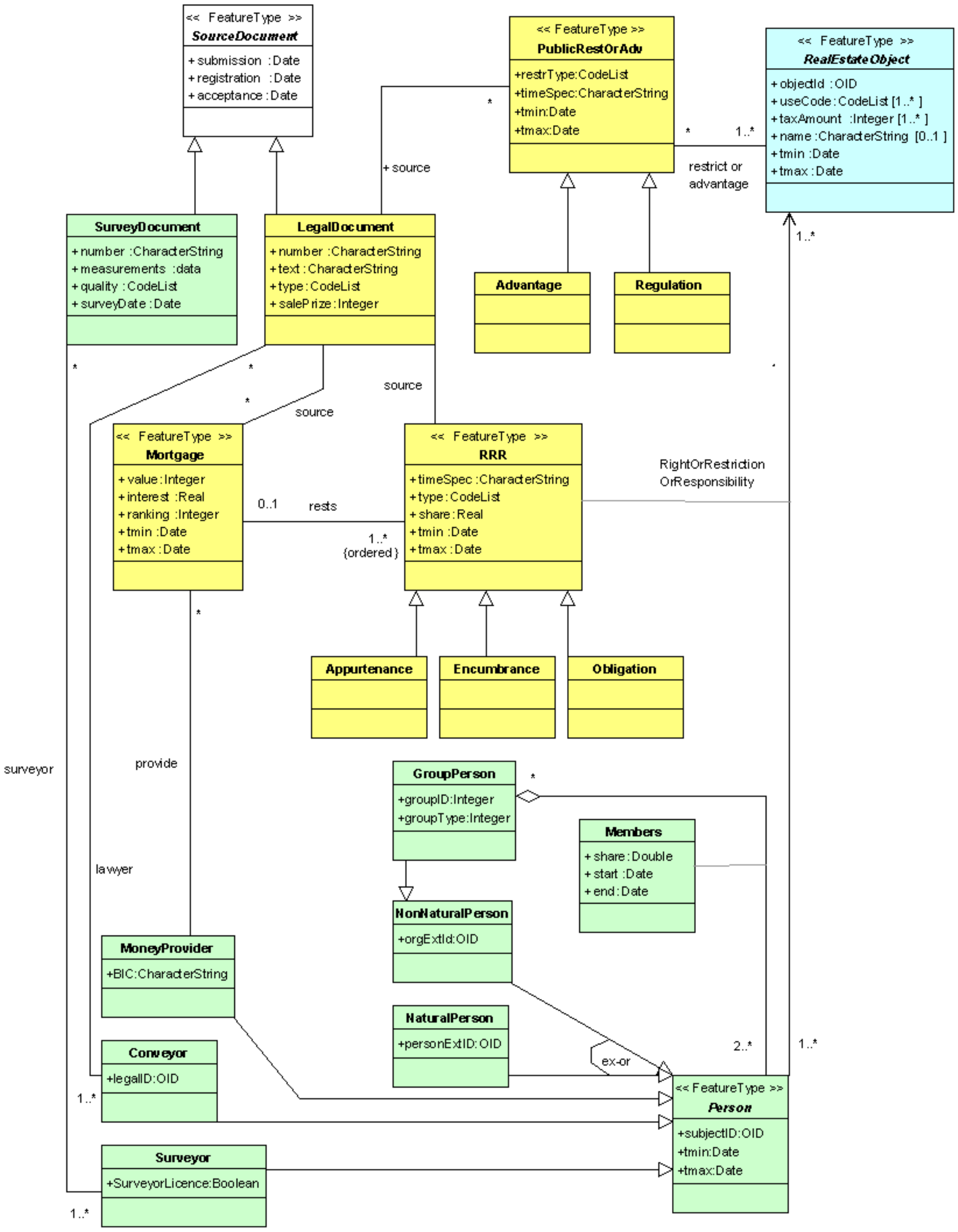

Figure 3: The administrative side of the new version of the model

The class RRR as such represents the strongest right, for instance ownership, freehold or leasehold on underlying state domain. Connected to this strongest right certain interests are added, or subtracted from this strongest right. Conferring to the terminology introduced in (Paasch 2004) we use the terms Appurtenance (for benefits, like the right to walk over your neighbours land) and Encumbrance (for burdens, like the fact that your neighbour can walk over your land). A point of discussion remains how to represent the example just given. The same feature of one person walking over a certain parcel, is an appurtenance to the ownership of one property, where it is an encumbrance to the neighbouring property. In the present model both will be represented, meaning that the same feature is represented twice, although it might be better for consistency to represent it only once (compare Zevenbergen 2004). Although some definitions of encumbrance seem to include the obligation to do something (as described under responsibilities before), we added it here as a separate specialisation Obligations to avoid any confusion on allowing the registration of responsibilities (if and when the legal system is tailored for that).
The relation between Mortgage and RRR has remained the same. A mortgage is always vested on a RRR, and should never be seen as a separate relation between person and object. On the other hand a mortgage is usually vested as collateral for loan. Therefore the one providing the money, the mortgagee, is connected to the Mortgage as MoneyProvider; one of the specialisations of the abstract class Person.
The fact that the different (public law and private law) RRR's find their base in some kind of establishing or transacting document is represented by connecting them to LegalDocument which is now a specialisation of the abstract class SourceDocument (as is SurveyDocument). The one responsible for drafting the document (for instance a notary, lawyer or conveyancer) is connected to this as Conveyer; again a specialisation of the abstract class Person.

The legal/administrative package as just described is tailored to the type of land tenure system and (legal and administrative) stability that is only found in the more mature market economies, like in Western Europe. It is also based on the notion of having one strongest right and other more derived rights from this. This can be found in most continental European countries, which start with 'ownership' and built derived rights on top of this. Much English literature, however, talks about the bundle of sticks that make up the right(s) in land. The sticks can be freely arranged, and one can not really differentiate between a strongest and more derived rights. This approach is also used in (Paasch 2004). Further research is needed to see if the model in this way can support land tenure systems based on the 'bundle of sticks' notion as well.

Land administration systems that have to underpin customary land tenure systems, informally arranged land use or conflicting claims to rights, and whose objects might not be clearly identifiable (fuzzy), not (yet) clearly identified or whose areas overlap are in need of other classes to allow for those type of situations (Lemmen et al 2004b). Often in such countries or jurisdictions both types of situations (strictly legal and formalised and more fuzzy and informal) are to be found in the same area, and should therefore be able to co-exist in the cadastral system, and thus in the core cadastral domain model.

5.2 Embedding the model in ISO/TC 211

In the context of GIS and Spatial data there is currently a lot of effort to standardise the modelling and exchange of this type of data. Most of the standardisation effort is concentrated in the OGC Consortium and in ISO/TC211 and a combined effort has resulted in a harmonised model. This model is described in the ISO19100 standard series. Since most cadastral data is spatial the core cadastral model should be based on these standards. This will allow us to build on the rich model of geo objects as defined in these standards and ensures that the model fits well in GIS software.

In order to adhere to the ISO standard a model has to adhere to certain modelling rules (ISO19109) and the spatial types as defined in (ISO 19107) have to be used. Other relevant parts of the standard are about: temporal modelling and geodetic coding.

In the model the influence of the standard can be seen in various ways:

- All base classes that relate to ISO features get the <<FeatureType>> stereotype (in our model this applies to all classes either directly or indirectly via inheritance);
- The geometry (GM_ datatypes such as GM_Point, GM_Curve, GM_Polygon, DM_Surface, GM_Volume) and topology (TP_Node, TP_Edge and TP_Face) model is based on the ISO19107 topology model;
- In the future when the ‘timeSpec’ is further modeled (instead of a CharacterString) the also the ISO temporal model should be used.
- Class names start with capitals (ParcelBoundary) and attribute names start with non-capitals (surveyDate);
- The model fits in the metamodel as defined in ISO19109;
- Basic types have got another name (it was ‘int’ now ‘Integer’ and it was ‘char[]’ and it is now ‘CharacterString’).

5.3 Encoding in GML

One of the advantages of modelling in UML is that it gives the possibility to generate an exchange format for the data in a standardised way. The GML3 standard (ISO 19136) describes how to translate an UML model to an GML Applications Schema. This Application Schema uniquely defines an exchange format for data in the UML model. For the correct generation of such a schema the UML Model has to adhere to the encoding rules that are given in the GML Standard.

Below an example of how a parcel with one obligation can be encoded. The xlink:href is used to encode a reference to the obligation. This reference can stored in the same document (internal link) or somewhere else (external link).

```
<Parcel>
    <objectID>DEL00A 07564</objectID>
    <useCode>residential</useCode>
```

```
      <taxAmount currency="euro">1000.00</taxAmount>
      <name>Casa Grande<name>
      <tmin>1968-04-05T02:08:00+02:00</tmin>
      <tmax></tmax>
      <legalArea uom="squareMeter">42</legalArea>
      <parcelName>Casa</parcelNameame>
      <computedArea>41.4341572</computedArea>
      <geometry>
         <gml:Face xlink:href="#DEL00A07564></gml:Face>
      </geometry>
      <Obligation xlink:href="#rrr?1686-44-058"/>
   </Parcel>
```

Various tools exist that automatically convert an UML Model to an GML Application Schema. The ShapeChange tool (Portele, 2004) reads an UML Schema in the XMI exchange format and writes an XML Schema. The UML/INTERLIS Editor (Eisenhut, 2004) has an export button to generate an GML Application Schema.

6. CONCLUSIONS

In this paper an improved version of the CCDM has been presented based on the outcome of the Bamberg workshop. Though the scope of the model did remain the same, several new classes and attributes have been added. This corresponds to further making implicit knowledge and structure explicit. The drawback is that it makes the model look more complex. However, this is not really the case as one could also look at the generalized classes and the model will look simple again. It is really tried to remain within the original scope of the model and not extend it with related domain models of topography, geology, geo-technical and soil information, pipelines and cables, addresses, buildings, polluted areas, mining rights, fishing/hunting/grazing rights, cultural history, (religious) monuments. (non-)natural persons, ship- and airplane (and car) registrations,…

The foundation of the new CCDM is a 3D spatio-temporal parcel (actually four dimensions) with possible fuzzy boundaries. This does not mean that every cadastral system should have four dimensional fuzzy parcel, but the model gives the overall framework. The actual systems are in a certain sense ’special cases’ of this general model; a number of examples of systems fitting in the CCDM:

- a traditional 2D parcel based system (with exact boundaries)
- the system extended with 3D VolumeProperties
- a 2D system but with temporal rights, actually the RealEstateObjects do have fixed geometry, but the right, restrictions or responsibilities do change over time (could be in according to some kind of repeating pattern).
- a 2D system with well defined parcels, but extended (in certain areas) with more fuzzy types of parcels (SpagettiParcels and PointParcels)

The new version of the model is intended to be a kind of interoperable implementation specification version of Cadastre 2014 (which is at a more abstract level). Being at an implementation level, will guarantee that different systems adhering to this specification of the CCDM will be interoperable. The actual communication could take place via XML/GML encoding of the CCDM. An XML schema can be derived of the UML class diagram of the CCDM (as has been shown in Section 5). The current version of the CCDM is also 100% complaint with the ISO 19100 series of geo-information standards, including 'Rules for application schema' (ISO19109), 'Spatial schema' (ISO19107) and 'Geography Markup Language' (ISO19136).

Most of the Future work should include:

- dynamic aspects of the involved processes
- highlight the layer structure in CCDM (by giving a number of examples)
- modelling of the field survey with more structure/attributes
- model all buildings
- inclusion of a range of spatial units
- indicate which classes are real obligatory core (also for attributes and relations)
- generation of a full XML/GML schema (not just an example fragment)
- test with real data (in EULIS context) and test data exchange
- harmonize with other domain model (topography, water, cables/pipes, etc.)

As the CCDM covers both the legal/administrative side and the geometric side of the system (ontology), a better future name of the model might be 'Land administration model' (LAM)?

The CCDM has been reviewed by many experts in the field of cadastre and land registry. Co-operation with OGC and ISO in the further development of the model will be required. Before such step is made a review and/or validation by a platform as EULIS, Eurogeographics or the Working Party on Land Administration would have to be performed. It is of importance that also UN Habitat is involved in such a review – validation process.

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