Remarks and Observations related to the further development of the Core Cadastral Domain Model

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SUMMARY

In this paper a series of remarks and observations is presented on the Cadastral Domain Model as published at 'Digital Earth' in Brno 2003, see Lemmen, et al (2003). 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. This meeting has been organised by FIG Commission 7, 'Cadastre and Land Management' in close co-operation with UN HABITAT and the Institution of Surveyors in Kenya. Earlier versions of the Core Cadastral Domain Model, 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 core cadastral domain model. It is first discussed what should be considered the scope of the core cadastral model. There is a tendency to include more and more object types and relationships in the model as these are somehow related to the objects in the current model. However, is it better to demarcate the model and develop other core models for the related objects (which can then be accessed via well-defined interfaces of the Geo-Information Infrastructure). The requirements that do fall within the scope of the model are translated into proposals for the new version of the core cadastral model. Finally, the paper is concluded with some final remarks and suggestions to create a new version of the model.

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1. INTRODUCTION

In this paper a series of remarks and observations is presented on the Cadastral Domain Model as published at ‘Digital Earth’ in Brno 2003, see Lemmen, et al (2003). 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. This meeting has been organised by FIG Commission 7, ‘Cadastre and Land Management’ in close co-operation with UN HABITAT and the Institution of Surveyors in Kenya. Earlier versions of the Core Cadastral Domain Model, have been developed on the basis of experiences in Europe, the Nairobi meeting provides input from developing countries.
Further a number of remarks are included in this paper based on evaluation of the model by the authors. Part of this evaluation is included in this paper where it concerns the system boundary of the Cadastral Domain Model. In section 2 a short overview is given of the current core cadastral model, the ‘Brno 2003’ version. In section 3 some relevant experiences from a number of countries developing land legislation with attempts to integrate customary land tenure within a formal model. The requirements resulting from this integration are analysed with respect to the impact on the core cadastral domain model in section 4. Before trying to incorporate all requirements in the new version of the model, it is first discussed in section 5, what should be considered the scope of the core cadastral model. There is a tendency to include more and more object types and relationships in the model as these are somehow related to the objects in the current model. However, is it better to demarcate the model and develop other core models for the related objects (which can then be accessed via well-defined interfaces of the Geo-Information Infrastructure). The requirements that do fall within the scope of the model are translated into proposals for the new version of the core cadastral model in section 6. Finally, the paper is concluded in section 7 with some final remarks and suggestions to create a new version of the model.

2. THE CORE CADASTRAL DOMAIN MODEL: A SUMMARY

Until today many countries (or states or provinces) have developed their own cadastral system because there are supposed to be *huge differences* between the systems. The one operates deeds registration, the other title registration, some systems are centralised, and others decentralised. Some systems are based on a general boundaries approach, others on fixed boundaries. Some cadastres have a fiscal background, others a legal one. However, it is also obvious that the separate implementation and system's maintenance of a cadastral system are not cheap, especially if one considers the ever-changing requirements. Also, the different implementations (foundations) of the cadastral systems do not make meaningful communication very easy. Looking at it from a little distance one can observe that the systems are in principle mainly the same: they are all based on the relationships between persons and land, via (formal or perhaps also non-formal) rights and are in most countries influenced by developments in the Information and Communication Technology (ICT). The two main functions of every cadastral system are: 1. keeping the contents of this relationship up-to-date (based on transactions) and 2. providing information on this registration.

A *standardised core cadastral domain model,* covering land registration and cadastre in a broad sense (multipurpose cadastre), will serve at least two important goals: 1. avoid reinventing and re-implementing the same functionality over and over again, but provide an extensible basis for efficient and effective cadastral system development based on a model driven architecture (Siegel 2001, OMG 2002) and 2. enable involved parties, both within one country and even between different countries, to communicate based on the shared ontology implied by the model. The contributions of this paper consist of an improved and extended version of the existing cadastral domain model (Lemmen et al, 2003; see Figure 1), and the introduction of an explicit identification of the model scope, that is the model boundary. One of the main preconditions of the model development is to keep the model as transparent and simple as possible in order to be useful in practise.

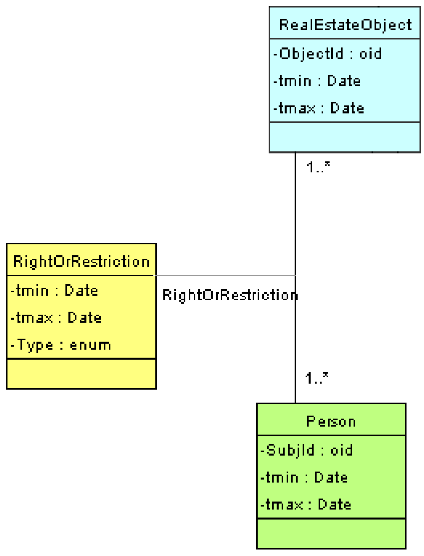

Figure 1. The three central object classes in the core cadastral domain model

A main characteristic of land tenure is that it reflects a social relationship regarding rights to land, which means that in a certain jurisdiction the relationship between people and land is recognised as a legally valid one (either formal or non-formal); see Figure 1. These recognised rights are in principle eligible for registration, with the purpose to assign a certain legal meaning to the registered right (e.g. a title). Therefore land administration systems are not 'just handling only geographic information' as they represent a (lawfully or customary) meaningful relationship amongst people, and between people and land. As the land administration activity on the one hand deals with huge amounts of data, which moreover are of a very dynamic nature, and on the other hand requires a continuous system maintenance process, the role of information technology is of strategic importance. Without availability of information systems it is believed it will be difficult to guarantee good performance with respect to meeting changing customer demands. Organisations are now increasingly confronted with rapid developments in the technology, a *technology push*: internet, (geo)-databases, modelling standards, open systems, GIS, as well as a growing demand for new services, a *market pull*: e-governance, sustainable development, electronic conveyance, integration of public data and systems. Cadastral modelling is considered as a basic tool facilitating appropriate system development and re-engineering and in addition it forms the basis for meaningful communication between different (parts of the) systems.

Standardisation is a well-known subject since the establishment of cadastral systems. In both paper based systems and computerised systems standards are required to identify objects, transactions, relations between real estate objects (e.g. parcels) and persons (also called subjects in some countries), classification of land use, land value, map representations of objects, etc. etc. The relationship between real estate objects and persons via rights is the foundation of every land administration. Besides rights, there can also be restrictions between the real estate objects and the persons.

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 collected and/or maintained by different organisations, 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 organisations have their own responsibilities in data maintenance and supply and have to communicate on the basis of *standardised processes* in so called value adding production chains.

One should not look at the whole mode (all packages together as presented in Figure 2) 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 specialisations, blue, pink and purple: geometric/topological aspects.

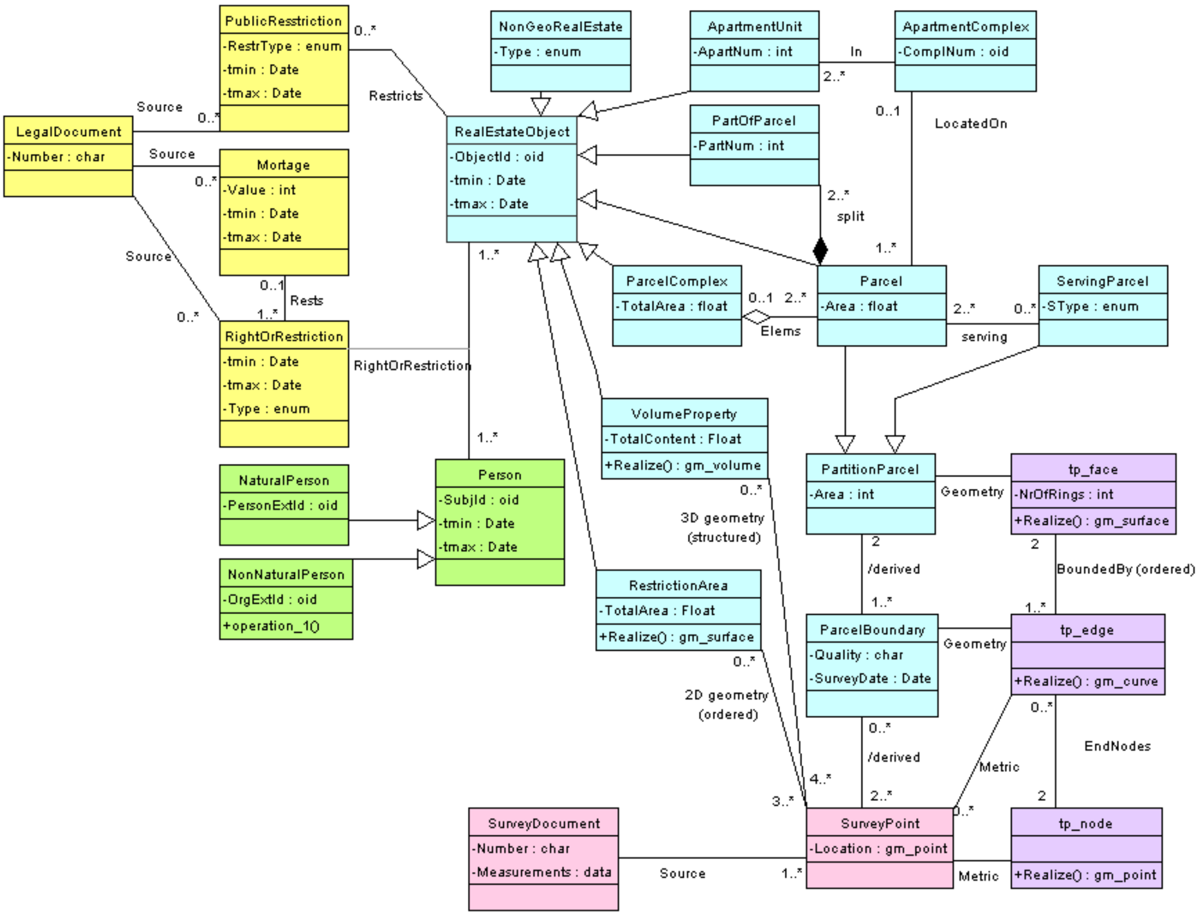

Figure 2. The current 'Brno 2003' version of the core cadastral domain model

3. OBJECT-RIGHT-SUBJECT

Experience reveals that some countries develop land legislation, which endeavours to integrate customary tenure within the formal system. Bosworth (2002) reports on Uganda where the Land Act enacted in 1998 provides for methods to adjudicate on customary rights and the issue of certificates of customary ownership and occupation certificates for tenants on *mailo* land as well as the establishment of a Land Fund to assist in the market-based transfer of rights between tenants and landowners. These certificates will be mortgage able. Consequently the Act recognises group rights to land by means of the registration of communal land associations with elected management committees. Quadros (2002) reports on Mozambique, where the new Land Act, 1998, recognises customary rights in the form of co-titling and the need to consult with the local communities as part of the authorisation process for new investments.
In Namibia a new Land Law is pending that will address the broad issues of communal land reform by means of the creation of regional land boards (Pohamba, 2002). A flexible land tenure system has been proposed by Fauerholm Cristensen (2004). A similar approach can be recognised in Tanzania (Kironde, 2004) where residential licenses in urban area's are to be converted to full title later. In Ethiopia a certification in two phases is under development (Abebe-Haile, 2004), in Uganda certificates of ownership and occupancy are used in parallel

(Oput, 2004), in Lesotho 3 forms of leases are under development: primary, demarcated and register able (Selebalo, 2004).
Van den Berg (2000) states that under a new Act in South Africa communal titles can be granted to Communal Property Associations.
In Bolivia the INRA Act (1996) (Ley Instituto Nacional Reforma Agraria) provides for the recognition of *Tierras Comunitarias de Origen* (TCOs), i.e. land belonging to indigenous groups (Zoomers, 2000).
The recognition of customary rights also devotes attention to rights of sheep and cattle farmers. In many countries there are serious conflicts between traditional nomadic sheep or cattle farmers and arable farmers about grazing and farming lands (such as Kenya, Tanzania, Rwanda). Tanzania's new village Land Act provides for the sharing of pastoral and agricultural land by sheep and cattle farmers and arable farmers on the basis of adjudication and mutual agreements (Mutakyamilwa, 2002). In analogy with pastoral rights, the problem of *overlapping rights* has yet to be resolved in many countries.

This brings us to the issue of the nature of the spatial unit, which forms the basis for registration. Objects on which customary rights are exercised are not always accurately defined (Neate, 1999). Within this context Österberg (2002) advocates a flexible and non-traditional approach to the spatial component. Land rights might pertain to a relationship with the land that is in accordance with the standards and values of the relevant community, although these rights will need to be defined to provide third parties with meaningful information. In these situations the parcel of land, i.e. the object on which the rights are exercised, might be defined in a manner other than accurate land surveys and geometrical measurements. Österberg (2002) shows pro's and con's of various perspectives.
Fourie (2002a, 2002b) notes that 'the high accuracy's and expensive professional expertise associated with the cadastre has meant that there is too little cadastral coverage in Africa'.

When viewed from a land-tenure perspective land administration systems entail the registration of the existing land tenure in a manner, which imparts a given added value – i.e. the certainty offered to the persons possessing registered rights that those rights will remain in force until such time as they might be revoked in a legal and comprehensible manner. In our opinion the meaning of the term *legal* within this context should be understood as any system of standards and values that offers transparency, reliability and predictability to the relevant community. This in turn implies that customary rights or indigenous standards should be regarded as being fully eligible for land registration and cadastral purposes. In fact this also needs to extend to what are referred to as *informal settlements* (irrespective of their precise nature); these should also be eligible for the purposes of registration of titles to land, subject to the proviso that the land relationships are generally accepted and perceived as being legitimate within society – i.e. provided that the relevant society regards the rights to land as being legitimate, and provided that the population is familiar with the rules pertaining to the allocation, acquisition and transfer of land. This once again demonstrates that in essence it is possible to register or maintain records of relationships between man and land irrespective of the nature of the country's jurisprudence; this ability offers opportunities for the integration of statutory, customary and informal arrangements within land administration systems.

The conclusion to be drawn from this Section is that the conventional basic concepts of land administration are affected in three ways:

- the subject: group ownership with non-defined membership
- the rights: the recognition of types of non-formal and informal rights
- the object: units other than accurate and established units

4. IMPACT ON THE CORE CADASTRAL DOMAIN MODEL

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 numbers of categories of land rights. Because property and ownership rights are based on (national) legislation, extendable 'lookup tables' can support in modelling this. E.g. (Fauerholm Christensen, 2004) proposes rights related to 'starter tiles', 'landhold titles' and 'freehold titles' as a 'step by step' development in Land Registration in Namibia. This can be classified in a model. 'Customary Right' related to *a region* or 'Informal Right' can be included; from modelling perspective this is not an item for discussion. For example the observation of Ősterberg (2002) that 'in customary land tenure systems land use rights are allocated based on the traditional rules, and once acquired, the rights are exercised individually within the family structure' can be modelled in the 'object', 'right' and 'subject' approach. The same is valid for forest and rangelands, which is often under common property management in customary systems. State owned and controlled land can be represented in this model. The same is valid for possession, occupation, use, usufruct, tenancy or long lease. Or: 'indigenous' rights. Of course, for the actual implementation in a given country or region, this is very important. Customary, informal and individual rights, or even a variety of tenures (Fourie, 2002a) can be integrated in one standardised system. Even *'illegal relationships'* between persons and land, e.g. in case of uncontrolled 'privatisation', see Trindade, 2003, could be represented (reflecting the reality of the real world in the system), as well as 'unknown', cases of 'disagreement', 'occupation' or 'conflict', resulting in overlapping claims to land. In this way a systematic registration of conflicts on lands could support to solutions.

The class 'Person' has as specialisation classes 'NaturalPerson' or 'NonNaturalPerson' (see figure 2) like organisations, companies, communities, co-operations and other entities representing social structures. It should be noticed that a person can hold a *share* in a right, e.g. in case of marriage. A share could be an attribute to RightOrRestriction depending on the type of right.

Person identification is not a primary responsibility of cadastre and land registry but might be of relevance in cadastral processes. Biometric approaches are coming more and more available.

In the 'Brno 2003' version of the core cadastral domain model, as it is under development now (Lemmen et al, 2003), parcels are considered as RealEstateObjects. 'Parcels', 'PartitioningParcels' and 'ServingParcels', are not explicitly represented as 'closed polygons' in the *ideal* situation, but as faces in a topological structure representing the planar partition. 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 possible inconsistency between the different representation, causing all kind of 'gap and overlap' problems, which don't have a meaning in reality. This means planar 2D topology in the represented parcel objects as *an ideal* situation. An intermediate situation can be a representation of boundaries without topology, e.g. in case spatial data are being built up from different data sources (existing maps, aerial photographs, satellite images, etc.; see below). In case of overlapping claims a 'closed polygon' approach is required. The overlapping areas have to be identified and modelled; this could result in three faces: face 1 that only belongs to parcel A, face two that only belongs to parcel B, and face that belongs to the region which is disputed between parcel A and B. Another, even more unconventional way is just using the co-ordinates of its centroids. For further approaches see (UN 2004, under printing). Single point representation must be possible in the standard model (Home & Jackson, 1997). This approach as investigates the potential for applying spatial technologies (GPS, GIS/LIS) to record progressive land rights of informal settlements at the level of community controlled land office. Note: such office could perform in a standardised environment, standardisation does not mean by definition centralisation (but there must be a central unit responsible for the contents and extensions of standards).

The concepts as presented above imply that it should be possible that the following RealEstateObjects:

- Parcel
- Apartment
- Spatial Unit

could be represented in the Cadastral Domain Model as:

- a single Point
- a spaghetti of Lines (incomplete topology)
- a Polygon with low geometric accuracy
- a Polygon with high geometric accuracy

Quality labels are introduced now (accuracy labels), the geodetic solutions available in defining and providing those labels are outside the scope of the Core Cadastral Domain Model, see section 5 of this paper.

Rights could be:

- Formal Ownership
- Customary
- Indigenous
- Tenancy
- Starter, landhold, freehold
- Possession
- Mortgage
- Usufruct
- Long Lease

- Restriction related to right
- Restriction related to object
- State ownership
- Informal
- Unknown
- Disagreement
- Occupation
- Uncontrolled privatisation

This overview could be extended, depending on the local situations. Conflicting claims result in overlaps or have to be identified as such in case of representation in planar topology. An attribute related to right could be *share*.

Subjects could be:

- Natural Person
- Company
- Municipality (other government organisations: province, water boards, ministry)
- Co-operation, Community
- Group, Tribe
- Group of families or group of groups

Again: this 'list' could be extended. The biometric identification or digital signature could be attributes related to person, this might be a requirement in cadastral maintenance processes, but person identification is considered to be outside the scope of the Core Cadastral Domain Model, see section 5 of this paper.

5. 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 op 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 (Aalders et. al, 2004). 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, 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.

6. MAIN PROPOSED CHANGES

In the previous sections several 'new' requirements for cadastral systems were formulated, which are currently not completely covered by the core cadastral model ('Brno 2003' version). A part of these requirements can be satisfied by related models (and systems) not part of the cadastral system itself, but accessible via the geo-information infrastructure. However, this still does not cover all the requirements formulated in the previous sections and therefore a number of refinements and extensions to the core cadastral model are proposed in this section.

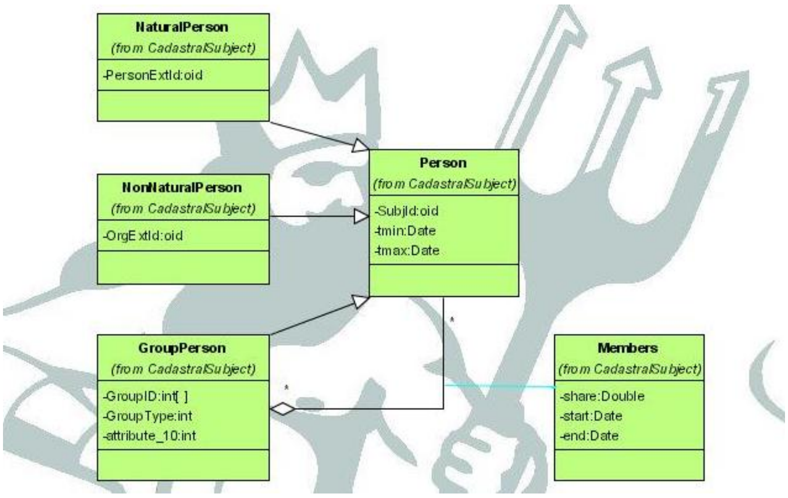

Figure 3. A possible extension of the core cadastral model with a GroupPerson

The first refinement is the introduction of a new type of Person, besides the specialisations NaturalPerson and NonNaturalPerson, a third specialisation is added GroupPerson. The difference between the NonNaturalPerson and the GroupPerson is that the first is intended to represent instances such as organisations, companies, government institutes (with to explicit relationships to other Person), while the second is intended to represent communities, co-operations and other entities representing social structures (with possible explicit relationships to other Persons, optionally including their 'share' in the GroupPerson and associated RightsOrRestrictions to RealEstateObjects). Note that a GroupPerson can consist of all kinds of persons: NaturalPersons, NonNaturalPersons, but also of other GroupPersons. In case of more informal situations the explicit association with the group member Persons is optional. Further, a Person can be a member of 0 or more GroupPersons. The composite association between GroupPerson and Person could be developed into an association class 'Members', in which for each Member certain attributes are maintained; e.g. the share in the group and the start and optionally end date of the membership.

The second refinement or perhaps this case should be called modification of the model is that it should be possible to represent parcels not only as faces of a planar partition (that is, a set of areas without overlaps and without gaps), but also in alternative ways. A Parcel could (initially) be represented with single point or a spaghetti polygon, which is not adjusted with it neighbours in a topology structure. The whole domain is subdivided into two types of regions: 1. regions based on a planar partition (type PP) and 2. regions not based on a planar partition (type NPP). Together the PP and the NPP regions cover the whole domain. This means that the object class PartitionParcel is further specialised into NPPRegions, besides the existing specialisations Parcel and ServingParcel. Note that an NPPRegion does not have any associated Person (or RightOrRestriction), that is, it is not a RealEstateObject. On the other hand, the class RealEstateObject gets two more specialisations: PointParcel and SpaghettiParcel. These two new 'alternative' non-face representations of a RealEsateObject can only exist in NPPRegion areas (and does not influence involve the Parcel and ServingParcel areas). This can be represented via an additional (geometric) constrained in the model. A parcel may change its presentation over time from PointParcel to SpaghettiParcel or to Parcel (but not back). However, this does not need to be the case in situation that the PointParcel or SpaghettiParcel fulfils the needs. Perhaps, the point and spaghetti representation of a parcel should be interpreted as a parcel description with a certain fuzziness (all 'fuzzy faces' belonging to the same 'conceptual' partition of the surface).

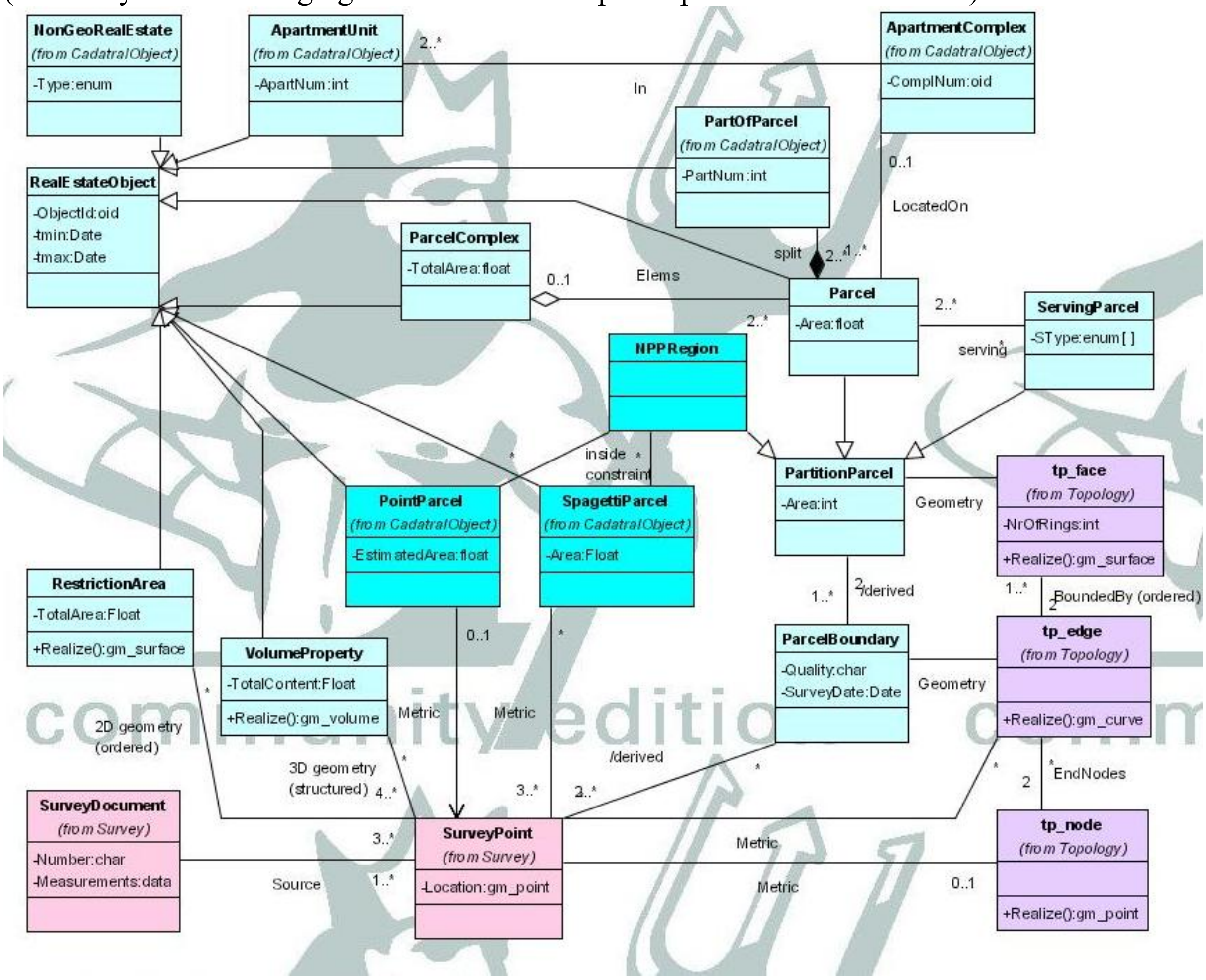

Figure 4. Another possible extension: the introduction of PointParcel and SpaghettiParcel

The third possible modification to the 'Brno 2003' version of the core Cadastral model is related to what was already discussed in that version: 3D and temporal aspects of the representation (Onsrud, 2002, Mattson 2003, Queensland Government 2003a, 2003b). Until today the (2D) planar partition of the surface parcel is still the geometric foundation of the model (now extended with PointParcels and SpaghettiParcel). The whole 3D column is implied with a surface parcel. So, actually a 3D volume partition of space in implied. The

VolumeParcels are an exception to the 3D column representation and they should be extracted from the column (Stoter and van Oosterom 2003, Stoter 2004). The result is then a 3D partition of space represented in a certain (practical) manner in the model and not in a full 3D topology structure. The conceptual model behind is a 3D volume partition (and one can imagine that also over here we have PointVolumeParcels and SpaghettiVolumeParcels).

However, from the requirements of the previous section it becomes clear that certain RealEstateObjects have a dynamic aspect, that is, time is involved. Therefore, the most fundamental unit of the cadastral model could be a *3D spatio-temporal parcel (actually four dimensions) with possible fuzzy boundaries*. 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.

7. CONCLUSION

At data collection side modern technology can be integrated with positioning systems. Barodien and Barry (2004) recognise that effective upgrading of informal settlements require accurate and up to date social and spatial information. Home & Jackson (1997) use a point position (collected with hand held GPS) to relate the property identifier number, land cover, crop type, soil condition, and number of structures, etc.. In San Pedro Sula (Honduras) 130,000 parcels, both urban and rural were identified. Montoya (2002) combines Digital Video, GPS and GIS as a rapid ground data capture methodology from a car. Compare the use of the Cyclomedia system in some European cities. A similar approach should be investigated in relation to LiDAR (Airborne Laser Altimetry). Combination of the results with tape measurements (street level) and GPS (inner side of the street blocks) could, in our opinion, result in cadastral maps produced in an efficient way. In general a ‘move’ from national reference systems to WGS/UTM has to be considered. Further research may be: the relevance of field sketches (could be based on ortho photo’s where people identify their properties), the use of cheap laser devices replacing tapes, the use of satellite images (see for example Trindade, 2003), the development of quality labels related to spatial data representing the level of accuracy and providing information on how many co-ordinates are within this level of accuracy, area calculation (legal and calculated area, allowed difference), link to SDI, mapping of trees (in some area’s more important then the parcels), the use of forms for collection of legal administrative data, electronic conveyancing, introduction of postal addresses.

Besides the cadastral system model and (distributed) architecture and new developments in (geographic) data collection, another important aspect of the cadastral system is data distribution. At data dissemination side it looks that a thin client approach in a 3-tier architecture with a web based seems to be the recommended approach today. Data protection and secure remote access, is of vital importance (https, firewalls, virus scanning).
A number recommendation can be obtained from this paper:

1. Based on the confrontation of the initial core cadastral domain model with actual cadastral systems world-wide (both developed and developing countries) a number of refinements and extensions (possible additional packages) is proposed.
2. Good demarcation of the boundary of the core cadastral domain model is also important in order to avoid extending with more and more packages. However, related core domain models must be harmonised with each other (within the Geo-Information Infrastructure)
3. To speed up the development of cadastral systems standardised (but extendable) data models and standardised inter-organisational work processes combined with standardised functionality should be developed by GIS industry. The link to surveying processes has to be included.
4. Combinations of data collection methods and technologies for cadastral purposes should be further investigated

It is the intention of the authors to provide a new version of the model during the FIG Working Week and the 8th International Conference of the Global Spatial Data Infrastructure (GSDI 8) in Cairo, Egypt, 16-21 April 2005. After presenting the current paper at the Bamberg workshop (9-10 December 2004) and discussion the possible refinements and extensions, decisions have to be made with respect to the next version ('2005 version') of the model. Of course, also the results from other presentations and sub working group sessions at the workshop in Bamberg will be included in this version of the model.

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REFERENCES

Aalders, H., Bulens, J., Janssen, P., Oosterom, P. van, Reuvers, M., Uitermark, H. and Quak, W. Basismodel Geo-Informatie, versie 0.9 (NEN3610, versie 2), Ravi report, 15 september 2004 (in Dutch).

Abebe-Haile, S., 2004, ‘A Reality Check on the Quest for Tenure Security and Land Administration in Ethiopia’, Expert Group Meeting on Secure Land Tenure, Nairobi, Kenya, November 2004

Barodien & Barry, 2004, ‘Palm Computers for Spatially Referenced Social Surveys in Upgrading Informal Settlements, New Zealand Surveyor No 294

Berg A. J. van der., 2000, Initiatives towards creating an equitable land market in post apartheid South Africa, Proceedings FIG Commission 7 Hamburg

Bosworth., J., 2002, ‘Country case study of Uganda’, World Bank Seminar Kampala

Fauerholm Christensen, S., 2004, ‘The Flexible Land Tenure System – The Namibian solution bringing the informal settlers under the register’, Expert Group Meeting on Secure Land Tenure, Nairobi, Kenya, November 2004

Fourie. C., 2002a, ‘Comment on Österberg’s paper on viable land administration systems’, Proc. World Bank Seminar on Land Policy, Kampala

Fourie, C., van der Molen, P., Groot R., 2002b, ‘Land Management, Land Administration and Geo-spatial Data: Exploring the Conceptual Linkages in the Developing World, Geomatica Vol., 56 Nr 4 (2002)

Home & Jackson, 1997, 'Our Common Estate: Land Rights for Informal Settlements: Community Control and the Single Point Cadastre in South Africa', RICS

ICSM, 2002, ‘Harmonised Data Manual – The Harmonised Data Model’, Intergovernmental Committee on Surveying & Mapping (ICSM), 2002.

Kaufmann, J. & Steudler, D., 1998, 'Cadastre 2014, A Vision for a Future Cadastral System', FIG

Kironde, L., 2004, ‘Capacity Building for Secure Tenure: the Role of the University College of Lands and Architectural Studies (UCLAS), Dar es Salaam, Tanzania’, Expert Group Meeting on Secure Land Tenure, Nairobi, Kenya, November 2004

Lemmen, C., Molen, P. van der, Oosterom, P. van, Ploeger, H., Quak, W., Stoter, J, and Zevenbergen, J.: ‘A modular standard for the cadastral domain’, Digital Earth, Brno, 2003

Mattsson, H., 2003, Towards Three Dimensional Properties in Sweden, European Faculty of Land Use and Development, 32nd International Symposium, 24-25 October 2003, Strasbourg

Molen P. van der., 2003 Future Cadastres, Proceedings FIG Paris

Montoya, L., ‘Low-cost Rapid Ground Data Capture, DV, GPS and GIS Offer Great Potential in Urban Management’, GIM International, January 2002.

Mutakyamilwa, F., 2002, ‘Country case study Tanzania’, World Bank Seminar Kampala

Neate, G., 1999, ‘Mapping landscapes of the mind: a cadastral conundrum in the native title area’, Proc. International Conference on Land Tenure and Cadastral Infrastructures Melbourne

OMG, 2002, Object Management Group, Unified Modeling Language Specification (Action Semantics), UML 1.4 with action semantics, January 2002

Onsrud, H., Making laws for 3D cadastre in Norway, FIG Congress, Washington, USA, April 2002

Oput, R., 2004, ‘Piloting of Systematic Adjudication, Demarcation and Registration for Delivery of Land Administration Services in Uganda’, Expert Group Meeting on Secure Land Tenure, Nairobi, Kenya, November 2004

Ősterberg 2002, ‘Designing viable land administration systems’, Proc. World Bank Seminar on Land Policy, Kampala

Quadros, M.C., 2002, ‘Country case study of Mozambique’. World Bank seminar Kampala

Queensland Government, 2003a, Land Title Regulation, 1994, Land Title Act 1994, Reprinted as in force on 1 July 2003

Queensland Government, 2003b, Registrar of Titles -- Directions for the Preparation of Plans, Department of Natural Resources and Mines, version 3.3, 1 May 2003

Selebalo, C., 2004, ‘Creation of Land Records Prior to Formal Registration in Lesotho’, Expert Group Meeting on Secure Land Tenure, Nairobi, Kenya, November 2004

Siegel, J. and the OMG Staff Strategy Group (2001), Developing in OMG’s Model-Driven Architecture. Object Management Group White Paper, November 2001 (rev 2.6)

Stoter, J.E. and P.J.M. van Oosterom, 2003, Cadastral Registration of Real Estate Objects in Three Dimension, URISA Journal, Volume 15, Number 2, pages 51-60.

Stoter, J.E., 2004, 3D Cadastre, PhD thesis, Delft University of Technology, September 2004.

Trindade, C., Do Valle K.B. and Bruschi S, 2003, ‘Informal Settlements Upgrading in Manica City, 4th International Symposium Remote Sensing, Regensburg, Germany

UN/ECE/WPLA, 1996, Land Administration Guidelines, UN New York/Geneva

UN/ECE/WPLA, 2004, 'Guidelines on Real Property Units and Identifiers', to be published in due course

Zoomers, A., 2000, ‘Current land policy in Latin America’, KIT Amsterdam NL

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