Social Tenure Domain Model
Requirements from the Perspective of Pro-Poor Land Management

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SUMMARY

Land is the key issue behind slum formation. Addressing the slum challenge means taking the land issue seriously. Given that experience has shown that it takes 15-25 years to change a country's land administration system, we cannot afford to wait if we wish to improve the lives of slum dwellers now in the short-term.

Many people think that the way to solve the problems of insecurity of tenure, homelessness and the development of slums is through large scale land titling (Biau, 2005). While this approach is of course important and necessary, it is *not enough* on its own to deliver security of tenure to the majority of citizens in most developing counties, especially in Africa. The best figures available indicate that less than 30 percent of the land in developing countries is titled. In many countries of Sub Saharan Africa, this drops to one percent. There are many reasons for this, such as the fact that customary tenure has a very strong influence. Individual land titling often works against the needs and aspirations of ordinary people, including in urban Africa where informal forms of land tenure are often adaptations of rural customs.

Land administration systems with colonial roots do not really support the registration of customary or informal rights. This means that socio-technical innovations are required. It should be noticed that in the technical field, there is often an insufficient focus on pro poor technical and legal tools. In the development of the FIG Core Cadastral Domain Model, efforts are being made to avoid such criticism. This pro poor approach is being strengthened by undertaking further research into domain modeling, especially in regard to the proposed Social Tenure Domain Model as a specialization of the Core Cadastral Domain Model.

A partnership between FIG and UN HABITAT within the frame work of the Global Network of Pro-Poor Land Developers could be the basis for a further analyses and development of the Social Tenure Domain Model. This Network is being facilitated by UN-HABITAT together with partners such as FIG, the World Bank, ITC, the Lincoln Institute, Swedish and Norwegian aid, to be able to identify and solve some of the key blockages to the delivery of security of tenure for the poor. An appropriate pro poor Social Land Tenure Domain Model is considered one of the priority tools.

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1. INTRODUCTION

The subject of land in Africa is both a critical and a sensitive one. UN-HABITAT's global mandate covers all human settlements, and the organization is known as the agency for cities and other human settlements. (Augustinus, 2005) In the cities of the developing world, slum upgrading is one of UN-HABITAT's key tasks, where security of tenure and land are of critical concern. In 2001, 924 million people, almost one-third of the world's population, lived in slums. The majority of these people are in the developing regions, accounting for 43 percent of the urban population. Sub-Saharan Africa had the largest proportion of the urban population living in the slums in 2001 at over 70 percent. It is projected that without serious mitigating action in the next 30 years, the global number of slum dwellers may double to about 2 billion.

There is growing concern about slums, as clearly stated in the year 2000 United Nations Millennium Declaration (Augustinus, 2005). In light of the increasing numbers of urban slum dwellers, governments have recently adopted a specific target on slums. It is contained in the Millennium Development Goal 7, Target 11, which aims to significantly improve the lives of at least 100 million slum dwellers by the year 2020. Given the enormous scale of predicted growth in the number of people living in the slums, the Millennium Development target on slums should be considered as a bare minimum that the international community should aim for. Because land is literally at the base of slum formation, addressing the slum challenge means taking the land issue seriously. Given that experience has shown that it takes 15-25 years to change a country's land administration system, we cannot afford to wait if we wish to improve the lives of slum dwellers now and to meet the Millennium Development Goals.

Many people think that the way to solve the problems of insecurity of tenure, homelessness and the development of slums is through large scale land titling. While this approach is of course important and necessary, it is not enough on its own to deliver security of tenure to the majority of citizens in most developing counties, especially in Africa. The best figures available indicate that less than 30 percent of the land in developing countries is titled. In many countries of Sub Saharan Africa, this drops to one percent. There are many reasons for this, such as the fact that customary tenure has a very strong influence. This means that family and group rights are important to ordinary people. Land titling programmes are generally based on the privatization of land and the awarding of land titles to individuals. Individual land titling therefore often works against the needs and aspirations of ordinary people, including in urban Africa where informal form of land tenure are often adaptations of rural customs.

To reach the Millennium Development Goal of improving the lives of at least 100 million slum dwellers by 2020 will require the development of innovative approaches to security of tenure that are not based on land titling alone. UN-HABITAT's Global Campaign for Secure Tenure, has a focus on advocating change and assisting Member States to introduce innovations which strengthen the tenure security of majority of people, especially the urban poor. The focus of the Campaign is unambiguously aimed at promoting a set of policies, strategies and *(technical) tools* that will directly benefit the urban poor throughout the world. It addresses the issues of forced evictions, secure tenure for both men and women and, equally important, the right of women to equal inheritance. It enables UN-HABITAT to engage with organizations of civil society, local authorities, professionals and policy makers in order to promote policies and practices favorable to the urban poor.

It is not possible to deliver security of tenure without a land administration system. Land administration is defined as the 'process of determining, recording and disseminating information about tenure, value and use of land, when implementing land management' (UNECE, 1996). Land administration is not an end in itself, but serves society. (van der Molen, 2003) Increased understanding is required on the way land administration systems support land policy, land rights and security of tenure in area's such as:

- The development of a land policy that can be implemented in a multi level government environment,
- The implementation of such land policy through measures relating to g land tenure, land markets, land taxation, land use planning, land reform and the management of natural resources,
- The principles of good governance and the rule of law as a context,
- Adequate institutional conditions in regard to the legal framework and the mandates in the public administration system, which the land administration system needs in order to serve these functions,
- Organizational conditions of business goals and IT policy at a strategic level, and work processes and supportive IT architecture at an operational level to make land administration systems work, and the development of geo-information systems for land administration.

This is applicable because the 5th FIG Regional Conference in Accra, Ghana, is focusing on land administration and good governance as conditions for sustainable development. These topics will be discussed also through the technical tools that modern surveying technology can offer in promoting these main goals. Sub-themes of the conference include: modern technology and land administration; professional qualifications and standards, quantity surveying, urban-rural interrelationship in land administration, positioning and measurements, surveying and geo-informatics education and mine surveying.

Modeling the relationships between people and land as a basis for land administration and/or land management is of a complex nature. Experiences from practice teach us that it should and can be done in both a computerized and paper based environment, and for formal rights as well as for social land tenure systems (customary, informal).

The focus of this paper is on *data modeling* and on the related knowledge behind it; independent of the level of formalization of the people-land relationships. As Omar Razzaz, a lawyer, states, "property relations which are endowed with the protection of legal rights and duties are only a subset of the universe of property relations." (1993). That is, the data modeling in this paper is a search for a domain model that can be used for a land administration system that can support all forms of land rights and claims, not registered land rights.

In the development of the FIG Core Cadastral Domain Model (CCDM) efforts have been made to include customary and informal tenures.

Does the functionality provided in the CCDM really cover the social land tenure system requirements? Could it support the implementation of Pro-Poor Land Management as launched by UN-HABITAT? Could it support in the management of geo-information derived from multiple sources for the maintenance of people-land relationships? Could it support the delivery of economic and social services to informal settlements and rural areas where there are no cadastral parcels? Could the CCDM be recommended to GIS and Database Management suppliers or to 'open-source' communities as a functional and technical tool to be supported by their software products? Could it be used for the land management system representing land records with a minimal spatial component? Could it be further specialized to a Social Tenure Domain Model?

In answering these questions this paper will discuss the requirements for a flexible standardized Social Tenure Domain Model. The requirements for the model are defined by using papers discussing social land tenure systems and land administration in Sub Saharan Africa and elsewhere. The requirements for the model are then assessed as to what extent they can be done, or not, or whether the functionality developed for the CCDM needs to be re-developed in a specialized Social Tenure Domain Model.

The development of a flexible standard for the Social Tenure Domain is relevant because it can be used as a basis for data and process modeling for software to be used in customary area's and informal settlement areas, or as guidelines for the development of a paper based system. A flexible standard means that it can be extendable and adaptable to local circumstances and it can support both cadastral and non-cadastral approaches. Non cadastral approaches include a move to land management, e.g. for slum upgrading, to manage conflicts or to allocate land to Internally Displaced Persons (IDPs) and refugees. This means that some level of (non parcel based) object identification has to be supported.

2. RE-USE OF FUNCTIONALITY OF THE CCDM

There is an urgent need to have a land information system that works very differently from the conventional land information system. (Augustinus, 2005)

It is likely that in most countries in the developing world there is less than 30 percent cadastral coverage that actually conforms to the situation on the ground. Instead there vast slum developments of up to 70 percent in some cities, as well as customary and/or rural areas that remain untitled. Given that the cadastral parcel is conventionally the core data set in the land information system to which other attributes are linked, this means that all those areas outside of the cadastre are outside of the land information system, at a micro level. Where there is no or little land information, with the attributes linked to it, this means that there is no or insufficient management of the land etc in these areas (Augustinus, 2005).

As indicated above, we have known that conventional land information systems cannot service non cadastral areas adequately for a long time. A start was made in outlining the problem by (Fourie, van der Molen, Groot, 2002). Further debates followed in the framework of the core cadastral data-modeling (FIG/COST, 2004; Lemmen et al, 2005, Annex to this paper). At this point the issue has not yet been addressed by the writing of software, let alone the experimentation with this software in a pilot project in a country which has slums, customary communities and over lapping and non polygon rights and claims, or in a post conflict society. That is, there is still a long path to walk to get to the point of implementation.

The key issue here is that, in the technical field, there is *often an insufficient focus on pro poor technical and legal tools*. In the development of the CCDM efforts are being made to avoid such criticism; a lot of useful functionality has been developed but the name of the Model, class names and used terminology is still too much aligned to formal systems. For that purpose the Social Tenure Domain Model is being proposed as the next step for research, which could be a specialization of the CCDM based on Domain related terminology. This approach is called the re-use of functionality, which is a normal approach in information systems development.

Land administration results in an extensive set of paper based, or digital, *data* to be maintained. Efficient access to this data is a relevant issue, and there are many examples of paper based administrations which cannot really be accessed. In our opinion Pro-Poor Technical tools need to include both data- and process modeling. Such models are of importance for the development of land management systems, including statutory, customary and informal systems. Standards are useful in designing such models as long as they facilitate extensions and adaptations to the local situation.. Also, cadastre-less approaches should be able to be supported.

As in the CCDM, a Social Tenure Domain Model will serve at least two important goals:

- Avoid reinventing and re-implementing the same functionality over and over again, while at the same time providing an extendable and adaptable basis for efficient and effective cadastral system development, and
- Enable involved parties to communicate, based on the shared ontology implied by the model.

The second goal is important for the creation of standardized information services, which would allow Social Land Tenure semantics to be shared to facilitate translation.

As in the CCDM, important conditions during the design of the Social Tenure Domain Model are: it should cover the common aspects of social tenures, follow the international ISO and OGC standards, and at the same time the model should be as simple as possible in order to be useful in practice.

A main characteristic of land tenure is that it reflects a social relationship between people and land which is recognized as being a valid one (either formal or non-formal). Land management and land administration systems should be designed to take into account the whole variety of such social relationships. Information technology is of strategic importance to be able to deliver systems that can underpin this variety of tenures, meet changing customer demands, reduce land disputes, assist in upgrading informal settlements, and improve agricultural production through better land management.

Standardization is a well-known subject which started with the establishment of cadastral systems. In both paper based systems and computerized systems standards are required to identify objects, relations between objects and persons (also called subjects in some countries) for accessibility and information supply purposes.

The Social Tenure Domain Model would 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. The model can also be implemented for one or more maintenance organizations operating on national, regional or local level. This underlines the relevance of this model; different organizations have their own responsibilities in data maintenance and supply and have to communicate on the basis of standardized processes.

3. SOCIAL TENURE DOMAIN MODEL: A FIRST ANALYSES OF THE REQUIREMENTS RELATED TO RE-USE OF THE CCDM FUNCTIONALITY

Reports of a number of United Nations Expert Group Meetings have been analyzed to provide input for a user requirement analyses. Some of these reports include:

- An Expert Group Meeting held at the United Nations Economic Commission for Africa, Addis Ababa, Ethiopia, 23-26 November 1998 on Integrated Geo-Information (GIS) with emphasis on Cadastre and Land Information Systems (LIS) for decision makers in Africa, (UNCHS, 1998);
- An Expert Group Meeting held at UN-HABITAT, Nairobi, Kenya, 11-12 November 2004 on Secure Land Tenure: New Legal Frameworks and Tools (FIG, 2005);
- An Expert Group Meeting held at the United Nations Conference Center in Bangkok, Thailand, 8-9 December 2005 on Secure Land Tenure: New Legal Frameworks and Tools in Asia and the Pacific (FIG, 2006).

These reports are used to interrogate the CCDM model and to assess to what extent it is useful and or whether and how it needs to be re-formulated to fit better. Specific themes are raised followed by a range of research questions. Is the *functionality* included in the CCDM or not. If not, should it be included, or is it outside the scope – or the system boundary – (see Oosterom, van, et al, in FIG/COST 2004) of the model. The intention is to open the debate on the development of a Social Tenure Domain Model.

3.1 Can Formal and Informal Tenure Systems be Merged in one Environment?

A crucial issue that should be taken into account is that one of the major challenges confronting most countries is the issue of laws and regulations introduced by a colonial administration to serve the interests of the colonial power. Such laws were not designed to serve the needs of the whole country or population. As a result, separate cadastres have often developed, operating as informal systems in parallel to the cadastral system based on the colonial legislation. It is required that formal and informal land tenure systems be merged. An Land Information Management system should include information that covers the whole spectrum of formal, informal and customary. Also, low value land surveyed to lower accuracies should be kept at the local land registry, along with the local high value land surveyed to higher accuracies.

Research Question 1:
Can formal and informal tenure systems be merged in one environment?

3.1.1 Analyses

This requirement is relevant in relation to the implementation of UN-HABITATs 'Continuum of Rights' and seems to fit completely to the goals and functionality of the CCDM; some topological aspects require further attention, see below.

In case of lacking or incomplete spatial (object) information, e.g. in case of informal area's, so called 'non planar regions' with 'spaghetti' boundaries, text and point labels could be used.

It seems that a substantial set of the CCDM functionality, derived from data modeling of the people-land relationship can be re-used for this purpose.

3.2 Can Reversibility from Database to a Paper Based System be Guaranteed?

The use of computer based technology is faced with human resource constraints in both operation and technical support (Lunnay, 2006). The same is valid for modern survey technology. Another restriction is related to costs: computerized systems may be expensive; but it should not be forgotten that paper based systems are not cheap.

A major advantage of computer based approaches is in the possible reconstruction of data in the case of disasters, see for example Winoto (2006).

During an expert group meeting in Bangkok Rajasekhar stated that computer based data must be reversible to paper.

Research Question 2:
Can reversibility from database to a paper based system be guaranteed?

3.2.1 Analyses

The CCDM is not designed for paper based environments, except the inclusion of SourceDocument. It has to be investigated if the LegalDocument, as included in the CCDM, can be re-used as a type of LandRecordCertificate. This means that people can have copies or originals of documents at home. The same applies to Banks, Conveyancers and land administration organizations. In further research it has to be investigated if a re-used class named LandRecordCerticate could support on the production of such certificate.

The core of a Social Tenure Domain Model is expected to be the representation of the people-land relationships; this part of the CCDM could be re-used for that purpose but under alternative terminology. E.g. it has to be investigated if a class 'SocioTenureRelationship' has to be introduced. This could, preferably, be a specialization of the class 'Right' or it could be an alternative way of associating 'Person' and 'ImmovableObject. The class 'Right' in the CCDM suggests a legal basis, SocioTenureRelationships may not have a legal basis in all cases. But the relationship between people ('Persons') and land ('ImmovableObject') exists in the Social Tenure Domain Model in a similar way as in the CCDM. This allows for the introduction of attributes to the SocioTenureRelationship, e.g. a 'share' in this relationship. Further research is required on the re-usability of the so called specializations of 'ImmovableObject'as in use in the CCDM. Note: in UN-HABITATs Continuum of Rights, see below, the word 'Right' is also used, so further research on proper terminology is needed.

Costs of a computerized implementation should be weighted against the costs of inefficiency of paper based systems or complete absence of land information. Costs of dispute management, sensitivity to corruption, lack of transparency, the growing digital gap between the so called developed and less developed world, the impossibility of reconstructing destroyed paper based data in case of disasters, wars, conflicts, etc. are issues to be considered in comparing paper based and a computerized environment. On the other hand it can be stated that contrary to popular belief in many countries, Information and Communication Technology (ICT) is not the only answer to the problems countries are facing. Appropriate ICT investments and capacity building are necessary conditions for sustainable development, alignment and implementation of the institutional, organizational and technical tools of land management. Government at all levels requires information in order to govern. Information on people and on the land where people live and work. Information on the location of administrative boundaries and of objects like buildings, roads. Information on land tenure, which can have long traditions, value and (future) use of the land. This type of core data/information can help governments to determine how they deal with

land in their policies to combat poverty, to achieve sustainable settlement goals and to manage natural resources.

The CCDM is designed for a digital environment, reversibility to paper environment seems complex and expensive but must be analyzed.

The need for both a paper based and computerized version of a Social Tenure Domain Model has to be further investigated; including efficient data acquisition methods.

3.3 In Case Spatial Information is Included in a Social Tenure Domain Model Could Such Information be Represented in both Existing Geodetic Networks and in New Spatial Frameworks?

A spatially referenced framework should be developed which can be understood and used by a wider range of stakeholders and decision makers (Pieri,1997), with visualization being a core component of such a framework for a range of spatial information products and users. At the same time, the framework should not ignore the needs of measurement experts. Such a national overarching framework should accommodate:- high and low value land, people in the capital city and rural areas, skilled professionals and technicians with basic training, raster and vector spatial data from a range of techniques and technologies, GPS (centimeter, sub-meter, uncorrected -hand held), conventional terrestrial approaches – measuring tape, plane table to theodolite), remotely sensed images (satellite and photographic). It should also accommodate graphical (pictorial) data, geometric (measurement based) data and topological (connectivity not absolute position) data (Dale and McLaughlin,1988). In many areas of Africa, like other developing areas of the world, the basic geodetic networks are not good enough resulting in variable accuracies or no data being available. The establishment and use of regional and sub-regional data-bases could be very difficult.

Requirement 3:
In case spatial information is included in a Social Tenure Domain Model could such information be represented in both existing geodetic networks and in new spatial frameworks?

3.3.1 Analyses

Standardization of the spatial reference frame work is a Domain in itself; there is a separate standard in this domain which could be applicable to the Social Tenure Domain Model as it was to the CCDM.

One example from Africa is AFREF which is a planned surveying reference system for all 53 African countries. The principles were presented and adopted by all African nations during the United Nations Economic Commission on Africa UN ECA-CODI meeting held at Addis Ababa, Ethiopia, May 2003. The AFREF initiative is supported by NEPAD, UN ECA-CODI, United Nations Office of Outer Space and the UN Millennium Development Goals for Africa. Early 2006 a meeting is planned in the Republic of South Africa to formulate an

action plan for AFREF. The aim is to set up data holding center in 5 regions covering the whole continent, North, West, Central, East, and Southern Africa. Invitations will be sent to all mapping (related) organizations. An example will be taken to the EUREF system in Europe and the SURDAS system in South America. A good geodetic network forms the basis of GSDI since all other applications are based on it. AFREF will also be very important for civil aviation. The big question is now, "how do we get AFREF up and going and keep it going?" A good cost estimate should be produced and a good spacing of receiving stations will have to be established and the distribution of data should be fast in order to be useful. Some documents in PDF files will become available shortly dealing with a lot of these issues and it is good to check the websites of UN ECA-CODI and the Regional Centre in Nairobi, Kenya at regular intervals. (Sipkes, Lemmen, 2005).

The impact of this development, and similar developments in other regions is that existing co-ordinates in existing frameworks are expected to be transformed to new 'versions' of these co-ordinates in the future. This means that it should be possible to represent one point in two co-ordinate systems or may be even three co-ordinate systems if local co-ordinate systems have to included too. Of course only one co-ordinate pair is the 'actual' one, but a conversion from local to existing national to new national reference system is expected to be a requirement which has to be supported.

A very interesting issue, from research perspective is the accommodation of graphical (pictoral) data. In case any spatial reference is missing those documents can only be accessed using the object identifier.

The CCDM supports already 'SurveyDocuments' as a source document presenting observations from the field and observed connectivity's between points and with points already existing in the spatial database. Co-ordinates of already existing points, not necessary geodetic control points, allow for a adjustment of new co-ordinates to the 'map' or spatial database. It is expected that this CCDM 'SurveyDocument' can be re-used; evt. with a specialization 'PictoralSurveyDocument' and/or 'LocalSurveyDocument'.

The CCDM supports representation of area's topologically well structured data and area's with topologically not well structured data, see the discussion below and the Annex.

3.4 Is it Possible to Link a Social Tenure System Domain Model Containing Spatial Data to Other Systems Containing Spatial Data?

In a phased design, *linking mechanisms* should be possible to set up so that a Social Tenure Domain Model can be coordinated with other systems. Linking systems to other systems has proved to be very problematic in practice.

Requirement 4:
Is it possible to link a Social Tenure System Domain Model containing spatial data to other systems containing other forms of spatial data?

3.4.1 Analyses

Domain related development is in alignment with an important 'new wave' in geo-information standardization: after the domain independent basic geo-information standards (current series of ISO and OGC standards), the new standards based on specific domains will now be developed. This is of importance for development of Spatial Data Infrastructures (SDIs). In this way the linking mechanisms can be provided. The Social Tenure Domain Model as introduced in this paper should be considered as such a specific domain - where a lot of functionality is expected to be re-usable from the CCDM. If research points out that the Social Tenure Domain Model can be a specialization of the CCDM the standardization effort is expected to be far less comprehensive. Given the fact that in the development of the CCDM attention has been given to the inclusion of Social Tenures this seems to be achievable.

Unique object identification is another basis for linking; this requires a clear description of responsibilities between organizations – who is responsible for object identification? Further research is required in the definition of a -wide range- of object identifiers and a wide range of Spatial Units, see the discussion below.

In case no spatial data is collected on an object there will be no basis for linking unless the object is 'spatially identified'.

3.5 What are the Conditions for Implementation of a Social Tenure Domain Model in a Distributed and De-centralized Environment?

Where information exists, it is often spread among several government departments and accessing it is difficult. Most developing countries, and Africa is no exception, need to reduce the excessively high number of institutions involved in land management and information flows. A land management system should serve decision makers at national, regional and local level, with the emphasis on decentralized decision making. Such decentralization should allow *the creation of better vertical coordination between 'bottom up' information and local interest and 'top down' information and policy guidance which can harmonize overall national development policy with local programs.* Also, the fragmentation of information which takes place when different agencies at the central level are responsible for collection and dissemination should be limited, when decentralized systems of data collection are put in place.

It should be possible to map general land tenure and land use information (with no legal status – ownership or zoning) at any central point using remotely sensed images. This is important for economies of scale. At the same time the information could be made available locally, either through the transfer of digital information and/or the distribution of paper maps. While it is possible to create current general land tenure and land use information remotely, it is not possible to do this with cadastral and titling information, as users drive the updating of this information on a parcel by parcel basis. Social Tenure Domain Models need

to be decentralized in order to facilitate local land management and information currency, otherwise they become too expensive and/or fall into disuse.

While local information is not always of the highest accuracy (spatial data) or completeness or correctness (textual), the symmetry and richness of information at local level often largely makes up for deficiencies in relation to accuracy (Government of Namibia,1995). For example, if valuation, registry and tax information is required about the same parcel in the capital city it is very difficult to obtain if the records are in different departments and do **not** have the same parcel numbers. To obtain the same information at the local level becomes relatively simple because many people know (can visualize) the parcel and its owner/occupant (Government of Namibia, 1995). Gathering such information is more cost effective because it forms part of the consultation/negotiation exercise.

By decentralizing, information could be provided by people with fewer skills using lower grade and cheaper technology. This is possible because:

- The graphical (pictorial) nature of the base map, distributed at local level (paper maps or digitally), allows a textual description of features in the field, making it possible to use lower accuracy surveys produced by local surveyors using plane tables, hand held GPS and other methods;
- Surveys will generally be topologically correct relative to each other and to the graphical features;
- Local level information symmetry and knowledge (visualization) makes it possible to check and improve less accurate information.

The work of local surveyors often supplies sufficient security of tenure to local people because these people have local knowledge (visualization over time) and because it is linked into the public witness system.

If the cadastral and land registration information records are decentralized, and land use decisions made in the capital city are not finalized without the consultation of those in occupation of the land, it should not be necessary for the capital city to hold all the cadastral and land registration records. To avoid costs, no record of the low value land should be maintained at national level, and if the authorities wish to alter the rights of any land, local investigations by professionals should be undertaken first. This should mean that the lengthy technical processes, because of the number of steps, will be short circuited for low value land, which should improve the costs of such surveys. Holding the records at the local level should also make land management more efficient and effective; and build local capacity to undertake land management, thereby increasing sustainable land use.

Bogaerts and Zevenbergen (2001) see, in relation to centralized or decentralized cadastral systems, different solutions; but recognize that the discussion is influenced by two technical developments: the database technology and the improvement of telecommunication. It could be too difficult to keep many decentralized databases. With modern telecommunications the

place were the database is stored and kept is less relevant, except in countries with poor telecommunications.

Note: this could imply a (step by step) centralization/concentration of cadastral and land registry data in case database and mobile telecommunications come more and more available combined with an evolution from paper based to computerized systems. Mobile telecommunication will not support broadband in all cases; this has impact on the volume of information packages which can be communicated.

Research question 5:
What are the conditions for implementation of a Social Tenure Domain Model in a distributed and de-centralized environment?

3.5.1 Analyses

The CCDM is designed for implementation in a distributed and de-centralized environment. It is not excluded that also the Social Tenure Domain Model will most likely be implemented as a distributed set of (geo-) information systems, each supporting the data acquisition and data maintenance activities and the information supply of parts of the dataset represented in this model (diagram), thereby using other parts of the model. The model can also be implemented for one or more maintenance organizations operating on national, regional or local level. This underlines the relevance of the model; different organizations can have their own responsibilities in data maintenance and supply and communicate on the basis of standardized processes in so called value adding production chains, including upgrading of accuracy where required and the 'level' of the people-land relationship. Again it is expected that a substantial part of the CCDM can be re-used in the Social Tenure Domain Model.

3.6 How can a Social Tenure Domain Model be Applicable in an Environment with Different Source Data with Different Accuracies?

Surveyors are often reticent about changing existing legal frameworks, or relaxing current registration systems (Williamson, 1997). Yet high standards of accuracy linked to legal accountability issues often make cadastral systems cumbersome and inflexible. This in turn slows down information creation processes (UNCHS, 1998), makes it difficult to form institutional alliances within government in the information field and increases costs. All this directly affects the amount of information available to decision makers, as well as its timing; it should be possible to use information of varying (UNCHS,1990; UNCHS,1997) accuracies within a Social Tenure Domain Model. Varying accuracies should be accepted because:

- Of the cost of generating accurate and comprehensive standardized information (Dale and McLaughlin, 1988; Ezigbalike,1996);
- The approach that precise surveys are needed to prevent possible problems in the future is adding to present day problems, because there is insufficient information for decision making (Dale and McLaughlin, 1988);

- Of the difficulty in harmonizing standards when high accuracy sets the standard against which all other information is assessed (UNCHS, 1990);
- There is a lack of human and financial capacity (Dale and Mclaughlin, 1988; Ezigbalike,1996B);
- There is a possibility of using information produced for other purposes and by non surveyors and/or non professionals to populate the LIS/GIS;
- There is a range of new cheap technologies available, which make it possible to generate lower accuracy information quickly and in quantity;
- Use of lower accuracy surveys produced by local surveyors using measuring tapes, plane tables, hand held GPS and other methods should be possible (combination of data acquisition methods, see Molen, van der and Lemmen, 2005).

In regard to high value land, such as land with mineral rights, cash crops or high rise buildings, professionals should use higher order surveys linked to the geodetic to produce the requisite legal evidence for investors/developers. They should do this in conjunction with an investigation of the local land registry and on site inspections, accompanied by adjudication and negotiation, to be able to create a clear title, defensible in the highest courts of the land (Government of Mozambique, 1998). Note: Global Navigation Satellite Systems (GNSS) are more and more relevant in this context.

Rawlins (2005) describes how: 'In order to spatially identify the original boundaries a simple hand-held GPS was used. Typically, arable plots were defined in terms of how much land could be cleared in a particular season for cropping as well as how much time and resources people had at their disposal to plough the land. The wide variation in the original spatial description meant that the relative inaccuracy of a non-corrected GPS reading would be a sufficient means of survey'.

Rawlins also describes how: 'The sizes of the arable and residential allotments were calculated using a GIS and compared with the other two sources of data. At this stage it was determined that a step was in fact approximately 1 meter as this was a consistent error factor between the reported size of properties and the surveyed size. This was verified with a sample of questionnaire respondents who were asked to demonstrate 10 steps, which was then measured using a tape.'

'The other key importance behind the GPS surveys was that it allowed the community to participate directly in the process. The results were presented back to them for endorsement before being submitted to the Land Claims Commission.'

Requirement 6:
How can a Social Tenure Domain Model be applicable in an environment with different source data with different accuracies.

3.6.1 Analyses

The CCDM includes imported OGC/ISO TC211 (ISO, 1999a,1999b, 2003, 2005) classes for Geometry and Topology. This allows for linking of accuracy attributes, data collection modes (photogrammetry, satellite images, method of field survey (measuring tape, total station, plane table, etc)), source codes (data producer), date of survey (including name of surveyor or observer), date of creation, etc to polygons, lines and/or points. A point can be a geodetic control point. A point can have an identifier. Type of monumentation can be registered (in case a point is monumented in the field). Methods could be developed to provide the impact of points with different accuracy on area calculation, same for adjustments of co-ordinates based on field observations or observations from other sources (images) to existing points in the spatial database. This functionality could be re-used in a Social Tenure Domain Model.

It has to be noted that the accuracy discussion is not only relevant for geometry. For example names have to be correct. Examples from practice teach us that the registration of names of neighbors for each parcel or spatial unit can cause many errors, if a parcel or spatial unit has x neighbors each name is (at least) written x+1 times. Many people do not know the exact spelling of the names of neighbors. Similar statements can be made on approaches in object identifications, these approaches have to work in the field in case of initial data-collection.

3.7 What are the Requirements for the User Interface at Local Level?

For land registration and/or land records to work in Africa the system itself should become more accessible, both in terms of location, cost and user friendliness. The land office should be at the local level and be user-friendly to poor, often uneducated people. Such an approach challenges many existing land registration systems.

Requirement 7:
What are the requirements for the user interface at local level?

3.7.1 Analyses

The user friendly-ness requirement is probably not explicit within the scope of a Social Tenure Domain Model. But a standardized system contributes in itself to user friendly-ness and the avoidance of bureaucracy via a transparent approach. Point of attention in standardization is in the number of attributes to be collected. In principle this number has to be multiplied by the number of subjects, objects and interrelationships. Minimizing the number of attributes supports in quality control. Data have to be reliable, otherwise people will not rely on the usage of data. It is better to have a minimal set of reliable attributes then a comprehensive set of bad quality data. Identifiers are important. A complicating factor is that an identifier could be temporal (for efficient data acquisition).

The local level access has been discussed above.

Access in paper based system is sometimes very time consuming because of a lack of indexes or inaccessible archives.

3.8 How Should a Participatory Approach be Optimally Supported?

The technical processes related to land record production should be based on participatory land use decision making, so that land rights and land use rights are adjudicated and negotiated at the same time. This should facilitate information flows within the land registry/record system and cadastral/spatial information system. Information collected and made available at the local level should be passed on to the national level and vice versa, in an appropriate way. There should be female and local participation in any decision making process in regard to the land and its use, especially during any adjudication and titling exercise.

Research question 8:
How should a participatory approach be optimally supported?

3.8.1 Analyses

The existing CCDM is not in conflict with a participatory approach. It has to be investigated as to whether the inclusion of a class 'local committee' (with decision making power) and a class 'regional committee' is sufficient to support the participatory approach.

3.9 How Could a Social Tenure Domain Model Support in Full and Equal Access to Land?

A land administration or land management system should ensure that men and women have full and equal access to the economic resources of the country. Security of tenure is a condition for all and sustainable human settlements development in an urbanizing world. (UNHCS, 1996). The land administration system should aim to remove all barriers to women's access to resources, including land (UNHCS, 1996, see also FIG, 2001).

Requirement 9:
How could a Social Tenure Domain Model support in full and equal access to land.

3.9.1 Analyses

Shared rights (relationships) are supported; this functionality could be re-used from the CCDM. Methods have to be developed to calculate shares based on legal or otherwise accepted principles. Certificates should be provided to male and female in the case of shared rights.

3.10 Which Types of Spatial Units and Parcel/Spatial Unit Identifiers should be Supported; How to Support Flexible (Changing over Time) Boundaries, Fuzzy Boundaries?

Undocumented customary tenure is the most common form of land holding in rural sub Saharan Africa (UNCHS, 1990; UNCHS, 1991; Bruce, 1985). Undocumented and/or cloudy title tenure, sometimes linked to a parcel but often not, is the most common form of land holding in urban sub Saharan Africa (UNCHS, 1990; UNCHS, 1991). Data bases should accommodate a range of identifiers, geo-referenced parcels, un-referenced parcels, lines and points. Both parcels and non parcels can then be used when information is collected, analyzed or disseminated (Latu, N.D; Davies, 1998; Törhönen and Goodwin, 1998). One of the major problems in the information field has been the integration of different data from different sources, which was captured using different methods, at varying accuracies and resolutions, and stored in different formats, using diverse referencing mechanisms. To overcome this problem, and be able to integrate information from diverse sources within an Land Iinformation Management system, there should firstly be a referencing mechanism which is common to every system. Secondly, a range of identifiers should be used, not just accurately surveyed parcels (Latu, N.D). Conventionally LIS systems have used parcels as identifiers. Parcels have been the basic unit of data collection and the linking mechanism to other information in the data base. This has meant that most information about the land in developing countries could not be utilized in a land management system, as the information is not always parcel/polygon based, let alone cadastral parcel based (see below). A graphical (pictorial) reference framework should also make it possible to use information from a range of sources which could not otherwise be used, through the use of non parcel based identifiers, both when acquiring the information, and as the linking mechanism. The type of identifiers, of varying accuracies and scales, which a land management system should be able to accommodate are:

- Points, geo-codes (sometimes known as dots on plots), lines and polygons (Latu, N.D.; Davies, 1998; Durand Lasserve, 1997; UNCHS, 1990), in vector or raster format;
- Polygons with fuzzy boundaries (Jackson, 1997);
- Text, including lists of names (Ezigbalike and Benwell, 1994) and unique numbers;
- Parcels -poorly surveyed, non geo-referenced (Törhönen and Goodwin:1998:03-4), and geo-referenced;
- Sketch maps (Törhönen and Goodwin:1998), and photographs, in the absence of any better identifier (UNECA Expert Group meeting, 1998).

Aside from the property parcels of privately owned registered land, based on work by Davies (1998), Cowie (N.D.), Latu (N.D.), information in the form of thematic polygons of low accuracy should be created showing the location and approximate boundaries of the informal settlement and the customary areas. Lists of leaders (Ezigbalike and Benwell, 1994) in the informal settlement and/or customary areas should be attached to such thematic polygons for the purposes of identifying stakeholders and decision makers who should be involved in negotiating land use and/or land right changes. It is not possible to use the cadastral parcel as the only identifier.

In these situations a more useful identifier could be a geo-code (and text) against a location (Latu, N.D.), such as an informal site, or house, or part of a house (UNCHS, 1998; Davies, 1998; Durand Lasserve, 1997). A geo-code could also be used to identify existing, but unmapped infrastructure, with the geo-code being used as a crucible against which information can be tagged, while the complete picture is being created Jeyanandan –personal communication). By using a geo-code as an identifier, information on the informal settlement could be acquired in a logical way and organized within an Land Information Management system (Davies, 1998).

A range of indicators, besides a polygon for the administrative units, should be used because:

- Land management decisions are more often taken by socio-territorial units, such as chiefships, clans or extended families, rather than by administrative units (de Wit, N.D.; Fourie, 1994; Törhönen and Goodwin, 1998). Rarely do the boundaries of the administrative units and those of the socio-territorial areas coincide (de Wit, N.D.; Fourie, 1994). Most of the time there is no information on the boundaries of the socio-territorial areas, even at the level of chiefships, as they have generally not been mapped;
- Often the socio-territorial areas overlap each other (Törhönen and Goodwin:1998), for example their might not be agreement about clan boundaries (Fourie,1994).

Boundaries of socio-territorial areas are flexible and can change over time (Fourie, 1994). It should be possible to use a geo-code or point identifier, which should consist of selected points representing an area or feature of interest, as specified by local people. It should also be used as the spatial referencing mechanism (Latu, N.D.). Lists of names of leaders (Ezigbalike and Benwell, 1994) should be attached to the socio-territorial areas to facilitate efficient and more sustainable decision making by local stakeholders. Also, fuzzy boundaries and/or boundaries which are purely illustrative and have no fixed accuracy might well be more useful than definite boundaries (Jackson, 1997).

A data rich source should be used to create such a graphical base map, such as aerial photography or satellite imagery. The use of imagery should be much more cost effective than individual and expensive ground surveys. However, full use should be made of any existing information in the countries (Nino-Fluck and Chodota, N.D.). Data should also be obtained from topographic maps where they exist, and if they do not exist or their quality is poor, from the satellite imagery.

Lemmen, van Oosterom and van der Molen observe, in relation to spatial units, in their paper presented at a workshop on cadastral modeling, held in Bamberg, Germany, December 2004 (FIG/COST, 2004): the spatial unit, forms a basis for registration/recording. 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 the 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'.

The example below from Ethiopia is *quoted* from Abebe Haile (2005): 'In Amhara National Regional State (ANRS), an innovative LA project whose objective was developing 'a way of working' has been piloted. The pilot covered a combined area of about 3500 ha. The project led to developing a doable methodology save the part that dealt with getting a spatial framework (boundary demarcation). In the context of a pilot project, the boundary demarcation exercise involved in the use of total stations along with GPS and this has naturally turned out to be time consuming and costly. Except for this aspect of the exercise, scaling-up and implementing most activities tested during the piloting through out the region is now envisaged. Thus, the final region-wide registration and certification would involve activities in two phases leading to two types of certifications:

Primary Book of Holding-PBH will be issued during the first phase of the land certification process and the time frame of this would the coming few years. This will have no conventionally surveyed spatial framework (boundaries). In this context, parcel boundary demarcation will rely on the use of unconventional (non-geometric) methods like the use of relative location which is a way of referencing some body's plot in relation to the holders of neighboring plots. With this approach, determining the extent of rights would just be a task left for right holders and LA will have no means to record, reestablish, etc boundaries. Hence, its usefulness for boundary dispute resolution, land transfer, etc would be limited. In comparison with conventional methods, this is a low cost and quick approach that would entail considerable savings in money and time. It is thus no wonder that the simple method is attractive to the authorities who had to do something about the land rights stalemate. Nonetheless, the work, even with this approach, would be quite involving and the amount of information to be generated is quite enormous. That is why a census type campaign is to be instituted to accomplish the task.

Secondary Book of Holding-SBH will be issued during the second phase. The time frame here would be a little longer as, if nothing else, the project managers would need time to take stock of first phase activities and also to raise funds needed to finance the most costly surveying and mapping task which, inter alia, is expected to be undertaken at this stage. The SBH is expected to incorporate cadastral maps. Within this framework, the envisaged land information tasks would be carried out at two levels. Thus, the first level will embrace demarcation and measurements of district (woreda), kebele, sub-kebele, communal, and service area boundaries. The second level will involve demarcation of individual parcel boundaries through out the region and as it stands, the plan is to use orthophotos and secure appropriate spatial framework. Looking at the magnitude of the task one would wonder if this could be tantamount to mapping of the inhabited part of Amhara.'

Rawlins, (2005) observes in a case study that key problems were identified in relation to boundary disputes:

- "Pegs missing;
- Cost (of transport);
- (Survey) Standards (with respect to methodology and accuracy);
- Coverage (holes in the parcel-based system);
- Boundary encroachment."

Research question 10:
Which types of spatial units and parcel/spatial unit identifiers should be supported; how to support flexible (changing over time) boundaries, fuzzy boundaries.

3.10.1 Analyses

In the CCDM a range of immovable objects is already supported. This concerns topological well structured area's with planar topology. Non planar partitions are supported with fuzzy boundaries, text labels, overlapping polygons. If boundaries are more accurately observed later in time the old represented boundaries in a CCDM system will not disappear because history is maintained. It is expected that this functionality can be re-used in a Social Tenure Domain Model. However, it has to be investigated if versioning of (parts of) boundaries can be included in the Social Tenure Domain Model, if this is really required and therewith if the available functionality is sufficient. Fuzzy boundaries have to be linked with an attribute. The possibility of using different data sources has been discussed above under accuracy.

A person can be member of a group, a group can be member of a group of groups.
A person (natural, non natural), a group of persons or a group of groups can have a one or more rights or socio-tenure-relationships associated, where each right concerns one or more polygons; polygons can overlap or can be identified with a label. A right or socio-tenure relationship is always in between persons and land. A right can be undocumented, in that case the source document is 'no document'.

Re-use of this functionality for a Social Tenure Domain Model makes sense further analysis is required as to whether this covers all requirements.

A range of parcel identifiers is discussed below under 3.11.

Concerning data acquisition and pegs missing: this could be organized in such a way that point (vertices of boundaries) are re-constructable in the field. Global Navigation Satellite Systems could be supportive in this (see for example the approach by: Gustavson, 2005). The accuracy related to data collection methods comes in here, and this is always a concern of surveyors and not always understood because of related costs.

3.11 Can the Social Tenure Domain Model Accommodate an Overlap Between Different Tenures on the Same Parcel of Land?

Prior to upgrading and/or regularizing an urban informal settlement, information is required about occupation patterns and what exists there legally (UNCHS, 1998; Davies, 1998). Large scale informal settlement development often occurs contiguously over a range of legal land tenure types such as:

- State land. Often the state does not have an inventory of its land. Also, often state land has not been parcelled. Generally the informal settlement boundaries do not coincide with the state land boundaries (Jenkins *et al.*,1986; Fourie, 1994);
- Privately owned land. Again the location of the informal settlement does not always precisely match the cadastral parcels and is likely to cover many properties in one spatially contiguous unit (Jenkins *et al.*, 1986);
- Customary land which is conventionally not parcelled (Okpala,1992; Latu, N.D.);
- A mixture of these (Jenkins *et al.*, 1986; Fourie, 1994).

Research question 11:
Can the Social Tenure Domain Model accommodate an overlap between different tenures on the same parcel of land?

3.11.1 Analyses

This has to be further investigated, it could be of a complex nature from the perspective of re-using functionality of the CCDM if topology comes in. Further it has to be investigated if overlap in non-planar- regions are possible.

3.12 How can Optimal Flexibility in Linking all Types of Attributes and Identifiers be Supported?

Decision makers have to deal with conflicting uses when making decisions, such as for urban land, which is needed for housing, industry, commerce, infrastructure, transport, green spaces; and between water, sanitation and health, between the economy and the environment, between cities and the hinterland. Decision makers also need the information in a combined form, such as the combined needs of all stakeholders, including cultivated and grazing land, water supplies, firewood, building material etc; and the economic, social, legal and institutional framework within which negotiations are taking place and actions being delivered. Finally, decision makers require information over time, so that they can compare such things as rates of change, degradation and different options.

Rawlins (2005) presents an example where juridical attributes (ownership, occupier and boundaries), fiscal attributes (valuation, accounts, payment history, purchase price and rates), service attributes (water, electricity and refuse) and land use attributes (aerial photogrammetry, building plans and zoning) are related to parcels. A unique identifier (the Land Parcel Key) is associated with all information relating to the parcel thus enabling the

Deeds, Survey, Financial, Planning and Engineering systems to communicate with each other. Rawlins observes that the problem with this model is that it does not allow for overlapping parcel information or informal rights; see also above: overlapping spatial units. The issue of overlapping parcels exists within the formal cadastre in the form of Sectional Titles and Leased Portions. Sectional Titles and Leased Portions are located on top of existing erven. To cater for this the Land Parcel Key structure was amended by appending the Sectional Unit or Leased Portion number onto the Land Parcel Key for the underlying erf.

Research question 12:
How can optimal flexibility in linking all types of attributes and identifiers be supported?

3.12.1 Analyses

A Social Tenure Domain Model should support the use of all kind of data types (dates, co-ordinates, photographs, digital fingerprints, a matrix of attributes); it is expected that this will be not a problem from technical perspective. The complexity will be in minimizing the number of attributes.

Geo-coding approaches have to be further investigated in practice; re-constructability in case of use of co-ordinates for this purpose is a point of attention here.

Parcel identification can be related to a hierarchy of administrative units or parcels; methods have to be developed to further support this. E.g.: it should be possible to include temporal identifiers during adjudication in the field. It may be possible that at that moment the relation to administrative area's is unknown. This could mean that a temporal identifier (sequential, related to surveyor or local committee) could be useful. Later a final identifier could be linked.

3.13 How can UN-HABTAT's 'Continuum of Rights' be Modelled?

Lavigne Delville (2005) presents a Typology of Rights with reference to Ostrom and Schlager, Chauveau, Le Roy), including operational and administrative rights

"Operational" Rights
Access: the right to enter a given space
Withdrawal: the right to gather natural products
Cropping: the right to plough, seed, and harvest the product of one's work
Investments: the right to transform the space (trees, terraces, etc.)
Administration Rights
Internal Management: the right to distribute and regulate use of the land
Inclusion/Exclusion: the right to determine who shall hold operational rights
Transmission: the right to determine how and to whom the above rights are transmitted or transferred
Transfer: the right to freely dispose of all the above rights (including via sale)

Lavigne Delville speaks about levels of "co-management" to be identified (that is to say the social groups defining right holders for a given piece of land or resource), and identify the concrete rights the group holds as a group and that its members hold, with the possible restrictions on prerogatives held.

Lavigne Delville gives an example of bundles of rights in a family in south-eastern Côte d'Ivoire with reference to (Colin and Soro, 2004):

Rights Held	**Family Group Council**	**Head of Family Group**	**Right-holder within the Family Group**
Operational Rights			
Right to cultivate an individual plot for annual cropping (but not for tree planting)	–	+	+
Right to cultivate tree crops	–	+	–
Administration Rights			
Right to delegate cultivation rights through a share-cropping arrangement	–	+	+
Right to delegate cultivation rights through renting	–	+	–
Right to lend	–	+	–
Right of allocating plots within the Family Group	–	+	–
Rights to sell	+	–	–
Rights to bequeath	–	–	–

Apart from "customary" rights, Lavigne Delville (2005) speaks about legal rights (titles, use permits, etc.) and hybrid rights (users installed by the state without legal status, customary lands purchased, etc.). Rights can be temporal.

Rakodi (2005) speaks about plots in a public-private partnership serviced plot programme. Further she presents a case where for many newly formed households, especially the relatively poor, the only way of accessing land is through

- *plot sharing*, either from the outset (e.g. by buying half a share and thus half a plot in an informal subdivision in Eldoret) or through the subdivision of a plot by a parent for a child (Eldoret, Kampala, Maseru).
- inheritance, at least until the plots are too small for further subdivision and sharing amongst children, at which point the prospect of being able to inherit a plot will decrease.

Rabé (2006) notes that policy makers and housing rights professionals worldwide are interested in "land sharing" as an instrument of slum improvement and secure tenure provision in urban areas. The technique involves partitioning a piece of land so that it can

accommodate land occupants on one portion of the site, and landowners or commercial development on the other portion, thereby solving a land dispute through compromise instead of through force. The net result of land sharing is that residents of informal settlements obtain the legal right to stay in the city, in new housing and on land they have occupied (often for a long time) instead of being evicted. At the same time, private development can also proceed.

Rurangwa (2005) speaks about 'urban' and 'rural' land with different rights related

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, see above), 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.

We are likely to see an increase in a range or continuum of rights, as well as incremental *upgrading* of these rights over time. Again without appropriate land information systems it will not be possible to undertake this work at scale. UN-HABITAT advocates a continuum of land rights and legal instruments, with land titling being only one of the legal instruments.

Adverse possession, legal protection against forced eviction and use/occupancy rights without certificate are some examples of tenure types in UN-HABITATS land rights continuum that provide a certain degree of security of tenure. For each of these types, however, improvements can still be made. A version under development is presented in Figure 1.

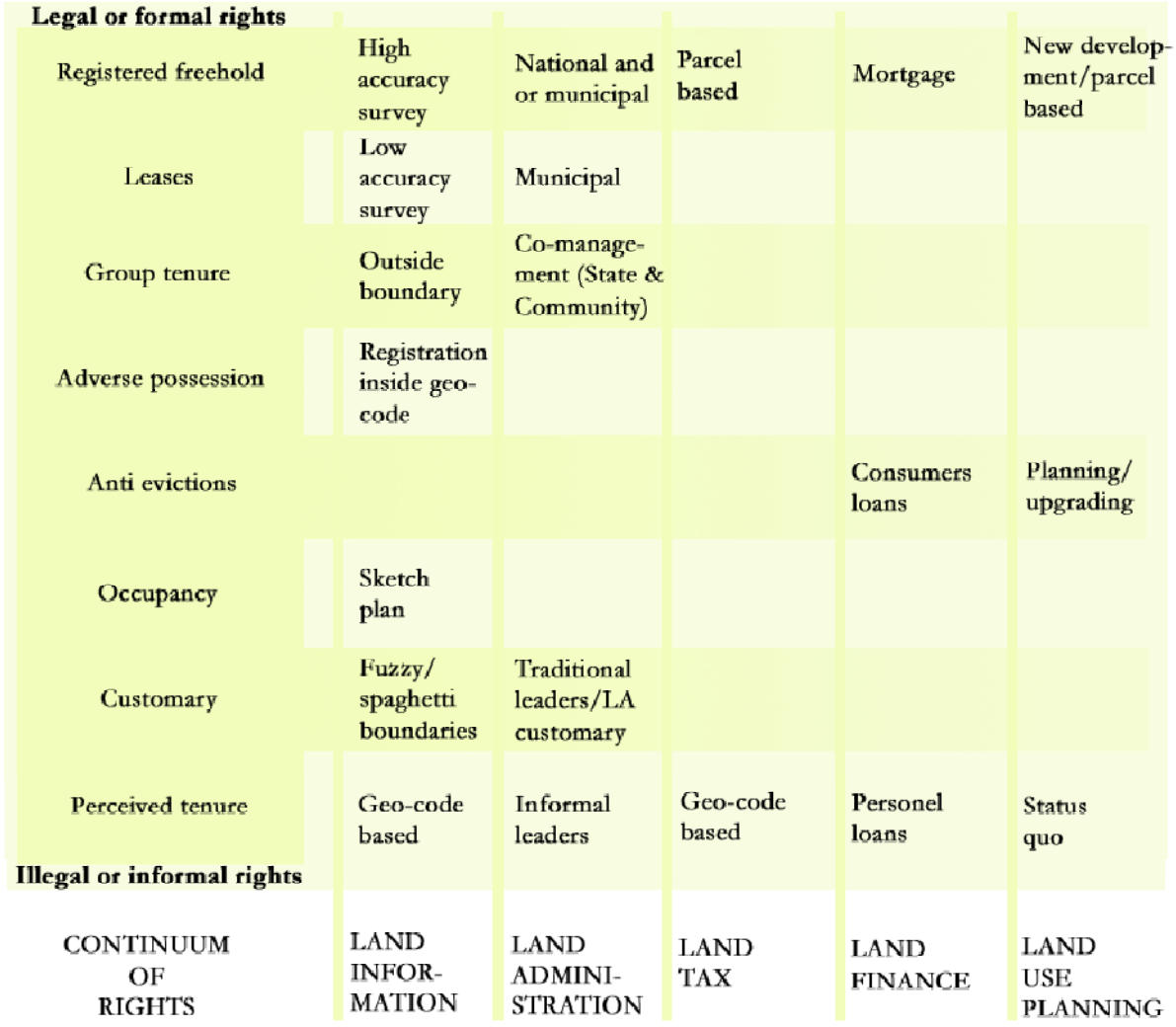

Figure 1: UN-HABITATs Continuum of Rights (under development)

De facto recognition of occupation (e.g. political patronage, proof of payment of utility bills, oral evidence, informally recognized customary rights, perceived secure tenure etc.) form a major part of tenure types found in slums and in informal settlements. The level of security of tenuew that they provide depends on various local circumstance, and whether any other protection against forced evictions are accompanying them. They are the basis from which an incremental approach to tenure improvements can be developed.

Research question 13:
How can UN-HABTAT's 'Continuum of rights' be modeled?

3.13.1 Analyses

The CCDM supports catalogues of rights which have to be 'filled' per country per tenure system. Rights can be temporal in the CCDM. This approach is expected to be re-usable. It is repeated here that in the CCDM:

A person can be member of a group, a group can be member of a group of groups.
A person (natural, non natural), a group of persons or a group of groups can have a one or more rights or socio-tenure-relationships associated, where each right concerns one or more polygons; polygons can overlap or can be identified with a label. A right or socio-tenure relationship is always in between persons and land. A right can be undocument, in that case the source document is 'no document'.

It should be recognized that this CCDM functionality could be very useful functionality for a Socio Tenure Domain Model and that it is expected to be relevant for the Continuum of Rights. A pre-condition is always in the proper (unique) identification of persons, immovable objects and documents describing the socio-tenure relationships/rights.

Operational and administrative rights can be categorized by legal experts. Rights related to families or groups may be difficult to maintain if all individual persons have to be registered; from CCDM perspective this is not an issue.

The Social Tenure Domain Model has to provide functionality that supports inclusion of the Continuum of Rights. This is a main research challenge; land tax and land use may require further attention is this research.

3.14 What are the Spatial Information and Land Record Requirements in Conflict Situations?

Conflict occurs in most regions of the world, and unfortunately there seems to be no end in sight. (Augustinus, 2005). Therefore we need to cater for land administration and other related issues in post conflict societies. Issues in regard to land administration and land information management after disaster and conflict are becoming more prominent and hopefully better researched and structured. UN-HABITAT already has an extensive track record in this area. The agency is a member of the Executive Committee for Humanitarian

Affairs, which is the key committee overseeing the operations of all UN humanitarian agencies. The agency is involved in a range of post-crisis recovery situations relating to land, including Afghanistan, Kosovo, the tsunami areas, Somalia, Rwanda, Occupied Palestinian Territories etc. This is done within the context of its policy on Sustainable Relief and Reconstruction. UN-HABITAT is also starting to play a key role in the monitoring of peace and development accords in particular within the Balkans states. UN-HABITAT is taking the lead in the UN system in developing guidelines on housing, land and property in post crisis situations. This is an enormous task because land is so complex, and land and conflict both have specific national and local characteristics. A specific component deals with post conflict, land administration and gender. Also, UN-HABITAT and the International Federation of Surveyors co-organized a conference in May 2004 on post conflict and land administration.(FIG, 2004).

To be able to operate in a post conflict society technical people need to have more than technical knowledge. (Augustinus, 2004). They also need to be able to undertake strategic action planning in a fluid and politicized environment. Very often land is a critical part of the conflict situation. It is not feasible to use conventional conceptual frameworks based on a hierarchy of land policy, land administration and land tenure to underpin strategic action planning in post-conflict environments and, in fact, to do so might prove both inefficient and biased.

Instead, soft systems thinking should be used for analyzing post conflict societies.

This is because the principles underlying soft systems thinking, when applied to the cadastral field makes it possible to move away from the conventional simplistic, hard interventionist, focused design exercises. Instead, by integrating cadastral and soft systems theory, it is possible to undertake holistic analyses of complex situations, *which include human behaviour and a range of non-static land management systems* – all of which are hard-wired into post-conflict situations.

A number of characteristics found in post-conflict society's show why a conventional hierarchical analysis should not be used. A few of these post-conflict characteristics include:-

- A lack of land policy at the national level, written or unwritten and/or broadly agreed upon by policy makers.
- A land management and land administration system that is largely dysfunctional, either because it has been wholly or partially destroyed and/or because it does not extend to the majority of the population.
- A breakdown in the land management/administration and justice system allows powerful actors to grab public and private land with impunity – these include elites, criminal elements and municipalities.
- A land planning system that has not been updated for decades because of conflict, added together with a great need for land by refugees, Internally Displaced People (IDPs) and returnees. This leads to large scale infringement of the land plan.

- A breakdown in law and order and/or a weakness of the central state in extending its functions to the local level throughout the country.
- Invasion of land by the poor, homeless, Internally Displaced People, returnees, and refugees.
- Overlapping rights and claims over the same parcel or house owing to previous owners returning after the conflict; government's having allocated the house or land to someone else; different groups at different times in the conflict allocating land and housing; and the issue of women's rights, especially widow's rights, being infringed.
- Large scale destruction of buildings which, in turn, leads to the need for rapid re-development of houses often outside of formal processes.

Requirement 14:
What are the spatial information and land record requirements in conflict situations?

3.14.1 Analyses

Post-conflict situations are extremely fluid with a range of new institutions being developed, with a lack of clarity about where land functions are placed in government, with gaps, ambiguities around the law and policy, and large scale opportunistic behaviour. Strategic action planning in this environment means that it is not possible to take a purely technical perspective.

Problems in the cadastral system in unstable situations will not be correctly diagnosed and addressed without using something similar to a soft systems approach.

What is needed is an information system that shows all the *claimants and rights holders*. Such a system would make it possible for the authorities to assess the size of the problem and the best method to deal with the individual conflicts, also because often in these situations individuals claim more than one parcel of land or house. It has been analysed already, during discussions at Delft University that this requirement deserves further attention. Mr. Vladimír Stromček, a PhD Candidate from Slovak Republic observed a similar requirement in relation to land registration in post communist area's. In the CCDM it is a matter of classifying, and categorising types of rights and claims and types of persons. The basic set of people – lands relationships supports this requirement, but further research is needed to include this requirement into the CCDM, also to be re-usable re-usable in the Social Tenure Domain Model.

However this means that the land information system would have to cater for different types of claims and rights, accuracy and legal evidence; this has been discussed already above.

Also the land information system would have to be able to deal with *overlapping rights,* parcels and non parcels, multiple users including ordinary people, and women, many of whom in these situations are illiterate. It would have to do this virtually in real time, as often emergencies arise in post conflict environments that are a matter of life and death. Such a system should be used to find land for the location of Internally Displaced People and

refugees, and it should assist with the allocation of building permits when houses have been destroyed. The allocation of these building permits in most situations cannot be based on land records alone, and other non conventional evidence needs to be used as well. The information on the system also needs to be secure and have integrity, so that it can be trusted by all parties. All this would be a major challenge not only to the systems design, but also to rapid information acquisition and to integrated institutional management. Those issues have been discussed already above and require further research in the context of post conflict area's. In general a lot of functionality is available to support conflict management, it is a matter of redefining terminology of classes and attributes to provide support in land management or land information systems in post conflict area's. It may be so that sresearch results in a Post Conflict Land Domain Model as another specialization of the CCDM.

It can be concluded that requirements on post conflict situations have to be further analysed.

4. CONCLUSION

A first analyses of functionality for a Social Tenure Domain Model is presented in this paper. This analyses learns that it can be expected that substantial part of the FIG Core Cadastral Domain Model can be re-used or specialized into a Socio Tenure Domain Model.

It can be concluded that the CCDM can be used as a starting point for further research on development of the Social Tenure Domain Model, CCDM functionality is re-usable but has to be further reviewed and assessed by experts in Social Tenure.

RECOMMENDATION

A partnership between FIG and UN HABITAT within the frame work of the Global Network of Pro-Poor Land Developers could be the basis for a further analyses and development of the Social Tenure Domain Model. This Network is being facilitated by UN-HABITAT together with partners such as FIG, the World Bank, ITC, the Lincoln Institute, Swedish and Norwegian aid, to be able to identify and solve some of the key blockages to the delivery of security of tenure for the poor. An appropriate pro poor Social Land Tenure Domain Model is considered one of the priority tools.

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BIOGRAPHICAL NOTES

Clarissa Augustinus has a Ph.d in Social Anthropology from Rhodes University (South Africa). After working in the NGO field, in land and informal settlements, she became a senior lecturer in the Department of Land Surveying in the Faculty of Engineering at the University of Natal for 6 years. Her focus was on teaching land tenure and land management/administration, also at post graduate level. She is widely published. She has also done a wide range of consulting for multi-laterals and bi-laterals in the land field in Africa and S.E.Asia. She is currently Chief of the Land and Tenure section, Shelter Branch, Global Division of UN-HABITAT, the city agency.

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Peter van Oosterom obtained a MSc in Technical Computer Science in 1985 from Delft University of Technology, The Netherlands. In 1990 he received a PhD from Leiden University for this thesis "Reactive Data Structures for GIS". From 1985 until 1995 he worked at the TNO-FEL laboratory in The Hague, The Netherlands as a computer scientist. From 1995 until 2000 he was senior information manager at the Netherlands' Kadaster, were he was involved in the renewal of the Cadastral (Geographic) database. Since 2000, he is professor at the Delft University of Technology (OTB) and head of the section 'GIS Technology'. He is guest editor on Cadastral Systems for the International Journal on Computers, Environment and Urban Systems CEUS.

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Annex: The Core Cadastral Domain Model

The CCDM is presented in Unified Modeling Language, UML (Booch, Rumbaugh, Jacobsen, 1999).

The relationship between real estate object (e.g. parcels) and persons (sometimes called 'subjects') via rights is the foundation of every land administration. Besides (informal) rights, there can also be restrictions between the real estate objects and the persons.

A person can be involved in any number of RRRs and an RRR can involve exactly one person. In the model there is no direct relationship between Person and RegisterObject, but only via RRR.

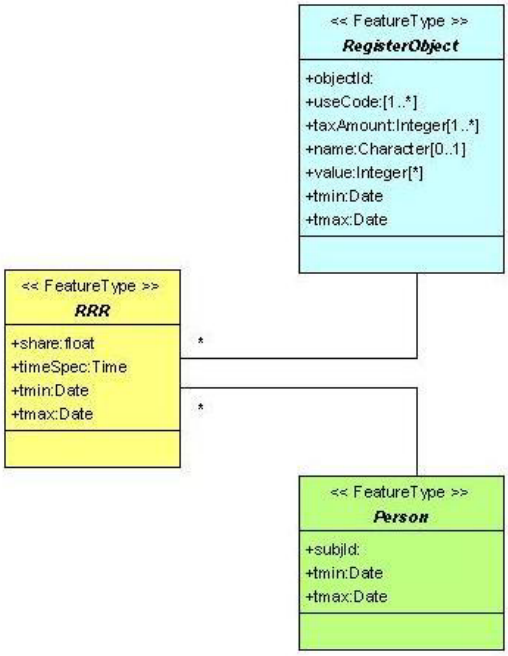

Figure 1: Core of the CCDM: Person, RRR (Right, Restriction, Responsibility) and Registerobject

The CCDM contains both legal/administrative object classes like persons, rights and the geographic description of real estate objects. This means in principle that data could be maintained by different organizations. 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. The model can also be implemented for one or more maintenance organizations operating on national, regional or local level. This underlines the relevance of this model; different organizations have their own responsibilities in data maintenance and supply and have to communicate on the basis of standardized processes in so called value adding production chains.

One should not look at the whole model (all packages together as presented at the end of this section) at once as the colors are representing UML 'packages' or coherent parts of the model:

- Yellow: legal/administrative aspects,
- Green: person aspects,
- Blue: immovable object specializations,
- Pink: surveying aspects and purple:
- Geometric/topological aspects.

The advantages of distinguishing several packages are: being able to present the CCDM in comprehensive parts, maintain and develop packages independently, possibility to use a package to implement one type of functionality. The idea is that basic packages could be implemented by software suppliers, e.g. GIS suppliers.

It should be noted that though this is the core cadastral domain model, it has not the intention to be complete for one specific country. It is very likely that additional attributes, operators, associations and perhaps even complete new classes are needed for a specific country or region.

RegisterObject has a number of specialization classes, in this case two: Immovable and Movable. The Movable objects, such as airplane, ship, train, and car are outside the scope of the model.

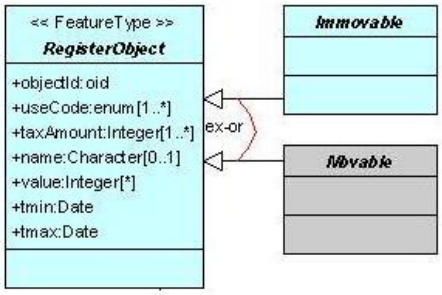

Figure 2: The top level specifications of the RegisterObject: Movable, Immovable

1. SPECIALIZATIONS OF IMMOVABLE

The Immovable objects are further refined into two main categories: land, or in 3D space, objects (the 'parcel' family in 2D and 3D in 'light blue') and the other objects (in 'blue'). The specializations of the Immovable class are represented in the 'light blue' and 'blue' package; see Figures 3 and 4. The different types of land (space) objects include ('light blue', see Figure 3): RegisterParcel, SpaghettiParcel, PointParcel, TextParcel, ParcelComplex, PartOfParcel. These classes can all have actual instances and these instances somehow describe a piece of land (2D) or space (3D). The other immovable register objects (blue) include: Building, Unit, NonGeoRealEstate and OtherRegisterObject. All these

specializations of Immovable have associations with one or more Persons via the RRR class. There are parts, called ServingParcels in the model, which only have direct associations with two or more RegisterParcels. Characteristic is that it serves a number of other RegisterParcels, and that it is held in joint ownership by the owners of those RegisterParcels.

In the UML class diagram RegisterParcel, ServingParcel and NPRegion are specializations of the topologically structured Parcel, which all-together form the partition (subdivision without gaps and overlaps) of the territory where land administration applies. The Parcel-family of classes is shown in Figure 3. A ParcelComplex is an (optional) aggregation of RegisterParcels. A ParcelComplex situation might occur in a system where a set of RegisterParcels -could be in one municipality or even in another administrative unit- has a legal/customary meaning. A RegisterParcel can also be subdivided in two or more PartOfParcels. This case could occur when 'preliminary' RegisterParcels are created during a conveyance where the RegisterParcel will be split and surveying is done afterwards. It could also be helpful to support planning processes, based on cadastral maps, where establishment of RegisterParcels in the field is done later in time. Or in case where a RegisterParcel is determined from aerial or space imagery.

The model also offers the possibility to represent parcels not only based on a topological structure (in 2D or in 3D), that is, a set of cells without overlaps and without gaps, but also in alternative ways. A land (or space) Immovable/RegisterObject could (initially) be represented with a textual description (label), a single point or a spaghetti polygon, which is not adjusted with it neighbors in a topology structure. Spaghetti polygons can overlap each other and can be identified. A land administration 'territory' can be covered by two types of regions:

- Regions based on parcels with a topological structure, and
- Regions not based on parcels with a topological structure.

Together those regions cover the whole territory. The object class Parcel is therefore also specialized into NonPlanarRegion (NPRegion). A NonPlanarRegion is a region without topological structured data. Note that the NPRegion itself does not have any associated Person (or RRR), that is, it is not a RegisterObject. On the other hand, the land objects in Immovable class include the following specializations: TextParcel, PointParcel and SpaghettiParcel. These three 'alternative' non-topology representations of a land object can only exist in NPRegion areas. A parcel may change its presentation over time from TextParcel (e.g. associated to Person or RRR later in time), to PointParcel to SpaghettiParcel to RegisterParcel. However, this does not need to be the case in situation that the TextParcel, PointParcel or SpaghettiParcel fulfils the needs. Perhaps, the text, 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).

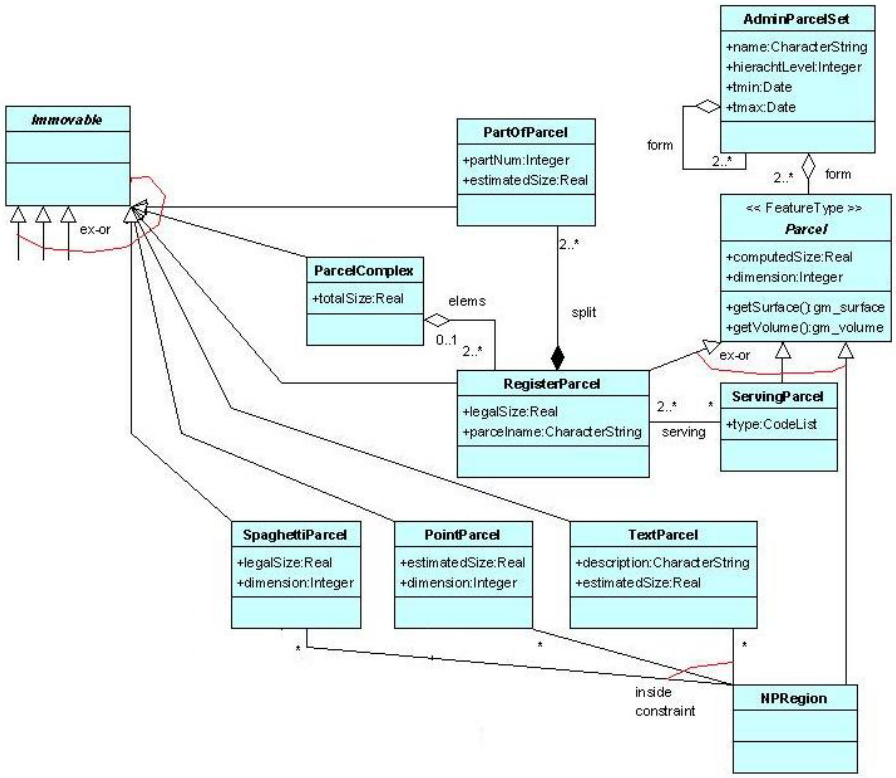

Figure 3: The land (2D) or space (3D) 'Parcel family' package refined ('light blue' part); note that the other specializations of Immovable are depicted in Figure 4 ('blue' part)

As mentioned above, the other immovable register objects, the non-land (or space in 3D) subdivision objects, include: Building, Unit, NonGeoRealEstate and OtherRegisterObject (see Figure 4). In the CCDM there is no explicit association between Building and a parcel as this can be derived from the geometry and topology structures. In case this would not be possible, for example because a TextParcel (without geometry) is involved, an explicit association could be added in that specific country. There are two or more Units in a Building. Note that a Unit is intended in the general sense, not only unit for living purposes, but also for other purposes, e.g. commercial. In other words, all building units with legal/registration significance are included here.

In most cadastral systems a restriction is associated to a complete RegisterObject (RegisterParcel) and this is also reflected in the presented model: a Person can have a Restriction (specialization of RRR) on a RegisterObject. Note that OtherRegisterObjects are modelled as closed polygons in 2D or polyhedrons in 3D and there is no explicit topology between OtherRegisterObjects, that is, they are allowed to overlap. Typical examples of OtherRegisterObjects are: geometry of an easement (such as 'right of way'), protected region (as a consequence of sustainable management of national resources or nature preservation), legal space around a utility object.

The class NonGeoRealEstate can be useful in case where a geometric description of the RegisterObject does not (yet) exist. E.g. in case of a right to fish in a commonly held area (itself depicted as a ServingParcel), where the holder of the fishing right does not (or no longer) hold rights to a land parcel in the area.

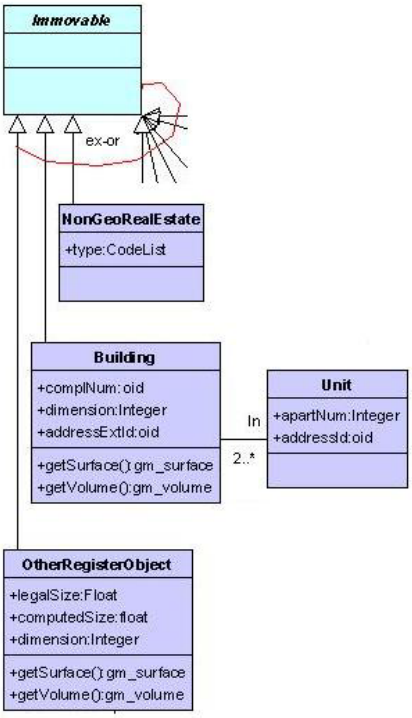

Figure 4: The non-land (space) package refined: Building, Unit, NonGeoRealEstate and OtherRegisterObject ('blue' part); note that the other specializations of Immovable are depicted in Figure 3 ('light blue' part)

2. SURVEYING CLASSES

Object classes related to surveying are presented in pink color; see Figure 5. A cadastral survey is documented on a Survey Document, which is a (legal) source document made up in the field. This document may contain signatures; in a full digital surrounding a field office may be required to support this under the condition that digital signatures have a legal support. Otherwise paper based documents should be considered as an integral part of the cadastral system. Files with terrestrial observations -distances, bearings, and referred geodetic control- on points are attributes of SurveyDocument, the Measurements. The individual SurveyPoints are associated with SurveyDocument. One SurveyDocument can be associated with several SurveyPoints. The SurveyPoints form the metric foundation of both the topology-based objects and the non-topology-based objects.

In case a SurveyPoint is observed at different moments in time there will be different SurveyDocuments. In case a SurveyPoint is observed from different positions during a measurement there is only one association with a SurveyDocument. One of the attributes of a

SurveyPoint is the pointCode, which indicates the type of SurveyPoint; this could for example be a Geodetic Control Point (GCP). If the 'same point' is resurveyed several times and the location does change significantly the there are two options in the model: replace the old SurveyPoint with a new SurveyPoint (with a new id) and all associated classes (Building, but also Parcel node, edge,..) must be updated in order to refer to this new id. An alternative is to make a new version of the old SurveyPoint (keeps same id, but gets different timestamps). The associated classes do not have to be updated, only the SurveyPoint itself: new time stamp, better, better coordinate and association to new SurveyDocument. Pervious locations of a specific SurveyPoint can be found via its id, which remains the same. In general the second option is preferred in case the location of the SurveyPoint is changed as this offers all the functionality with a relative small adjustment in the data set. Further, instead of a resurvey there could also be other reasons for changing coordinates, for example map improvement or switching to a different coordinate reference system (or new calculation of same reference system). Also in this case the second option, new version of SurveyPoint (keep id) is to be preferred.

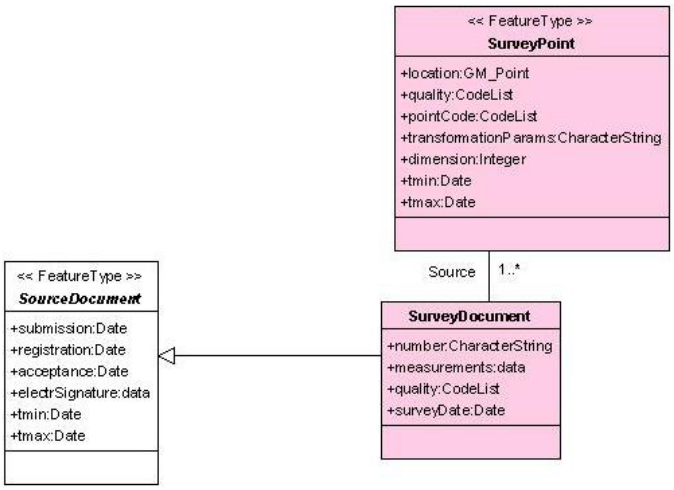

Figure 5: The Survey Package, 'pink'

3. GEOMETRY AND TOPOLOGY: IMPORTED OGC/ISO TC211 CLASSES

Object classes describing the geometry and topology are presented in purple; see Figure 6. The CCDM is based on already accepted and available standards *on geometry and topology* published by ISO and OGC (ISO, 1999a, 1999b, OpenGIS Consortium 1998, 2000a, 2000b, 2000c and 2000d). *Geometry* itself is based on SurveyPoints (mostly after geo referencing, depending on data collection mode: tape, total station, GPS, etc) and is associated with the classes tp_node (topology node), tp_edge (topology edge) and tp_face (topology face, only in 3D case) to describe intermediate 'shapes' points between nodes, metrically based on SurveyPoints.

Parcels have a 2D or 3D geometric description. In 2D a geometry area is defined by at least 3 SurveyPoints, which all have to locate in the same horizontal plane (of the earth surface). In

3D a geometry area is defined by at least 4 non-planar SurveyPoints; this would result in a tetrahedron, the simplest 3D volume object.

Parcels have a 2D or 3D geometric description. The 2D or 3D (ISO/OGC) topology structures are valid at every moment in time. There are never gaps or overlaps in the partition. However, to edges belonging to different time spans (defined by tmin-tmax) may cross without a node. The temporal topology must also be maintained: that is no time gaps or overlaps in the representations. Therefore the structure is based on spatio-temporal topology.

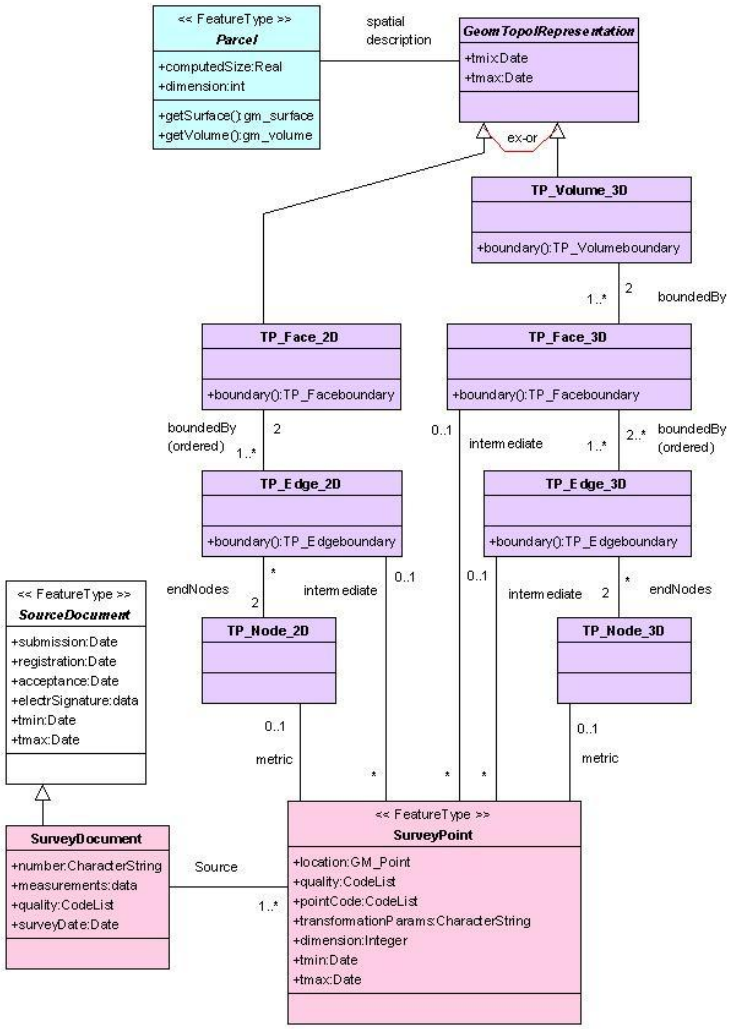

Figure 6: The Geometry, Topology and some related packages, purple

Current cadastral registration systems, based on 2D topological and geometrically described parcels, have shown limitations in providing insight in (the 2D and 3D) location of 3D constructions (e.g. pipelines, tunnels, building complexes) and in the vertical dimension

(depth and height) of rights established for 3D constructions (Stoter and Ploeger , 2002; Stoter and Ploeger, 2003; Stoter, 2004). 2D and 3D are treated in the same manner throughout the model; not only for Parcels but for all types of Immovable's. It is important to realize that there is a difference between the 3D physical object itself and the legal space related to this object. The CCDM only covers the legal space. That is, the space that is relevant for the cadastre (bounding envelope of the object), which is usually larger than the physical extent of the object itself (for example including a safety zone). The registration of the 3D objects themselves (or even 2D or textual presentations) is outside the CCDM, but could be maintained in another registration (building, utility) to which the cadastral registration is linked via the GII.

4. PERSON

'Person' (see Figure 7) has as specialization classes NaturalPerson or NonNaturalPerson like organizations, companies, co-operations and other entities representing social structures. Further there can be a third specialization: GroupPerson. The difference between the NonNaturalPerson and the GroupPerson is that the first is intended to represent instances such as organizations, companies, government institutes (with no explicit relationships to other Persons), while the second is intended to represent communities, cooperation's and other entities representing social structures (with possible explicit relationships to other Persons, optionally including their 'share' in the GroupPerson and associated RightsOrRestrictions to RegisterObjects). 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.

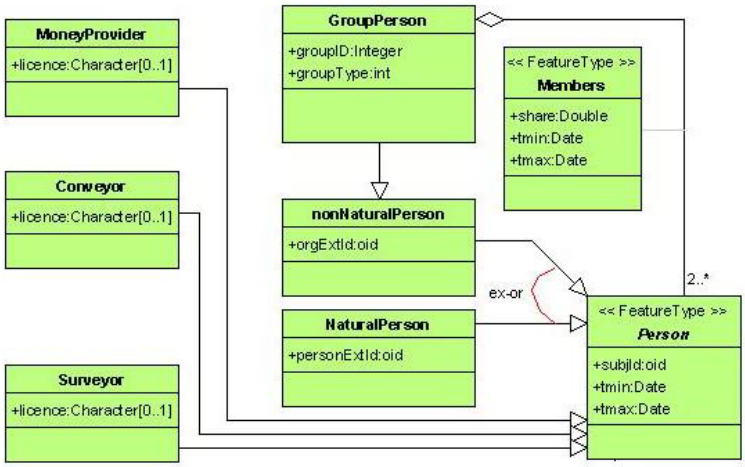

Figure 7: The Person classes ('green' package)

5. LEGAL/ADMINISTRATIVE CLASSES

Object classes presented in yellow cover the refinements in the Legal/Administrative side; see Figure 8. The main class in this package is the abstract class RRR with specializations Rights, Restrictions and Responsibilities. In principle, all RRRs are based on a LegalDocument as source. The essential data of a LegalDocument are can be represented in the classes RRR and Mortgage. A single legal document may even create of mix of these three types. In the other direction, a RRR or Mortgage is always associated with exactly one LegalDocument as its source.

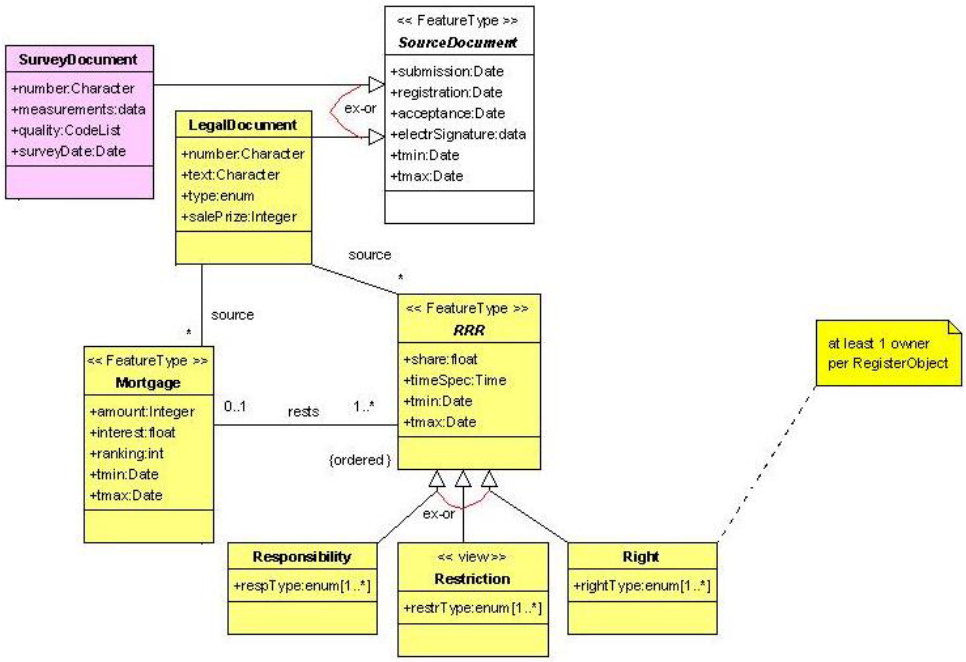

Figure 8: The legal/administrative classes (yellow)

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

The aforementioned rights are primarily in the domain of private law. Usually the rights are created after an agreement between the person getting the right and the person (e.g. the land owner) who restricts his right by the newly created right. The rights and restrictions usually 'run with the land', with means that they remain valid even when the land is transferred after the rights was created (and registered). This is called a right *in rem* in many jurisdictions.

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

In addition to those private law restrictions, many countries also have public law restrictions, which are usually imposed by a (local) government body. The 'holder' of the right is a fake Person (either "the government" or "society-at-large") and usually they are primarily seen as restrictions. Some of them apply to a specific RegisterObject (or right therein) or a small group of them, for example most pre-emption rights, or the duty to pay a certain tax for improvements on the road, or the duty to repair damage or perform belated maintenance.

Each non-ownership Right by a third part (be it government or a private Person) causes a Restriction. These Restrictions have their own place in the CCDM: they are modeled as views. That is, not intended to be stored, but to be derived on demand when needed.

Right (a specialization of the abstract super class RRR) is compulsory association between RegisterObject and Person, where this is not compulsory in case of 'Restriction' and Responsibility (the other specializations of RRR). The class RRR allows for the introduction of 'shares of rights' in case where more than one Person holds a undivided part of a 'complete' Right (or Restriction or Responsibility). Object classes presented in yellow cover the refinements in the Legal/Administrative side; see Figure 8.

The first refinement is the extension of the class RRR (which used to be called RightOrRestrction) to explicitly include Responsibilities as well. In current thinking and literature on cadastral and land administration issues usually the three Rs 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.

The class RRR, used to be presented as an association between Person and RegisterObject. In the current version of the model, this has been replaced by a normal class RRR with associations to both Person (exactly one) and RegisterObject (exactly one) as suggested (Zevenbergen 2004 and Paasch 2004). It is still possible that one RegisterObject is related to several Persons (via RRR associations) and reversibly, that one Person is related to several RegisterObjects (again via RRR associations). There is always at least one instance of Right (subclass of RRR) in which the type of right represents the strongest (or primary) right, for instance customary or statutory ownership, freehold or leasehold. Connected to this strongest right certain interests can be added, or subtracted from this strongest right. A point of discussion is how to represent the subtractions (Restrictions) as they are already implied by a non-primary right of a third party. The fact a neighbor is allowed to walk over your Parcel is an additional Right (appurtenance, positive-side) to the ownership of his property, where it is a Restriction (encumbrance, negative-side) to your property. In the present model both sides are represented, but it is the intention to only store the positive-side and derive (compute) the negative side when needed (compare Zevenbergen 2004).

A mortgage is always vested on a RRR, and should never be seen as a separate relation between Person and RegisterObject. On the other hand a Mortgage is usually vested as collateral for loan. Therefore the mortgagee, is connected to the Mortgage as MoneyProvider; one of the specializations of Person (see Figure 8, but also Figure 10a, 10b and 10c in the Annex). The fact that all the different (public law and private law) RRRs find their base in some kind of establishing or transacting document is represented by connecting them to LegalDocument which is a specialization of the abstract class SourceDocument (as is SurveyDocument). The one responsible for drafting the document is connected to this as Conveyer.

The legal/administrative package as just described is based on the notion of one strongest (primary) right, with other limited rights derived from it. This notion can be found in most continental European countries, but it also fits to the different approach found in the Anglo-American law. That starts from the concept of property rights as 'estates' held in the land. Ownership in this approach is often seen as a 'bundle of sticks'. Separate 'sticks' of the bundle can be acquired in different ways, can be held by different people, for different periods. When a person owns all the rights, he is said to own the fee simple title. When he owns only some of the rights, he has a partial interest. This approach is also used in (Paasch 2004). Further research is needed to ascertain that the CCDM can support land tenure systems based on other legal concepts as well; e.g. as in Arab and/or Islam countries.

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 (van Oosterom et al 2004). Often in such countries or jurisdictions both types of situations (strictly legal and formalized 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.

6. HISTORY AND DYNAMIC ASPECTS

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

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

The temporal aspect is generalized to a TimeSpec attribute. This attribute is capable of handling also other temporal representation such as reoccurring pattern (every week-end, every summer, etc.) Note that nearly every object inherits the TimeSpec attribute via either RegisterObject, RRR or Person. It would have been possible to introduce a new object (TemporalObject with a TimeSpec attribute) from which in turn these three mentioned classes would inherit their temporal attribute (mainly because of legitability this was not done). In addition to the event and state modeling, it is also possible that the 'parent/child' associations between the Immovables (RegisterObject) are modeled (lineage); e.g. when a cadastral parcel is subdivided. However, as these associations can also be derived from a spatio-temporal overlay, it was decided to not further complicate the model with the explicit parent-child relationships. In case of Person and RRR it does not seam useful or meaningful to maintain lineage at all.

Besides the data modeling aspect of the dynamic processes within the CCDM, one could question how are the functions and processes related to each other? The UML class diagram should further be completed by diagrams covering other aspects, e.g. via state (use case, sequence, collaboration, state or activity) diagrams. Figure 9 shows a state diagram of the splitting of a parcel. Activity diagrams show how processes are related to the information (data) and how one 'flows' from on to the other. In all the other mentioned types of UML diagrams, actors or organizations play an important role and this may be quite dependent on the (national) set-up. The introduction of different 'stages' of a parcel (one-point, image, surveyed), a right (start, landhold, freehold) and a person could further reflect the dynamic nature of the system.

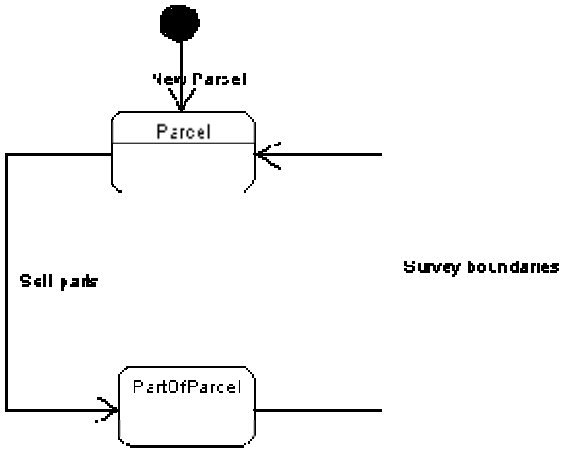

Figure 9: State diagram of splitting a PartionParcel. If a part of a parcel is sold, the parcel is split into several PartOfParcels, which become regular parcels again only when their boundary is surveyed.

The following three figures show the compete CCDM: Figure 10a the legal and person part of the model, Figure 10b the immovable object classes, and Figure 10c the Geometry and Topology classes from ISO TC211.

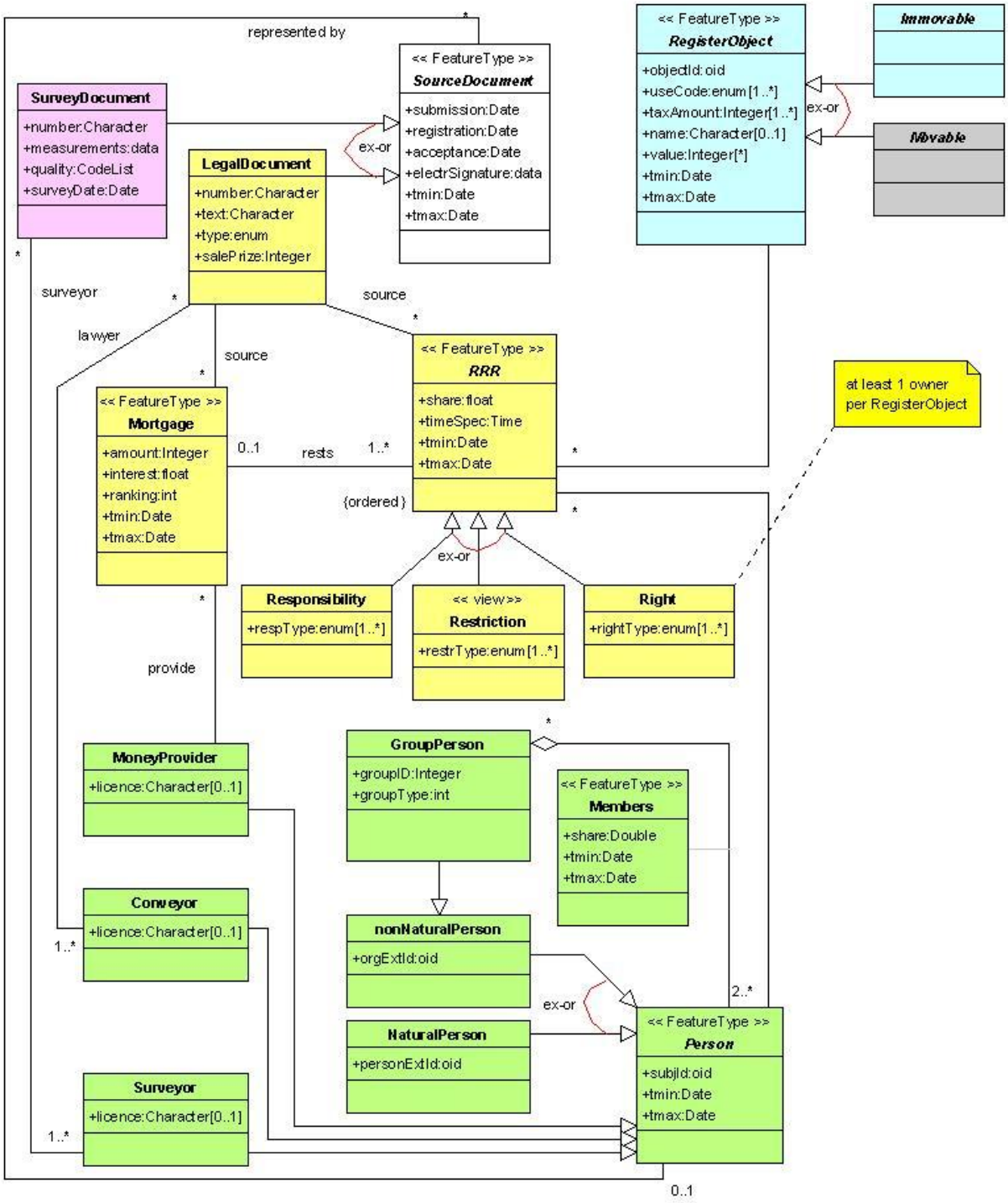

Figure 10a: The legal/administrative and person classes

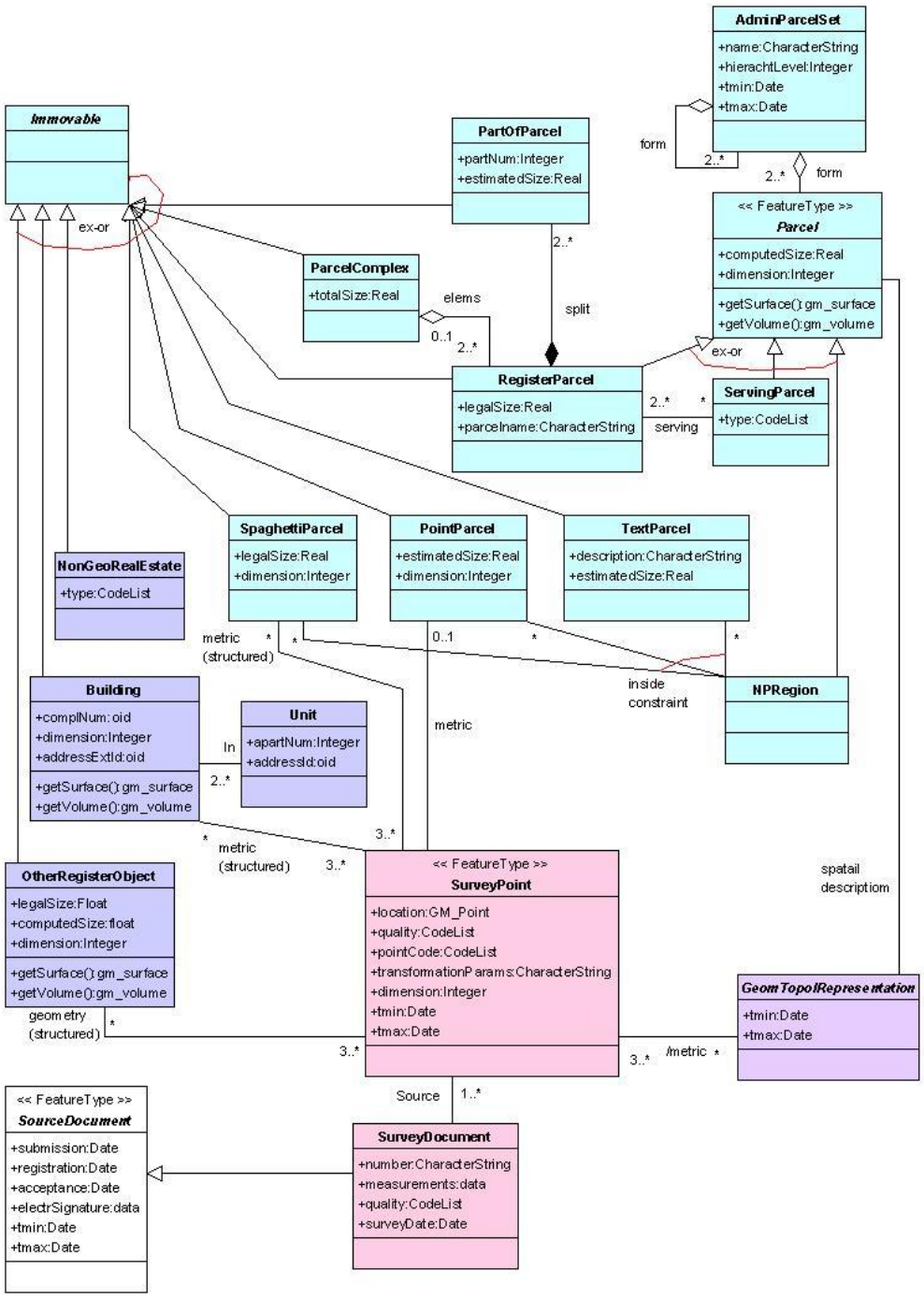

Figure 10b: The different types of Immovable object classes

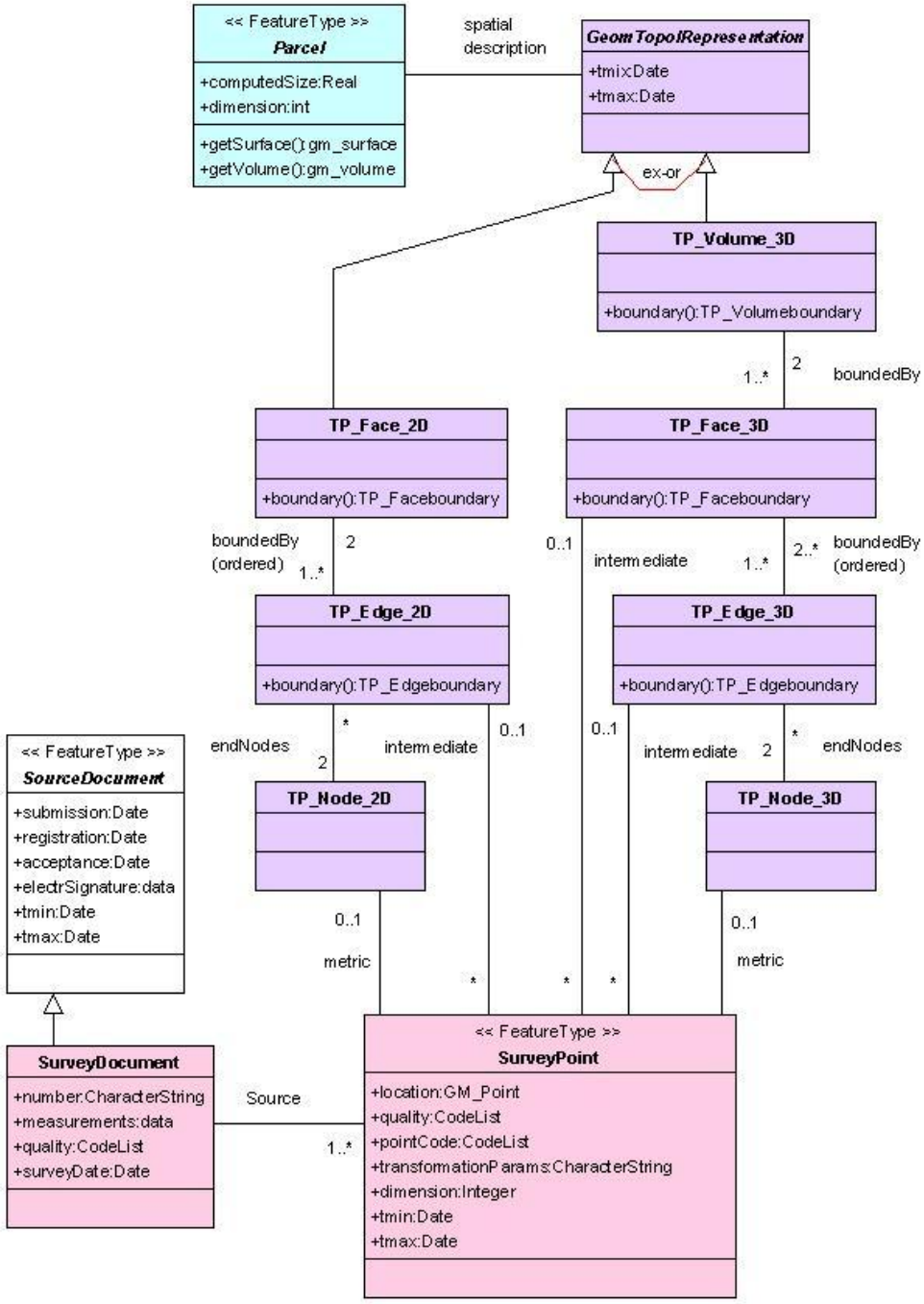

Figure 10c. The Geometry, Topology and some related packages, purple

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