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STANDARDIZATION IN THE CADASTRAL DOMAIN

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Standardization in the Cadastral Domain

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Preface

Peter van OOSTEROM, The Netherlands
(chair of the scientific program commitee)

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

1. GOALS OF THE WORKSHOP

As indicated above standardization of the cadastral domain serves several purposes. In order to develop this, the workshop will try to bring together representatives from different communities and disciplines involved in the cadastral domain: legal specialists, surveyors, ICT-specialists, etc. from different organizations (land registry and cadastral organizations, standardization institutes, industry and academia). An initial model has been developed based on the results of a first workshop (Lemmen et al., 2003) and will be used as a reference for further development. However, the workshop is not limited to this specific model alone and also includes (1) efforts at the national level that do not (directly) aim at an international standard, (2) work that goes beyond the current scope of the core cadastral model and addresses for instance process modelling.

The specific goals for this workshop are to bring together the different communities, publish the results (in this book) and standardize the cadastral domain model, with emphasis on:

1. Further developing the administrative/legal aspects of the model: rights of persons to lands, customary and so called 'informal rights', 3D aspects, legal and survey based source documents;
2. Further formalizing the model (semantics ontology, knowledge engineering);
3. Testing the current model in different countries (evaluation);
4. Involving the geo-ICT industry and standardization institutes (support for implementations of the model).

Of great importance for the implementation of interoperable cadastral and land information data could be the Land Information Initiative of the OpenGeospatial Consortium (OGC), covering among others the translation between LandXML and Geography Markup Language (GML) XML encodings of relevant object classes.

2. FORMAT OF THE WORKSHOP

The workshop will consist of a mixture of presentations and discussion (PD) sessions and sub-workgroup (SWG) sessions on specific themes, according to the following format:

- 9 December 2004, morning: two PD sessions
- 9 December 2004, afternoon: four parallel SWG sessions, and one PD session
- 10 December 2004, morning: one PD session, one block (continued) of parallel SWG sessions
- 10 December 2004, afternoon: one PD session, one closing session (results of SWG sessions)

3. MOTIVATION

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

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

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

Elma Bast is gratefully acknowledged for putting the 'last dots on the i' during the production of the book version of these workshop proceedings.

REFERENCES

Lemmen, C., P. van der Molen, P. van Oosterom, H. Ploeger, W. Quak, J. Stoter, and J. Zevenbergen, (2003). A modular standard for the Cadastral Domain, Digital Earth 2003 - Information Resources for Global Sustainability The 3rd International Symposium on Digital Earth, 21-15 September 2003, Brno, Czech Republic. *(This reference paper is included as last paper in those proceedings).*

COST- the acronym for European **CO**operation in the field of **S**cientific and **T**echnical Research- is the oldest and widest European intergovernmental network for cooperation in research. Established by the Ministerial Conference in November 1971, COST is presently used by the scientific communities of 35 European countries to cooperate in common research projects supported by national funds. The funds provided by COST - less than 1% of the total value of the projects - support the COST cooperation networks (COST Actions) through which, with only around €20 million per year, more than 30.000 European scientists are involved in research having a total value which exceeds €2 billion per year. This is the financial worth of the European added value which COST achieves. A "bottom up approach" (the initiative of launching a COST Action comes from the European scientists themselves), "à la carte participation" (only countries interested in the Action participate), "equality of access" (participation is open also to the scientific communities of countries not belonging to the European Union) and "flexible structure" (easy implementation and light management of the research initiatives) are the main characteristics of COST. As precursor of advanced multidisciplinary research COST has a very important role for the realisation of the European Research Area (ERA) anticipating and complementing the activities of the Framework Programmes, constituting a "bridge" towards the scientific communities of emerging countries, increasing the mobility of researchers across Europe and fostering the establishment of "Networks of Excellence" in many key scientific domains such as: Physics, Chemistry, Telecommunications and Information Science, Nanotechnologies, Meteorology, Environment, Medicine and Health, Forests, Agriculture and Social Sciences. It covers basic and more applied research and also addresses issues of pre-normative nature or of societal importance.

FIG – the International Federation of Surveyors was founded in 1878 in Paris. It is a federation of national associations and is the only international body that represents all surveying disciplines. It is a UN-recognised non-government organisation (NGO) and its aim is to ensure that the disciplines of surveying and all who practise them meet the needs of the markets and communities that they serve. It realises its aim by promoting the practice of the profession and encouraging the development of professional standards.
FIG's activities are governed by a plan of work which is regularly reviewed against a longer-term strategic plan. The current plan of work focuses on the surveyor's response to social, economic, technological and environmental change and the particular needs of countries in economic transition. FIG also recognises that markets for surveyors' services are constantly changing. The plan accordingly lays emphasis on strengthening professional institutions; promoting professional development; and encouraging surveyors to acquire new skills and techniques so that they may be properly equipped to meet the needs of society and the environment.

Comparing European Cadastres
Methodological Questions

Andrew U. FRANK, Austria

1. INTRODUCTION

Every surveyor claims that the cadastre in his country is the best and the most efficient. Erik Stubkjaer suggested a few yeas ago that we should systematically investigate this question. Not only to resolve the "Olympic" international competition but also as an aide to the countries in transition which all have to create methods to organize administration of land ownership in registries and should be informed about efficient and less efficient solutions.
The original goal of the action under the social science program of COST was set somewhat more general and used a broader perspective focusing on the real-estate market that is served by land registration.

> The main objective of the COST action G7 is to improve the transparency of real property markets and to provide a stronger basis for the reduction of costs of real property transactions by preparing a set of models of real property transactions, and then assessing the economic efficiency of these transactions. … For selected European countries a comparative analysis of the economic efficiency of transactions involved in the transfer of property rights will be presented, supplemented by an exploratory analysis of relations between transaction costs and national practices regarding land management, education and governance (Stubkjaer 2001).

The main benefit of the COST action is that governments, professions, and holders of property rights achieve an improved understanding of how to reduce the cost of the transactions for real estates. The developed model serves for drafting new ordinances, for education of professional staff, and to guide scientific research. The outcome of the comparative analysis can point to opportunities for improving the efficiency of the procedures. The provided descriptions of effects of different organization of property transactions can serve as inspiration for other countries to draft regulations, which reduce cost and improve transparency in the real-estate market. This ultimately improves the national economy.
As this COST action comes to a close it is useful to review what was achieved, what can be learned from the COST action both methodologically and substantially for the organization of real estate registration in general. We have achieved the following results:

- The procedures for registration of real state transaction have been systematically described for several countries.
- Cost of transactions can be deduced from their descriptions; it is possible to assess the time necessary for a transaction and compare the differences in registration procedure across different countries.

- A method to describe and compare the procedures used in different countries has been developed. With this schema the procedure in another, new country can be quickly captured and compared with the countries we have analyzed.

This overview paper concentrates on methodological questions and will not report about country details. It argues first why and how transaction cost influence the market and through optimal or non-optimal allocation of resources the common wealth (Smith 1993). In section 3 definitions for the most important terms are given: transaction, procedure, and cost. Then different ways to assess the transaction cost are listed in section 4. The following section discusses how the delay to complete a transaction influences the cost. Section 6 starts the description of procedures, where I describe in section 7 the minimal procedures necessary for protection of ownership rights and then in section 8 other goals associated with the legal procedure for transfer of ownership.

2. INFLUENCE OF TRANSACTION COST ON MARKET VOLUME

Classical national economy assumes that transaction have no cost. However, everyday experience tells that transactions are costly. Everybody has experienced the effort necessary to buy, for example, a new car. One has to obtain information about the cars offered and then to select one, negotiate a price, etc. Similarly, there is an effort by the seller to advertise, to contact prospective buyers, etc. Therefore, there is a substantial difference in the price asked when buying and when selling the exact same car.
Douglass North has introduced the concept of transaction cost in economics and received the Nobel prize in 1993 for this contribution (North 1997). Cost of transactions is important in today's business; the competitiveness of a country in the international market is influenced substantially by the transaction costs in the country and when dealing with businesses in other countries. Hence, the need to compare the transaction cost across Europe.
Transaction cost are not only important per se but have an indirect effect as they influence the market and therewith the optimality of allocation of resources. Following a contribution of Lavrac the change in market volume results in a change in the transaction cost. The diagram shows the market volume which is obtained at a certain difference between the economic value of a piece of land to buyer and seller. The figure shows the amount of transactions which would take place at a low transaction cost *b* and not at a higher transaction cost *a* (Fig. 1).

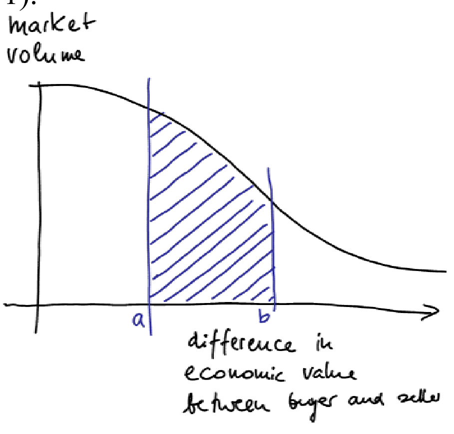

Figure 1: Market volume as a function of transaction costs.

Higher transaction cost result in a smaller market volume: the difference between the value of the utility of the real estate to the current owner and the higher value to a prospective new one must be higher to overcome the cost incurred in the transaction. Allocation of resources is not optimal compared with the allocation when transaction costs are zero and all land is allocated optimally. This is a loss for the economy as a whole.
This viewpoint is not exclusively in monetary terms and includes external cost, primarily social costs. Low transaction cost for real estate may result in too much change in the environment: if new constructions replacing old ones at a rapid pace, faster than what society can adapt too easily, we face equally cost for adaptation.

3. SEMANTICS: WHAT ARE WE TALKING ABOUT?

Clarification of terminology and strict definitions are crucial for all scientific research (Gottman, Murray et al. 2002). In a project investigating real estate, the terminology is the terminology of the national law. What is meant by terms like real estate, ownership, mortgage, etc. is defined in the law (Navratil,). (Navratil 2002; Navratil and Frank 2003). Therefore, comparison across countries is notoriously difficult, because the same term may be used very differently. Clarification of terminology and strict definitions are crucial for all scientific research (Gottman, Murray et al. 2002). In a project investigating real estate, the terminology is the terminology of the national law. What is meant by terms like real estate, ownership, mortgage, etc. is defined in the law (Navratil,). (Navratil 2002; Navratil and Frank 2003). Therefore, comparison across countries is notoriously difficult, because the same term may be used very differently.

3.1 Definition Real Estate and Real Property

> Real property: Land and anything growing on, attached to, or erected on it, excluding anything that may be severed without injury to the land; real property can be either corporeal (soil and buildings) or incorporeal (easements). – Also termed realty; real estate. (entry Property, subentry Real Property (Black 1996))

This definition of a legal term points both to a physical object, which is also a legal object, and to non-physical objects, which is only a legal term.

3.1.1 Factual term: Real Estate

The first part of the definition is a definition of physical land and buildings: the term real estate is prototypically used to describe land parcels, buildings with the land they are sitting on, but also flats when they are separately owned, etc. This definition seems precise enough. It is considered a term describing a physical object in the tiered ontology (Frank 2000).
After the semicolon, the definition expands the applicability of the term real property to other—non-physical—objects related to land, primarily rights, like easements, securities for debt, etc. This identifies the term 'real property' as a social construction (Searle 1995).

3.1.2 Legal term: Real property

The law differentiates between mobile and immobile goods (check with law dictionary) and gives special provision for the transfer of ownerships and other right in immobile objects (for example the Swiss Civil Code (Schoenenberger 1976)). Not every object considered by a layperson as real estate is real property in legal terms and, of course, not everything in the terminology of the law described as real property is seen as real estate by the public (Fig. 2).

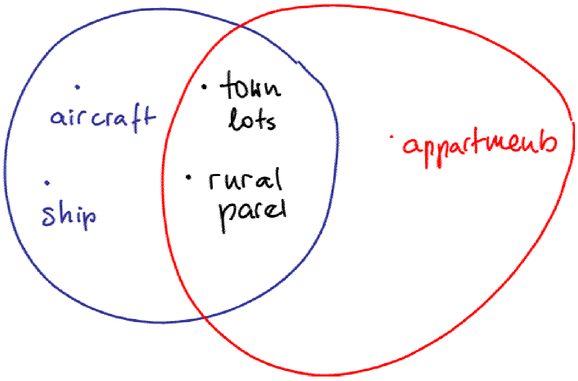

Figure 2: Examples for real property.

The national laws select appropriate words from their language to describe physical objects and legal concepts; these terms do not correspond even between countries, which use the same language. For example, the term *Kataster* is used in Austria to indicate what in Germany is called the *Liegenschaftsbuch*.
The conceptual agreement in European law is based on common roots: the Roman law as collected in the Justinian's Digest. Many national laws originated with the codification of civil law in the time of Napoleon and have evolved since (for example, France, Spain, and South America). Important is the Prussian development of civil and administrative law. Other countries, especially the Nordic countries, Russia but also Muslim countries have separate traditions. This makes it very difficult to find corresponding concepts and to fix translation to a single common terminology. In general, I have tried to use the English language terms in Black's law dictionary (Black 1996) closest in meaning.
Differences are substantial what a national law admits as incorporeal real property. Typically, rights to secure credit (mortgages) and easement (for example a right-of-way) is constructed legally as real property. For the purposes of this study, we admit everything, which can be registered as real property. Countries differ mostly what they exclude: property of apartments in buildings are often constructed as real estate, but not always; sometimes the ownership of land is separated from the property of the building erected on it, etc.

3.2 Ownership

> One who has the right to possess, use, and convey something; a proprietor (entry owner (Black 1996)).

The concept of ownership seems to be both a factual term and a legal term. The law sometimes separates ownership from possession; possession includes only the right to use, but not the right to convey the object to another owner.

3.3 Basic law concepts and prototypical transfer

In order to achieve comparable definitions we had to identify a small number of comparable situations, situations for which comparable definitions are available in all countries. We have used:

1. real estate: a piece of land with everything built on it,
2. transfer of ownership: the full process of selling respectively buying a piece of real estate.

To compare concrete situations we had to select a well-defined, often occurring transfer of ownerships of real estate. The acquisition of a single-family dwelling in a small town recommends itself: it occurs often and in all European countries equally. It is an important transaction in many families' lives, often the most important one in a lifetime.

3.4 Procedure

The transfer of ownerships is a *transaction* and performed following a prescribed *procedure*. Steps in a procedure may be seen as sub-procedures consisting again of steps.

4. ASSESSMENT OF TRANSACTION COST

The assessment of the transaction efficiency is based on the cost of the transaction. This is first a question of the determination of the different cost components and their addition. We found that we had to select a single point of view to determine costs consistently. Unfortunately, different points of view must be taken to answer different questions; definition of costs used in one viewpoint does not translate to costs under another view.

4.1 Definition *cost*

The use of a resource—labor, but also other inputs into a process—are prototypical costs. However, other cost categories must be considered. North separates enforcement and measurement cost. In a recent article Quigley differentiates six different types of costs, which I explain here with examples from selling or buying a parcel:

- Search Cost: the cost to obtain information about available properties and to identify the one to acquire.
- Legal cost: the cost for assistance with the legal aspects of the acquisition; assessing the legal status of the property offered and guidance with the process.
- Administrative cost: cost of administrative procedures.
- Adjustment cost: cost of adapting the current situation to the new situation.
- Financial cost: the cost of the capital required during the transaction; typically, payment for the new property is expected before the previously owned property is sold.
- Uncertainty cost: the cost associated with the risk involved in the transaction.

Our study concentrates on legal and administrative cost but includes some of the other costs. We found that risk is a substantial factor in some countries, especially in the transition countries.

4.2 View points to assess cost

There are at least three viewpoints to assess cost: cost occurs to the parties involved, we can try to collect all the direct costs a transaction produces and there is the viewpoint of the national economy.

4.2.1 Parties involved

The cost of the transaction for buyer and seller should be added, because the split of costs between buyer and seller does only influence the net price for the parties compared to the selling price and is defined by local traditions. The cost of the transaction is not influenced by the division of cost between seller and buyer. (Fig 3).

The total transaction cost is the difference between the total acquisition cost to the buyer and the net proceeds to the seller. This transaction cost definition determines if they enter into a transaction, or not. This cost influences the volume of the market (see fig. 1).
In the direct cost of the transaction to the parties, we have to include the taxes and fees, which must be paid. *Fees* are payments to the administration, which cover the cost to the administration to provide the desired series to the parties. The amount of a fee is set such that the sum of the fees covers the cost of providing the service; generalization when assessing fees are permitted. *Taxes* in contradistinction are payments to the government to cover general expenses of the state and are not related to services rendered.

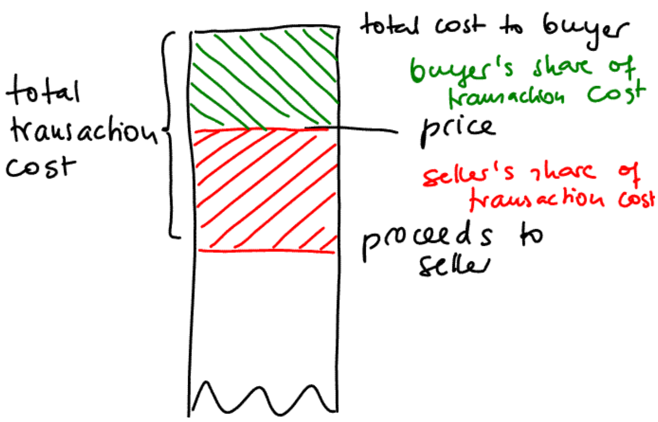

Figure 3: Transaction cost split between buyer and seller.

4.2.2 All Direct Cost

A transaction causes expenditures not only for the parties involved but also for the public administration, which maintains the registries. To estimate these cost is possible but difficult.

From the national budgets one can obtain figures for the total expenses of the parts of administration, which is concerned with land registration procedures. National accounts are not often precise enough and it is sometimes necessary to calculate cost of a service based on the numbers of employees in the different groups multiplied with an average personnel cost. Next, the total number of transactions is obtained and the cost of the service divided by number of transactions. This gives an average cost of one transaction, which is not necessarily the typical transaction we are interested in.
The cost to the parties plus the cost to administration gives the total direct cost associated with the transfer of a real estate property. Care must be taken to avoid double counting of fees paid for service by the administration (included in cost to the parties) and the expenses for the same services contained in the expenses of the administration (fig 4).

4.2.3 <u>National Economy View point</u>

If we want to compare the efficiency of real estate registration systems across countries, we should embrace the viewpoint of the national economy as a whole. This means that we have to exclude taxes from the cost of the transaction because they are a transfer within the national economy and do not affect efficiency over all (see figure 4).

5. TIME USED FOR A TRANSFER

An important element in assessing the efficiency of a method to transfer of ownership in real estate is the time necessary to conclude a transaction.

5.1 Prediction of time necessary to complete a transaction

The method to describe procedures we have selected gives immediately the critical path and its length. The time necessary for operations and the avenge wait time until operations start are separated. This allows the assessment of the total time necessary to complete a transaction and identify delays added by administrative problems like insufficient staff, etc.

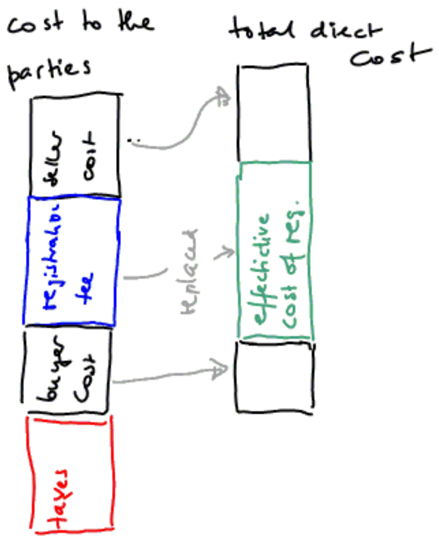

Figure 4: difference between cost to the parties and total direct cost.

5.2 Cost of time

The time necessary to complete a transaction must be translated to cost to make an overall comparison. The delay from deciding on the transaction till it is completed adds cost in two forms. Firstly, during the transaction, capital is fixed. Secondly, during the transaction, the parties are exposed to more risk: fraud, bankruptcy etc is more likely because the guarantees of the registration are not yet available. Hence the longer the delay between deciding on a transaction and its completion, the higher the risk will be.
Delays in completing the transaction must translate at least at the current interest rate to cost of the capital bound during the transaction. The assessment of the risk depends on the country and the current political and administrative situation. The "corruption index" (Research) could be used to obtain some justification but it is not clear how to translate this index in a risk factor and added to the interest rate. It is a general observation that risk is perceived as high in the transition countries and as low in the Nordic countries; this coincides with the figures from the corruption index.

6. DESCRIPTION OF PROCEDURES

To compare procedures we have first to describe them in a comparable format. A procedure to transfer ownerships of a property is like a project. It consists of individual steps that must be carried out one after the other and that are linked in a network of dependencies.
We have therefore used the terminology of project descriptions and used corresponding software to organize the descriptions. The software leads to a subdivision of procedures in tasks and associates with each task the time necessary to complete the task. This allows to determine the critical path and to calculate the minimal time necessary to complete the procedure. For each task, the cost to carry out the procedure in terms of manpower and other related cost can be identified. Additionally taxes to be paid by the parties must be recorded.
With these descriptions, it is possible to compute total cost to the parties or total direct cost for a transaction as defined above. This permits the comparison of cost and time necessary across countries. It is possible to compare the cost or duration of individual tasks or parts of the procedure as well.

7. WHAT CAN BE COMPARED?

The comparison across different European countries for the prototypical case we investigated shows substantial differences in the number of procedural steps, cost, time necessary and taxes to be paid. In this section, we discuss points where the procedures are comparable and the next section lists issues where comparison is difficult if not impossible.

7.1 Separation between the registration of real-estate ownership per se and additional tasks

The process of registration of real-estate ownership per se requires a public registry with a map and some indices to find entries for a given name of owner, buyer or seller, a property, etc. Transfer of ownership or other rights in real estate are recorded chronologically and referred to by the indices. This organization of registration is common in Romance language countries (figure 5). The Germanic tradition countries register in a book for each property the owner, mortgages and other liens, additional indices link names of owners to the properties. Logically the two methods of registration are equivalent: the same information can be retrieved. Practically they differ in resistance to error when entries are not complete, indexes wrong, etc.

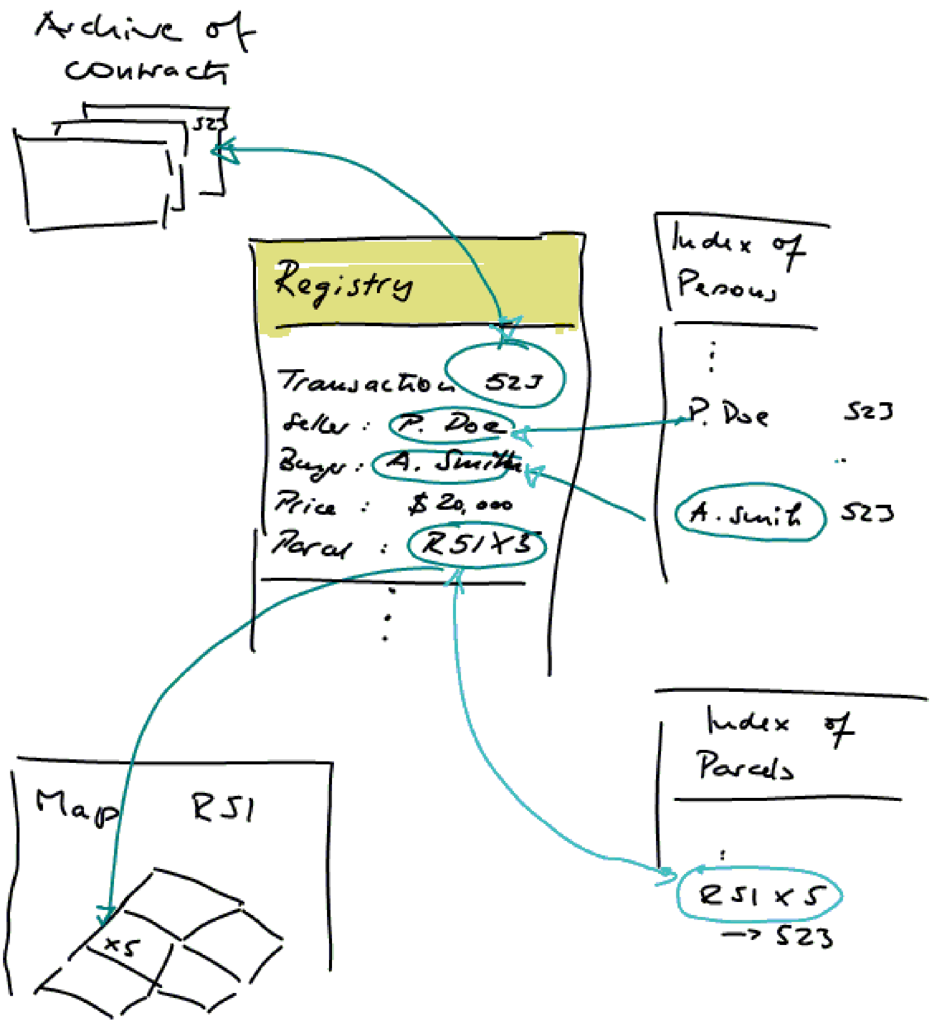

Figure 5: Database Schema for Small Cadastre.

7.2 The small land registry

The comparison across countries shows that the cost of running these minimal functions of a real-estate registry is comparable and the amount of time necessary for registration is similar, if one considers only working time. Substantial differences are reported in the expected (average) wait time until the transfer can be registered—many countries have large backlogs. For example in Slovenia the registry of real estate was neglected during the socialist years and required a restructuring of the institution, with additional staff etc; a special program is now underway to reduce the backlog and the wait times for transactions are reduced. In other transition countries, the situation is similar.

7.3 Small property registration procedure

The minimal procedure for registration of a property transfer consists of the following steps: Parties draw up a contract, which must mention minimally the names of the seller and buyer, the property and include an instruction to register the transfer.
The registry enters the contract in the journal with date and hour of presentation. Later an abstract of the contract is entered in the registry (with date and hour of the journal entry), provided the seller is the current registered owner. The original contract is archived and the name of the new owner and the transfer is entered in the indices.
The cost of this procedure can be computed by adding the cost of the necessary steps. The result for cost and time necessary are very similar across Europe. A comparison with the registration procedure in the USA and the cost of title insurance where required gives similar figures.

7.4 Differences in the registration procedures

Substantial differences are found between the registration processes in different countries. These differences are not related to the goal of securing ownership per se, but should achieve other goals. This will be discussed in detail in the next section.
Differences are also found in the distribution of the tasks between the parties and the public administration, and possibly other professionals. For example, the survey, which is necessary for the subdivision of a land parcel, is in some countries carried out by a private surveyor selected by the owner, in some countries by a private surveyor contracted by the public administration, and in some countries by a public official with surveying expertise. Likewise, the maintenance of the registry itself is often part of the public administration, sometimes part of the judiciary and sometimes contracted to a notary public in private practice (so-called Roman notary system); an extreme case are areas in the USA, where the whole registration process is carried out by a private company, the so-called title insurance companies, which are not really insurance companies that spread the risk of an accident among a larger group, but private registries that 'insure' only property for which the title insurance company has sufficient proof of ownership.
Discuss this earlier in a second prototypical case
Most experts assume that the two functions of a cadastre—for registration of land to achieve a fair taxation—and the function of an ownership registry—to assure secure ownership do not require two separate registries. But only one country reports a single registry that serves both purposes (Schoenenberger 1976); Austria has a single electronic registry, jointly managed by the ministry of justice and the ministry of finance. This computerized database contains what was before two separate registries and is maintained by two different types of registration offices accessing each the part of the database, which is relevant for its operation. This joint database reduced greatly the potential for discrepancies between the two registries and the need for communications between the offices.
Most countries seem to have two or even three different registries, operated by different agencies (e.g., ministry of justice, judiciary, ministry of finance, ministry of housing, ministry of agriculture, etc.). The widespread tradition of a separation between ownership registration

and tax registries is perhaps justified. Ownership registration is part of civil procedures and works under strict, typically constitutional guarantees of ownership rights; procedures can only be initiated by the parties. Tax registration is an administrative procedure, initiated by the tax office. Constructing a tax registry from scratch is a feasible proposition, to establish a property register is very difficult and requires special legislation. Ultimately, the difference between two registries, which register what seems to be the same thing—namely ownership of land—is the result of very small differences in the definition of the terms in different laws (civil law and tax laws).

8. OTHER GOALS ASSOCIATED WITH THE REGISTRATION OF REAL-ESTATE

The comparison revealed an enormous variety and number of other goals the national legislators have linked with the registration procedures. They are primarily and nearly everywhere the goal of collecting a tax, but there is a diverse list of other goals, which will be discussed here:

8.1 Taxation of ownership

One of the original functions of a cadastre is the equitable taxation of land. Land registration is based on a survey map and therefore all land is necessarily included and taxed. The base for taxation is the assessed value, computed from historical assessments. We have heard that Slovenia plans to use modern mass appraisal methods to update their land values for taxation.
Taxation of land value and ownership—specifically when the actual value is taxed at a reasonable rate has most likely positive effects on allocation of land. It becomes more expensive to 'park' wealth in land, e.g., a parcel in town, and not develop it. Land parcels, which have access to all public services but are not used, are at a cost the community for providing services, which are not used. They indirectly produce additional cost to the community because new land must be developed and services extended to quell the demands for land; this makes towns less compact, reduces efficiency of public transportation, etc. An empirical study has shown that the energy consumption of a town is proportional to its area, not proportional to the number of inhabitants!

8.2 Taxation of transfer

Legislators have also found that the time of a sale of land is a good opportunity for taxation: the seller most likely has cash. Therefore, land transfer is also, and separately from ownership, taxed, typically based on the value of the contract.
This tax has several effects: First, the parties are induced to mention in the contract a lower price than what was actually paid. Second, parties are lured to have private (unregistered) contracts—in some South American countries, I have found the practice to use adverse possession as a method to register sales: the parties swear that the necessary period of undisturbed use has been completed. This form of registration of ownership based on undisturbed adverse possession is not taxed, whereas sales are taxed by different authorities and to get the necessary documentation that the taxes are paid is difficult.
Taxation of transfer has negative effects on allocation of land; the difference between new use and current use must be larger to overcome the hurdle of the transaction cost. It has also

negative effects on the reliability of reported sales prices, which in many countries are used to compute average prices for land for national statistics.

8.3 Preemption rights

When a parcel changes ownership it is a perfect time to allow others to preempt the contract and to acquire the property at the same price than the negotiated buyer. This should reduce cheating with underreporting of sales prices (because the preemptor will pay only the reported price).
Preemption rights, to be effective, must give the party, which can use the preemption right, a reasonable amount of time to learn about the contract and to make a decision. This time is added to the time necessary to complete the transfer and increases its cost by increasing the risk.
It makes land transaction much more risky, because the parties are never certain that the transfer will occur as planned. The up-front cost of the buyer to investigate the parcel and to make a decision may be wasted. Preemption rights further require seller (or registry) to inform the potential preemptor about the sale, further adding to the cost.
Are there any preemption rights for another price than the sales price, i.e. making it possible that the seller gets less?
Protection of family farming is often furthered by a provision that neighbors can preempt a sale. Preemption for family members is also often encountered, but preemption rights may also be given to the town.

8.4 Certifications

By certification, we mean all procedures, which introduce other parties—public agencies—which must make some positive statement that the procedure should go forward. For registration of an ownership transfer often some certification is required. Certifications are introduced to further some interests of the state at the time of transfer of ownership. This may be the protection of farming or land use planning, already encountered as a reason for preemption rights. For example Austria requires for a subdivision in agricultural land certification from the ministry of agriculture that the new parcel maintain form and access necessary for productive agriculture. In some Scandinavian countries, a certification of conformance with the planned land use must be issued by the commune. Certification is used in Austria to protect certain classes of sellers to make it more difficult for them to sell their property (e.g., the church).
Certification is always costly and increases the length of the procedure. The cost can be direct when the parties must acquire the certification themselves from a public agency or an authorized agent. The cost can be born by the public, when certification is obtained by the registry as part of its internal procedure; this cost is sometimes passed on to the client as part of the fee.

8.5 Generalization to 'social burdening' the registration process

We can see these different procedures, which are linked to the registration of ownership as 'social burdens', which are linked to the transfer of ownership. They have the same effect as taxes: they reduce the volume of transfers and thus move the economy from an optimal

allocation of the resource land. This in itself may however be socially beneficial, as it reduces social strain connected with change; Portugali has shown in simulations that slow transfer—in his case of changing the family apartments, either by lease or ownership—affects the mixing or separation of different social groups in a city (Benenson and Portugali 1995).
It is tempting for the legislator to burden the transfer of ownership in real estate with various other social goals. It seems difficult to achieve an assessment of the benefits and compare them with the cost: they arise to different masters, at different times. It is a political decision, whether the cost outweighs the advantages. Sceptics may think that the cost is real, but the benefits are not, or not as clearly as imagined by the politicians.

9. CONCLUSIONS

This project was teaching us some important lessons:
First: Good science starts with clear terminology (Gottman, Murray et al. 2002). Scientific investigation in a field where terminology is confused or not comparable across national boundaries is extremely difficult. Social science is often faced with this problem and this project was not an exception.
A major result of the project is the method found to compare non-comparable terminology by identifying physical objects, which are the same across cultural boundaries (or close) and basic social processes (use, full economic control, inheritance, security, etc.), which again are comparable across nation boundaries. We found—the hard way, denying initially the need—that we had to construct a new terminology.
Second: comparison shows that comparable parts of the system of ownership registration and transfer of real estate ownership are similar across nations and the differences in efficiency and cost are bound to disappear. Typically, countries in transition have difficulties with renewing and rebuilding their land registries, educate the necessary personnel and cope with the large number of updates in conjunction with the transition from socialist to market economies at the same time results in backlogs.
Third: legislators are tempted to burden the process of registration of an ownership transfer with various other socially desirable restrictions. Taxes associated with the transfer of ownership are nearly universal but various other goals are furthered by restrictions on the transfer of ownership. They invariably increase the cost of the transaction financially and by slowing down the transfer. These differences as not part of a simple comparison; they are as political decisions not directly related to the goals of securing ownership of real estate. It is, however a worthy goal of scientific research to assess the cost of such burdens and provide information to the legislator who can then decide if the cost is worth the expected benefits.

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Ontology-based Verification of Core Model Conformity in Conceptual Modeling

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Key words: Conformity verification, schema evolution, ontological modeling

SUMMARY

Reference models, often called core models are developed in various application domains. Until now, no computational support exists for the task of verifying the conformity between such core models and their domain models. The approach developed at Bamberg University uses Semantic Web technologies to examine whether or not a domain model is a derivation of a core model. This ontology-based conformity verification supports an iterative modeling process in which core or domain models are modified. Inference services as provided by ontologies can be used to analyze the relationships between core and domain models. For example, it is possible to formally prove which specific relations hold between two types of models and compare the result with the intentions of the domain experts involved in the modeling. As a consequence, knowledge not explicitly represented is revealed. In case that the domain model does not conform to the core model, an interpretation of the inference results is provided in ordinary language giving the domain experts hints on how to modify either the core model, the domain model or both. We evaluated our approach by applying it to the core cadastral model proposed by Lemmen et al. (2003) and a national cadastral model, the Greek model (Tzani, 2003) which both are results of research activities within the European COST Action G9 “Modelling Real Property Transactions”. Although our approach to conformity verification was only evaluated with the cadastral models, it can be used for conformity verification in various applications domains due to its generality.

1. INTRODUCTION

Core conceptual models that act as a reference or standard for modeling activities play an important role in the development and the use of information systems. Such core models facilitate not only the reuse of existing software components during the realization of new systems, but also permit the translation from one conceptual realm into another. Generally, the purpose of a core model is not to provide a standard to which everybody is forced to adhere, but rather to represent general modeling knowledge that can be reused for specific domains. This is to say that domain models will use the core model as a basis, and extend it to their own requirements. National models that conform to a core model like the core cadastral model will not result in a unification of existing legal and administrative but in interoperable cadastral systems which still reflect the particular demands of the different countries. This way of standardization was already successful in other contexts such as Enterprise Resource Planning (ERP). ERP systems establish de facto standards which are flexible enough to be parameterized to the specific demands of each company. ERP systems consider not only the requirements imposed by legislation but also best practices of companies. Such standardization is also conceivable in the cadastral domain. Best practices and common technologies of cadastral systems are discussed in projects like the COST Action G9 “Modelling Real Property Transactions” and could be integrated in cadastral software which is customizable for each country. Core models play a vital role in this context as they reflect the basic ideas implemented in cadastral systems. They support the comparison of processes and structures of the individual national cadastral systems and those offered by the standardized system. Parts to be customized are therefore easily identified. If we can show that national cadastral models conform to a core cadastral model, then the development of cadastral software included its customizable parts is facilitated. Up until now, there is no formal approach for verifying conformity between domain models and the core model. In the following, a formal, ontology-based approach to the verification of core/domain model conformity is presented which is illustrated by applying it to the field of cadastral standardization.

The approach proposed can be applied to two basic cases of use. Firstly, it helps domain experts in modifying the domain model to be a derivation of the core model when the core model is intended as a normative standard. Secondly, the approach supports the inductive development of a core model on the basis of several already existing domain models. In the cadastral domain, we find a mixture of the base cases. The cadastral core model described by Lemmen et al. (2003) was developed on the basis of several national models already available in UML. However, domain models which are models of national cadastral systems are modeled as extension of the core cadastral model. Thus, the verification process should be able to guide domain experts in modifying core and domain models.
The next section compares our approach with current research activities applying Semantic Web technology and inference services to quality improvement in conceptual modeling. Section 3 explains the notion of “conformity” and the steps proposed to verify it. This process is illustrated in the subsequent section 4 with examples of the conformity verification between the core and the Greek cadastral model. The approach is evaluated in section 5. Finally, the conclusion summarizes results and highlights areas for future research.

2. RELATED WORK

The approach presented in this paper is based on ontologies, a technology promoted in the context of the Semantic Web research activities. Knowledge representation and reasoning capabilities provided by ontology modeling languages are used. In conformity verification, relations between core and domain model are formalized in an ontology language and inference services check consistency, compute the type of identified relations, and make implicitly defined knowledge explicit. Inference services also support the conceptual modeling of information systems in other approaches, similar as in conformity verification.

Franconi and Ng (2000) assist with their tool i•com the conceptual modeling of integration information systems such as data warehouses. The modeling of single and multiple schemas for databases with inter-schema constraints are supported. I•com therefore facilitates the integration of different data sources into a data warehouse. The conceptual models are extended Entity-Relationship (EER) models offering a wider range of modeling primitives than standard Entity-Relationship models. For example, is-a hierarchies and additional constraints, such as disjointness, can be expressed. As Literate UML models are used in the conformity verification, it is not the standard models, i.e. ER models or UML models that are used for conceptual modeling, but their extended version in which additional constraints can be encoded. Inconsistencies are not likely to occur without these supplementary modeling primitives. Inference services based on the representation of the conceptual models in an ontology modeling language, such as the Literate UML models in the conformity verification, or a Description Logic, such as the EER models, would not infer "interesting" facts. These results would not help in the i•com tool to improve the design phase of information systems, and in the case of conformity verification, to substantiate the decision on conformity. Although both approaches use inference services, the conceptual models are represented in a different way. The i•com tool transforms the EER models in the Description Logic *SHIQ*. The conformity verification does not use a particular Description Logic, but technology being developed for the Semantic Web, namely the ontology modeling language DAML+OIL (World Wide Web Consortium, 2001).

Berardi et al. (2003) use Description Logic for reasoning on UML class diagrams. The aim is to provide automated reasoning support to make implicit facts explicit and to detect inconsistencies in the models. The UML class diagrams without arbitrary OCL constraints are encoded in the Description Logic *ALCQI* which provides the capability to reason about UML class diagrams. Current Description Logic-based systems implement this Description Logic and may be used as core reasoning engines in the future implementation of sophisticated CASE tools. (Berardi et al. (2003), Berardi (2002))
These CASE tools would be a great help during the modeling of core and domain models. In this work, models serving as input for the conformity verification are not necessarily correct. Inconsistencies and implicit facts are detected during the conformity verification, but it would be sensible to use correct models for the verification process. Such CASE tools offering inference services would be a great help for the initial models, but conformity verification could not be provided because only reasoning about one model is permitted. There is no possibility of identifying corresponding elements in both models and continuing with reasoning.

3. CONFORMITY VERIFICATION

In the cadastral domain, most national administrations have – at least semi-formally – described a cadastral domain model which reflects their legislation and special demands (Lemmen et al., 2003). Our computational approach supports the task of analyzing whether or not heterogeneous domain models are, in spite of all their differences, conform to a core model. In other words, we present a way to formally define and then examine with a software tool – the conceptual conformity checker (CCC) – the conformity between national models and the core cadastral model.
Intuitively, we could say that models conform to a core model if they extend it to a particular domain without altering its essential properties. But how can we check our intuition about the conformity between two models? Formal criteria and a formal verification process are required. Figure 1 shows the complete verification process.

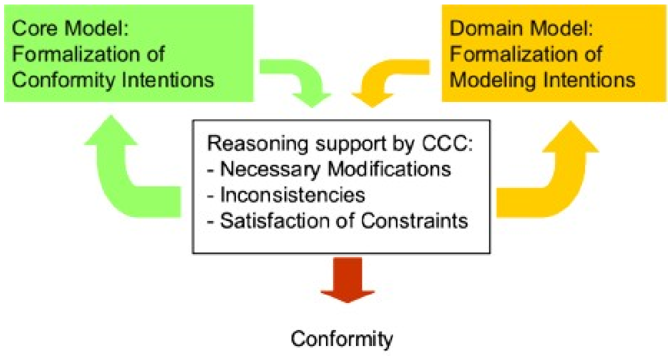

Figure 1: Iterative Process of Conformity Verification.

The formalization of the problem is achieved by two parallel processes. On the one hand, the experts that author the core model specify their intentions about the kind of conformity domain models should satisfy in terms of constraints. These constraints describe which classes of the core model must have a corresponding class in the domain model and constitute a formalization of the *conformity intentions*. On the other hand, domain experts formulate their *modeling intentions*, by stating for classes of the domain model to which classes of the core model they should correspond.
The core model with its conformity intentions and the domain model with its modeling intentions serve as input for the ontology-based conformity verification by the CCC. Both are formalized in an ontology modeling language into which core and domain models are transformed. Identified relations are integrated in one single ontological model consisting of core and domain model. This permits to compute the "similarity" of the classes with identified correspondences by ontological reasoning. A set of queries is sent to a reasoner. Thus, "conformity" means that the resulting relations meet the conformity constraints, or more concretely, that all conformity constraints are satisfied by having classes being as similar to each other as required by the constraints. The individual steps are described in the next chapters in more detail.

Core and domain models are adapted in an iterative process during which conformity is established. Ideally, the core model is already fixed and the interpreted output of the conformity verification is used as basis for changes in the domain model in the next iteration. Modifications in the core model or its conformity constraints are normally more tedious because their impact on other models, already declared as "conforming", must be considered.

3.1 Transformation UML to DAML+OIL

The formal language for expressing both, conformity intentions and modeling intentions is the ontology modeling language DAML+OIL. Since the cadastral core model as well as many national cadastral models have been described using UML or literate UML, there is the need to transform from UML into DAML+OIL. Literate UML is founded on the idea of "Literate Modeling" proposed by Arlow, Emmerich, and Quinn (1999). It means that constraints or further relationships between elements are described in the natural language text in which the UML models are embedded. This technique is also used for the core cadastral model (Lemmen et al., 2003).

The transformation of the Literate UML models into ontology models therefore requires two steps. Firstly, the models themselves are translated into the ontology language. Such a transformation and its rules are proposed by Falkovych et al. (2003). Secondly, the information provided in the text surrounding the models has to be added to the class or attribute definitions in the ontology language.

Figure 2 illustrates the transformation of a part of the UML core cadastral model, serialized in XMI (Object Management Group, 2002) and the Literate UML belonging to it, into an ontology model in DAML+OIL. It becomes clear that ontological modeling provides an enhanced expressiveness compared with UML in the sense that not only the UML models but also the additional textual constraints can be expressed in the ontology model.

UML:
```
<UML:Class xmi.id = 'a15'
      name = 'Person'
      visibility = 'public'
      isSpecification = 'false'
      isRoot = 'false'
      isLeaf = 'false'
      isAbstract  = 'false'
      isActive =  'false'>
   …
   <UML:Attribute xmi.id = 'a373'
      name = 'tmin'
      visibility = 'private'
      isSpecification = 'false'
      ownerScope = 'instance'>
   …
   </UML:Attribute>
   …
</UML:Class>
```

Literate UML:
```
"Each Person is either a
NaturalPerson or a
NonNaturalPerson. No Person can
be a NaturalPerson and a
NonNaturalPerson."
```

DAML+OIL:
```
<daml:Class rdf:about="#Person"
      rdfs:label="Person">
  …
  <daml:Restriction>
    <daml:onProperty>
      <daml:DatatypeProperty
      rdf:about="#Person_tmin"/>
    </daml:onProperty>
    <daml:hasClass rdf:resource=
      "http://www.w3.org/2000/10/
      XMLSchema #date"/>
  </daml:Restriction>

  <daml:disjointUnionOf rdf:parse
      Type="daml:collection">
      <daml:Class rdf:about=
        "#NaturalPerson"/>
      <daml:Class rdf:about=
        "#NonNaturalPerson"/>
  </daml:disjointUnionOf>

</daml:Class>
```

Figure 2 : Transformation UML to DAML+OIL.

3.2 Identification of Correspondences and Update of the Ontology Model

Correspondences between core and domain models are identified by the domain experts responsible for the domain model. As the domain model was designed as extension of the core model, relations between classes and attributes of both models can be identified by domain experts. An important question is as to whether or not the results of the conformity verification give hints for a manual identification of correspondences. Taking into account the effort invested in the modeling of core and domain models, it is justified to use a manual identification guaranteeing to preserve their high quality. A completely automated approach would fail to yield satisfactory results. State-of-the-art solutions to automated matching, like lexical analysis of class names, are not easily applicable to the cadastral models as names are not necessarily provided in the same language and even if they were, they are often quite different due to the historical development of national cadastral systems. Considering the high quality and the small size of the models, it would currently only be sensible to assist the user in identifying correspondences by a semi-automated process suggesting relations, but not to establish an automated matching.

In the following, we propose a workflow for the identification of correspondences and the update of the ontology models with these correspondences. During the stepwise refinement of correspondences in the workflow, it is often not possible to formulate relations directly, but heterogeneity problems must be considered. Heterogeneity problems occur because models reflect the specific requirements of their application domain, in the case of the cadastral models the different legislation and administration of the respective country. They can be divided in two groups (Wache, 2003). On the one hand, *structural heterogeneity* can be observed. That means that semantically equivalent elements are stored in different data structures, e.g. one model uses the attribute *name*, another model has two attributes, namely *first_name* and *last_name*. On the other hand, *semantic heterogeneity* can be found because of the different interpretation of information which is syntactically the same. For example, the attribute *price: double* may describe a price in euros or in dollars. This differentiation cannot be made based on the UML class diagrams. Domain experts should be aware of it and avoid it during modeling. In the course of the workflow description, structural heterogeneity problems are discussed in the steps in which they can occur and how to resolve them.

The workflow follows a set of generic mapping relations that supports the user in identifying correspondences and in dealing with heterogeneities. The set of generic mapping relations consists of relations between elements which can directly be added to the ontology model of core and domain model. A translation for each of the relations into an ontology modeling language is provided. The mapping relations are based on Wache's classification of data schema integration conflicts (Wache, 2003), but they are adapted to the needs of the verification process. Wache's classification aims at a translation of data from one application to another. In contrast to this classification, the conformity verification does not consider the instance-level but only the schema-level. The grouping is based on the different modeling primitives, i.e. classes and attributes and not on the different kinds of heterogeneity problems, as proposed by Wache. Domain experts who identify correspondences are more familiar with the elements they already use for modeling than with possible heterogeneity problems.
In the set of generic mapping relations, we distinguish mapping between:

(a) Classes
(b) Attributes
(c) Classes and attributes

Each of these relations can be bilateral, i.e. 1:1, or multilateral, i.e. 1:n, m:1 or m:n.

The workflow for identifying correspondence between the elements of two models is divided into several steps, each of which will be illustrated in the following by an example from the cadastral domain. It is designed for one pair of corresponding classes (or groups of classes) and must be repeated for every new pair.

<u>1. Domain experts identify semantically equivalent parts in core and domain model:</u>
Conformity between two classes could only be claimed if a class of the domain model contains the same information as a class of the core model, i.e. if they are semantically equivalent.

In our example, we start with the knowledge that a concept describing the owner of land can be found in every cadastral system (Lemmen et al., 2003). In the core model, the *Person-classes* describe the owner of land and in the Greek cadastral model, the *BENEFICIARY-classes*.

2. Refinement of the relation on the class level:

The relation between a pair or group of classes, identified in the previous step, is considered by analyzing its cardinality.

(a) Bilateral relations between classes:

There are two directly corresponding classes in the core and domain model.

(b) Multilateral relations between classes:

One class corresponds to several classes due to a different distribution of the attributes among the set of classes. Before continuing with the next step, this structural heterogeneity problem is resolved. The set of classes is merged into one single class, i.e. the multilateral relation between classes is transferred to bilateral.

(c) Relation between attribute and class:

In some cases, an attribute corresponds to a class. This results from the reification of an attribute to a class. Such discrepancy at the meta-level can be reduced to a bilateral relation between classes and bilateral relations between the attributes of these classes.

Continuing with the example, we concentrate on the relation between the classes *Person* and *BENEFICIARY*, which correspond directly to each other, i.e. there is a bilateral relation between both.

3. Refinement of the relation on the attribute level:

In the third step, the relations between attributes are considered, i.e. semantically equivalent attributes are identified. Only bilaterally corresponding classes need to be considered as all other relations can be reduced to bilateral ones. Attention has to be paid to structural and semantic data heterogeneity between attributes.

(a) Bilateral correspondence between attributes:

Two attributes with the same, or convertible datatype, correspond to each other.

(b) Multilateral correspondence between attributes:

One attribute corresponds with several attributes of a class of the other model. By merging the set of attributes, if the datatypes permit it, bilateral correspondence between attributes can be established and the structural heterogeneity problem are resolved.

In the example, a correspondence can be established between the attribute *SubjID* of the class *Person* and the attribute *BEN_ID* of the class *BENEFICIARY*. The third step will be repeated as long as correspondences between the attributes of the selected classes are found.

The model consisting of the ontological representation of core and domain model is updated with the identified correspondences. Ontology modeling languages offer modeling primitives to express the equivalence between attributes and between classes. Table 1 lists these modeling primitives. The updated merged model serves as input for the computations described in the next chapter.

Relations	DAML+OIL	OWL
Bilateral relation between attributes	samePropertyAs	equivalentProperty
Bilateral relation between classes	sameClassAs	equivalentClass

Table 1 - Ontology Modeling Primitives for the Mapping Relations

In our example, the resulting part of the ontology model would look like in ***Figure 3***.

```
<daml:ObjectProperty rdf:about="core_cad.daml#Person_SubjID"
      rdfs:label="Person_SubjID">
    <daml:domain rdf:resource="core_cad.daml#Person"/>
    <daml:range rdf:resource="core_cad.daml#oid"/>
    <daml:samePropertyAs rdf:resource=
       "Greek_cad.daml#BENEFICIARY_BEN_ID"/>
</daml:ObjectProperty>
```

Figure 3: Updated Ontology Model.

3.3 Inference Services for the Conformity Verification

An identified correspondence between a core and a domain model class does not mean that these two classes are absolutely identical, – divergence is still possible. This difference, called *semantic domain heterogeneity*, arises from the different conceptualizations of objects in information systems (Wache, 2003). The results of the inference services on the models show to the user which classes of the input models are equivalent, which class of the domain model is a specialization of a class of the core model, or whether two classes correspond merely approximately.
The types of these exact and approximate correspondences are computed by a reasoner. Prerequisite for this computation is the identified relations on the attribute-level. In order to establish a correspondence, the user looks at the concrete definition of the attributes, i.e. at the intensional view of the concepts[1]. The reasoner however has an extensional view of the concepts in which a concept is defined as a set of individuals. This is a set-theoretical interpretation as used for defining the semantics of concepts in Description Logics. In other words, a concept denotes the set of all individuals that satisfy the properties specified in the concept definition (Baader et al., 2003).

Two concepts are determined by the reasoner as equivalent if both concepts have exactly the same extensions. Thus, according to the intensional view adopted by domain experts, all attributes of the core model class must have a corresponding attribute in the domain model class and inversely. The left part of Figure 4 shows two UML classes without any generalization classes. Correspondences are identified between the attributes *a1, b1* and *a2*,

[1] In the context of object-oriented modeling, the terms “class” and “attribute” are used. In ontology modeling, the expressions “concept” and “property” are often used as synonyms. “Class” and “attribute” are favored in the context of UML diagrams, “concept” and “property” for ontologies.

b2. The right part illustrates the extensional view. Concept *A* is the set of all individuals which satisfy properties *a1* and *a2*. Concept *B* is, by analogy with *A*, the set of all individuals satisfying properties *b1* and *b2*. Concepts *A* and *B* are determined by a reasoner as equivalent.

Figure 4: Equivalent Concepts.

Subsumption means that one concept is more general than a second. A subclass restricts possible extensions by adding further attributes to the class when compared with its superclass. Figure 5 shows on the left two UML classes, for which correspondence between the attributes *a1* and *b1* is identified. According to the extensional view demonstrated in the right part, concept *A* is the set of all individuals satisfying property *a1*. Concept *B* is the set of all individuals satisfying properties *b1* and *b2*. Due to the correspondence between *a1* and *b1*, all extensions of concept *B* are extensions of class *A*, but not inversely. Class *B* is therefore a specialization of class *A*.

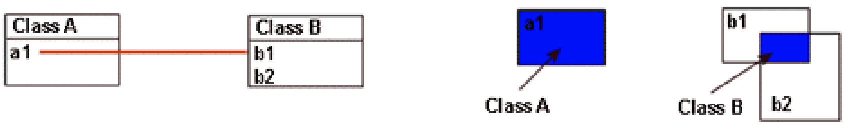

Figure 5: Subsuming Concepts.

Overlapping is the weakest relation between exactly matching concepts. Transforming the first class into the second, there will always be a loss of information but required information is unavailable, too. Overlapping indicates only that there is some relation but that this relation is weak and will pose problems when mapping the models. Overlapping classes are pairs of classes where some, but not all of the extensions of the first class are also extensions of the second class. Inversely, the same applies. This is illustrated by Figure 6.

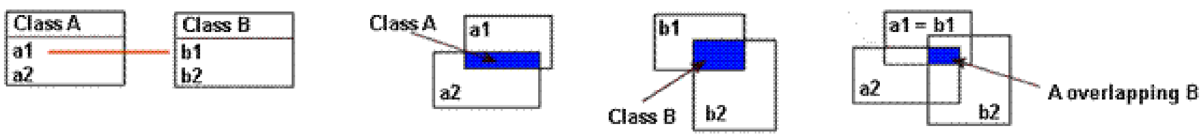

Figure 6 - Overlapping Concepts.

Domain experts can identify a relation between concepts where the reasoner cannot determine a direct correspondence but nevertheless these two concepts are “similar” to each other. Figure 7 shows an example. Approximate mapping could be used, if two concepts do not overlap because of the disjointness of some attributes, such as *a2* and *b2* in the example.

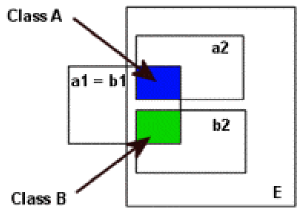

Figure 7: Approximate Matching Concepts.

A reasoner can prove the similarity of two classes in a formal way. The least upper bounds of a concept are determined, i.e. all minimal generalizations of a concept. They are computed by successively generalizing the datatypes of the properties. In the above example, the least upper bounds could be either computed for class *A* or *B*. The range of the properties *a2* or *b2* is generalized. Figure 8 shows the least upper bounds of class *B* which result of the generalization of the range of property *b2*. A reasoner could compare the original class *A* with the least upper bounds of class *B* by sending the standard queries. Having computed the least upper bounds only for one class, the resulting type is specialization.

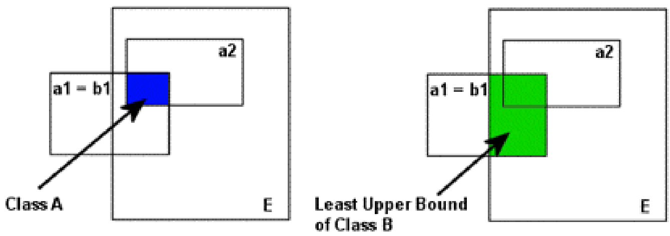

Figure 8: Least Upper Bounds.

Equivalence and subsumption can be directly computed by the reasoner. For example, a query checking the equivalence of two classes is formulated in the syntax of the reasoner RACER[2]: `(concept-equivalent? |file:/C:/CoreModel/CoreCad.daml#Person| |file:/C:/GreekModel/GreekCad.daml#BENEFICIARY|).`
The types overlapping and approximately matching can only be computed indirectly. Helper classes must be generated and used in the reasoner queries. Table 2 gives an overview of required actions and corresponding queries.

Type of Correspondence	**Action**	**Query in RACER-Syntax**
Equivalence	-	concept-equivalent?
Specialization	-	concept-subsumes?
Overlapping	creation of the intersection class	concept-satisfiable?
approximate mapping	computation of the least upper bounds	concept-subsumes?

Table 2: Actions and Reasoner Queries.

[2] http://www.sts.tu-harburg.de/~r.f.moeller/racer/

Note that the type of a correspondence is not necessarily the intended type because classes are embedded in a hierarchical structure. Implicit knowledge is made explicit, i.e. knowledge encoded in the models which might be missed by human readers is determined by the reasoner. Even if in the first iterations, in which the models are perhaps incomplete, only relatively trivial relations can be inferred, information about the inferred knowledge becomes more and more important with the increasing complexity of the relations between the models. In a highly complex model, it is difficult to consider all the side-effects of a newly identified correspondence. Inconsistencies can occur in core or domain models but also across both models because of identified relations. They are detected by using inference mechanisms. Thus, complete knowledge of the effects of the formalized correspondences is available. These results are communicated to the user in the scope of an interpretation and reporting component. All results are edited in ordinary language, for example whether or not a conformity constraint is satisfied. Basic instructions are given in the case that conformity constraints are violated, e.g. which relation has to be strengthened for the subsequent iteration.

4. TEST CASE

A prototype implementing all basic features of the theoretical approach was developed in order to evaluate the approach to conformity verification. It was tested with the core cadastral model and the Greek cadastral model. As both models were described as Literate UML models, they were translated from UML into the DAML+OIL ontology language. DAML+OIL was chosen because its successor OWL (World Wide Web Consortium, 2004) was not yet standardized when this work was started. Textual constraints in the Literate UML models were added to the ontology model of core and domain model. A first set of correspondence was integrated into the ontology model. Figure 9 shows a small part of the relations used for the first iteration. The reasoner RACER analyzed the relations between both models.

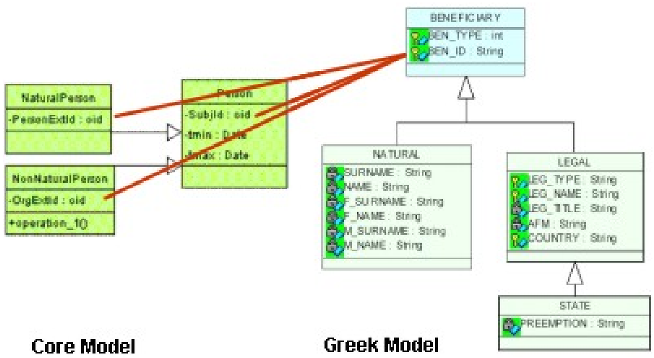

Figure 9: Correspondences for Iteration 1.

In the first iteration, the reasoner could only compute the overlapping type for most identified relations. Thus, conformity constraints of the specialization or equivalence type were not satisfied. On the basis of the results presented in the interpretation component, we strengthened the relations between core and Greek model in order to obtain relations of the specialization or even equivalence type. Exemplarily for all relations, the refinements of the relation between the person-classes are discussed. The following modifications show how such a refinement can be made. The decision whether or not these modifications should be realized is completely up to the Greek domain experts.

(a) If the attribute *Ben_Type* is added to the class *BENEFICIARY* in the Greek model only due to implementation issues, then this attribute could be removed.
(b) In the class *NaturalPerson* of the core model, the attribute *PersonExtID* specifies information related to the Person-Registry of a country. In contrast, the class *NATURAL* of the Greek model lists attributes which can be imported from the Person-Registry. Therefore, the attributes *Name*, *Surname*, *F_Name*, *F_Surname*, *M_Name*, *M_Surname* should be merged to an attribute "*AdditionalID*" corresponding to the attribute *PersonExtID*. The same applies for the class *LEGAL*.
(c) Additionally, we will remove for this second iteration the attributes *t_min* and *t_max*. We do not suggest this in general, but only for this example. It would be better to include a representation of temporal aspects in the Greek model.

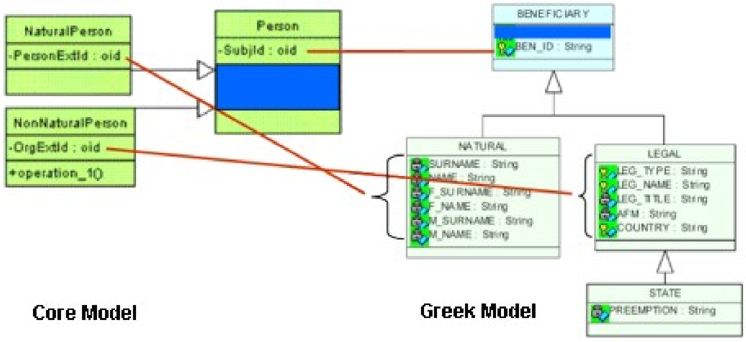

Figure 10: Correspondences for Iteration 2.

Figure 10 illustrates the proposed modifications. If these modifications are used for a second iteration, the following classes will be identified as equivalent by the reasoner: *Person* and *BENEFICIARY*, *NaturalPerson* and *NATURAL*, *NonNaturalPerson* and *LEGAL*.
The results of this second iteration in the conformity verification between core and Greek cadastral model must be reviewed by the Greek domain experts. They can decide whether this updated formalization reflects their modeling intentions in a better way than the correspondences of the first iteration resulting in relations of the overlapping type.

5. EVALUATION

Since the modeling work is still proceeding on both the core and the Greek cadastral model, we cannot expect the reasoner to come up with a result of the type "domain model conforms to the core model". However, an analysis of the reasoner's results can give indications on the modeling steps to take in the next iteration of the modeling process. For instance, a large number of overlapping concepts show that conformity constraints and intended correspondences need to be strengthened.
The experience obtained by the conformity verification between the cadastral models shows that the verification process can provide useful advice for future development of the models. The computations made by the reasoner seem to be a good basis for interpretation. In the

current implementation, the interpretation component is rather simple as it gives only short explanations. It should be revised in future implementations of the prototype.
Applying the conformity verification to the core and Greek cadastral model, we noticed that it might be helpful to have more types of relations for the identification of corresponding elements. Apart from correspondence between classes, other types of relations such as "complement of" would be useful. Relationships between attributes could also be divided up. Modeling primitives are available in ontology modeling languages in order to declare a property as "subproperty" or as "inverse" of another.

In its current version, the prototype demonstrates an implementation of conformity verification with Semantic Web technologies, but it is not yet a product. A good understanding of ontologies is essential for the conceptualization and implementation of such ontology-based tool. For example, the exchange of ontology models between different Semantic Web tools is rather difficult because of differences in the serialization of ontology models. Provided that tools for preparatory parts such as the transformation from UML into an ontology language are available, it should be possible to implement a product for the conformity verification which is usable by domain experts without the help of knowledge engineers.

6. CONCLUSION

This work presented ontology-based conformity verification. Core and domain models were represented as ontology models and updated by the correspondences that domain experts had intended between the elements of both models. Domain experts obtained direct feedback because of the ability of the reasoner to formally prove the intended relationships. Reasoning permitted to detect inconsistencies in each model and across both models and revealed implicit facts. Thus, complete knowledge of the effects of the identified relations was provided. A consideration of this knowledge in subsequent versions of the models can increase their quality.
The results of our initial approach to conformity verification show that work in this area is incomplete. Future work should focus on the extension of the theoretical background. For example, this work has only touched on the inconsistencies in and across core and domain models. Examining the reasons for inconsistencies and providing solutions for resolving them would be an interesting research topic for conformity verification as well as for other ontology-based approaches such as information integration. Furthermore, an automated preliminary selection of corresponding elements could be realized so that domain experts would only need to confirm the identified relationships and this would save time during the verification process.

Verification of core model conformity can be useful in various application areas. It is claimed that the approach is not restricted to the cadastral domain although the approach was only evaluated with cadastral models. Great importance was attached to the generality of the approach and so subsequently no step has specialized on cadastral systems. Another example of use is that several business units in a company agree on a common data model which serves as a core model for the individual data models of each department and abstracts from their differences. Conformity verification could prove the relations between the department models and the core model.

Our approach reveals problems in the conformity verification with the core cadastral model as it actually is. The core cadastral model must be refined in close cooperation with experts for the national cadastral systems who in the other way round must be willing to modify their national model in order to achieve conformity. It is important to discuss core and national cadastral models on the same level of abstraction. There will always be problems in the conformity verification and the subsequent use of the models in various applications if some of the models are close to the implementation level representing directly the underlying databases and other models are more on the conceptual level abstracting from the concrete implementation.

But even if core and the national cadastral models are in an early stage, the core model with national models which conformity was shown by the conformity verification represent a promising approach to standardization in the cadastral domain. Our results permit to expect concrete applications on the basis of conforming models. The core model can be the basis of a core software application which is only adapted to the local requirements expressed in the domain models. Furthermore, data could be exchanged between organizations and institutions of different countries with the help of the core model representing the minimum common data of all domain models. The next step would be to realize software in of these application areas.

This work concentrates on conceptual models, but we plan to extend our approach to the verification of core model conformity to process models. There would be for example standardized process models for transactions of land property and conforming process models in the various national cadastral systems.

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BIOGRAPHICAL NOTES

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The Cadastral System as a Socio-Technical System

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Key words: system approach, cadastral system, socio-technical system, modelling systems, designing systems.

SUMMARY

From an increasing interest in large scale complex systems a research to these systems defining them as being socio-technical is conducted at Delft University of Technology. In this paper the ideas and concepts in this research are explained and used in analysing the cadastral system.

Socio-technical systems consist of social and technical elements and agents. We argue that social elements are of a fundamental different nature than technical elements and, therefore, need to be treated differently. System theories in engineering and in social sciences do not take this distinction sufficiently into account.

The cadastral system is based on the social concept of ownership of real estate. Nevertheless technology plays an essential role in modern cadastral system. Therefore I argue that the cadastral system is a socio-technical system with a social core.

This has far going implications for modelling and designing the cadastral system. The idea of designing seems to vanish completely, while with regard to modelling the dynamic aspects of the social character of the system have great impact. Neither the Cadastre 2014 document nor the (Lemmen et al. 2003) model (both aiming at future cadastral systems) do take sufficient notion of the nature of the cadastral system.

1. INTRODUCTION

There is an increasing interest in system research. Both in engineering and in social science the importance of understanding the working of large-scale, complex systems in society is acknowledged. Research institutes and academic departments studying them are founded and conferences dedicated to them are organized. Additionally, there is a drive from society seeing itself faced with bigger and more interdependent systems, where failure of one system may cause considerable damage throughout society. Not only technical failure may cause such damage, but also failure due to organizational issues. The robustness of large-scale, complex systems is therefore not only based on sound technical elements, but depends increasingly on social aspects as well. In the light of this increasing importance a research project studying socio-technical systems, as we will call them, has been initiated at Delft University of Technology. Existing systems theories in engineering and the social sciences define systems as composed of elements linked by various relations, without making a distinction between social and technical elements. The Delft research project is based on the idea that the differences between technical and social elements are so fundamental that they should be clearly distinguished.

The research project proceeds by conceptually analyzing several systems that we consider as being in the socio-technical realm, like a civic aviation system or the energy-infrastructure. While most systems engineering is about systems that have technology at their basis, the cadastral system seems to be of a different breed. Since the whole concept of ownership is essentially social, the cadastral system has a social basis instead of a technological one. Due to technological innovation, however, especially the total reliance on GIS data, technology is so deeply involved in the cadastral system that it must be considered a socio-technical system. Therefore, our analysis of socio-technical systems should apply to the cadastral system as well.

In this paper I will introduce the concept of a socio-technical system. I will tell into more detail why I think the cadastral system is a socio-technical system and why it has a social basis. Furthermore I will tell something on implications this has or can have for modelling such a system and in particular give some comments on attempts to do so as well as on consequences this social side has in implementing a model in the real world.

The leading research questions, to the answering of which this papers aims to contribute, are:

- What are socio-technical systems?
- Is the cadastral system a socio-technical system?
- What are implications of being a socio-technical system for designing and modelling the cadastral system?

2. SOCIO-TECHNICAL SYSTEMS

The following table from (Kroes et al. 2004) summarizes a distinction we make between three kinds of systems.

	Without agents	With agents
Without social institutions	1) Landing gear	2) Airplane
With social institutions	-	3) Civic aviation system

Table 1: Three kinds of engineering systems.

The first kind is a system without agents or institutions performing a sub-function in the system. An example is the landing gear of an airplane. A landing gear does not need someone to manually turn the wheel, and, although subject to a great many regulations, it is not dependent on any of these regulations for its functioning. If these regulations suddenly cease to exist, the landing gear is still able to ground the airplane. Next we move up to a more complex type of system: the whole airplane. Here human agents fulfil sub-functions, like piloting the plane. But still an airplane does not need any regulations to function (and presumably airplanes function in the absence of regulations in some countries). If we then move up again to systems of the third kind, for instance, the complete civic aviation system, we see that, apart from human agents, institutional elements now also fulfil sub-functions. They are essential for the system as we know it to function. Without insurance, for instance, no airline company will send its planes in the air (as was the case after 9/11), passengers will stay away, and pilots might refuse to fly. In this kind of system there are many

interdependencies of a social kind, which determine the functionality of the system. It is also evident that, for example, a billing system, an air-traffic system with agreed routes, et cetera, are essential to the functioning of the civic aviation system as well.
The third kind of system in this distinction we call socio-technical systems. These systems consist of technical elements (1), and additionally of non-technical elements like agents (2) and social elements (3), including the aforementioned institutions. In our analysis we will use this preliminary distinction between the three kinds of elements and the six relations (i – vi) these elements are involved in to gain more insight in these systems (see Figure 2).

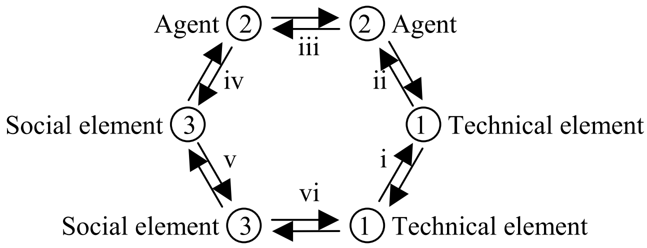

Figure 1: Elements (1-3) and relations (i-vi) in a socio-technical system.

In (Ottens et al. 2004) we characterized these relations as either physical, functional, intentional or normative, where the latter two kinds come into play when socio-technical systems are considered.

Our interest in the cadastral system arises from the peculiar nature of this kind of system. While we originally looked at systems where the social elements come into play due to for example an increase in scale or complexity of the system, by for example moving up in the system hierarchy, this does not seem the case for the cadastral system.

Systems come in different builds. A transportation system for example is about the physical transportation of goods and persons. This necessarily involves physical technology. As discussed in the above case these systems can be 'stripped' down to individual objects that can be used for the same means without social elements playing (an important) role. These systems have technology as their basis. When we look to the cadastral system and try to do a similar exercise we end up with a different basis. The cadastral system is based on the notion of ownership of real estate. Ownership is a social concept that can exist without any reference or link to technology. The core of the cadastral system is therefore social and not technical as in the case of for example transportation systems.

From the above it is clear that if we consider both systems to be socio-technical systems, the notion of socio-technical comes to include a wide variety of systems. By applying a concept to a wide variety, there is always the danger that it becomes excessively generalized and is rendered useless. We think, however, that the distinction we made between the different kinds of elements is useful in both kinds of socio-technical systems, since it is not based primarily on either technical or social elements. It focuses mainly on the differences in these elements, and these differences exist in both systems.

In this focus our approach differs from 'established' approaches in the fields of engineering and social sciences. In engineering, and more specific system engineering, social elements are to a great extent excluded from the system and agents are modelled from a functional and/or physical perspective. On the opposing side, in the social sciences, intentions are taken into account, but in their interaction with technology the latter is either black-boxed or, for example in the actor-network theory, technical elements are modelled as entities that act just like agents do.

We argue that social elements, technical elements and agents are different in their nature. Social elements are not subject to the laws of nature in the same way as technical elements and physical agents are. Of course, it is not denied that humans are subject to the laws of physics and chemistry, and the design of technology obviously takes this into account concerning the operation of machinery and in safety precautions. The point is that the description, anticipation and understanding of the behaviour of agents and social elements does not refer to the laws of nature but to principles of action and to social rules. This difference in nature between social and technical elements implies a difference in the way they are treated with regard to the modelling and designing of socio-technical systems.

3. AN ANALYSIS OF THE CADASTRAL SYSTEM

I use the notion of cadastral system as used by (Bogaerts 1999; Zevenbergen 2002; Zevenbergen and Bogaerts 2000) as a system that combines both the registration of land ownership and use (the administrative/legal component) and the definition of parcels of land (the spatial component).
A lot of research is already done on the cadastral system. For example the article by (Zaibert and Smith 2003) gives an excellent view on the concept of ownership of real estate. This concept is at the basis of the cadastral system. The system is not merely a tool to help in providing information on who owns what, but, as I will argue, that it is part of the legal framework that is needed to socially enforce ownership. In order to gain a greater understanding of the cadastral system, I will analyze the system using our ideas about socio-technical systems, taking a closer look at the (social) concepts involved and at the role of technical elements in the system.

3.1 Social concepts (or elements)

3.1.1 Real estate

As (Zaibert and Smith 2003) argue, for ownership of real estate to be conceivable it is necessary to socially define what real estate is. This is not the case for the ownership of, for example, a watch. It is simply clear to everyone what the boundaries of a watch are. When it comes to real estate, the situation is more difficult. Here the defining properties are not, or at least not that obviously, related to physical properties. (Zaibert and Smith 2003) point out that exchanging 'all' the soil between two real estates does not change the definition of the real estates. They also remark on the other hand that the social choice to use geographical coordinates for defining real estate parcels might run into problems as well since the surface of the earth is not immovable itself.

3.1.2 <u>Ownership</u>

Next to the problem of clarifying what real estate is, there is also the question about what ownership is. The expression "possession is nine-tenth of ownership" might work for a watch but is problematic for real estate. It is easier to capture that I own the watch or t-shirt I wear or the car I drive than that I own the land I walk on or cultivate or the place I work or even live. Of course more forms of use of immovable and movable objects exist: you can also lease a car, rent a house or probably even rent a watch. Another interesting point that can be made about ownership is that because it is a purely social term, it can also be declared not to exist (by for example a new political regime).

3.1.3 <u>Owner</u>

Not only real estate and ownership are socially defined, but also the notion of an owner is. Of course people are not socially defined, but legal bodies are. In most systems real estate can be owned by companies or organizations as well as by real people. Although it is perhaps an extreme example, it can socially be defined that a tree be appointed as the owner of the piece of land it stands on. In fact, certain rights and restrictions on land use are motivated by the presence of rare plants and animals on the land. This is currently conceived as restricting the rights of the human or corporate owner, and the layered model covering all rights and restrictions on land, proposed in the Cadastre 2014 (Kaufmann and Steudler 1998) document, conforms to this. However, developments in environmental ethics and animal rights might change this.

3.2 Legal framework and dynamic aspects

So what is needed for a system about ownership of real estate is a sound social definition of what real estate is and what owners are, and a stable concept of ownership itself. All this has to be embedded in a sound legal framework. This legal framework does not only include the laws that state *what* ownership and real estate are and *who* (or what) can be an owner, but also *how* someone can own.

A question would now arise about the position of the cadastral system relative to this legal framework. Can the cadastral system be seen as existing and functioning separate from the legal framework or is it perhaps part of this framework.

It seems to me that the cadastral system itself is part of the legal framework. Disputes about property will not be resolved on the legal concepts of real estate and ownership, but also or probably even more on information from the cadastral system. If I would argue that I own a parcel of land, I would refer to the cadastral system. Also when for example some claims unrightfully usufruct on my parcel (because three generation of land-owners ago this usufruct was cancelled) I need to defend my case by referring to the cadastral system.
This is because we are dealing here with social concepts. As argued before, we cannot go back to social laws to analyze the dispute, which could be seen as a malfunctioning of the system. In principle we can trace back a malfunctioning in a technical system to the laws of nature and the physical make-up of the system, though this can prove quite complicated in

practice. However, even though ownership, owner and real estate are socially defined through the law, exceptions can be and are made as long as they are in the 'spirit' of the law, or the law can be changed. This while the laws of nature that apply to physical (technical) objects do not allow exceptions, nor can we change them as we see fit.

The above relates to the how question in the legal framework. Not only should the framework contain social definitions of what and who, but also on how, on procedures to register what and who and the precise relation between what and who. This implies a dynamic nature of the cadastral system. Both (Zevenbergen 2002) and (Molen 2002) argue that the cadastral system must be seen as a dynamic system rather than just a static one. Changes are usually seen as changes concerning the owner (for example a new owner), the parcel (it can be split up or change from rural tot urban land), or the character of the relation (different rights or restrictions can apply). Because of the social character of the system however, changes can also be of a more fundamental type. The kind of owner can change, as can the kind of real estate as is argued before. Since these concepts are socially defined, a material object or even an abstract entity may become eligible for ownership, and the real estate can, instead of being linked to specific coordinates on the surface of the earth, be linked to the position of the sun or the moon. These examples are of course exaggerated. It would not be practical to model a system to be able to cope with such penetrating changes. It seems to me, however, that it is important to recognize this social and therefore fluid nature of the system, since similar changes can also be of a less rigorous form, such that you would want your system to be able to incorporate them. For example (Mattson 2003) mentioned an 'Everymans's Right' on certain real estate. It is also not inconceivable that new kinds of relation will come in existence, for example rights and restrictions regarding environmental issues, as mentioned before.

3.3 Technical elements

In the analysis so far I have discussed every aspect of the system as being social. Does this not imply that the cadastral system is a social system instead of a socio-technical system? If not, then where do the technical elements come into the system and what is their role? Are they not better seen as standing apart from the cadastral system, merely supporting it? I will argue that this is not the case. Technical elements are this deeply integrated in the system that they cannot be seen as separate.

First of all I will go back to the definition of real estate. Boundaries of real estate are defined by coordinates. This is possible because of technology. This technology is not only used in defining real estate parcels, but also in processes of change like splitting up parcels or in disputes. If the cadastral system only stores these coordinates, and if all technology to locate these coordinates fails, then the information in this database can no longer be used to solve disputes. Hence the concept of real estate will become unclear and the cadastral system will fail.

The ongoing development of technology not only made the transition possible from a map-based to a database-based cadastre, but will also make a 3-dimensional cadastre possible. A shift to a 3-dimensional cadastre will bring a vast amount of new legal issues, which a cadastral system has to deal with, but on the other hand also helps in avoiding awkward legal arrangements (Mattson 2003). As said above, the surface of the earth is not immovable, but buildings are even more subject to move. Coordinates can be determined very accurately relating to (the surface or centre of) the earth while big buildings might shift just due to the inclination of the soil or whole areas might incline because of the extraction of natural resources (like gas). If a building would shift enough I could end up living in the real estate space of my below neighbour. It is clear from this example that a change towards a 3-dimensional cadastre is not a question of technology alone; it will have legal implications as well.

Secondly the database itself is part of the cadastral system. If all information is stored in the database and in the database alone, legal claims are made upon what the database provides. Because of the changes towards the integration of the cadastre and land administration system and the size and complexity of the system the database is not only a tool for the storage of information but becomes an essential element. Choices in modelling the future cadastre are based upon possibilities that arise from the use of ICT.

3.4 The cadastral system as a socio-technical system

I argued that the cadastral system is a socio-technical system where both social elements and technical elements play a role and are even strongly integrated. Furthermore I argued that the core of the cadastral system is social. The examples of systems I used in the previous chapter (airplane systems, transportation systems) have technology at their core. This makes the cadastral a different breed of socio-technical systems. The social side is much more important; upon abolishment of the social concept of ownership, the cadastral system would cease to exist. The interesting questions now are what this ‘being a socio-technical system’ means for modelling and designing the cadastral system and if the social basis has special implications.

4. IMPLICATIONS FOR DESIGNING AND MODELLING

In the following statement by Brian Mar[1], taken from an introductory presentation on systems engineering, the way traditional (systems) engineering deals with the outside, social, world is clearly indicated. This quote emphasizes the importance of and interest in understanding socio-technical systems with a view to modelling and designing them.

> At the moment the capability to deal with the outside world is non-existent. Therefore it is usually treated as constraints. There are only a very few people who deal with it, try to improve the world for the benefit of their system. Usually system engineers use risk analysis and design the system so it can deal with these risks. In the future there might be new capabilities, for example, to talk better with the people who design the rest of the world and integrate them in the system design process, or to do something else than risk analysis to handle the outside system. Risk analysis is one way, but hopefully we’ll find a new better way to deal with it.

[1] Brian Mar is a Systems Engineering Fellow, one of the founders of the International Council on Systems Engineering, and Emeritus Boeing Professor of Systems Engineering at the University of Washington.

In this section I will discuss the implications of the aspects of the cadastral system that came up in the previous section for the task of modelling and designing them.

4.1 Designing

Since social elements are of such a different breed from technical elements, it is not clear whether the same notion of designing (as engineers use the term) would apply to both. It is even questionable whether a notion of designing is relevant at all with regard to social elements. This is emphasized by (Kaufmann and Steudler 2004). The statements that involve technology, like the switch to IT infrastructures, are on 'schedule' or only slightly behind, but the statements of the Cadastre 2014 document that require the most far going changes in social elements are the ones that are most behind 'schedule'. For example, the inclusion of public rights and restrictions in the system requires a much deeper institutional change. The existing social institutions dealing with public rights on land might not have the same goals as the cadastre and the land registration institutions. To gain more insight in these changes more research needs to be done on social systems. Useful leads on this particular subject might be a multi-actor approach (as taught at the faculty of TPM, Delft University of Technology), which includes for example stake-holder analysis and process design and management (Bruijn et al. 2002). However, the multi-actor approach states explicitly that the solution of the problem has to emerge from the process and cannot be set beforehand. It will be negotiated during the process among the different stake-holders involved. In working towards a standardized cadastral system this is not a very satisfactory thought, since every country might negotiate a completely different system.
This, however, is not reason enough to abandon this idea. Because of the highly social nature of the cadastral system and the many stakeholders involved this might just turn out the way it works. What can be given are arguments in this negotiation process, so a well made model of the cadastral system could be of great value. I doubt, however, whether this process of change will be achieved by 2014.

4.2 Modelling

The foregoing comments on designing put the modelling of the system and environmental conditions in a different light. It no longer functions as a basis for designing but as an argument in negotiation. Nevertheless, since the cadastral system is not purely social, but involves technology as well, some parts can probably be designed straightforward from a model.

4.2.1 <u>Boundaries of the system</u>

A recurring question in system modelling, which is closely related to the dynamic aspects, is the question where to draw the boundaries of the system to be modelled. As Mar mentioned, engineers now usually leave out the social aspects, but, as I argued, this is impossible in the case of the cadastral system. The question of boundaries is closely related to the part about dynamicity. It would be useful to make the system adaptable to certain changes, but a system that can handle all possible changes is probably not feasible, or would be useless because of its complexity. A dramatic change in the concept of ownership, as for example has happened in the Soviet-Union, is not a change that is useful to take into account; it would render the system useless. Certain social aspects, like for example the definitions of real estate, ownership and owner are probably best placed outside the system to be modelled, but when designing the system they have to be taken into account. They will probably need adjustment due to choices made in modelling, so they should be dealt with in a more than contextual matter.

4.2.2 Elements and relations

In the previous chapter I described several elements and relations in the system. In modelling I think it is essential to recognize and state the nature of the elements. This will help in gaining more insight in the system and aid in designing the system. By putting emphasis on relations not only within the system to be modelled, but also across the chosen boundaries, dependencies can be found that might cross boundaries in a bidirectional way. The definition of ownership can for example be seen as contextual, yet it is of utmost importance for the functioning of the system. Nevertheless this is not necessarily reason enough to include it in the system to be modelled. In designing however some work might be done to assure a sound definition of ownership suitable to the cadastral system.

4.2.3 Procedures

Not yet clearly defined in our model of socio-technical systems are processes (or in the more formal sense procedures). With regard to the dynamicity and costs related to these dynamic aspects, procedures play an important role. As was mentioned and done at the COST Action G9 workshop in Riga (October 14.-16. 2004, http://costg9.plan.aau.dk/) researching the procedures involved in real estate transactions seems an intelligible way to gain more transparency and insight in costs. The sixth statement of the Cadastre 2014 document and one of the aims of Cost Action G9 are about gaining transparency in the costs involved in real estate transactions in order to make the system cost recovering and make systems in different countries better comparable. It seems not likely that the change towards a digital cadastre will considerably change the amount of costs involved. Legal procedures are still needed to assure the legal validity of the system and will not change because of the change to a digital system. On the other hand costs of retrieving information (for non-legal purposes) might decrease considerably. Neither Cadastre 2014 nor the (Lemmen et al. 2003) model (both aiming at future cadastral systems) deal explicitly with procedures.

5. CONCLUDING REMARKS AND SOME DISCUSSION

In modelling the cadastral system social elements are very important, because of their nature they need to be modelled differently from technical elements. One has to take into account that the definition of the element to be modelled is social and therefore can change; a certain possibility of change needs to be incorporated in the model.

Because of this fluid nature of social elements it is important to think about what degree of change you want to incorporate in your model. You need to think about where and on what grounds you want to draw the boundaries of your system to be modelled.

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

In our research we look at boundaries in a more general manner, if for example the boundaries can be drawn based on the aim or the function of the system. When socio-technical systems are considered it seems, however, unlikely that one aim or function exits. This is especially the case when multiple actors are involved. It would be interesting to see whether such an approach would be useful in the case of the cadastral system. (Zevenbergen 2002) used such an approach in studying the cadastral system. Another interesting research might be aiming at finding an ontology of procedures. This might prove very difficult, since they are all social themselves, based on different social concepts of ownership of real estate. Also the question whether a social knowledge exists and can be used in the shaping of socio-technical systems is something that would be interesting to research.

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BIOGRAPHICAL NOTES

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From Models to Data: a Prototype Query Translator for the Cadastral Domain

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Key words: Query translation, conformity verification, interoperability

SUMMARY

The missing possibility of exchanging cadastral information between different countries in an efficient way leads to rather complicated procedures of collecting and analyzing cadastral data in land transactions with multinational parties. In this paper, we propose an approach to query translation based on the core cadastral model (Lemmen et al., 2003) which serves as connecting piece between various national cadastral systems. We will show by demonstrating a query translation from one national cadastral model into another that interoperability between cadastral systems conforming to a core model can be achieved. A prototype Query Translator demonstrates the practical use of our approach.

1. INTRODUCTION

To facilitate cross-border exchange of cadastral information, a number of initiatives have been taken. As it is not feasible to install one single cadastral system in all European countries, other approaches are required. Lemmen et al. (2003) proposed a core model for the cadastral domain representing basic concepts of most cadastral systems. National domain models adapted to the particular requirements in the respective countries can be modeled as extensions of this core model. In this work, we show by demonstrating a query translation from one national cadastral model into another via the core cadastral model that interoperability between cadastral systems conforming to a core model can be achieved.

Until now, the exchange of cadastral data between different countries – even in the European Union – is not possible in a completely automated way. For example, it is not easily feasible for a bank to verify the cadastral information indicated by a customer asking for a loan when the property is situated in another country. Cadastral information must be collected with the help of local experts or a local branch in this country (Ollén, 2002). Our approach to query translation between national cadastral systems would be helpful in this context. In the above example, it would be possible for the bank to check the cadastral information of the customer by sending the corresponding queries directly to the supplier of cadastral data in the foreign country in consideration. Our approach is characterized by the fact that the employee of the bank does not need to know the concepts and the processes of each foreign country in detail but only those of its own country. The query translation permits to formulate the query with the concepts of the cadastral system of the home country, familiar to the bank employee, and to present the results again in the terms of the cadastral system of the home country. This facilitates the cross-border exchange of cadastral information because it is not required that users are familiar in detail with all connected cadastral systems. It is guaranteed by the transformation via the core model that semantically equivalent concepts are retrieved.

The prototype which we developed in order to show the feasibility of applying our theoretical approach could be integrated into a service-oriented architecture for the cadastral domain which might be accessible via the Web. Services as described above could be offered to the various users of cadastral information. Cross-border exchange of cadastral information is not only interesting in the real property financial market, but also for authorities, for example in land management and infrastructure development, and for international companies, e.g. in their property management.

This paper is structured in the following way. In section 2, we discuss different approaches to query translation and compare them with our approach. Section 3 describes how the mapping works in our query translation. The next section presents use cases characteristic for the queries that can be handled by our prototype Query Translator. The use cases are based on actual cadastral models and test databases. Section 5 evaluates the results of our tests. Recommendations on the basis of our experiences are discussed in section 6. The last part, section 7, summarizes our work and discusses restrictions of our current implementation which could be addressed in future work.

2. RELATED WORK

In the following, we set our approach to query translation in the context of research in data integration. Then, we will discuss how the exchange of cadastral data is realized in other projects from the cadastral domain.

2.1 Approaches to Data Integration

Integration of information from different heterogeneous data sources is an ‘old’ subject in computer science and database research. Before the advent of Internet, integration of heterogeneous data sources was already an issue in situations where data from several databases had to be combined to get the requested information. Halevy (2003) gives a useful overview of the research questions in data integration that are still not solved. With the Internet, there is now an extra dimension: the technology to access, retrieve and query information on remote servers exists. But because of the loose coupling of all this information, the fact that the user group is not known and the unpredictable nature of the queries that will be posed, the information integration issue has only become more imminent.

Many research disciplines are involved in data integration: from computer science and database research to artificial intelligence, the Semantic Web and Description Logics (see e.g. Borgida et al, 2003; Wache, 2003; Stuckenschmidt, 2003).
Our Query Translator approach uses concepts and techniques from the Semantic Web, in the form of using an ontology language to specify the correspondences and relations between the data models of the cadastral systems of different countries and the core model. However we do not use a semantic reasoner that computes semantic relations ‘on-the-fly’. In the Query

Translator prototype the semantic relations between the models are established beforehand, during the conformance verification process (Hess, 2004).
From the database research there is an interesting distinction between the GAV (Global as View), LAV (Local as View) and GLAV (sometimes called BAV, i.e. Both as View) approaches to data integration (Halevy, 2003). If we would position the Query Translator in this spectrum, it is close to the GLAV/BAV approach: a 'global' query model is used to pose the selection queries to several heterogeneous data sources with the structure and terminology of that query model. Via the ontological mapping the query is then reformulated into the right classes and attributes of the 'local' data sources. Attributes of the local data sources that are not in the global model are still presented to the user, because these should also be available for narrowing down the search conditions in the query. So the approach is a mix of GAV and LAV.

Finally, there is no direct mapping between the national models in the Query Translator: the core model always acts as 'intermediary' or central model. This is also how e.g. FME (Feature Manipulation Engine) works, a software product for conversion between various technical file or data formats. The advantage that is mentioned by the designers of FME is, that changes in a file or data format only lead to a change in the mapping between that format and the internal intermediary model that FME uses. With pair-wise conversion all mappings between the changed file format and all other formats would have to be changed (Murray, 2002). For the same reason we also chose a two-step translation for the Query Translator. In section 5 we will see, that this choice also has some disadvantages.
In contrast to this approach to integration via an intermediary model or format, there is currently also much research into another strategy for data integration, such as peer-to-peer data integration (see Halevy, 2003).

2.2 Exchange of Cadastral Information

Cross-border exchange of cadastral information is also part of the project European Land Information Service (EULIS)[1]. The goal is to provide a single entrance to land and property registers across several countries. Just like our approach to query translation is embedded in the overall context of the COST Action G9 "Modelling Real Property Transactions", the query translation in EULIS is only one part of the project. With our query translation we also aim at improving the exchange of cadastral information between national cadastral systems, but there are many differences from the technical point of view.
In contrast to EULIS, in which national cadastral information can be accessed via one portal but with separate connections to every national cadastral system, our approach to query translation provides one single query interface for all national cadastral systems. Furthermore, our query interface permits to formulate queries in the terms of the user's cadastral system, i.e. in a language familiar to the user. Thus, it is not necessary to provide an explanation of the retrieved concepts as in EULIS. An important difference is also that the translation is realized in our approach on the basis of a common core model connecting the national cadastral systems. This is not the case in the EULIS project. This different approach in the EULIS project results in the fact that there is no mapping required between the

[1] http://www.eulis.org

different national cadastral systems as each of them is queried individually. But the mapping between the national cadastral models and the core cadastral model is central to our approach.

3. QUERY TRANSLATOR

We present an approach for a prototype Query Translator that uses the formalized relations between two models as input for a 'mediator' component to query and retrieve information from actual, 'real life' cadastral data sets. Goal of the Query Translator prototype is to function as a proof of concept:

- Demonstrate the possibilities to exchange cadastral data arising from core and conforming national models.
- Investigate the possibilities and limitations of a 'semantic mediator' based on the Web ontology language OWL for data integration in the cadastral domain (W3C, 2004).

3.1 The Core Cadastral Model

The core cadastral model plays a central role in the architecture of our query translation. The core cadastral model was proposed by Lemmen et al. (2003). This core model reflects features found in most or even every cadastral systems and models them according to international standards from ISO and OGC (OpenGIS). The main advantages of the core model are in two different areas. One the one hand, it represents the core software component of cadastral systems. On the other hand, it facilitates the exchange of cadastral data between the cadastral systems of different countries. (Lemmen et al., 2003)
In the following, we concentrate on the second point and show how the core model can be used as basis for data exchange. The core cadastral model serves as connecting piece between the national cadastral systems. Mappings need not be formalized between every pair of national models but only between each national model and the core cadastral model. The query translation is established on the basis of the mappings that can be defined for each of the national models and the core cadastral model.

3.2 The Mapping Ontologies

In this paper, we built on the results of the conformity verification research. Conformity verification analyzes – in the case of the cadastral models – the relationship between a national cadastral model and the core cadastral model. An approach to ontology-based conformity verification between core and national models was proposed by Hess (2004a, 2004b). This approach and the software implementing it – the conceptual conformity checker (CCC) – captures domain experts' modeling intentions, i.e. the relations they intend to hold between national models and the core model. Inference services compute the type of these identified relations that is equivalence, subsumption or overlapping. Furthermore, conformity constraints are defined. They formalize a set of concepts in the core cadastral model for which a corresponding concept must be available in the national cadastral model. The type of the correspondence has to be the type required by the conformity constraint.
Thus, conformity means in this approach that all conformity constraints are satisfied by the identified correspondences. Conforming national cadastral models are therefore extensions of

the core cadastral model. The conformity verification guarantees a minimum of exchangeable information between all European cadastral systems because the conformity constraints define a base model as part of the core model that is reflected by every national model conforming to the core model.

The mediator component uses the formalized correspondences that have been discovered in the conformity verification process and their computed types as translation rules between data sources. This is possible because the relations are described in an ontology language, in this case OWL (Web Ontology Language) (2004), the successor of DAML+OIL. But in order to use the output of the conformity verification demonstrated by Hess (2004a, 2004b) as input for the query translation, the verification results must be changed into the form required by the Query Translator prototype. The cadastral models used in the conformity verification are represented as one ontology model that contains the core and the national cadastral model as well as the relations identified between both. This model does not include the results of the computations made by the reasoner. This was not necessary for the conformity verification as the results can be reproduced by sending the ontology model again to a reasoner. Results were analyzed and their interpretation given to the user. In the query translation, we maintain core and national in separate files because cadastral systems are stored in a distributed way. The architecture for the exchange of cadastral data is based on the fact that the cadastral systems with their databases are maintained in each country individually. Furthermore, suppliers of cadastral data offer an ontology model of their national cadastral system including the mapping relations between their national model and the core cadastral model. Thus, we have one ontology model of the core cadastral model and one ontology model for each national cadastral system with all its mapping relations to the core cadastral model.
Figure 1 shows a part of an ontology model with the mappings between the Greek cadastral model and the core cadastral model.

```
- <owl:Class rdf:about="greek_cad.owl#STATE_RESTRICTION">
    <owl:equivalentClass rdf:resource="core_cad.owl#PublicRestriction" />
  </owl:Class>
- <owl:DatatypeProperty rdf:about="greek_cad.owl#BENEFICIARY_BEN_ID">
    <owl:equivalentProperty rdf:resource="core_cad.owl#Person_SubjID" />
  </owl:DatatypeProperty>
```

Figure 1. Example of OWL mappings

In this architecture, modifications in a national cadastral system will not influence any other national cadastral system. Having modified a national cadastral model, the experts that are responsible for this model renew the conformity verification and use its output directly for the query translation. It will be helpful if future versions of the conformity verification are able to generate the results in the format required by the query translator.

Our approach to query translation permits a formulation of queries and the presentation of their results in the terms of the query model, i.e. the terms used in the cadastral system of the user’s own country. The conformity verification ensures that the results of the query translation from the data source, i.e. the model from which the user wants to select cadastral information, correspond semantically to the concepts of the query model which were used for the query formulation. This semantic equivalence is guaranteed as the mapping models are based on the correspondences identified by the domain experts during the conformity verification. The user of the query translation system therefore does not need to know the terms of the data source model but only those of the "own" national cadastral system.

3.3 The Query Translator

The Query Translator prototype is set up as a Web application that accesses an Oracle Spatial database. The user selects a 'data source' and a 'query model'. This 'query model' can be the model of the data source itself, but can also be another model (the core model or another national model). For our tests at this moment we have the choice of three query models: the core, the Greek (Tzani, 2003) and the Dutch model (van Oosterom and Lemmen, 2001). For the data sources two test data sets are available: a data set with Greek cadastral data and a data set with Dutch cadastral data.
The 'Advanced' button gives access to a Selection form that helps the user to specify the query. The Selection window is a dynamic HTML page that is generated 'on-the-fly' using the OWL ontology for the model as input. Presented to the user are the classes and subclasses of the query model that was chosen, with their attributes.
The user enters selection criteria and submits. The Query Translator software searches in the ontology document(s) and retrieves the translation rules that map concepts from one model to concepts in the other model. The Query Translator then rewrites the query into the terms and structure of the model of the data source. The query results are either presented in terms of the data source, or in terms of the chosen query model.

The prototype is based on very standard Web technology: (dynamic) HTML, JavaScript, and XML and XSLT. With XSLT (eXtensible Stylesheet Language for Transformations) it is possible to read an XML document, retrieve its content and transform it into other XML or HTML. Because the OWL ontologies are coded in XML, XSLT is a practical solution for handling the mediation and query translation in the prototype.
The Dutch and Greek test data sets are stored in Oracle Spatial. We can access the data itself via a Web service, but to make 'offline' tests possible we stored the output of the Web service (in GML, or Geography Markup Language) in local GML files, so we were more flexible.
The prototype is at present built solely for testing, thus the user interface itself is very straightforward. With it however we can test several scenarios (selection queries) and evaluate the success and also the limitations of our query translation approach.

Queries can be formulated on two different levels of complexity. In the lower complexity level, *equivalence* is defined in a weaker way. Equivalence means only that there is an extensionally equivalent concept in the query model and the data source. It can be used for rather general queries, e.g. `select * from core:Person` with the Greek model as data source. This query would retrieve all beneficiaries form the Greek cadastral system. The results describe the same extensions, i.e. the owners of a piece of land. For more specific queries – which will be the normal case in the query translation, equivalence is defined in a stronger way, i.e. by requiring structural equivalence. For example, the query `select from core:NaturalPerson where name='...'` with the Greek model as data source assumes that the data entries in the Greek database implementing the concept *NATURAL* have an attribute that corresponds to the attribute *name* of the concept *NaturalPerson* in the core cadastral model. The name of the attribute may be different but there must be a mapping between the attributes encoded in the mapping model. This correspondence was established during the conformity verification and can be used later on in the query translation.

Test queries will be formulated both against the administrative part of the cadastral data source, and against the spatial part, i.e. the actual parcels with parcel-boundaries, survey points, etc.

4. USE CASES

We describe a number of test cases, from simple queries to more complicated ones.
An example of a 'simple' scenario is the following case: a class in the data source has another name and maybe other names for attributes as a class in the core model, but is intended as the same concept: core:NaturalPerson versus greek:NATURAL.

Core model:
```
select * from naturalperson where name[2] = '...'
```

Greek model:
```
select * from natural where name = '...'
```

An example of a more complicated scenario is a query that involves an association between two or more classes. This would mean – in relational database terms – a join between two tables:

Core model:
```
select name, address, type_of_right from naturalperson, right
where person.id = right.person_id
and municipality = '....'
```

Here the complicating factor is not the different names for classes and/or attributes, but different (names for) associations between classes plus knowledge about the join attributes (foreign keys) that must be used.
In this second case it might not be trivial to rewrite the query based on the semantic relations formalized in the merged ontology models. One of the research questions is therefore whether not only the basic query statements but also the more complicated ones like joins between tables can be correctly generated from the formal definitions in the ontology documents.

5. EVALUATION

The first tests with the Query Translator prototype lead to the following observations and preliminary conclusions:

[2] We obtained the attribute *name* by splitting the attribute *PersonExtID* of the class *NaturalPerson* which refers to the external Person-Registry into the attributes *name*, *lastname*, etc. as being available in the Person-Registry.

System boundaries of the models

The system boundaries of the core model are stricter than those of the national cadastral models. Classes from 'outside' the cadastral domain, e.g. (Postal) Address, are not incorporated in the core model. On the other hand, such classes and attributes exist in the national models and are very important for selection purposes.

Conceptual versus technical models

Both the Greek model and the Dutch model that we used for testing our Prototype Query Translator are close to the data as stored in the database. They are based on the implemented (technical) data models. The core model however is a mix of conceptual and technical data modeling. It reflects the conceptual level of a cadastral system and is therefore abstracter than a national cadastral model that is based on the concrete implementation of the cadastral system. As we work in the query translation on the databases of the respective cadastral system, we prefer models that reflect directly the structure of the database. In order to map concepts of the national, implementation-level model to concepts of the core model, we must modify in some parts the core model in order to be more "implementation-like". A match between concepts in the models as they are is often not found and structural equivalence can not be established while on an intentional level (see section 3.3), a correspondence does exist.

Examples are:

a. In conceptual models, many-to-many (n : m) association between classes are frequently used. This can be expressed with the help of one association class as it is modeled in the core model. In the national models this is not the case. Because the national domain models we tested are closer to the database, a many-to-many association will be modeled as two 1:n associations.

b. The core model has a *Person* class with two subclasses *NaturalPerson* and *NonNaturalPerson*. In the Dutch test data source there is only one table, hence class in the model, called '*Subject*' that contains both natural and non-natural persons, but there is an attribute called '*subjectType*' that holds a value to distinguish between the two categories. So there is (conceptually) a correspondence here, but it will not be found (in the present prototype).

Translation via the core model

One of the basic principles of the Query Translator prototype design is to use the core model as intermediary between national models instead of a direct mapping between all national models. As the core model is less detailed than the two national domain models, a number of possible matches between the two national models are 'lost', especially between properties.

6. RECOMMENDATIONS

Based on our experiences with the query translation by our prototype Query Translator we make some recommendations for future modifications in core and national cadastral models.

6.1 Extent of the Core Cadastral Model

For harmonized access to the different national cadastral data sources, it is necessary to recognize and define the most important search criteria. The core cadastral model should contain all classes and attributes that are known to be used by end-users in selection queries. These classes and attributes could be selected on the basis of a use case analysis of actual search queries in the national context, or in the context of EULIS. Attributes that will most likely be used for selection purposes are for example:

- address
- name (of a person or an organization)
- cadastral parcel number
- type of right

It is very probable that in many queries the geometry and topology aspects will be 'shielded' from the end-user. He or she will e.g. zoom in or zoom out on a map, or click on an object, but will not directly specify coordinates. It is rather the 'administrative' selection criteria (address, name, parcel-number) that will be used. The core model should therefore contain these concepts as abstract classes that function as 'placeholders' for the localized classes, for example *dutch:PostalAddress*, *greek:PostalAddress*.

This does not mean that it is recommended to model all the components of for example *Address* ('street', 'house-number', 'town', 'district'), but just the (abstract) class '*Address*', maybe with two subtypes '*PostalAddress*' and '*LocationAddress*'. A Greek address is, also in the real world, different from a Dutch address, so the core model can never offer the right 'structure' for both situations. Thus, the core model should offer more classes that are strictly conceptual and that do not have a 'structure' in the sense of a list of attributes. Only in the national cadastral models these classes will get a data structure by extending the core model classes.

It is important to find the appropriate level of detail. The core model should contain all essential selection properties, but also less technical detail such as the attributes *tmin* and *tmax* for the temporal aspects, but an abstract class e.g. '*VersionInfo*' or '*Temporal*'.

6.2 Modeling Issues in Core and National Cadastral Models

The following recommendations are only small changes in the modeling of core and national cadastral models, but would make the translation between models much more successful. The chance to find matches between the national models, especially in a two-step process with the core model as intermediary, will increase.

First of all, we recommend providing more classes for groups of attributes in core and national cadastral models. These complex data types group as 'attribute classes' the attributes that belong together. Candidates are for example: Address, PersonName, OrganizationName, PostalAddress, LocationAddress, ParcelNumber etc.

Secondly, a harmonization of attribute values would improve the query translation. For selection queries with conditional statements, it can be necessary to have knowledge of the list of attribute values that can occur. In the following example there would be the problem that the user does not know what to fill in as selection criteria for '*typeOfRight*' if it is not clear what can be chosen. These can be implemented as 'drop down' lists in the user interface supposed that the list of permitted values is finite. Precondition for such harmonization is that the permitted values are defined in the UML models of core and national cadastral models.

6.3 Architecture of the Query Translator

Another approach to solve the problem that the national models are closer to implementation then the core model would be to make the national domain models used in the Query Translator more conceptual and therefore to have e.g. one n:m association, instead of two 1:n associations. So this means that the Query Translator has to map from one conceptual model to the other (if the user wants this) and from the conceptual model to its technical data model. This can be handled by the Query Translator, but could also be part of the Web service application software that accesses the cadastral data source. This last architecture set-up would move the responsibility for correct mapping/translating between the conceptual and the technical model to the Web service provider, and leave it out of the 'middle layer' to which the Query Translator belongs in the overall architecture. This is of course a more fundamental change in the Query Translator design.

7. CONCLUSIONS AND FUTURE RESEARCH

In this work, we presented the translation of queries between two national cadastral systems via a common core model, the core cadastral model. By reformulating queries from the Dutch into the Greek cadastral system via the core cadastral model, we demonstrated that data can be exchanged between different information systems which have no direct links and no common historical background but which are only extensions of a common core model. Both systems were not adapted to each other but modeled to reflect the basic concepts of European cadastral systems as defined by the core cadastral model as well as the particularities, e.g. in legislation or administration, of their countries. Concepts in the core model which are present as equivalent or specialized concepts in every national cadastral system can therefore be exchanged between these cadastral systems. The relations between national models and the core cadastral model were identified by domain experts during the conformity verification which is used as basis for the query translation. The benefit of a query translation via the core cadastral model is that even without complete correspondences between all national cadastral systems, meaningful data exchange can take place. The use of mapping documents that are based on the conformity verification ensure that only semantically corresponding information is retrieved. Also a partly conforming model can be included in this way into a cadastral information exchange infrastructure.

In the current version of the Query Translator, we translated queries on the basis of matching concepts in the Dutch and Greek cadastral models. We tested translation based on equivalency between classes in two models, between attributes and between (simple) associations. Our results with the first version of the prototype Query Translator are encouraging, but it was difficult and with the current version almost impossible to deal with the following heterogeneity issues.

Firstly, national models can extend the core model in very different ways. Thus, it might be the case that data is not available on the same level of detail in both cadastral systems. This means that there are differences in the generalization-specialization hierarchies of both models. Approximate queries based on the hierarchical structure defined in core and national models and supported by ontological reasoning on this hierarchy would offer a solution to this problem.
Secondly, the differences in the abstraction level, i.e. the core model is more conceptual and the national domain models are closer to the technical implementation, lead to problems during the identification of mapping relations and the rewriting of queries. Recommendations were discussed in previous sections.
Thirdly, the Query Translator offers no translation for those parts of the national model which have no corresponding part identified in the core cadastral model. It is clear that there are aspects, e.g. in the legal context, which are very difficult to represent in the core model in such way that correspondences can be identified between all – or at least most – national cadastral systems and the core model. In the query translation, we could therefore benefit from improved relations between the core cadastral model and the national models.
Future work on the query translation should address the above mentioned problems and be used as feedback for further development of core and national cadastral models.

In general, the benefits of using OWL ontology files in the Query Translator were clear. OWL can not only easily be used in Internet applications due to the fact that OWL is serialized in XML but its constructs ‘equivalentClass’, ‘equivalentProperty’ and ‘sameAs’ provide a good basis for the definition of mapping relations.

In the present Query Translator prototype, the query is only sent to one single data source. It presupposes that the end-user knows in which country’s cadastral database to look. The current design of the user-interface reflects this: now, when the data source has more attributes than the query model or attributes that cannot be translated to the query model these are also presented to the user as extra selection criteria and in the query results. If, however, we want to answer a query like ‘Select all real estate property of this firm in Southern-Europe’, it must be sent to a number of national data sources at the same time. In a distributed setting, such service would be based on a number of separate national Web services, similar to EULIS, but which can be reached by one single query formulated in the terms of the chosen query model. Such a cross-border selection query needs a different user-interface, one that is truly ‘pan-European’. The role of the core model will become even more important in such a completely connected system. If the core model would be extended with classes that are relevant for selection queries and when also lists or taxonomies of possible selection values would be incorporated, this would greatly improve its potential to act as mediator model between European cadastral systems.

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BIOGRAPHICAL NOTES

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Cadastre 2014 – From Vision to GIS

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Key words: Cadastre 2014, GIS, database design, topology, versioning, transaction, indexes, web services, open system, interoperability.

SUMMARY

This paper presents suggestions on how to proceed from a Vision expressed in a scheme to building a physical GIS database. It focuses on three main areas namely expression of a physical design for a GIS database, supporting multi user environments and finally provides suggestions on what to consider when making data public available using Web Services. In designing GIS databases discussions are promoted on defining spatial relationships between object classes. Multi user support in enterprise environments discusses options for versioning and disconnected editing. Web services introduce openness and interoperability. Throughout the paper suggestions are made on what to consider when designing GIS databases.

1. INTRODUCTION

With the Cadastre 2014 initiative the traditional Cadastre transforms from a description and registration of parcels to include description of the complete legal situation on the land including public rights. It proposes (Kaul and Kaufmann, 2003; Kaufmann and Steudler, 1998):

- That an inventory of data concerning all legal land within a certain country or district is methodically arranged in land objects defined by either private or public law (This presumes including all elements of civil, common and statutory law where those exist);
- That the definition/outline of a land object is either based on survey of object boundaries or through other means of boundary definition like legal descriptions of boundaries;
- That land objects are systematically identified and arranged in groups of legal land objects each sharing the same characteristics namely the legal aspect that defines them;
- That the outlines of the property, the identifier together with descriptive data, may show for each separate land object the nature, size, value and legal rights or restrictions associated with the land object;
- That land can be modeled using multiple representation of land objects each identified by unique group definition;
- That in identifying land through land objects, relationships can be established between land objects or groups of land objects;

- That any Cadastral system no longer should be seen as individual and isolated but rather being a part of a larger group of systems receiving and contributing with Cadastral information.

The sharing of Cadastral data and models across multiple systems allows for integration between maps and registers. The perception of maps is changing from maps being legal documents storing information to temporal, user defined representations of the cadastral object model. From the cadastral object model maps can be created at different scales and registry data in different forms/reports.

1.1 GIS evolution

During the last decade Geographic Information Systems (GIS) has evolved from PC based applications, with georelational file structures, into enabling spatial data to be stored in relational databases and accessed through Enterprise wide application services with the ability to:

- Define, manage and maintain spatial and spatial related data sets and their relationships;
- Visualize information and generate cartographic products;
- Analyze geographic data sets to create derived information;
- Support query-based information services;
- Share data with other systems through industry specified interchange and communication standards.

With its ability to design and implement database schemas with spatial objects, their spatial and associated relationships, main and strong use of web services for data publication GIS technologies has matured to fit the vision of Cadastre 2014. Developing methods and technologies to accommodate the recommendations of the Cadastre 2014 represents the real challenge for the Cadastral communities.

1.2 Designing the GIS database

From a GIS perspective the design of any GIS database initially involves three steps (Arctur and Zeiler, 2004):

- The first step is to verify the conceptual design, which involves the identification of the products that will have to be produced by the application. What are the information requirements and what would be the key spatial and spatial related objects to represent these requirements?
- The second step is the logical design, which involves the definition of the tabular database structure and behavior of descriptive attributes, spatial properties of the datasets and preliminary GIS-database design.
- The third step involves the physical design, which implements, reviews and refines the preliminary GIS-database design and further defines workflows to conform to the organizations business practices.

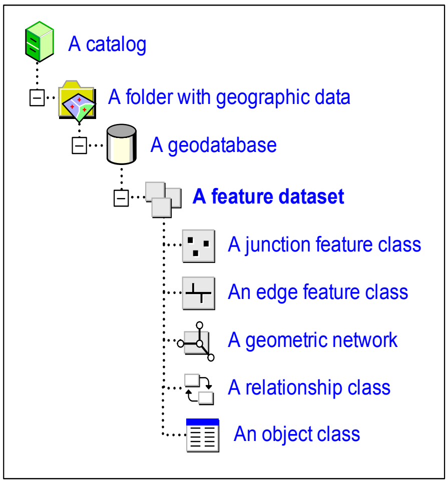
The Cadastre 2014 is expressed as a cadastral object oriented model and represents a generic formulation of best practices within the Cadastral community. As such it expresses parts of the conceptual and logical design in the GIS database modeling process. Being a generic model however it represents an excellent starting point for defining a modern cadastre but likely needs to be adapted and modified to the individual needs of any Cadastral organizations. This presentation suggests three areas to consider when moving from vision to physical design of the Cadastre 2014:

- Develop a physical design;
- Support for multi user environment;
- Openness and Interoperability.

2. DEVELOP A PHYSICAL DESIGN

A GIS database is different from an ordinary database structures in its ability to work with spatial objects and spatial and associated relationships. Designing a GIS database scheme from the Cadastre 2014 vision should include options to define:

- Spatial associated objects like parcel owner name, zoning restrictions, rights obtained through common law, conveyance;
- Spatial objects like point, lines, polygons, annotation or dimensions outlining monuments, survey boundary lines, parcel identification, measurements;
- Subtypes for optional grouping of objects within an object class or table with common domains or topology rules;
- Relationship classes to manage thematic relationships between spatial associated objects (tables), spatial objects or a combination like parcel to owner identification, survey point to coordinate;
- Topology for describing special relationships between spatial objects like Survey Boundary shares boundary with parcel;
- Rules to define legal attribute values, thematic relationships between objects/classes, topological relationships between spatial objects or subtypes like range values for measurements.



Cadastre 2014 was developed through an object oriented modeling approach using the Unified Modeling Language (UML) syntax. The UML syntax can be used to define object classes with spatial representation (point, line and polygons), subtypes and associated tables. UML however does not include syntax to describe spatial relationships like topology rules and spatial relationship classes.

2.1 Defining spatial relationships

A spatial relationship defines relations between spatial objects like the boundary of a zoning district is determined by the boundary of parcels, which again is defined from the survey boundary line. Modeling of spatial relationships can happen through general association between object classes, topology rules that determine the topological integrity of the object data and network structure like cadastral networks. Associated relationships are typical defined as joins or relate associations being either defined in the GIS database design process or generated ad hoc during user interaction with the GIS database. After building the initial GIS database with classes and associated relationships (using UML schema) GIS software allows for the definition of topology rules to validate the spatial integrity of data. Topology rules can be either permanently defined in the GIS database or created on fly during a user editing session. A third type of spatial relationships is reference established between objects in a point class and objects in associated point, line or poly object classes. In a Cadastral GIS database the location of monuments can be determined from either field measurements like terrestrial survey or Global Positioning System. In either case monuments are defined by a physical reference to a coordinate system. Monuments define survey boundary lines, which again defines parcel boundaries. Any change in the location of the monument will be reflected in its dependencies, which will update their own location. More popular this type of relationship has been termed survey linking. In the GIS database this can either be modeled through permanent relationships, which are rather resource intensive, or through on-the-fly computation of displacement vectors.

2.2 Defining topology

Within GIS topology has moved from a traditional stored topology being a spatial data structure ensuring format consistency to a rule based topology represented by a collection of tools and techniques for modeling consistency between different spatial objects and supporting different types of relationships between these. Stored topology has been used to ascertain that spatial data structures were consistent and had a 'clean' topological fabric like polygon closes and lines were snapped together. All topology rules for point, lines and polygons were stored in table structures. Any updates to the geometry of the spatial objects would require either geometric modifications of individual objects based on user defined settings and/or an update of the point-node topology. These updates included an update of all content in each tables defining the stored topology. Another shortcoming was the inability of the model to support intersecting lines without creating a split. An example is survey measurement lines which can intersect without splitting lines into segments.

Alternatively a topological relationship between spatial objects could be expressed by topological rule like: "A legal description polygon object **must share boundary** with a surveyed boundary line". Rule based topology validates spatial relationships on the fly and provides tools to manage shared geometry between spatial objects and flag any inconsistencies hereby maintaining the referential integrity between objects. Once established it only verifies rules on altered objects in participating object classes and hereby minimizes the load on the database when checking the rules and updating the object geometry.

When defining a topology, spatial object classes that will participate in that topology will have to be associated to the topology. Topologies can contain one or more spatial object classes whereas a spatial object class only can participate in only one topology. Using topology to maintain shared geometries cluster tolerance, ranking and topology rules can be defined.

- Cluster tolerance, is the distance range in which all vertices and boundaries are considered identical or coincident between two spatial object classes. Vertices and endpoints falling within the cluster tolerance are snapped together.
- Ranking is defined at an object class level, and controls how much the objects in that class can potentially move in relation to objects in other classes when a topology rule is validated. The higher the rank, the less the objects may move in relation to objects from other classes. For example, a topology is defined with two spatial object classes: parcels and survey boundary lines. These two object classes need to be coincident, but in some cases they are not. In the cases in which the object classes are not coincident, the parcels should move and snap to the survey boundary lines. To accomplish this, the parcel lines are given a lower rank than the survey boundaries.
- Topology rules define a condition in the topology, which is a problem or possible problem in the topology objects. Topology rules can be defined for the objects within an object class or alternatively for objects between two object classes.

Dirty areas are associated to a topology and represent regions where the spatial objects participating in the topology have been modified (added, deleted, or updated) spatial integrity of the topology has not been validated (Hoel et.al, 2003). When a topology is initially created the full extent of the spatial object class is regarded as dirty area and needs to be validated according to the topology defining them. Validation is a process that manages object geometries and identifies violations in the defined rules. Based on the cluster tolerance and ranking, objects are snapped together and aligned based on an underlying integer grid ensuring that coincident points stays coincident. After geometry updates topology rules are verified and any violations are marked as errors. Once an error has been identified it is up to the user to correct the error or mark it as an exception. Errors can have three states:

- Leave the error unresolved in the database;
- Fix the error with available tools;
- Mark the error as an exception.

When marked as a legal exception subsequent validations of the objects will not regenerate an error. Allowing errors to exist and persist in the GIS database creates an environment in which many diverse workflows can be applied. Because errors are stored in the database users have the option of saving edits (as well reconcile and post – see versioning) without fixing the errors. This topology structure supports a variety of workflows and allows objects to be displayed without having to validate them.

One advantage of the shared geometry approach is that when polygon objects are stored as closed rings, meaning that the boundary between polygons is stored with each polygon object coincident boundaries can easily be generated on the fly. Edits to one shared boundary will then affect other shared boundaries. Compared to query performance from traditional stored topology structures this on the fly discovery of shared geometries has proven to increase performance significantly. Further storage through shared geometries makes editing more flexible.

2.3 Queries and Indexes

One important thing to note when designing a GIS database is to ensure its ability to maintain performance during different loads. Careful analysis has to identify what queries, being spatial and non-spatial, are necessary to execute against the database and estimate the effectiveness of those queries from a load perspective. A simple example, to stress the point, could be to manage error estimates for a given survey measurement. One design approach is to store all error estimates for a given survey with each individual measurement record in measurement table. Every time an error estimate for a given survey has to be updated a SQL SELECT statement will have to identify all the measurements belonging to that survey and UPDATE the relevant fields in each record with the new value. Through normalization a Survey Meta Information table can be defined storing error estimates for each survey in one record. Updating error estimates now only requires selecting and updating one record. During the physical design process of the GIS database prototyping and testing of performance and scalability running scenarios with expected data load and simultaneous user access is an utmost necessity. The point is that improper database design can have huge performance and scalability implications potentially failing projects.

Once a solid database design has been developed and tested using the main queries (as well as a sampling of the organizations project data), indexes can be introduced into the physical design process to further optimize the performance of the queries against the GIS database. Indexes allow speeding query performance of commonly used columns and thus improving the overall speed of the database. Indexes are pointers to the individual fields in records which supports fast retrieval of data from queries. Two types of indexes are: Clustered indexes and non-clustered indexes. The clustered index represents a physical sorting of the rows in a table allowing for only one clustered index per table. The non-clustered indexes are created outside the database table and contain a sorted list of references to the table itself. It is worth noticing that non-clustered indexes will affect the performance process of the database when doing inserts and updates. For this reason it is important during the design phase to test queries to be implemented to verify and tune indexes in the data model. Some GIS software allows for the creation of indexes to object classes and associated tables during the physical design process of the GIS database. To further enhance performance indexes and spatial indexes are often generated default by the GIS software when generating GIS databases from the database schema.

3. SUPPORT FOR MULTIUSER ENVIRONMENT

Cadastral systems have a potential to develop themselves towards large enterprise systems managing and associating itself with a variety data. Many types of users will be associated working with information from the Cadastre from collecting field data, to manage, use and publicizing cadastral data through either map services, intra net or web applications and portals providing information to public and professional communities. Each of these users will have different needs and requirements to the interaction with the cadastral system. Thus the system will have to support maintainability, scalability, usability and interoperability.

3.1 Scalability of the GIS database

Two technologies are currently competing in introducing GIS enterprise systems being either database vendor driven and GIS software vendor driven. The database vendor driven developments are based on traditional database design where a number of tables are established and different vendor applications maintain the relationships. In this configuration most of the processing load is placed on the data server with little load on the application server. In a small scale (large) multi-user environment this approach could lead to an overload of the database server. In the GIS vendor driven approach the load is balanced between the client server(s) and the database server(s) thus optimizing processing time when doing querying. If performance is an issue and the number of records in a table is less than 10^8 a binary structure in the database schema will provide some advantages. The binary structure compresses data into a single row structure thus providing lesser data volume. Having data in a single row further optimizes performance since data will not have to be processed out of a VARRAY structure or from multiple rows as would be the case with complex linear or polygon data as could easily be the case with Cadastre 2014. If data corruption is a concern GIS vendor drive server technology performs integrity checks of the data through business rules in the application. This environment maintains the integrity of the object geometry, which cannot be destroyed through SQL statements that may be executed directly against the database.

3.2 Scalability of user environment

An enterprise cadastral solution must provide support for many users creating and updating large amounts of geographic information. In providing this functionality, the editing environment must have the capability to support edit sessions that typically span longer periods, undo or redo changes made to the database, and a facility to monitor how data and the database have evolved over time. The established workflow processes for many cadastral applications are based on a cycle of job definition, -execution, -approval, and -maintenance - processes that requires many people to simultaneously edit data in an environment that allows them to make those changes visible only to those who have an interest in seeing them. Any GIS solution for a Cadastral system should approach long transaction and history management and be capable of supporting this type of project workflow in a simultaneous fashion.

Due to the inherent connectivity and spatial relationships in the Cadastral 2014 vision a more flexible approach is required to multi-user editing, which does not depend on row locking tables. This is so, because the types of edits typically done on spatial data may introduce lock escalation and deadlock situations, which would ultimately degrade performance. The following provides an example. Although related to surveying it serves well as a general example. Suppose there are two editors both working on a cadastral network. One editor makes changes to one of the object classes involved in the cadastral network; the observations of a survey boundary line, while another editor updates spatial elements of a related object class; applying GPS observation to a monument (Survey points). Changes made to objects in either object class could have an adverse effect on objects in the other. For example, GPS observation on a point could move the survey boundary line. In a row locking environment this situation could introduce lock escalation (when row locks become page locks, page locks become whole table locks), and deadlock situations (where two transactions are waiting for each other to unlock data, preventing any further updates to the data until the deadlock is resolved). This can have a huge negative impact on database performance and scalability. Once committed to the database, such transactions are also difficult to undo, because the database has only one state—namely the most recently committed transaction.

An alternative approach is to implement an optimistic concurrency data-locking model called versioning, which means that no locks are applied to the affected features and rows during long transactions. Versioning involves recording and managing changes to a multi-user GIS database by creating a 'version' of the database— which is an alternative, independent, persistent view of the database that does not involve creating a copy of the data and further supports multiple concurrent editors. A version is a type of virtual workspace, and typically could represent a job or a historical snapshot of the database. As the changes made to each version are recorded independently, versions are unaffected by changes occurring in other versions of the database—editors can simultaneously update the features or rows in one version without explicitly applying locks that would prohibit other users from modifying the same data in another version. Once the edits in a specific version are complete, the editor will submit them for posting to the master version, which constitutes the production database. During the posting process edits from the version (or virtual workspace) will be reconciled with the production dataset and potential edits posted from other version.

Although the absence of row locks introduces the inevitability of editing conflicts, versioning makes it easy to detect and resolve those conflicts. In real-world editing situations, conflicts are the exception rather than the norm. Given the small number of edits in comparison to the volume of data stored in a GIS database, the overhead of resolving these conflicts is relatively minor compared to the restrictions of prohibitive data locks or having to check features out of a central database to some local repository for the duration of a long transaction.

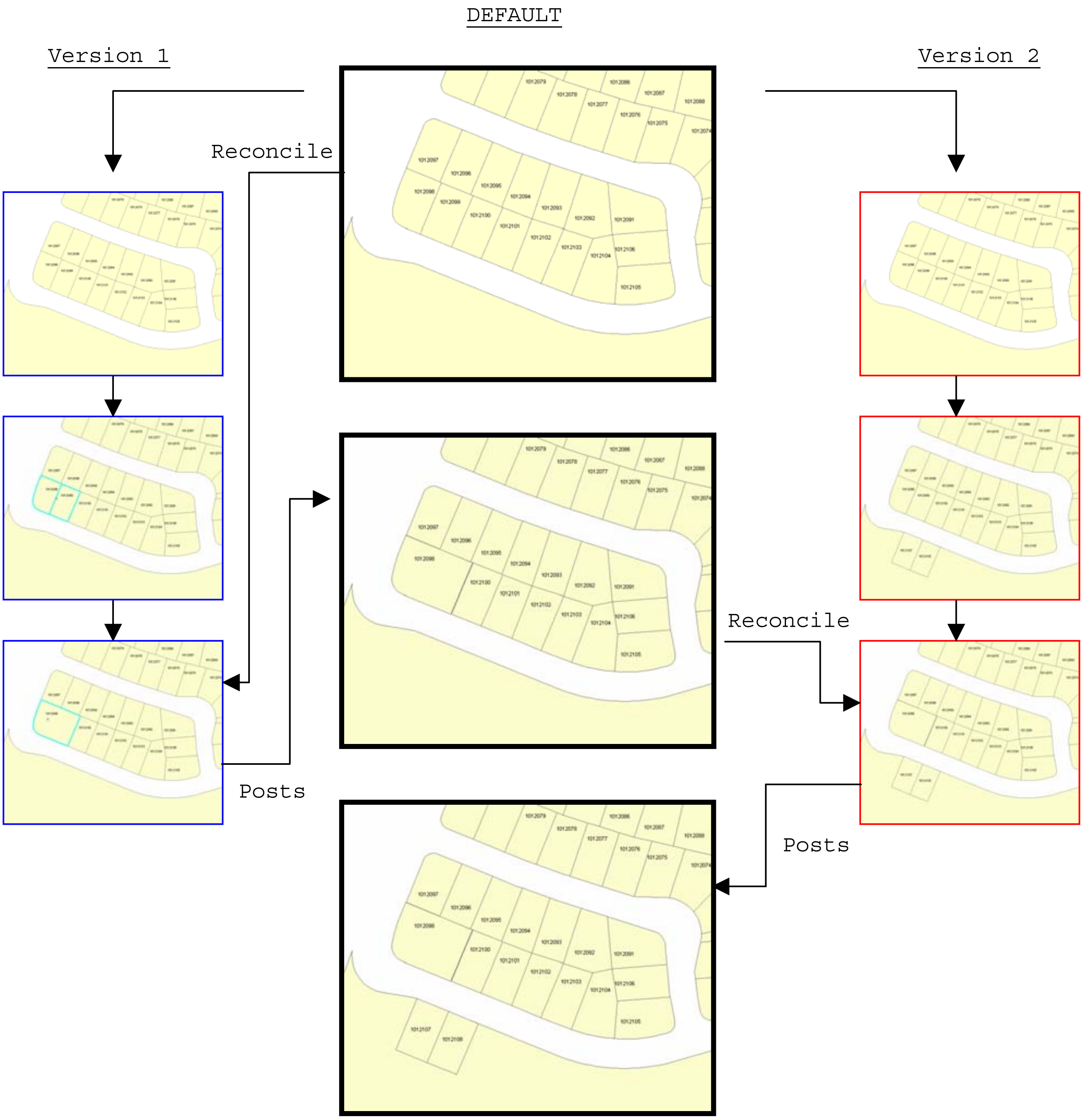


Figure 1: Two versions, Version 1 and 2, are created from DEFAULT. In Version1 two parcels are merged into 1 parcel. Version 1 is reconciled for changes in DEFAULT and posts it changes which then become DEFAULT. Two new parcels are added in Version 2 and Version 2 is reconciled with DEFAULT. Since a change has occurred to DEFAULT this change is reconciled into Version 2. No conflicts are detected and Version 2 is posted and becomes DEFAULT.

3.3 Disconnected editing

In supporting users another important design aspect is to determine how work processes will take place. Will users access the cadastral system online or is there a need for some users to work disconnected from the system. Disconnected editing is a concept that supports a system architecture where users inside an enterprise database are connected from the field or regional offices through a WAN or LAN. Maintaining an open connection for these remote users is either impossible due to physical constraints or will carry to heavy a load on the network increasing the interaction time with the system. Disconnected editing allows these users to edit an enterprise GIS database while physically being disconnected from the database server. Users generate a version in the enterprise database. The version is checked out and extracted to a local machine. The user performs edit operations and once connected to the enterprise system all changes are reconciled and posted back to the enterprise database.

4. OPENESS AND INTEROPERABILITY

The Cadastre originally had the focus, with rare exceptions, on individual, organizations. With the recommendation of the Cadastre 2014 the focus is on the integration of spatial data and analysis in the mission-critical business processes and work flows of the enterprise and on increasing the return on investment (ROI) in GIS technology and databases by improving interoperability, decision making, and service delivery. The cadastral model thus needs to support interoperability to be able to exchange information to share and transfer this information between organizations with different standards and software.

4.1 What is openness?

An open Cadastral system should allow for the sharing of geographic data, integration among different GIS technologies, and integration with other non-GIS applications. As discussed it should be capable of operating on different platforms and databases and scale to support a wide range of implementation scenarios from the individual contractor or mobile worker using GIS on a workstation or laptop to enterprise implementations that support hundreds of users working across multiple regions and departments. An open GIS should expose objects that allows for the customization and extension of functional capabilities using industry standard development tools.

A Cadastral chief surveyor, for example, would expect a Cadastral enterprise GIS solution to provide a spatial data warehouse supporting shared spatial data and services across multiple agencies such as tribal land, environmental protection, water rights, mining claims, and information technology (IT). Each agency might also have a local GIS database to update and maintain the framework data for which the agency is responsible and provide an e-government portal for public access. Today's "always on" availability requirements and the growing security considerations also dictate that any GIS solution operate in clustered, high-availability environments and be easily replicated to remote backup server locations.

4.2 What is interoperability?

Many organizations need a cadastral solution capable of integrating services and data from multiple sources and in different formats. Any GIS technology and products must support this level of interoperability. Spatial data within a Cadastral system should be easily accessible by other technologies and applications through data converters and direct read access like Spatial Data Transfer Standard (SDTS), Vector Product Format (VPF), imagery, computer-aided design (CAD) files, digital line graph (DLG), and TIGER®. Of equal importance, a cadastral GIS application should enable organizations to share services and communicate across different vendor implementations. An open, distributed, and networked GIS architecture provides the framework for sharing data and services.

4.3 Metadata

To build a strong spatial data infrastructure, metadata is crucial. Metadata and metadata servers should enable users of a cadastral system to integrate data from multiple sources, organizations, and formats. Metadata for geographical data may include the data source, its creation date, format, projection, scale, resolution, and accuracy. Some GIS vendors allow users to create, manage, and edit metadata stored in an XML representation of Federal Geographic Data Committee (FGDC) Content Standards for Digital Geospatial Metadata or of the ISO 19115 Metadata Standard. Metadata Services should be established to enable users to create a central, online metadata repository which facilitates publishing and browsing metadata over the Internet.

4.4 Web services

A cadastral publication solution based on Web services avoids the issues and complications of a Cadastral applications being tied to the spatial schema of a specific RDBMS vendor and allows GIS vendors to manage their own data using the best methods and formats for their tools in whatever database environment they choose. In addition, Web services allow server-to-server sharing of data and services, as opposed to integration only happening at the client level as it does with standards that are focused on the DBMS. Some GIS vendors choose to use an RDBMS with schema and methods that perform optimally for their tools. Others use file systems. Web services provided by GIS vendors means that each organization can build and manage its own GIS data and readily provide GIS services (data, maps, and geoprocessing) to a larger audience in a common environment. Web services provide a framework for fusing computing devices via open networks (the Internet, wireless, and local networks). In Web services, computing nodes have three roles: client, service, and broker. A client is any computer that accesses functions from one or more other computing nodes on the network. Typical clients include desktop computers, Web browsers, Java applets, and mobile devices. A client process sends a request to a computing service and receives results for each request. A service is a computing process that awaits requests, responds to each request, and returns a set of results. A broker is essentially a service metadata portal for registering and discovering services. Any network client can search the portal for an appropriate service. Server and broker technologies are typically used on UNIX, Linux, and Windows platforms. Web services can support the integration of information and services that are maintained on a distributed network. This is appealing in organizations, such as local governments, that have entities or departments that independently collect and manage spatial data (e.g., surveys, land records, administrative boundaries). At the same time, many of the functions of a local government require these data sets to be integrated. The use of Web services (a connecting technology) coupled with GIS (an integrating technology) can efficiently support this need. The result is that the various layers of information can be dynamically queried and integrated, while at the same time the custodians of the data can maintain this information in a distributed computing environment.

4.5 Communication

With the introduction of Web services, standards providing interoperability needs to be supported. Distributed multi vendor GIS services can be dynamically integrated into applications using the interoperable standards of XML and SOAP. Adapting OGC's Web Map Service (WMS) and Web Feature Service (WFS) connectors enables GIS to provide Web map services that adhere to the OpenGIS® Web Map Service Implementation Specification. The OGC WMS connector produces maps of georeferenced data in image formats (PNG, GIF, JPEG) and creates a standard means for users to request maps on the Web and for servers to describe data holdings. The OGC WFS connector enables GIS vendors to provide Web feature services that adhere to the OpenGIS Web Feature Service Implementation Specification. The connector provides users with access to geographic (vector) data, supports query results, and implements interfaces for data manipulation operations on Geographic Markup Language(GML) features served from data stores that are accessible via the Internet. GML is an OpenGIS Implementation Specification designed to transport and store geographic information. It is a profile (encoding) of Extensible Markup Language.

5. CONCLUSION

Implementing Cadastre 2014 represents just the beginning. Current GIS technology provides a variety of options for implementing a robust land records management system; as it should. A core cadastre data model should be the foundation of a system built upon industry standards and interoperable information technology. While the model needs to be flexible, adaptable, and extensible (Lemmen, et.al.), as represented in the Cadastre 2014 Data Model, there are other technical issues to be addressed as land administrators approach the design and implementation of such a model. Regardless of the GIS or database product chosen, whether open source or commercial, the design and implementation must follow a data modeling process, and support such land records functions as rule-based topology, multi-user access with version management, and interoperability of data and other systems. Finally with the mandate and growth of e-government, the Web has become the technology, which modern systems must reside, or support for open access to public domain data

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BIOGRAPHICAL NOTES

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Extensible Models and Templates for Sustainable Land Information Management – Intent and Purpose

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Key words: Standardization, Cadastre

INTRODUCTION

To arrive at a pragmatic core cadastral content standard and ontology and a comparative model of the related functions and processes, we have to share some understanding of the world we live and work in. We have to make some assumptions of what the future may be and ensure that the models we design will easily adapt to remain relevant in the future. We have to understand the characteristics, needs, and wants of users if our models and standards are to contribute to a better society.

This paper draws a parallel between the major motivations for the development of the Standardized Core Cadastral Domain Model and the FGDC Cadastral Data Content Standard. In Section 4 of this paper, I propose that the Standardized Core Cadastral Domain Model be renamed to the Standardized Core Cadastral Data Dictionary.

Cadastre 2014 provided a glimpse of what the future may hold for land information management land administration. We see global trends in the information and communication technologies (ICT) market. Notice that GIS is not called out separately in the previous sentence. In this context, what was formerly known as GIS – now more commonly called geospatial information processing – is a subset of mainstream information technology. Section 1 of this paper briefly reviews some pertinent ICT trends and futures.

Technology is crucial to effective land administration and a real estate market, and efficient property transactions require efficient processes for clear and timely communication between organizations that are geographically distributed using heterogeneous computing environments. It is thus necessary to critically review and understand each of the inexorably linked components – and the flows and interactions between them, as well as technological and societal trends – to arrive at templates and standards that will enable sustainable land administration infrastructures and affordable real property transactions.

Property registration provides a foundation for the real estate market, which in turn, requires a trustworthy banking and financial infrastructure. It is interesting to observe that property registration infrastructures remain mainly regional/local, while banking infrastructures are global. The real estate market has, at least for a subset of society, become global as well. In Section 2, discussion includes the information exchange models deployed or in development by mortgage banking associations, real estate agencies, and the land title insurance industry and provides an overview of how cadastral information is used these commercial environments.

The COST G9 and FIG Commission 7 Conference on Standardization in the Cadastral Domain will focus on the development of a shared set of concepts and terminology for the cadastral domain and consider international standardization of these concepts in the support of meaningful exchange of information between organizations, or component-based system development through applying standardized models.[1] A survey[2] of the previous work by COST/G9 and FIG Commission 7 on the subject matter leading up to this conference focuses on the development of core content standards, definition of the object and class relationships in the cadastral domain, and description of selected processes from specific European countries. The previous reports also identify the difficulties that exist in comparing processes and their cost and efficiencies across countries.

Section 3 provides an overview of a comparative model for property transaction costs based on ongoing work in the development of indicators for global comparison of real property transactions.

1. INFORMATION AND COMMUNICATION TECHNOLOGIES – TRENDS AND FUTURE

1.1 Simplicity Looms Large

Every computer user has struggled with computer problems. When a system suddenly crashes, when months of research data is corrupted, and we toil many hours to repair the damage, we have probably all wondered whether technology or the user is in charge. This is a simple example of what may be the IT industry's greatest challenge – conquering complexity.

It is safe to say that technology has made life more complex – true also in the cadastral domain. End-users in all industries are searching for solutions and applications to simplify their daily tasks.

In an October 30, 2004, survey on information technology published by *The Economist*[3], Donald Norman is quoted, "Today's technology is obtrusive and overbearing. It leaves us with no moments of silence, with less time to ourselves, with a sense of diminished control over our lives"[4] and "…. it is time for human-centered technology, a humane technology."[5]

Research from the IDC quoted in *The Economist*[6] leads to the conclusion that ICT complexity – and, by implication, complexity in the ICT infrastructures that support cadastral systems and real estate markets – will continue to haunt the operators and owners of ICT infrastructures. The IDC figures show that the ratio of expenditure on fixing existing systems vs. buying new systems (75 percent vs. 25 percent) has reversed from 15 years ago. A recent sample of firms surveyed by the IDC shows that 70 to 80 percent of their IT budget now goes toward fixing old systems. This leaves only 20 to 30 percent available for new purchases.

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[1] http://www.kinf.wiai.uni-bamberg.de/SICD/
[2] Survey of reports and presentations published on the COST G9 Web site. http://costg9.plan.aau.dk
[3] *The Economist*. October 28,2004. http://www.economist.com/surveys/PrinterFriendly.cfm?Story_ID=3307363
[4] D. A. Norman, The Invisible Computer (Cambridge, MA: MIT Press, 1998).
[5] Ibid.
[6] http://www.economist.com/surveys/PrinterFriendly.cfm?Story_ID=3307363

These IDC statistics have a direct impact on land information management infrastructures around the world. The figures validate investments that technology companies, such as Intergraph, Oracle, MapInfo, AutoDesk and LaserScan, have been making in standards and technologies for interoperability.[7]

In the context of the management of geospatial information some database vendors, such as Oracle, have addressed the simplification challenge and ensured that all Oracle databases are geospatially enabled by treating geospatial data simply as another data type, accessible through SQL and XML Query.

There should be no technical reason why property transactions or maintenance of data in a land information system should be more complicated than online home banking – after all, telecommuting is here to stay.

To achieve affordable, effective production and delivery of the appropriate information to the right place at the right time, land information management agencies (which are still very much government centered) continue to drive solution providers toward sustainable solutions that also simplify life for employees.

Google.com presents a very good example of simplicity. The user interface consists of approximately 31 words, a textbox, and two command buttons. This extremely simple interface hides some very complex logic and operations – a concept that we should seek to provide in land administration and real estate management.

1.2 Building Sustainable Infrastructures on Legacy IT Environments

In September 2003, the United Nations Economic Commission for Europe's Working Party on Land Administration (UN-ECE WPLA) reported that "Land administration reforms across the world during the past decades have focused on building or rebuilding land title registration and cadastral systems. Grants or loans that supported capacity building concentrated on providing the necessary skills to operate the new technologies. However, strategies for long-term sustainability were rarely built into these programs. The development of business skills and a business ethic has not always been regarded as a priority. Today the beneficiaries of many of these programs are facing difficulties since much of the technology of the 1990s is obsolete. It needs to be replaced but how can this be achieved? Who will pay for what some call a 'technology refresh'?"[8]

A sustainable land information management infrastructure can be achieved by designing it to remain functional and operational given the certainty that there will be variations and changes in environmental factors such as ideology, political priorities and goals, government, legislation, technology, and resource availability.

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[7] http://imgs.intergraph.com/interop/

[8] Report from Workshop on Spatial Information Management for a Sustainable Real Estate Market. Economic Commission for Europe. Working Party on Land Administration 3rd Session. Geneva, 17-18 November 2003. http://www.unece.org/env/hs/wpla/3Session.htm

There is evidence[9] that agencies with legacy systems are applying resources to improve internal operations using existing systems before replacing systems. To this end the technologies and services being sought are those that would help agencies integrate and simplify the once leading-edge, now legacy, systems using non-invasive integration methodologies.

To provide a robust and sustainable land information management infrastructure, in the context of a dynamic business environment, requires that certain foundation components exist to allow the infrastructure to rapidly adjust, adapt, and respond to influences while maintaining continuity in operations and service delivery.

Three of these components are:

- Continuity in the availability of skilled human resources
- Continuity in financial and logistical resources
- Information and information management Infrastructure

To optimize the odds of a land information management infrastructure's sustainability, it must be designed so that it can be maintained at length without interruption, weakening, or loss of efficiency, functionality, or quality, given the following:

- There is a real possibility that the first two components above will – from an in-house availability point of view – change for the worse in the future.
- The technologies underlying the information management infrastructure will change rapidly and continuously.

Studies have shown the data component of land information management systems to be one of the major cost items. Figures of between 50 and 75 percent of related total cost have been quoted. The data component includes items such as data modeling, database design, data capture, and data conversion and migration. This suggests the following:

- Operators of land information management systems would be well advised to ensure that the investment in the data component of the system or infrastructure is optimized and "future proofed."
- Land information management infrastructures must be designed so that the beneficial use of information will optimize cost/benefit ratio of the system across the land information value chain.

As mentioned in the UN-ECE WPLA quote above, the strategies for long-term sustainability were not built into these programs. Organizations must be realizing by now that they will forever be in a state of IT migration – legacy components will always exist in their IT infrastructure and in those of organizations they interact with. Organizational and industry strategies must take this reality into account and enable profitable and sustainable operations under these conditions. So must the designers of core-cadastral templates and the related operational and functional processes.

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[9] Various international requests for proposals and implementation specifications.

2. REAL PROPERTY INFORMATION EXCHANGE IN THE COMMERCIAL SECTOR

Commercial participants in the real estate market, such as mortgage banks, credit reporting agencies, title insurance companies, and real estate agents have a vested interest in the efficient exchange of transaction-related information and the improvement of transaction and approval processing times. Their quest for efficiency and speed is driven by customer satisfaction, the time value of money, and profitability.

Included in the information these companies exchange and reference is land information, such as property location or identification, property rights, value, and related title information. In developing data content standards and process templates for cadastral information, it is important to recognize early on in the development cycle that public agencies such as cadastral offices, land registration offices, and tax agencies are linked to the business processes required for property transactions. It is in this context that public agencies must be prepared for active participation in electronic commerce and electronic integration into the e-commerce value chains.

The UN-ECE WPLA recognizes the impact of electronic commerce (in the form of electronic conveyancing) in the following extract from their September 24, 2003, Report on Spatial Information Management for a Sustainable Real Estate Market:

> The emerging use of the Internet will impact heavily on land administration organizations. At the same time, it provides opportunities for better customer satisfaction and a reduction in operating costs, for example, in the submission of official documents concerning the establishment, transfer, or deletion of rights to land. There is no difference whether these documents are submitted by notaries, solicitors, or the parties involved in a transaction themselves. Increasing use of personal computers, text processing software and electronic signatures creates a demand for the electronic submission of deeds or civil agreements. The development of systems for electronic conveyancing in, for instance, the United Kingdom, Canada, and Lithuania, and the electronic submission of deeds in, for instance, the Netherlands are the result of this understanding.[10]

In the same report, the WPLA also comments that "The combined access to the cadastral archives and to other public archives, either locally or centrally maintained, can rapidly improve the way authorities at all levels can inform businesses or individuals. The interconnection with the online banking system offers significant benefits for the risk management of loans and mortgages. It could also reduce the overall cost of real estate investments and enhance land market activities with reliable rules for land and construction valuation."

[10] http://www.unece.org/env/documents/2003/hbp/wp.7/hbp.wp.7.2003.4.e.pdf

To provide a brief insight into what the e-commerce impact to a public agency may be, the data exchange standards of the U.S. Mortgage Industry Standards Maintenance Organization (MISMO)[11] are briefly reviewed.

2.1 The MISMO Commercial Mortgage Data Standards Initiative[12]

MISMO is developing a commercial mortgage origination data standard that provides both the content and format for borrowers and originators to transfer critical data to lenders. The data standard will use XML Schema to define the structure and format for moving data between parties involved in a mortgage origination transaction. These parties typically include the borrower, the lender, third-party report providers, due diligence providers, rating agencies, and, if appropriate, investors.

As is the case with the FIG Commission 7 Standardized Core Cadastral Content Standard, MISMO expects that users of the standard may have additional data requirements, and that some of additional data will be incremental to the standard. This MISMO standard is thus designed to be extensible, so that each participant can supplement the standard with its own unique requirements. It is also anticipated that not all the data in the standard would be applicable for all loans, and, therefore, there may be more data defined than would actually be used in originating a particular loan.

It is interesting to note that MISMO explicitly states that "the intent of the standard is only to provide guidelines for the data to be collected in the commercial mortgage origination process, and does not recommend underwriting methodology or computations. The standard assumes that each participant has its own methods for originating and underwriting." [p. ii]

In the development of this standard, the importance of workflow and process management in the origination process is recognized. The MISMO Working Group states that it "recognizes that the commercial mortgage lending process does not stop at origination. Clearly, the ultimate goal is seamless movement of data from the borrower through the lender to the servicer and investors." [p. ii]

Table 1: Property Identification Attributes.

Data Field Name	Definition
Number of Collateral Properties	The number of separate properties that serve as collateral for the subject mortgage
Property Name	The name of the property that serves as mortgage collateral or its street address
Attributes Description of Property	A narrative description of the physical characteristics of the collateral property including its general use and amenities, size and massing, construction methods and materials, age, and other attributes

[11] http://www.mismo.org
[12] Commercial Mortgage Data Standards Initiative Originations Data Dictionary. http://www.mismo.org/mismo/docs/C-MISMO%20Originations%20Dictionary%20Exposure%20Draft1.pdf

Data Field Name	Definition
Address 1	The street address of the property that serves as mortgage collateral
Address 2	Additional information provided to identify the property's location
City	The city in which the property that serves as mortgage collateral is located
Property County	The county in which the property that serves as mortgage collateral is located
Property Postal Code	The postal or ZIP code for the collateral property (in the United States, expressed as 5+4; for other countries, an alphanumeric combination)
Property Country	The country in which the property that serves as mortgage collateral is located
Property Area	An indication of the basic nature or character of the sub-market in which the property serving as mortgagee collateral is located
Property Type – Primary Use	A description of the primary function of the collateral property
Property Type - Secondary Use	A description of the secondary function of the collateral property

Table 1 lists the property identification elements specified in the data dictionary. It is interesting to note that there are no provisions for cadastral identifiers – which may be an artifact of the nature of the cadastral infrastructure in the United States.

Although MISMO is a U.S.-based organization, note that they do provide mortgage loans wherein non-U.S. property serves as collateral. This is evidence of the global nature of the property investment market.

MISMO's Specification for Title Request and Response V2.1[13], which is an XML-based specification, does, however, provide for an "AssessorsParcelIdentifier" as well as a physical property address:

```
<PROPERTY _StreetAddress="100 Broadway" _City="San Diego" _State="CA"
_County="San Diego" _PostalCode="92101" _TitleCategoryType="SingleFamily"
AssessorsParcelIdentifier="558996987" _SalesAmount="400000">
                <_LEGAL_DESCRIPTION _TextDescription="Would contain
the legal description of the property." _Type="MetesAndBounds"/>
</PROPERTY>
```

Cadastral domain experts from countries with more formal cadastral infrastructures may be surprised by the fact that MISMO seemingly allows for a "loose" or non-cadastral reference

[13] http://webster.mismo.org/mismo/specs_21.cfm

to the real property collateral. There is however food for thought in this "discovery," which is elaborated upon in the conclusion to this paper.

As suggested in Section 1 of this paper, the future IT landscape will be shaped by those who succeed in simplifying a complex world. This challenge extends into the cadastral domain as well – cadastral systems must become user friendly for citizens, property owners, and small and large investors. Formally adopting common property identifiers into the cadastral domain and content standard is one way we can simplify the system, increase its acceptability and usage, and improve its sustainability.

2.2 Workflow Interoperability

Executing a real property investment transaction, mortgage application, or a parcel subdivision transaction requires the completion of a process that transcends organizational boundaries. Section 1 suggests that legacy systems will remain part of every organization's IT infrastructure – this means that organizations may have internal process and workflow management solutions that could hinder the realization of the benefits of fully automated cadastral transaction processing or property transaction systems.

In an electronic conveyancing environment, the value chains that must be implemented to deliver on an e-conveyancing transaction could be implemented using a set of workflow definitions that have been created to support discrete segments of the entire process. This would, however, result in the creation of islands of automation in the end-to-end process.

To avoid or circumvent the efficiency barriers presented by these islands of automation, the workflow interoperability must be possible, enabling different workflow products to communicate with another by exchanging messages that control process interoperation and integration. This is analogous to the Oracle Interoperability Initiative[14] whereby major GIS software vendors, such as AutoDesk, Intergraph, Laser-Scan, and MapInfo, are cooperating to enable smooth interoperable access to an organization's geospatial data.

Figure 1 shows (cadastral or property) information and its relationship to process and organization.[15] The current modeling activities by FIG Commission 7 and COST G9 have so far focused mainly on the information component and are working toward specifications that would support the transport of information between the process and information components. Other organizations, such as the World Bank, the UN-ECE WPLA, and various commercial companies, are working to understand process and organizational issues.

Although some land administration service providers in Canada, United Kingdom, New Zealand, Denmark and the Netherlands in particular, have implemented electronic conveyancing and cadastral transaction processing, a large body of work and research remains to assimilate the workflow interoperability knowledge into the cadastral domain.

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[14] http://imgs.intergraph.com/interop/oracle.asp
[15] http://www.wfmc.org/standards/docs/Ref_Model_10_years_on_Hollingsworth.pdf

This paper includes the proposal for FIG to consider making the assimilation of this knowledge into cadastral domain a priority, and that participation in the activities of workflow standards organizations such as the Organization for the Advancement of Structured Information Standards (OASIS)[16] be considered.

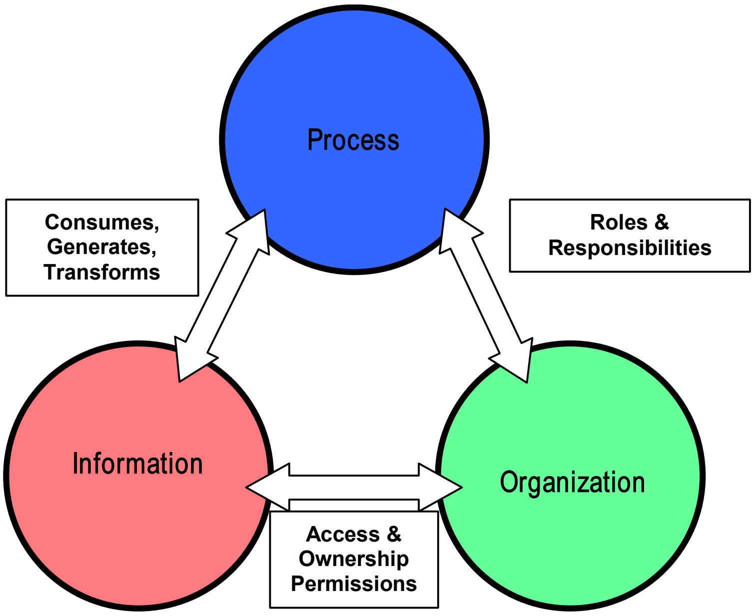

Figure 1.

3. A COMPARATIVE MODEL FOR PROPERTY TRANSACTION COSTS

The main objective of Action G9 is " … to improve the transparency of real property markets and to provide a stronger basis for the reduction of costs of real property transactions by preparing a set of models of real property transactions, which is correct, formalized, and complete according to stated criteria, and then assessing the economic efficiency of these transactions."[17]

Determining costs for a property transaction in a single country has proven to be a difficult endeavor.[18] Because of the differences in infrastructure and legal, social, and economic conditions between countries, it would be even more difficult to establish an absolute norm or cost for property transactions.

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[16] http://www.oasis-open.org

[17] Draft memorandum of Understanding for the Implementation of a European Concerted Research Action designated as COST Action G9 "Modeling Real Property Transactions." Brussels. 29 January 2001. http://cost.cordis.lu/src/pdf/G9-e.pdf and also at http://costg9.plan.aau.dk/CostG9Main.html.

[18] Zeverbergen comments on this difficulty in his "**Sale and subdivision in the Netherlands"** presentation at the WG2 Meeting in Hungary, September 2-3, 2004.

To meet the G9 objective as quoted above, optimum cost parameters for property transactions have to be established to determine if property transaction costs in a specific country are high and whether any adjustments or reforms are necessary.

International lenders and development aid agencies have long needed a comparative model that would support comparative analyses and measurement of country costs and efficiencies, including property transaction costs and efficiencies in different jurisdictions. To this end, the World Bank and the International Finance Corporation established the Rapid Response Knowledge Service (RRKS)[19] to provide policy advice on business environment reform and privatization policy in developing countries.

The RRKS compiles comprehensive assessments of the business environment in developing countries, through country-specific reports as well as comparative data used for benchmarking purposes. The comparative data is made available through the RRKS Doing Business database. One of the latest topics added to this database is property registration.

The database now includes indicators related to property registration, benchmarked to January 2004, indicating the ease with which property is registered in 145 countries representing the following regions and economies:

- East Asia and Pacific
- Europe and Central Asia
- Latin America and Caribbean
- Middle East and North Africa
- OECD High Income
- South Asia
- Sub-Saharan Africa

The property registration study[20] for the Doing Business database attempted to cover the complete sequence of procedures necessary to transfer the property title from a willing seller to a willing buyer when a business purchases land and a building in a peri-urban area of the country's most populous city.

To arrive at a result that would support comparative analyses across countries, specific assumptions about the property, the actors, and procedures were made. These assumptions are published on the RRKS Web site[21].

Some of the property registration indicators included in the database have a direct relevance to the COST G9 main objective. These key indicators include:

- The number of procedures required to legally register property
- The time[22] required to complete the legally required procedures

[19] http://rru.worldbank.org/Main/About.aspx
[20] The study methodology is developed in "Property," a forthcoming research project by Simeon Djankov, Facundo Martin, and Caralee McLiesh.
[21] http://rru.worldbank.org/DoingBusiness/Methodology/RegisteringProperty.aspx

[22] Time is measured in calendar days.

Official costs such as fees, transfer taxes, stamp duties, and payments to the property registry, notaries, public agencies or lawyers[23]

Members of the COST G9 research team should review the methodology and results of the RRKS's Property Registration Study to determine whether it should be used to achieve the G9 activity objective of " … assessing the economic efficiency" of property transactions.

4. INTENT AND PURPOSE OF THE STANDARDIZED CORE CADASTRAL DOMAIN MODEL

Experiences from around the globe have led to the conclusion that models such as the core cadastral domain model can be misinterpreted as an approved or proposed data model, rather than an extensible content template or ontology. This is especially true if the model or standard is endorsed by an international organization such as FIG.

In an attempt to avoid any such misinterpretation or misapplication of the FGDC Cadastral Data Content Standard in the United States, the following wording was introduced into the latest revision (v1.3) of the FGDC Cadastral Content Standard:

> 1.4 Applicability and Intended Uses of Standard
>
> The Cadastral Data Content Standard is intended to support the automation and integration of publicly available land records information. It is intended to be useable by all levels of government and the private sector. The standard contains the standardization of the definition of entities and objects related to cadastral information including survey measurements, transactions related to interests in land, general property descriptions, and boundary and corner evidence data. Any or all of these applications are intended to be supported by the standard.
>
> The intended geographic scope of the standard is all fifty states of the United States including all onshore cadastral as well as marine cadastral information. Applicability of this standard in other geographic areas and business processes, such as the Insular Areas of the United States has not been determined. ……
>
> The standard is not intended to reflect an implementation design. An implementation design requires adapting the structure and form of these definitions to meet application requirements. …."[24]

It is as important to state in clear and concise terms what the intent and purpose of the Standardized Core Cadastral Domain Model **is not**, as it is to state what it is.

The Brno paper[25] on the 3rd Version of the Standardized Core Cadastral Domain Model states the two primary purposes of the model as "enable effective and efficient

[23] The cost is expressed as a percentage of the property value, calculated assuming a property value of 50 times income per capita.
[24] http://www.nationalcad.org/data/documents/CADSTAND.v.1.3.pdf

implementation of flexible (and generic) cadastral information systems based on a model driven architecture…," and to "provide the common ground for data exchange between different systems in the cadastral domain."

The Brno paper recognizes data exchange (the second purpose) as the major motivator for the development of the model. This motivation parallels the motivation for the development of the FGDC Cadastral Content Standard.

It is in this context that these proposals are made:

1. Rename the Standardized Core Cadastral Domain Model to "Standardized Core Cadastral Data Dictionary" to reflect its primary purpose and development driver.
2. Add wording similar to that quoted from the FGDC Cadastral Content Standard to the next version of what will now perhaps be known as the "Standardized Core Cadastral Data Dictionary"

The proposals above will contribute to the correct application and use of the standard. Further reference to the FIG Core Cadastral Model in this paper will be using the new name proposed above.

CONCLUSIONS

The US mortgage industry's "loose" or non-cadastral reference to real property highlighted the following about society's awareness and knowledge of the cadastral domain:

- People unfamiliar with the cadastral domain do not share the same reverence for unique parcel identifiers as cadastral domain practitioners.
- Most people have no idea what their cadastral parcel identifier is. They do know their property addresses though.

As suggested in Section 1 of this paper, the future IT landscape will be shaped by those who succeed in simplifying a complex world. This challenge extends into the cadastral domain as well – cadastral systems must become user friendly for citizens, property owners, and small and large investors. Formally adopting common property identifiers into the cadastral domain and content standard is one of the ways we can simplify the system, increase its acceptability and usage, and improve its sustainability.

In the early 1990's , while in the African veldt in the Pilanesberg in what was then the Republic of Bophuthatswana (now South Africa), University of New Brunswick's John McLaughlin remarked about the future of cadastral surveying and land information management, stating that "rules and tools will be automated."

[25] Christiaan Lemmen, Paul van der Molen, Peter van Oosterom, Hendrick Ploeger, Wilko Quak, Jantien Stoter, Jaap Zevenbergen. A Modular Standard for the Cadastral Domain. 2003.

Our challenge remains to understand and represent these rules and tools in a sufficiently timely manner and format to those who need to know. To achieve this task in a timely manner, both researchers and industry have to be willing to co-opt existing and functioning non-proprietary standards and conventions.

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Observations on the Proposed Standardised Cadastre Domain Model – Where Do We Go From Here?

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Key words: OGC, FIG, domain models, consensus, cadastre, interoperability.

SUMMARY

The proposed Cadastre Domain Model is a standardisation effort of great importance that will benefit greatly from close coordination with the work of the Open Geospatial Consortium, Inc. FIG is proposing to standardize the content and some of the methodologies of cadastre management and OGC is perfecting a method to lower the costs and challenges of implementing the Model in computer software. As a not-for-profit consortium, OGC does not create computer software, but organizes the geospatial industry to produce a consensus standard for interfaces that link functional applications that will provide the cadastre automation needed. The end result is the ability of cadastre information from many countries, running on hardware and software from many different companies to work seamlessly as if they all used exactly the same data model, and computer hardware, operating system and application software.

1. INTRODUCTION

The proposed Cadastre Domain Model presented by Oosterom and others at the Brno Conference offers the Information Communications Technology (ICT) and Cadastre communities an important opportunity to converge on a number of critical fronts. First, the Model sets out a discipline based product defining user requirements for distributed processing across the community-at-large. Second, the Model provides a rich substrate for the two communities together to move the model forward into the engineering process. The Open Geospatial Consortium's (OGC) process for developing and enhancing service specifications, encodings and application schema, our recent accomplishments and current work agenda, plus the activities now underway by OGC's European subsidiary provide the best way for the next steps to occur. We agree with the authors' conclusions that it is appropriate to establish a working relationship between OGC and FIG to foster the continuing development of distributed Cadastre information systems. To elaborate on technical and business issues about European transnational property and land tenure information processing we believe the time is right for initiating collaborative FIG/OGC work efforts, along with member states, under the umbrella of Sixth Framework Programme (FP6) and/or European Science Foundation (ESF) programmes. There is precedent for this kind of strategic development and funding approach. Subject to approval by the membership, other internal OGC specification steps could be proposed.

The Model and OGC's efforts mesh perfectly in that the UML used in the former is an input to the work flow for the latter and the output from the OGC process is then used by FIG. A UML model, by its very nature is not suitable for direct use by computer software. It defines the system and the data that moves through it but the detail provided is inadequate for automated exploitation by software. OGC, on the other hand, has focused its work on the process of enriching the user specific model to the level needed for it to support computer processing. That work has produced an automated tool that ingests a UML model and creates an XML Schema Document (.xsd) encoded using the OGC's Geography Markup Language (GML). That schema defines the data being passed in sufficient detail for a software application to 'understand' the data based solely on the information found in the .xsd file that is passed with it. The UML model is a correct expression of what FIG has defined as required and the use of a Model Driven Architecture (MDA) tool ensures that any number of organizations can process the original data into an identical .xsd description. Figure 1, UML to GML Application Schema Process graphically illustrates the steps involved in transforming a UML Model into a GML schema. The Cadastre Model is merged with an individual country's content in the UML to GML Application Schema Tool (UGAS) that then creates a country specific GML application schema based on the Cadastre and the individual country content.

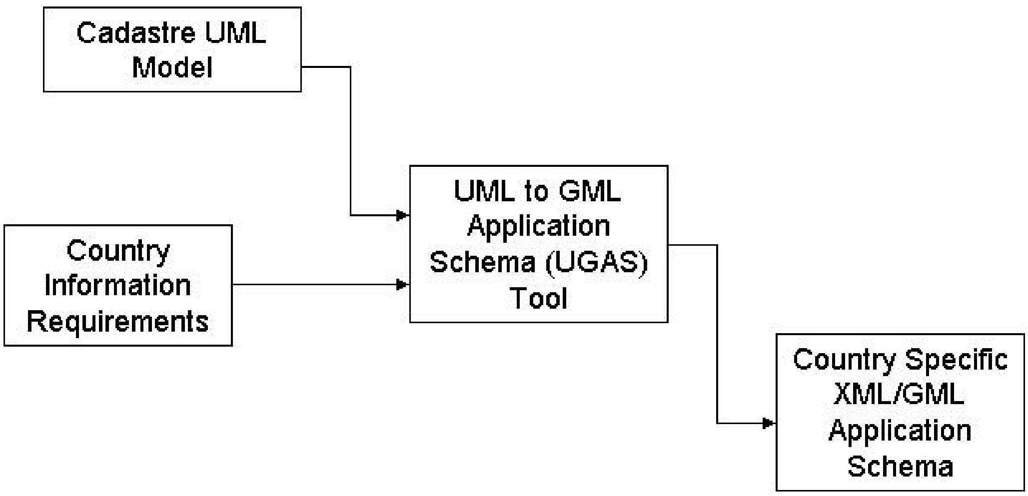

Figure 1: UML to GML Application Schema Process.

At the technology level, work undertaken over the past 2 years by OGC to converge geospatial and Web standards has prepared us to engage the Cadastral community and offer unprecedented capabilities related to publishing, discovering, processing and displaying land data, and capabilities for automating the translation of data from one information model to another. To realise these capabilities, in the form of Standards-based software products and services, we propose a series of activities that enable these capabilities to be introduced into the market over the next two years. The activities defined below promote the Cadastre's community needs to the ICT community so that both communities may collaborate to address the requirements in product and services.

The steps we define below constitute our ideas for activities that can take the Model forward. These include establishing an understanding about and the formulation of an agreed to method for architecture and architecture governance, conducting broader modeling activities to establish a business rationale, and to set the stage for establishing reference implementation facilities for testing and definition of operational requirements and other issues regarding adoption in National and sub-national settings. These steps we discuss are presented in a way to facilitate future dialog within the community on these issues and to arrive at more precise strategic and funding considerations.

2. SERVICE ARCHITECTURE: USE OF WEB SERVICES, WEB SERVICE AND OpenGIS® STANDARDS FOR CADASTRE INFORMATION SYSTEMS

Previous attempts at distributed computing (CORBA, Distributed Smalltalk, Java RMI) have yielded systems where the coupling between various components in a system is too tight and requires too much agreement and shared context among business systems from different organisations to be reliable for open, low-overhead B2B e-business.

Meanwhile, the trend in the application space is moving away from tightly coupled monolithic systems and towards systems of loosely coupled, dynamically bound components. Systems built with these principles are more likely to dominate the next generation of e-business systems, with flexibility being the overriding characteristic of their success. OGC believes that applications will be based on compositions of services discovered and marshaled dynamically at runtime (just-in-time integration of services). Service (application) integration becomes the innovation of the next generation of e-business, as businesses move more of their existing Information Technology (IT) applications to the Web, taking advantage of portals and e-marketplaces and leveraging new technologies, such as eXtended Markup Language (XML).

Service oriented architecture (SOA) is an architectural design style for developing modern web services. SOA which has its foundations within the business application domain, is now being applied to middleware technologies and is spreading into other domains (e.g., geospatial).

Without SOA, software application packages are written to be self-contained, with many application functions tied together in a complete package. The code to accomplish integration of application functions is often mixed into the code for the functions themselves. We call this approach to software design "monolithic applications". It is tightly coupled, in the sense that changes to one part of the code will have a big impact on code in another application function that uses it, and this leads to complexity of systems and expense in maintaining them. It also makes it difficult to re-use application functions, because they are dependent on too detailed knowledge of what happens in another application.

One of the distinguishing characteristics of an SOA is the separation of individual application functions from each other so that they can be used independently, as individual application functions or "building blocks"[1]. These building blocks can be used to create a variety of other applications inside the enterprise, or if desired, exposed externally for business partners to use in their applications.

The notion of a "service" is to construct these "building blocks" with standardised interfaces that are independent of the implementation details. Figure 2: Application E from A,B,C,D illustrates how this is done. Applications A and B are left entirely alone in their existing proprietary format as are Applications C and D, but by exposing them to integration via open interfaces it is possible to assemble Application E from the capabilities of A,B,C, and D. Applied to cadastre this would imply that all of the existing systems could continue and still be assembled into a cross-enterprise application.

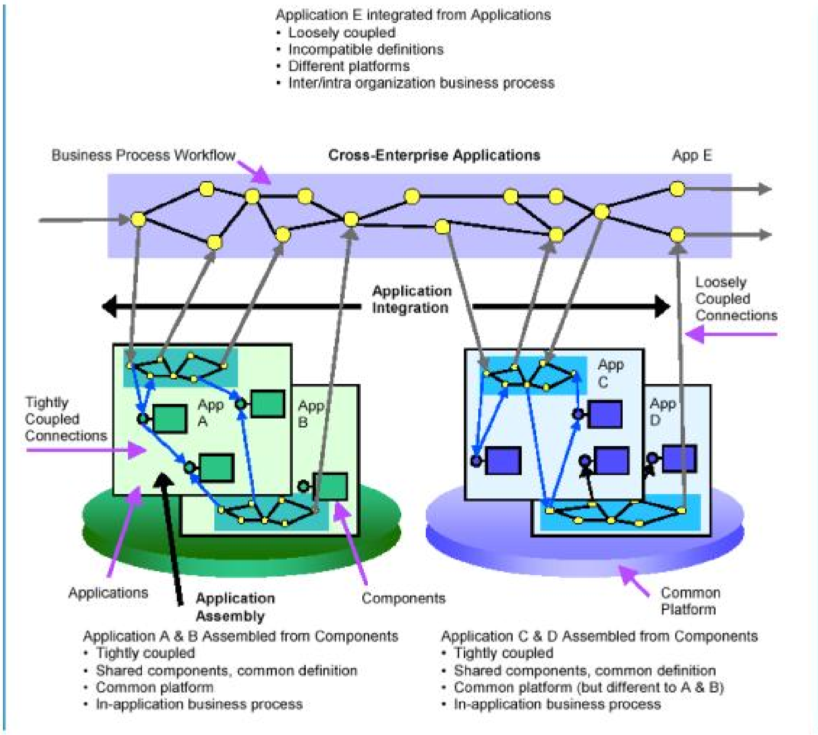

Figure 2: Application E from A,B,C,D.

[1] Building Blocks have generic characteristics as follows:

1. A Building Block is a package of functionality defined to meet business needs across an organisation
2. A Building Block has published interfaces to access the functionality
3. A Building Block may interoperate with other, interdependent, Building Blocks
4. Is reusable and replaceable, and well specified
5. It considers implementation and usage, and evolves to exploit technology and standards
6. It may be assembled from other Building Blocks
7. It may be a subassembly of other Building Blocks
8. May have multiple implementations but with different interdependent Building Blocks

Web Services is a set of standards that can be used to create an SOA. While it is possible to create an SOA without the Web Services standards (for example, people have used XML over HTTP or JMS to achieve a similar result, before the Simple Object Access Protocol (SOAP) standard), for interoperability with external software the use of Web Services standards is the best approach we have today.

The basic standards are in place for Web Services, and these can be used to implement a service-oriented architecture. XML and XML Schema have been standards since 1998 and 2001, respectively. SOAP 1.2 has been a standard since June 2003. Universal Description and Discovery Interface (UDDI) was standardised in summer 2003. Web Services –Security (WS-Security) became a standard in April 2004.

Aside from these official standards supported by well-known standards bodies such as World Wide Web Consortium (W3C) and Object-Oriented Administrative Systems-development in Incremental Steps (OASIS), many "technology proposal specifications" are well-accepted and well-supported as interim "defacto" standards. For example, until Web Services Description Language (WSDL) 2.0 is finished at W3C, most vendors claiming Web Services support in their products use the WSDL 1.1 specification. SOA is the basis for advanced capabilities in Web Services, such as the WS-Trust and Federated Identity Management specifications. Indeed the support we have today for Web Services standards from major software vendors has lead to widespread implementation of SOA using Web Services.

Web Services, such as WSDL, document a set of application services. They describe the names and types of data to be passed as inputs to request a particular service (for example, a "check inventory" function may require a part number) and the details of the response from the service (e.g., may return an integer representing number of units in stock).

On the geospatial front, OGC has constructed a suite of basic interface services for mapping, features, coverages, catalogs, location services, sensors, portrayal and encodings for XML. The market has responded with 227 products that implement one or more specifications. Many of these standards are adopted or in the pipeline to be adopted as international standards by ISO. We also have begun developing suites of application schema according to user requirement so that vendors may tailor their products to the precise needs of particular value chains. Much of the work of OGC's OWS2 testbed involved testing these standards within UDDI, WSDL and SOAP based messaging environments.

What is common across all web service developments is that functions appear to be the same whether the function is implemented in Java, C++, COBOL, etc, so the requester of the service does not need to know which language was used, and the request can be written in any required language. This allows services from one platform to be integrated in an application written for another platform. The key point here is that the request and response messages understand each other (e.g., using SOAP messaging where messages are coded in XML).

The Reference Model – Open Distributed Processing (RM-ODP), ISO-IEC 10746 is a repeatable process methodology upon which one architects an information system, such as an SOA for Cadastre. It provides a way to structure ideas that need to be considered for architecting, to guide engineering and ultimately construction of an information system. Other process methodologies include the Rational Unified Process (RUP) from IBM, MDA, and The Open Group Architecture Framework (TOGAF). Architecting an SOA can be accomplished using any one or combination of these process methodologies. What distinguishes RM-ODP is that it is the only process that possesses an ISO standard and that captures the relationships between service and content to a level of detail that enables an engineer to code them in product.

The primary benefit of Web Services is interoperability, which is the ability to use the functions between any kinds of platform, regardless of programming language, operating system, computer type, etc.

In the "check inventory" example above, the function may have been written as a service that was required for one application, for example one that monitors inventory and automatically reorders when required, but we could find later that the same service can be used without modifications to support a Web-based inventory monitoring tool used by a human clerk.

Internally, the reuse of application functions is a key benefit, because it leads to reduced development costs. A long-term implication of reuse of services is the reduction of redundant functions in the enterprise, a simplification of the infrastructure, and thus a lower cost of maintaining code. By organising applications as users of services, we stand to get a much more flexible and agile model of integration, allowing us to quickly revise the business process model, compared to traditional programming techniques.

Externally, SOA's enable a well-defined "contract" for interacting with a service to exist, and this leads to a "loosely-coupled" style of interaction between business partners that provides the required stability of integration, and a solution to the problem of changes to underlying software. While the message format stays the same, the software that supports it can change as much as required, so long as it still supports the message contract. The system could even be completely replaced with an implementation in another programming language, so long as it supports the same message format, the requester application would not require changes. When message contracts evolve and must change, it is easier to support multiple versions of application requests as a transitional strategy using versioning, compared to the rather difficult task of supporting multiple versions of program APIs and file formats.

The OpenGIS Reference Model (ORM) (http://www.opengeospatial.org/specs/?page=orm) is based on RM-ODP and provides a context for understanding how our specifications and other activities fit in the broader world of standards, product development and use. The ORM provides different views into the OGC architecture so that others can use it to guide the creation of their own systems. Organisations, be they government, private surveyors vendors, suppliers or integrators will need to track the Cadastre architecture from their own interdependent perspective – for policy development, business modeling, requirements analysis, product evaluations and product development. So, our message to the Cadastre community is that without a consistent process (such as RM-ODP) applied to the very important work, that starts with the Cadastre Domain Model, there can be little probability the market can interpret, understand and integrate this work into their respective business models and product development plans that can be delivered back to end user organisations.

Since 1999, OGC test beds and pilots have used RM-ODP processes. We have maintained this regime for developing OpenGIS specifications (service interfaces, encodings and application schema) as well as the high level architecture defined in the ORM. OGCE and others will be applying the RM-ODP process in two upcoming FP6 engagements -- RISE and MOTIIVE. These projects will develop application schema associated with the Water Framework Directive under the umbrella of GMES and INSPIRE. Consideration for using RM-ODP process is being analyzed for use in the Orchestra Integrated Project whose focus is establishing European service architecture for Risk Management. The general ICT market and the geospatial market are familiar with this regimen. In architecting cadastre information systems, we recommend a similar discipline apply.

3. USE CASE MODEL AND NEXT STEPS FOR THE CADASTRE COMMUNITY

The Model is the beginning point from which the Cadastre community can engage wider areas of necessary activity – particularly the technical architecture side. Not only do technical (semantics, distribution, engineering) aspects of the problem need to be addressed, but also a wider perspective dealing with the business rationale for migration. From this context, OGC suggests the community consider several overarching objectives for itself:

- To describe the current baseline business environment within the Cadastre/Land Tenure value chain
- To model the way information processes operate today
- To develop a target Cadastre/Land Tenure business architecture, describing the product and/or service strategy, and the organisational, functional, process, information, and geographic aspects of the business environment, and based on the business principles, business goals, and strategic drivers.
- To analyze the gaps between the baseline and target business architecture
- To use RM-ODP architecture viewpoints that show how stakeholder concerns would be addressed in the technical architecture.

Complex architectures that are extremely hard to manage, demonstrate this fact not only in terms of the architecture development process itself, but also in terms of getting buy-in from large numbers of stakeholders. What is required is a disciplined approach to identifying common architectural components, and management of the commonalties between them to decide how to integrate, what to integrate, etc.

Knowledge of the business architecture is a prerequisite for information systems architecture work (data, applications, technology), and is therefore an element of architecture activity that needs to be undertaken, if not provided for already in other organisational processes (enterprise planning, strategic business planning, business process re-engineering, etc.).

In practical terms, the business architecture is also often necessary as a means of demonstrating the business value of subsequent technical architecture work to key stakeholders, and the Return on Investment (RoI) to those stakeholders from supporting and participating in the subsequent work. Use of business modeling techniques illuminates the key business requirements and indicates the implied technical requirements for the IT architecture.

In undertaking business architecture activities, a key objective is to reuse existing material as much as possible. Where existing architectural descriptions exist, these can be used as a starting point, and verified and updated if necessary to bridge between high-level business drivers, business strategy and goals on the one hand, and the specific business requirements that are relevant to a Cadastre/Land Tenure architecture development effort. (The business strategy typically defines what to achieve - the goals and drivers, and the metrics for success - but not how to get there. That is the role of the business architecture.)

The extent of the work in this phase will depend largely on the enterprise environment and in Europe's case many key elements of the Cadastre/Land Tenure business architecture have been accomplished, or at least started, in the INSPIRE Initiative and the FIG and COST activities that led to formulation of the Model. Expression of these findings and results in terms that management will appreciate is most critical.

Aside from Activity Models, Use Case and Class modeling efforts accomplished by FIG and COST, other modeling tools and techniques may be considered, if deemed appropriate. For example:

- A **Node Connectivity Diagram** describes the business locations (nodes), the "needlines" between them, and the characteristics of the information exchanged. Node connectivity can be described at three levels: conceptual, logical, and physical. Each needline indicates the need for some kind of information transfer between the two connected nodes. A node can represent a role (e.g., a property examiner); an organisational unit (a planning authority); a business location or facility, and so on. An arrow indicating the direction of information flow is annotated to describe the characteristics of the data or information – for example, its content; media; security or classification level; timeliness; and requirements for information system interoperability.
- Using an **Information Exchange Matrix** documents the Information Exchange Requirements for Enterprise Architecture. Information Exchange Requirements express the relationships across three basic entities (activities, business nodes and their elements, and information flow), and focus on characteristics of the information exchange, such as performance and security. They identify who exchanges what information with whom, why the information is necessary, and in what manner.

These models are finding increasing use in throughout of governments globally, and their use in multi-organisational settings like the Cadastre community is well justified.

4. META-ARCHITECTURE CONSIDERATIONS AND NEXT STEPS FOR THE CADASTRE COMMUNITY

RM-ODP provides a standards-based, repeatable set of procedures to undertake technical architecture design work. Use of a disciplined set of activities that support technical architecture development method and consider the broader aspects of business, enterprise and meta architecture issues is thought worthy. The major benefit of this approach is the establishment of companion business architecture elements that compliment the heavily technical focus of RM-ODP.

The Cadastre is a meta architectural object in that it defines the needs of the community, but will never actually be built itself. It will be used to guide the creation of multiple, interoperable systems at the national and sub-national level. Cadastre taken as a unitary element of information is a collective of many enterprises that will need to be disentangled (to find and expose the inter-links among and between communication, processing and information, the areas where collaboration, information sharing, information exchange and services cross). Once disentangled at the meta level systems can then be designed to enable this collaboration and information exchange and sharing.

The market response to this kind of challenge is the trend for architecture developments to explore forms of "federated architectures" - independently developed, maintained and managed architectures that are subsequently integrated within a meta architectural framework. Such a framework specifies the principles for interoperability, migration, and conformance. This allows specific business units to have architectures developed and governed as stand-alone architecture projects.

The US government has undertaken and published leading work in the field of federated architectures, emphasising the need for integrated repositories and metamodels to aid integration and ensure interoperability. This work is very much at the leading edge of the state of the art, however, and what works in practice is still very much a matter of debate. There are two basic approaches to federated architecture development:

- The overall enterprise is divided up "vertically", into enterprise "segments", each representing an independent business sector within the overall enterprise, and each having its own enterprise architecture with potentially all four architecture domains (business, data, applications, infrastructure). These separate, multi-domain architectures can be developed with a view to subsequent integration, but they can also be implemented in their own right, possibly with interim target environments defined, and therefore represent value to the enterprise in their own right.

- The overall enterprise architecture is divided up "horizontally", into architectural "super-domains", in which each architecture domain (business, data, applications, infrastructure) covering the full extent of the overall enterprise is developed as a major project independently of the others, possible by different personnel. For example, an architecture for the complete overall enterprise would form one independent architecture project, and the other domains would be developed and approved in separate projects, with a view to subsequent integration.

Current experience seems to indicate that, in order to cope with the increasingly broad focus and ubiquity of architectures, it is often necessary to have a number of different architectures existing across an enterprise, focused on particular time frames, business functions, business requirements. In such cases, the paramount need is to manage and exploit the 'federations' of architecture.

A well-regarded starting point is to adopt a publish-and-subscribe model that allows any resulting architecture to be brought under a governance framework. In such a model, architecture developers and architecture consumers in projects (the supply and demand sides of architecture work) sign up to a mutually beneficial framework of governance that ensures that:

1. Architectural material is of good quality, up to date, fit for purpose, and published (e.g., reviewed and agreed to be made public).

2. Usage of architecture material can be monitored, and compliance with standards, models, and principles can be exhibited, via a compliance assessment process that describes what the user is subscribing to, and assesses their level of compliance; and a dispensation process that may grant dispensations from adherence to architecture standards and guidelines in specific cases (usually with a strong business imperative).

Publish and subscribe techniques like these cited above are beginning to being developed as part of general IT governance and accountability.

5. THE SIGNIFICANT GEOSPATIAL OPEN STANDARDS FOR CADASTRE: GML, LandXML, LandGML AND THE OpenGIS® CATALOG SERVICES SPECIFICATION

As was mentioned above, OGC has constructed a suite of basic interface services for mapping, features, coverages, catalogs, location services, sensors, portrayal and encodings for XML. In framing a program of work for Cadastre services and application schema, the following standards and results of OGC projects might serve as a basis for work:

- The OpenGIS® **Geography Markup Language (GML)**[2] 3.1 is the dominant XML schema for geospatial data, developed by the members of the Open Geospatial Consortium (OGC). The UK Ordnance Survey, the US Census Bureau (in its TIGER data) and other agencies have committed to GML. XML-encoded geospatial metadata are a keystone element of the OGC Web Services architecture that makes

[2] The **eXtensible Markup Language (XML)**, an encoding system for structured ASCII text is the lingua Franca used in the World Wide Web environment. XML can be described as a language for creating self-describing data files, that is, data files whose headers explain how to interpret the data that comes after the header. This has turned out to be a very powerful concept. Scores of industries and professional domains have seized on the opportunity to develop "XML schemas" (schemas are essentially formats) to capture the specific kinds of information that need to be shared within those industries and domains by organizations whose legacy systems are very different from each other's. Virtually all Web browsers now include software to process text encoded in XML. In the geospatial industry, the Web provides justification for something like a universal open format and GML is the resulting encoding.

possible detailed, complex, automated searches for spatial data and spatial services on the Web. The information model contained within the metadata schema is encoded in GML. Because GML separates content from presentation, the way in which data is presented (on desktop systems and PDAs, for example) is entirely under program control and can thus be tailored on the fly to suit user requirement with a given display device capabilities. Very importantly, one of the major breakthroughs with GML is that, when used with XML tools, GML makes it possible to resolve many of the difficulties associated with incompatible data formats. GML is an integral part of the OGC's system of standards. For example, an information system for cadastre operations or other spatial application that implements an interface that complies with the OpenGIS Simple Features Specification, will, when issued a "GetInformation" request for a data set, return an "application schema" for that data, that is, the information model for that data, encoded in GML. Requests for actual data cause the server to return the data in GML.

- **LandXML** is an industry-driven, open XML data exchange standard that provides interoperability in more than 40 software applications serving the civil engineering, survey and transportation industries. The LandXML.org Industry Consortium, initiated by Autodesk and now comprised of 190 companies, government agencies and universities, developed the standard.

- **LandGML** is a GML application schema, convertible to and from LandXML, which enables LandXML-encoded data to be used with applications, services and portals that comply with OpenGIS Specifications.

5.1 LandGML <> LandXML

In the summer of 2004, the OGC ran a LandGML Interoperability Experiment to test methods and tools for converting between LandXML and LandGML. The US Army Corps of Engineers, Engineer Research and Development Center (ERDC), Autodesk and Galdos Systems initiated the Interoperability Experiment. Participating organisations were invited to submit samples of their data for conversion. The goal was to bridge the gap between Civil Engineering data and geospatial data using LandXML and GML interoperability tools. Participants developed methods to automate the flow of civil engineering and land survey data directly into geospatial applications and back again using XML-based open standards. The Interoperability Experiment successfully produced two automated transformation tools to ease application development and direct end user use. Phase 1 created a LandGML schema and provided a LandXML to LandGML transform tool. Phase 2 created a LandGML to LandXML transform tool. These tools and commercial products based on them will enable land development, transportation and geospatial professionals to exchange high precision design data throughout the entire lifecycle of a project.

5.2 Bridging Diverse Metadata Schemas and Data Models

Efforts are underway in many countries to develop standard geospatial metadata schemas and standard information models. Achieving thoroughly consistent information models is not possible, but standard models will have an important role as “Rosetta stones” that enable each user to map their data to a common model. That is, software will be able to go from one local model to the national model and thence to the user's own local model that is different from the first. One-to-one mapping of data models is unworkable when there are thousands of models to map between. But GML enables a one-to-many solution.

One-to-many mapping of data models is made possible by XML tools (prototyped in OGC's OWS2, GOS-TP and CIPI-2 pilot projects) that map GML-encoded data from a local model to the national model and vice versa. The data thus becomes "as useful as possible" to the data sharing partner who uses a different model. Typically, certain elements of one model do not map to the other, but the XML tools make these inconsistencies plain in all their details, so that it is easy for data managers to focus on the critical schema elements that don't map. This makes both data sharing and data coordination much easier. It makes it easier for people at the local level to accommodate national standards in an affordable and practical way, and it makes it easier for people at the national level to work with local data that does not conform in all its details to the national standard.

Another benefit of the GML approach is that this technology makes information models easier for software vendors, integrators and data providers to support. Currently, content standards are expensive to support, and companies and governments that do not support them are at a disadvantage. The combined investment in existing data, sometimes called legacy data, is too large to be ignored and this approach enables easier use and exploitation at the same time that new data models are being implemented. The new approach thus enhances competition, increasing the choices available to users in the market.

5.3 Publishing and Discovery of Land Data

XML, GML and another OGC standard, the OpenGIS Catalog Services Specification, formally adopted by OGC members in August, 2004, enable Web-based publishing and discovery of geospatial data, geospatial Web services (on-line processing components), and schemas (such as information models in metadata that are encoded in XML). The Catalog Services specification provides the foundation for "spatial search engines" – catalogues – in which thousands of online geospatial resources will be registered. The specification documents industry consensus on an open, standard interface that enables diverse but conformant applications to perform discovery, browse and query operations against distributed and potentially heterogeneous catalog servers.

Because different Spatial Data Infrastructure (SDI) initiatives support different metadata schemas, a main advantage of the Catalog Services v2.0 specification is the support it provides for "application profiles" based on ISO 19106 (Geographic information – Profiles). Such application profiles are metadata schemas (and their included information model schemas) that conform to the ISO 19115/ISO 19119 metadata standard, but that are configured for a particular "information community" of people who share a common geospatial information model.

As organisations transition themselves to distributed services architectures, the revised Catalog Specification, in combination with application schema work, provides the Cadastre community with a window of opportunity to implement web services without having to dismantle its legacy.

6. CONCLUSION

The union of FIG and OGC to address web delivery of cadastral information is an ideal combination: OGC benefits from working with a highly precise and complex need that has been defined by a well coordinated community (FIG), and FIG benefits by leveraging the state of the art standards that OGC has already created. It is anticipated that both the Model and the OGC specifications will be improved by this coordination.

The OGC has always concentrated on its piece of the overall software world – software interfaces. We rely on dejure, (legal) bodies such as the International Standards Organization and expert community groups such as FIG to determine the user requirements for services and data content, and then use these requirements as the 'use cases' for which we engineer software interfaces. The Cadastre Model is especially important to us because it represents a very well defined, highly precise and demanding set of requirements. OGC looks forward to working with FIG and others to realise common and mutual objectives for connecting information processes and content within the Cadastre community.

BIOGRAPHICAL NOTES

Louis Hecht is chairman of the Open Geospatial Constortium (Europe) Limited. The OGC (http://www.opengeospatial.org) is an international industry consortium of more than 250 companies, government agencies and universities participating in a consensus process to develop publicly available interface specifications. OpenGIS® Specifications support interoperable solutions that "geo-enable" the Web, wireless and location-based services, and mainstream IT. The specifications empower technology developers to make complex spatial information and services accessible and useful with all kinds of applications.

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Profile Definition for a Standardized Cadastral Model

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Key words: Cadastral Modeling, Profiles, Gap Analysis, Domain Experts

SUMMARY

The move towards a standardized cadastral domain model is a challenging endeavour since the model must address an administrative or legal component, as well as a spatial component. The goal of any model is to simplify and provide an abstraction of a complex and diverse world. If the model can be standardized, interfaces between data, users, and systems can provide a mechanism that will allow the physical sharing of cadastral data among many implementations.

While considerable work has been done by a number of agencies to provide local models that define logical cadastral entities, attributes, domains and relationships, the models do not provide guidelines for publicizing the content of a cadastral database in a form that is understandable by stakeholders; some whom may not understand data model semantics but possess knowledge of the cadastral domain. This situation was identified in *Cadastral 2014 – A Vision for a Future Cadastral System* where most land recording systems consist of a land registry component handled by notaries and lawyers and a separate spatial component taken care of by surveyors.

In order to bridge the communication gap, a number of agencies are developing cadastral profiles that detail metadata attribute content and data dictionaries that support the transfer of a cadastral logical model to a physical model.

As outlined by a number of cadastral organizations, like the US Federal Geographic Data Committee, and supported by other organizations that have implement standards such as the International Hydrographic Organization (IHO), a profile is often the first step in a government effort to index cadastral information. These profiles and applicable standards define the metadata elements required to support enhanced data discovery and the development of information access systems.

Through this paper, the authors present criteria which governments might consider in documenting its cadastral profile, as well as the international standardization issues that must be considered in doing so in order to successfully move forward.
Finally, this paper reviews a methodology by which cadastral profiles developed by a number of agencies can be compared identifying their similarities and differences. In addition, the authors introduce collection criteria used to identify individual real world phenomena used to define features objects within a cadastral domain model.

1. INTRODUCTION

The interest and evolution of cadastral systems follow a cyclic pattern within the global community driven by social, economic and political reforms. Over the last decade there has seen a renewed interest in cadastral systems in response to the pressures of change (Dale, 2000). During this period of time we have seen:

- The emergence of a number of land reform programs, especially in the former Soviet Union, the Balkans and Latin America;
- The growing integration of economies and societies around the world; and
- Increased advancements being made in information technologies (IT), particularly in the fields of communications and data management.

In order to establish an agenda for the evolution of current cadastral systems Commission 7 of FIG reviewed very carefully institutional, economic, social and technologies changes affecting cadastral systems, partly in terms of developing a vision for the future. This vision was present in "Cadastre 2014" (Kaufmann and Steudler, 1998) that formulated six statements for the development of cadastral systems. In summary, the statements are:

1. Cadastre 2014 will show the complete legal situation of land, including public rights and restrictions;
2. The separation between 'maps' and "registers' will be abolished;
3. The cadastral mapping will be dead. Long live modeling;
4. "Paper and pencil" – cadastral will be gone;
5. Cadastre 2014 will be highly privatized. Public and private sectors are working closely together;
6. Cadastre 2014 will be cost recovering.

Overall Cadastre 2014 introduces a number of concepts that should be contemplated, which can be considered as jurisdictional, organizational and structural in nature. However, underlining these concepts is the utilization of technology and technological principals. It is important to realize that technology is not the solution but a set of tools used to assist in the design, deployment and operation of a cadastral system.

2. CADASTRAL DOMAIN MODEL

The complexities of cadastral systems can get bogged down in theoretical discussions. In order to facilitate a more practical discussion a Core Cadastral Domain Model was launched at the FIG Congress in Washington (Oosterom, van, Lemmen, 2002). It was viewed that a simple, generic, standardized data model could encourage and support the flow of information relating land property between different government agencies, and in turn to the public (Lemmen, Oosterom, van, April 2003).

One of the primary elements of presenting the Core Cadastral Domain Model was the use of the ISO standard modeling language UML (Unified Modeling Language). The use of a modeling language is important because it helps a development team visualize, specify, construct, and document the structure and behavior of a system's architecture. By using a modeling language, like UML, members of the development team can unambiguously communicate their decisions to one another (Unified Modeling Language; Booch, Rumbaugh, Jacoboson, 1999).

The basis for UML is the Rational Unified Process, which is a disciplined approach for assigning and managing tasks and responsibilities in a development organization. It captures many of the best practices used in modern software development and presents them in a tailorable form (Kruchten, 2000).

The use of best practices focuses on using commercially proven approaches to software development, when used in combination; address the root causes of software development problems (Chapter 1, Booch, 2000). Though a number of organizations list best practices as part of their software development process the Rational Unified Process identify the following:

1. Development is iterative;
2. Requirements are managed;
3. Use component-based architectures;
4. Visually model software and system architects;
5. Continuously verify software and system architects quality;
6. Control changes.

Since its introduction, the evolution of a Core Cadastral Domain Model appears to have adhered to the best practices of the Rational Unified Process. Since cadastral systems are complex, one of the notable acknowledgements is that the model will most likely be implemented as a distributed set of information systems; component-based architectures. This means that the model recognizes that different organizations have their own responsibilities in data maintenance and supply. This recognition is reflected in its use of colour coding allowing domain experts to focus on their area of interest rather than the whole model (Lemmen, Oosterom, van, April 2003). In draft version 2, the Core Cadastral Domain Model components were presented as:

- Green: real core;
- Green and yellow: legal/administrative aspects;
- Green and Blue: real estate object specializations;
- Blue, pink and purple: geometric/topological aspects.

However, since the whole model is presented there is a recognition that organizations have to communicate on the basis of standard processes, thus adding value to the entire system (Lemmen, Oosterom, van, April 2003).

The primary focus of the Core Cadastral Domain Model has been on the development of a class diagram using UML. The use of UML will enable database specialists all over the world to understand the direction the working group supporting the standard is heading and be to contribute to the standard (Lemmen, Oosterom, van, April 2003). In essence, the working group is using a standard to develop a standard.

The working group also recognizes that UML also provides support for the implementation of a cadastral system through the use of:

- Behavioral diagrams that model activities, use case, timing, communications, interactions, etc.
- Structural diagrams that encompass classes, objects, packages, deployment, etc.

The challenge for system integrators and consultants is: How do we get domain experts, such as registrars, surveyors, lawyers, etc., who can contribute to the behavior of a cadastral system to contribute to the structural development of the Core Cadastral Domain Model?
One proposed method is to have domain experts contribute to a gap analysis by comparing what they have to what the Core Cadastral Data Model proposes. If the gap analysis is modeled using UML then domain experts will gain an understanding of the UML standard, which in turn may allow them to participate in the development of the Core Cadastral Domain Model, or at least provide some feedback to the database specialists who are contributing to the working group.

3. GAP ANALYSIS

The exercise of doing a gap analysis is not new in establishing and adopting a standard. Two case studies of interest are users wishing to work with the:

- Cadastral Data Content Standard developed by the US Federal Geographic Data Committee (FGDC) that provides a standard for the definition and structure for cadastral data which will facilitate data sharing at all levels of government and the private sector and will protect and enhance the investments in cadastral data at all levels of government and the private sector. The standard is presented as entities and attributes as well as suggested domain values for some attributes. The presentation of the standard is organized as an entity-relationship model (FGDC, 2003).
- International Hydrographic Organization (IHO) Transfer Standard S-57 that is intended to support the exchange of vector (and later raster and matrix) hydrographic data among producers and users worldwide. The standard is comprised of a theatrical data model, presented as a UML class diagram, on which the standard is based. The standard also describes the data structure and a catalogue of objects (Guy, 1999).

The methodology for doing a gap analysis is best illustrated by the Internet user's guide supporting the FGDC Cadastral Data Content Standard (Section 5, Bureau of Land

Management, 2002). In the user's guide a gap analysis is referred to as a "Crosswalk" exercise. The objective is to determine which parts of an established database correspond to the Standard by comparing the standard logical model with entities in an established database.

The purpose of a crosswalk is to express data definitions and relationships on terms of the Standard. By doing this, domain experts would be able to recognize the similarities and differences thus facilitating discussions about the Standard.

Though the user's guide focuses on comparing entities and relationships within an existing database to the Standard the methodology can be expanded to non-digital environments.

For example, within the Core Cadastral Domain Model, version 3, there is a class "SurveyDocument" with attributes "Number" and "Measurements" (Oosterom, van, Grise, Lemmen, September 2003). Many cadastral offices still maintain survey documents in paper form. On the survey document there are reference numbers and measurements but there are also dates. People working with survey documents are domain experts in their own right and can contribute to the discussion by comparing their circumstances with the Model. In this example, which is easier to illustrate using attributes rather than classes, should date be part of the standard and if so what date; date of submission, registered date, etc. Inversely, should the date of a survey document be left as an extension to the Model invoked at the discretion of the organization?

In addition, when viewing the Model people can see that the "SurveyDocument" is associated to a "SurveyPoint", which in turn is associated to a "ParcelBoundary". This may or may not make logical sense to an organization but they can at least start understanding the Model and, if they wish, contribute to the discussion, even if they are not a database specialist.
A second example can be illustrated by doing a "crosswalk" comparing the FGDC Cadastral Data Content Standard with the Core Cadastral Domain Model. In doing so we can see that the Standard has identified entities such as "Coordinate Reference" and "Public Agency" that are not included in version 3 of the Model.

In the case of the IHO transfer standard, S-57, we are dealing with a much more mature model that is actively being used in the International community. Though the model is well established, it has been observed that some agencies produce specialized products and wish to extend the standard. More often this involves adding object classes and attributes. A gap analysis in this case identifies what organizations can inherit from the standard. More importantly the standard clearly defines a set of conventions used to define object classes and attributes (IHO-A, 2000 and IHO-B, 2000).

In performing a gap analysis the authors have found that the conventions used in the IHO transfer standard, S-57, assist in clarifying the definition of classes and associated attributes. By using UML to present the results there is an improvement when comparing contributions from domain experts with the Core Cadastral Domain Model.

4. CADASTRAL FEATURE CATALOGUE

The cadastral feature catalogue is the data schema for defining the content of a cadastre system that can be in either digital and/or analogue form. Its primary function is to provide a means of describing real world entities. That is entities, which actually exist (either physically such as a control monument or legally such as a land parcel) in the real world.
The cadastral feature catalogue is based on the theoretical model often described by the agency supporting a cadastre. The catalogue is composed of:

- A profile that is a physical representation of the theoretical model; and
- A data dictionary describing attributes supporting classes defined in the profile.

The theoretical model assumes that real world entities can be categorized into a finite number of packages or aspects. In version 3 of the Core Cadastral Domain Model these are defined as (Oosterom, van, Grise, Lemmen, September 2003):

- Specialized classes of a "RealEstateObject", as an abstract class;
- Surveying classes;
- Geometry and Topology classes;
- Legal and administrative classes.

It is the objective to categorize an existing cadastre using the aspects of the Core Cadastral Domain Model in order to define a clearer definition of classes when doing a gap analysis.
An instance of class, referred to as an object, (that is one specific parcel boundary or legal document or person) can be more precisely described by assigning to it a number of attributes and then specifying values for those attributes. A particular class is encoded by specifying the appropriate object class, attributes and attribute values.

The objective of the cadastral feature catalogue is to develop a description of each object class including a definition, a list of allowable attributes, etc.

The cadastral feature catalogue does not mandate the use of any attributes. However, for each instance of an object, a particular attribute may only be used once. In general terms it is up to the encoder to select from the appropriate list the attributes that are relevant to a particular object instance.

Attributes will be presented following the discussion on classes.
Each object class within the cadastral feature catalogue is specified in a standardized way, under the following headings:

- **Class** – A class name such as "ParcelBoundary". It should be noted that UML does not allow spaces so that some abstraction may be applied. If an abstraction is used clarification can be noted in the description of the class;
- **Acronym** – In order to cross-reference a class to a database schema acronyms are often used. In order to accommodate most database systems a six-character code for the class is used;

- **Code** – This is just an integer code to be used to index the object class;
- **Description** - Where possible each class should carry a definition. The objective is to clarify the class for other users;
- **References** – Used to identify the source of the class and/or meaning of the definition;
- **Remarks** – Used to provide additional comments and notes for the class;
- **Data Type** – This presently describes what spatial object type(s) is assigned to a class such as line, area, point, etc. Discussions are proceeding to define other types identified in the Core Cadastral Domain Model such as instrument, right, person, etc.
- **Constraint** – For every attribute that is supporting a class an organization may consider whether it is mandatory (M) and/or read-only (R).

For example, using the FDGC Cadastral Data Content Standard for the National Spatial Data Infrastructure, Version 1.3, the following standard would be used to define an object class for a Parcel.

Column	**Description**
Class	Parcel
Acronym *	CDPRCL
Data Type *	Area
Aspect *	RealEstateObject
Code *	44
Attributes	CDPID$ (M), CDPART (M), CDPARN, CDPRL1, CDPIDA
Definition	A Parcel is a single cadastral unit, which is the spatial extent of the past, present, and future rights and interests in real property.
References	FGDC Cadastral Data Content Standard – Version 1.3
Remarks *	Additional attributes may be added to support presentation of the object class and describe the administrative characteristics.

Table 1: Object Description for a FGDC Parcel.
** Denotes that this column is unique to the cadastral feature catalogue and not part of the FGDC description.*

The attributes used in this example are:

- CDPID$ - ParcelIdentifier
- CDPART – ParcelType
- CDPARN – ParcelName
- CDPRL1 – ParcelLabel
- CDPIDA – ParcelIdentifierAssigner

Each attribute is specified in a standardized way, under the following headings:

- **Attribute** - Attribute name such as "Survey Date". Like classes, it should be noted that UML does not allow spaces so that some abstraction may be applied. If an abstraction is used clarification can be noted in the description of the attribute;
- **Acronym** – Again like classes in order to cross-reference an attribute to a database schema acronyms are often used. In order to accommodate most database systems a six-character code for the class is used;
- **Code** - This is an integer code to be used to index the object class;
- **Attribute Type** – The following types can be assigned to an attribute:
  - **Enumerated** - The expected input is a number selected from a list of pre-defined attribute values. Exactly one value must be chosen. The number is associated to a code list;

    For example, for a digital data source attribute 0 - regular, 1 – digitised enhanced topographic base, 2 – property map, etc.
  - **List** - The expected input is a list where one or more pre-defined attribute values can be selected;
  - **Float** - The expected input is a floating-point numeric value with defined range, resolution, units and format;
  - **Integer** - The expected input is an integer numeric value with defined range, units and format;
  - **Coded String** - The expected input is a string of ASCII characters in a predefined format. The information is encoded according to defined coding systems e.g.: the nationality will be encoded by a two character field specified by ISO 3166 'Codes for the Representation of Names of Countries', e.g. Canada => 'CA';
  - **Character** - The expected input is a free-format alphanumeric string;
  - **Date** – Used to define an instant in time;
  - **Multimedia** – The expected input is a directory path or URL pointing to a multimedia file;
  - **Raster** – The expected input is to a directory path or URL pointing to an image file;
  - **Text** – The expected input is to a directory path or URL pointing to text;
  - **Unknown** – In certain circumstances the attribute has been identified but a specific type classification is still being defined. In order to continue developing a cadastral feature catalogue the user can flag this as "UNKNOWN" and edit the type later;
  - **Unsigned Character** – This is a blob or binary record. The standard format is to indicate the number of bytes at the beginning of the record followed by the binary record.

- **Description** - Where possible each object class should carry a definition. The objective is to clarify the attribute for other users;
- **References** – Used to identify the source of the attribute and/or description;
- **Remarks**- Used to provide additional comments and notes for the class;
- **Minimum Value** - The minimum value for the expected input is indicated for float, integer and/or date;
- **Maximum Value** - The maximum value for the expected input is indicated for float, integer and/or date;
- **Indication** - For coded string type attributes (S) it indicates the construction of the string. For integer (I) and floating point (F) type attributes it indicates the units and resolution of the input.
- **Example** - an example of coded input.

Following the previous example, using the FDGC Cadastral Data Content Standard for the National Spatial Data Infrastructure, Version 1.3, the following standard would be used to define attributes for a Parcel.

Column	Description
Attribute	Parcel ID
Acronym *	CDPID$
Attribute Type *	Integer
Code *	32
Description	The Parcel ID is the primary key, which identifies each record or occurrence in the Parcel entity. This is normally the system assigned number that manages record relationships internal to systems.
References*	FGDC – Version 1.3
Minimum Value*	1
Maximum Value*	
Indication	
Example	
Remarks *	No remarks

Table 2: Attribute Example for Parcel ID.

Column	Description
Attribute	Parcel ID Assigner
Acronym *	CDPIDA
Attribute Type *	Enumerated
Code *	33

Column	Description
Description	This is a designation for the agency, organization or jurisdiction that assigns and maintains the primary key. If possible, this designation should follow known naming standards, such as the Federal Information Processing System (FIPS) codes for jurisdictions. 0 – Unknown 1 – State Agency
References*	FGDC – Version 1.3
Minimum Value*	
Maximum Value*	
Indication	
Example	
Remarks *	No remarks

Table 3: Attribute Example for Parcel ID Assigner.

Column	Description
Attribute	Parcel Type
Acronym *	CDPART
Attribute Type *	List
Code *	34
Description	Parcel Type describes the function, purpose, resource or collective purpose for a parcel. The Parcel Type applies to the entire parcel. The parcel type is categorization that can be useful for display or management. The domains of values are listed as suggested content. The content of this attribute is not standardized. 0 – Unknown 1 – Taxable 2 - Right of Way 3 - General Common Element 4 – Water 5 – Ownership
References*	FGDC – Version 1.3
Minimum Value*	
Maximum Value*	
Indication	
Example	
Remarks *	No remarks

Table 4: Attribute Example for Parcel Type.

Column	Description
Attribute	Parcel Name
Acronym *	CDPARN
Attribute Type *	Character
Code *	35
Description	The Parcel Name is an identifying name or number for a

Column	Description
	Parcel. It may also be a project number or any other label for a parcel such as park name.
References*	FGDC – Version 1.3
Minimum Value*	
Maximum Value*	
Indication	
Example	
Remarks *	No remarks

Table 5 - Attribute Example for Parcel Name

Column	Description
Attribute	Parcel Labels
Acronym *	CDPAL1
Attribute Type *	Character
Code *	36
Description	Formerly Parcel Local Label. Local governments or other organizations may have a method or system for identifying and then applying a number for parcels. These numbers are often used for local administrative purposes. These attributes, and there may be many, refer to parcel identification systems that are sometimes called natural keys or other user recognizable identifiers. The form and content and rules for parcel labels should be included with the metadata. Parcel ID is a common name for this label in local governments.
References*	FGDC – Version 1.3
Minimum Value*	
Maximum Value*	
Indication	
Example	
Remarks *	CDPRL1 is considered the primary parcel identifier. If additional labels are required than extend the attribute list by adding CDPRL2, CDPRL3, etc.

Table 6 - Attribute Example for Parcel Labels

** Denotes that this column is unique to the cadastral feature catalogue and is not part of the FGDC description.*

5. MODELING THE CADASTRAL FEATURE CATALOGUE

The use of UML to assist in doing the gap analysis provides a number of advantages such as:

- The domain experts have a visual presentation of their existing "model", which is much better than leafing through a document;
- UML is a standardized process that helps remove ambiguities;

- UML lends itself towards an iterative process that can assist organization to compile to a standard;

- A number of UML modeling tools allow multi-models to coexist allowing existing models to inherit properties of a standard. (In order to place this paper in the proper context the authors of this paper use Enterprise Architect version 4.1 developed by Sparx Systems, which supports UML 2.0).

When setting up a UML model for a cadastral feature catalogue there is need to clarify some terminology with regards to "attribute". Within a class UML provides the ability to define attributes for that class. The cadastral feature catalogue data dictionary is also comprised of "attributes" supporting the classes defined in the cadastral feature catalogue profile. Within this document the data dictionary is comprised of "attribute classes".

A representation of a cadastral feature catalogue class is presented in Figure 1, which illustrates a SurveyPoint class generalized by the attribute class SurveyPointCatagorization.

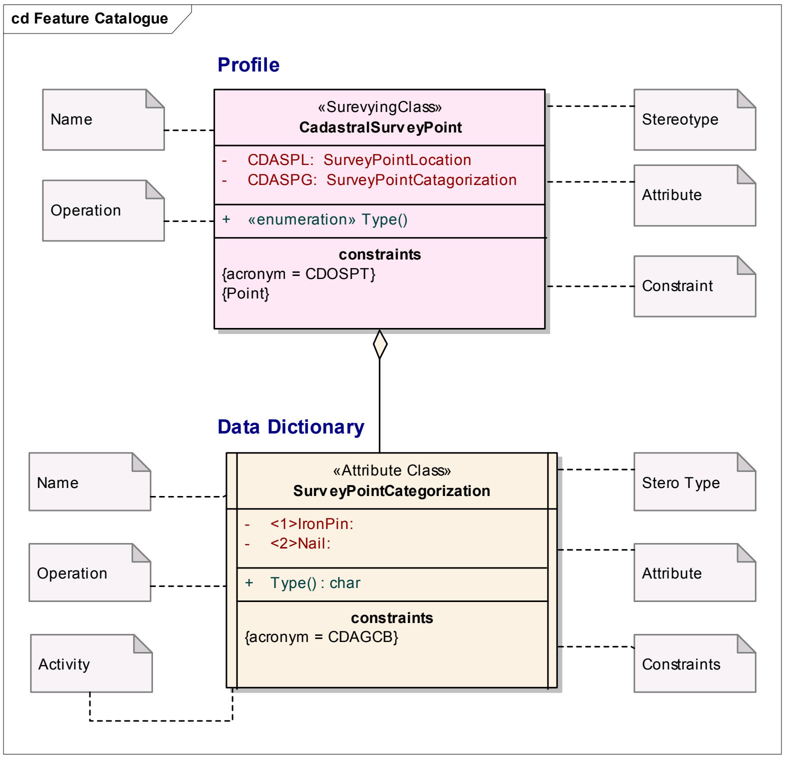

Figure 1: Cadastral Feature Catalogue Class and Attribute Class.

The following section describes the UML properties presented with the cadastral feature catalogue classes:

- **Stereotype** – The stereotypes define the "packages" or aspects defined by the Core Cadastral Domain Model (Lemmen, Oosterom, van, April 2003) plus the addition of Attribute Class;

- **Name** – This defines the name of the class. (Note that UML convention does not support spaces.)

- **Attribute** – An attribute is defined by "name" and "type".

In the case of a class grouped as an aspect the attribute field is populated with attribute classes. In this case the "name" is the acronym of the attribute class and the "type" is the attribute type. In addition the name can have an extension of mandatory (M) and/or read-only (R).

In the case of an attribute class attributes can be considered code lists that are general associated with attributes types such as enumeration or list.
The notation to the right of the attribute defines its "scope", such as private (-), public (+), protected (#) or package (~).

- **Operation** – This field is only used for attribute classes. It is defined by "name" and "returntype" for database definitions like integer, float, character, etc. or "stereotype" for the remaining attribute types like enumeration and list.

  In order to identify the operation as an attribute type the name "Type" is constantly used.

- **Constraints** – This field defines conditions that the class can exist. General one condition is that the class must have an acronym. Though UML tools support this option as an alias, having the acronym as a constraint allows for visual presentation.

  In the case of a cadastral feature catalogue profile class a constraint can also be a data type, such as a line, area, instrument, etc.

- **Activity** – This provides a visual presentation on the status of a class. A double line to the left and right indicate the class is active while a single line indicates it is inactive.

Based on the UML modeling tool being used a number of properties can be defined with the class such as descriptions, references, notes, status, phase, version, etc.

5.1 Example of Gap Analysis

In order to illustrate how UML can assist in a gap analysis a small example is illustrated in Figure 3. The example uses a portion of the Core Cadastral Domain Model version 3 (Oosterom, van, Grise, Lemmen, September 2003) and the FGDC Cadastral Data Content Standard version 3.1 (FGDC, 2003) modeled using UML. A small portion of both models was used to as an example in order to illustrate the objectives of a gap analysis. The focus of the example is on the class "Parcel".

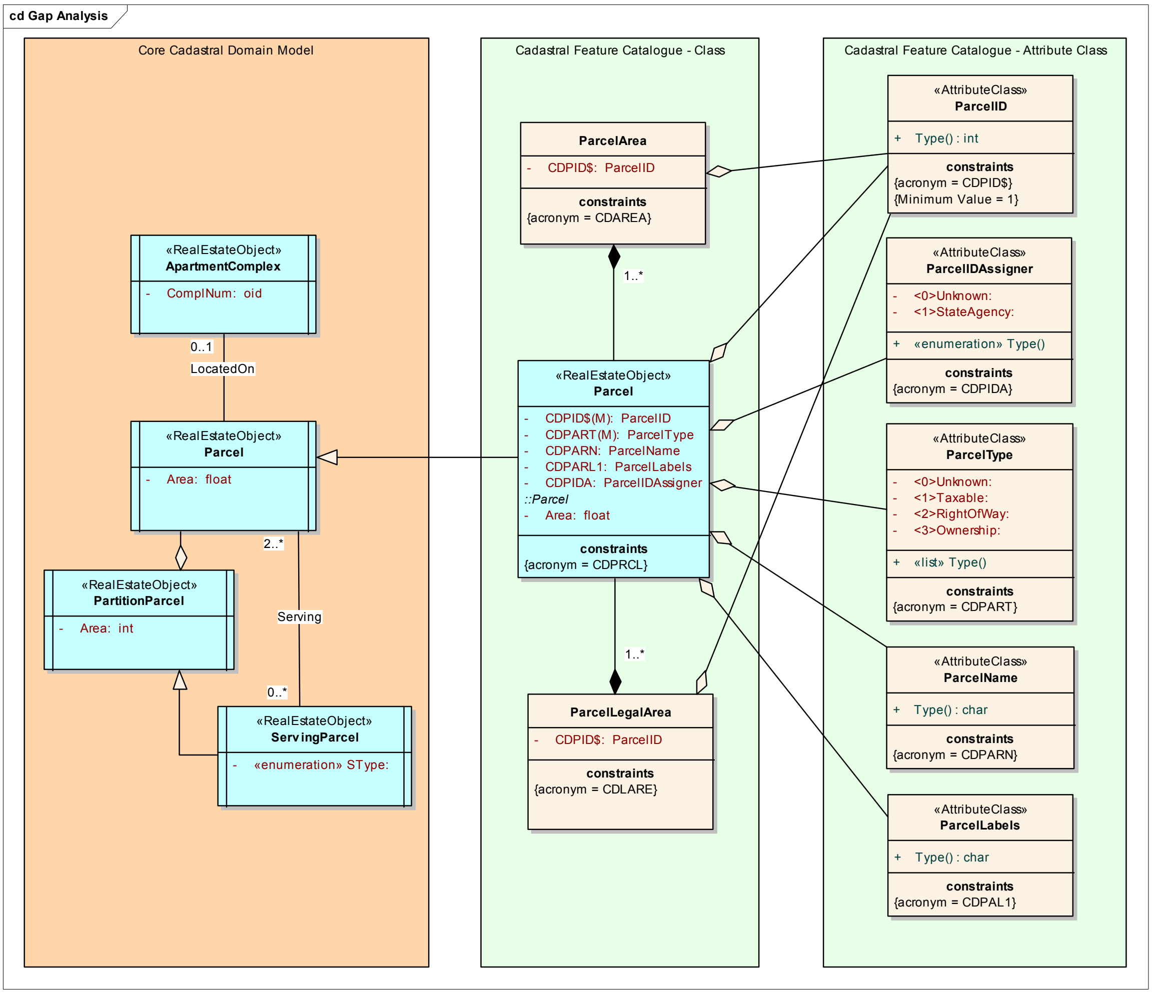

Figure 2: Example of a Gap Analysis using UML..

Following the construction of the FGDC Cadastral Data Content Standard UML model it should be observed that cadastral feature catalogue classes and attribute classes are separated into two data models. This allows for less clutter and confusion since the gap analysis can just be viewed without attribute classes. Also the Core Cadastral Domain Model places an emphasis on classes and their associations.

Since "Parcel" is recognized in both models the presentation (color) and the assignment of a stereotype can be applied in the Standard indicating general commonality. A generalization link can also be establish between the two classes using the Core Cadastral Domain Model as the target or destination since we are looking for compliance with the Model.

An observer can see that though there is a common class in both models there are differences in their association with surrounding classes that are linked to "Parcel". Most notably is that in the Core Cadastral Domain Model area is treated as an attribute will in the FGDC Cadastral Data Content Standard area is treated as a class with attributes.

6. CONCLUSION

The objective of this paper is two fold. First performing a gap analysis provides an effective methodology for comparing existing cadastres with the Core Cadastral Domain Model. Though this can be a daunting task at first glance it is best to work in small packages focusing on areas familiar with domain experts. By first establishing commonality and using an iterative process a proper evaluation can be achieved.

The second objective is designed to provide an opportunity for domain experts to contribute to the discussions involving the development of a Core Cadastral Domain Model. This objective places an emphasis on using a visual presentation available with modeling languages such as UML.

It has been observed by the authors that by using UML presentations domain experts that have little database skills can grasp organizational structures presented in a UML diagram. It is important to get the input of domain experts at an early stage since they may inherit the results of the working group.

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Directions in modelling Land Registration and Cadastre Domain – Aspects of EULIS glossary approach, semantics and information services

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Key words: property information, land register, cadastre, semantics, harmonization, standardization, modeling, terminology, ontology

SUMMARY

Experiences and lessons from the EULIS Project show that semantic modeling or standardization in land register and cadastral domain is possible to and should be based on real world functions. For carrying this through focus should be shifted more on services representing the real world context, instead of information contents and systems that only reflect the real world.

Ontology explication and semantic translators can be used as surrogates to connect the existing systems to the ICT infrastructure related. A roadmap to this with quality assurance by quality labeling has been outlined, detailing the harmonization-standardization process. The structuring process is naturalistic aiming to 'common sense' terms in terminology standardization and by measuring the quality against user needs, and maybe slightly heuristic searching for most likely choices of the information community.

As for cadastre, it may be stated that the legal aspects make up the 5th dimension in the information system domain. Another initiative for cadastral domain, and EULIS, is mapping the trustworthiness and matching the criteria for quality certification labels as detailed.

RESUMÉ

Les expériences du projet d'EULIS prouvent que modeler sémantique ou étalonnage le domaine cadastral est possible à et devrait être basé sur de vraies fonctions du monde. Pour accomplir ceci le foyer devrait être décalé plus aux services représentant le vrai contexte du monde, au lieu du contenu de l'information et des systèmes seulement reflétant le vrai monde. L'interprétation d'Ontology ou les traducteurs sémantiques peuvent être utilisés comme surrogats pour connecté les systèmes existants à l'infrastructure d'ICT reliée. Une carte routière avec la garantie de la qualité par marquer de qualité a été décrite, détaillant le procédé d'harmonisation-standardisation. Le processus structurant et naturalistique, peut être légèrement heuristique, recherchant des choix le plus évidents de la communauté de l'information et modifiés avec des enquêtes complètes d'utilisateur.
Quant au cadastre, on peut affirmer que les aspects légaux forment la 5ème dimension dans le domaine de système d'information. Une autre initiative pour le domaine cadastral, et EULIS, trace le trustworthiness et assortit les critères pour des étiquettes de certification de qualité comme détaillé.

1. STANDARDIZATION AND EULIS PROJECT

The EULIS Glossary and the approach applied have widely been considered successful. The aim of this contribution is to make a review of possible of benefits for cadastral domain modeling based on the same fundamental approach, and even for the INSPIRE context as well as further standardization of land and property information and process technology. The resulting guidelines and conclusions, which are to be understood as a whole, may perhaps reshape some previous views on the topic.

Fundamentally, the EULIS Project has not been a research project that aspires to achieve standardization or harmonization, but rather to produce comprehensive and easily comprehensible descriptions of land and property information (cadastre included) from different countries for the purpose of creating a Europe-wide portal that integrates and provides access to cross-border property and cadastre information services of EULIS member countries . These descriptions are produced, at the initial stage, by creating an all-applicable standard structure for uniform process and information descriptions, applicable regardless of the disparate systems and legislations (demonstrator available on www.eulis.org). (Gustafsson 2003)

The EULIS Glossary uses common and generic definitions of core concepts related to land register and cadastre and discovered by use of uniform process descriptions. The resulting generic definitions, specified as EULIS-definitions, identify the semantically harmonious and common concepts for which the EULIS-terms have been agreed, and act as semantic bridges between (national) concepts used in different jurisdictions. Thus the EULIS Glossary is, first and foremost, a translation aid to users through the EULIS portal. (Tiainen 2003, 2004b)

As for the standardization and modelling of the cadastral domain, the approach and results of the EULIS project need improvements, such as formal and sophisticated methods, further explication, and even ontology work. Further results could also be used to improve comprehensibility and conformity in the EULIS descriptions and terminology. Furthermore impacts can be envisioned on harmonization issues, and that improved transparency will promote interoperability and widen the scope of cadastral information services. (Tiainen 2004a)

2. PROCESS BASED APPROACH

2.1 Stepwise approach

The theoretical approach applied in EULIS reflects a rather practical approach. Therefore the creation of the concepts and generic definitions for the semantics of the EULIS Glossary is presented step-by-step, as originally worked out, for the purpose of suggesting the way forward in modelling and ontology.

2.2 Graphical description model

A uniform graphical description model was introduced for a high-level description of the essential phases and routines involving different parties in land transaction and the registration process. The principal legal effects of registration in each of these phases are also described (figures 1-3; examples from England and Wales, Finland and the Netherlands presenting the principally disparate cadastral system types).

It was necessary to include conveyance, titling, mortgaging and land survey or other property mapping was necessary in order to achieve the *necessary* common understanding.

Important aspects in modelling were the legal effects, such as

- Priorities and rights gained through registration
- Which property can be mortgaged and when (whether registration be required for property objects for mortgaging)
- Public knowledge – security against third parties
- State guarantee for registration

These essential legal effects, which are predefined as key stages of the process, are identified in the uniform structure as possible.

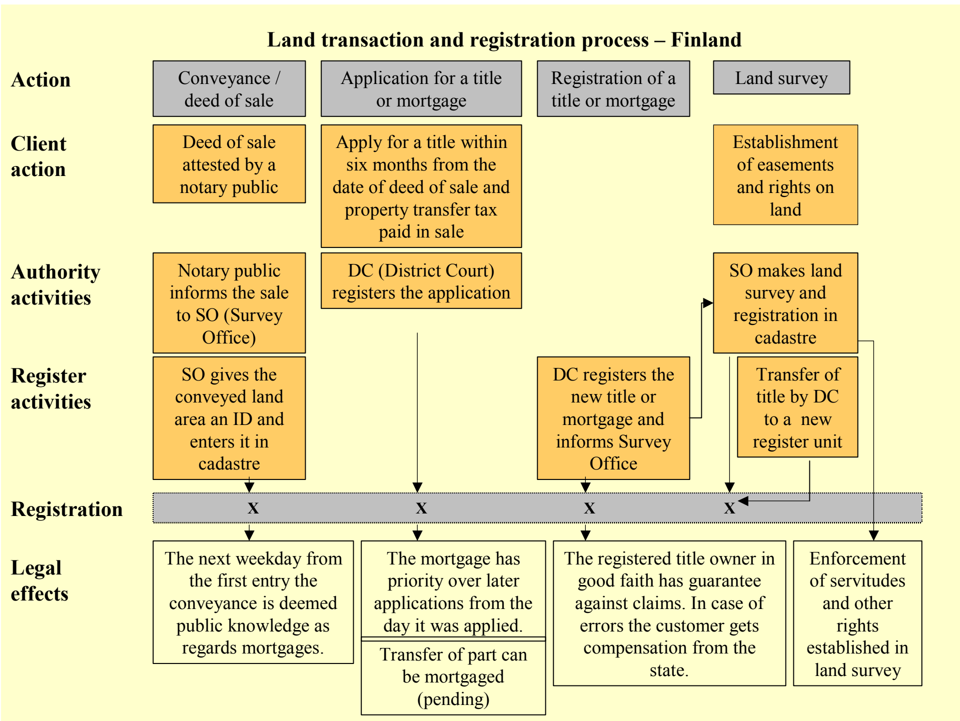

Figure 1: Land Registration system in Finland.

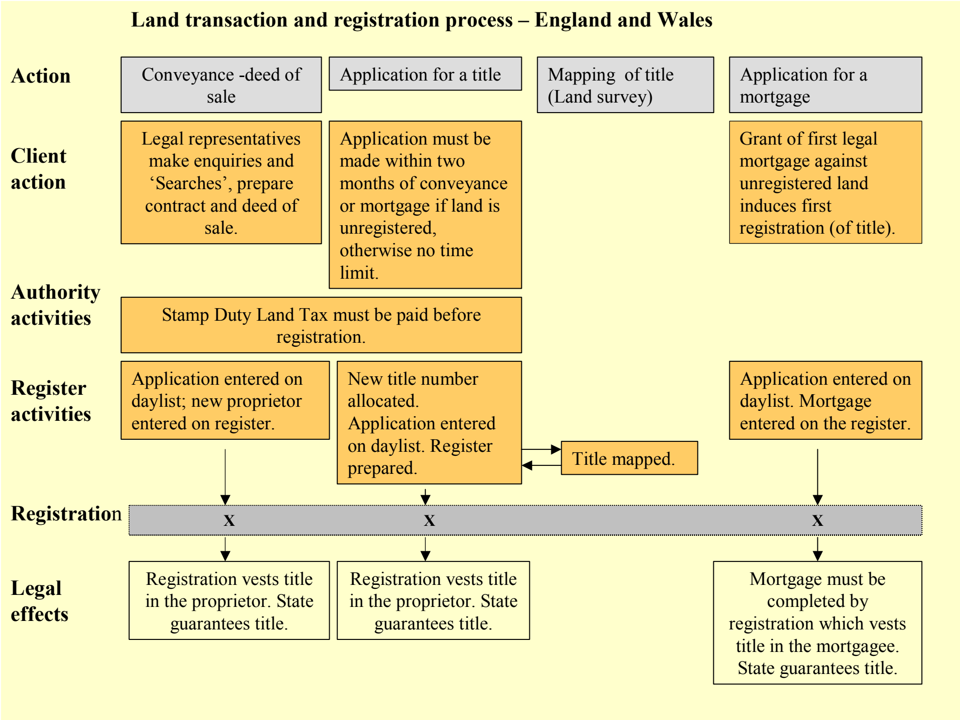

Figure 2: Land Registration system in England and Wales.

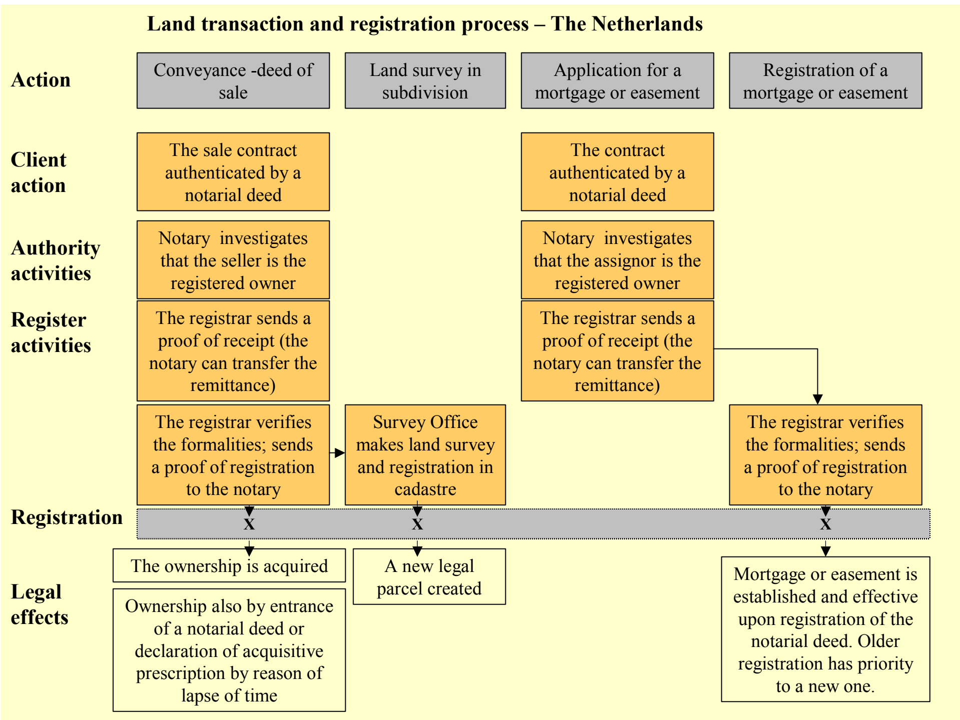

Figure 3: Land Registration system in the Netherlands.

2.3 Modeling method

The graphical descriptions of the processes also provide a meta-model view on the processes. Table 1 illustrates the overall method used in defining terminology. With the help of uniform diagrams:

- Identical phases, meanings and functions are identified
- Basic similarities are recognized and
- Level of present semantic integration is discovered;
- Common, generic definitions are depicted.

In parallel the level of country specific deviations can also be recognized with an analytic insight obtained in the process, thus approaching ontology of related terminology.

Property and cadastre information modeling method ◆ Metamodel level – Recognizing basic similarities to define the common definitions ◆ Conceptual level – Identifying the specific features versus common definitions

Table 1: Modeling process in EULIS.

2.4 Generic definitions as semantic bridges

Generic definitions with the descriptions of country specific features or deviations of correspondent national terms provide semantic translations of national terms. Table 2 shows, as an example, the EULIS term and definition, the national (Swedish) synonym and specification.

Concept (EULIS)	Definition (EULIS)	**National synonym**	**National description**
Guarantee for register information	Responsibility of register authorities to compensate for losses incurred.	Rätt till ersättning av staten i vissa fall/skadestånds-ansvar vid fel i vissa fall	In Land Code Chap 18 Section 4 the rightful owner is entitled to compensation from the State for his loss. Bona fide acquisition by virtue of title is possible due to Land Code Chap 18 section 1
Mortgage	A right in property granted as security for the payment of a debt.	Inteckning	In Sweden a registration of the mortgage refers always to the property. When a mortgage has been granted, a mortgage certificate shall be issued on the basis of mortgage. The right of lien is granted by the property owner surrendering the mortgage certificate as security for the claim or through registration in the mortgage certificate register.

Table 2: EULIS-term and definition, national (Swedish) synonym and specification.

Presently the EULIS Glossary consists of about 50 terms provided with definitions and national descriptions. From pull-down menu list the user can select the EULIS term, or a term in any native language to be translated into the selected language and the respective specification. It was intentional to leave the EULIS Glossary as such in EULIS Project, since using Glossary terms for instance as search words for textual descriptions of the reference information (country descriptions) would easily have caused inconsistency for the user because of the extent and complexity of these descriptions, especially the legal ones (Tiainen 2003).

2.5 Modeling features and interoperability

The process approach applied in EULIS proved successful, and includes a dynamic approach, which is indispensable (Visser and Schlieder 2002 p.15). It also provides

- Possibility to model different implementations in a common framework
- Possibility to identify generic terminology
- A contribution for the purpose of achieving legal conformity (legal effects, priorities)
- A temporal aspect on modeling (time pending from conveyance to title or cadastral registration, lifespan of the object from conveyance to registration)
- An objective description of land transactions and real property information.

EULIS is exceptional in providing essentially cross-border access to information. However regarding IT modeling the same conditions also applies to the interoperability of different environmental system domains, the cadastral system being one of the most primary information sources in general. According to Visser et al., each system that interoperates with other systems has to transfer its information into a common framework and then interoperability is achieved by explicitly considering the contextual knowledge in this (translation) process (Visser, Stuckenschmidt, Schuster, and Vögele 2002 p.7).

Furthermore, according to (Visser, Stuckenschmidt, Schlieder, Wache and Timm 2002 p.3) a conceptual model of the context of each information source provides a basis for integration on the semantic level. They call this process context- transformation, taking the information about the context of the source providing a new context description for that entity within the new information source. They specify context-transformation by classification and context-transformation with rules. Both of these apparently share the common goal of providing objective (explicit) definitions for concepts and the data entities representing these concepts.

To meet the requirements of objectivity it seems necessary to widen a contextual basis of definitions and concepts also to use or service directed. EULIS Glossary is based on a meta-model replicating the real world on high level, thus reflecting the universe of discussion on high level of objectivity. This composition provides the basis for the way forward in our ambitious plan to outline a safe roadmap for modeling cadastral domain through harmonization and standardization with the necessary level of semantic conformity.

3. HARMONIZATION AND STANDARDIZATION

3.1 Harmonization aspects in the EULIS approach

Harmonization is an issue that is difficult to disregard in connection with the EULIS Glossary, since

- The actual level of harmonization is recognized
- Land transactions of real property are described in an objective way
- National deviations are identified along with meaning and level of them.

Glossary with other descriptions is a possible tool in a harmonization study. Further analysis may reveal which differences can be overcome with minor adjustments of formal nature – and which require difficult or expensive changes in the basic structures. The latter involve strong professional traditions, disciplines and interests. Possible topics of interest may also be public-private relationship, the role of consumer protection etc.

Another point of view is that the transparency of national systems, like in the EULIS service and the EULIS Glossary with the comparative information on legislation, is likely to promote best practices in land transaction and registration process technology.

3.2 Stepwise process

Institutional changes are, as a rule, incremental. In these conditions swift changes and progress are not possible in harmonization because of legal, structural, financial, continuous provision of information services and other reasons. Thus harmonization shall, at the initial stage, be of technical nature. This in turn involves standardization. However it is important to clarify the stages involved in the harmonization and standardization in more detail, to initiate the process properly - and basically to determine which stage actually precedes the other.

On ontology level conditional terms, which can be divided into necessary conditions and sufficient conditions, are used as a typical application of ontology. It shows a larger extent of explication than the pure taxonomy of concept terms. A first step to gain more formality is to prescribe a structure to be used for the description (pre-standardization). (Visser, Stuckenschmidt, Schuster, and Vögele 2002 p.5 and 9, details in 4.2.1)

Furthermore we may see, e.g. from the lessons that EULIS has provided, that semantic pre-harmonization is a necessary prerequisite for standardization and, as stated in 2.5 above, ontology methodologies are promising tools and key issues in semantic modeling.

Another important question is where the added value is. One has to consider if EULIS, the Cadastral Domain initiative (Lemmen, C. et al. 2003) or INSPIRE are different in scope or regarding user segments. Any case furthers the discussion on the dilemma of how these approaches could support each other in a sustainable way, since their time perspectives in setting up the operational service (in different countries) seem to differ.

3.2.1 INSPIRE steps

INSPIRE presents the process of standardization and harmonization and finally integration identifying four steps in all. The process is generalized as follows (http://inspire.jrc.it/):

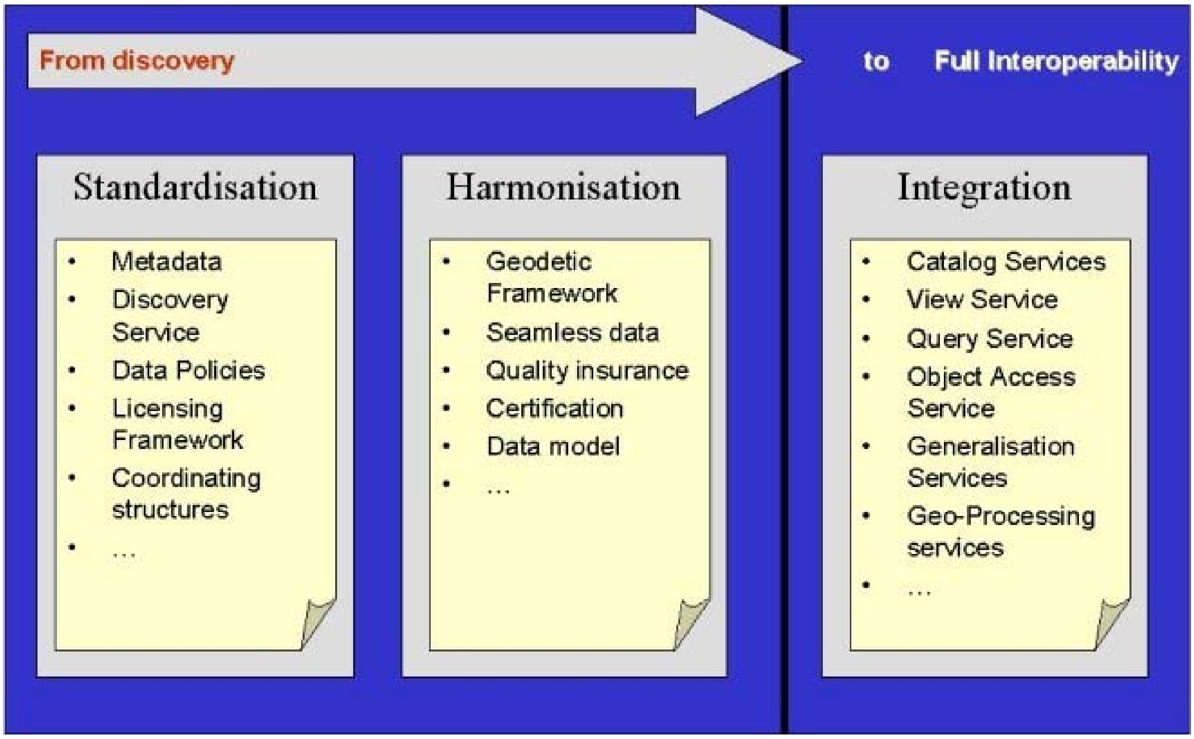

Table 3: INSPIRE stepwise approach.

An overall harmonization would be a major task, which is simplified by focusing on standardization and harmonization of documentation (metadata) at the initial stage.

In the second step accessing spatial data sets located by use of metadata is a step towards integration. An example given is "visual inspection of spatial relations between phenomena by overlay of datasets".

In the third step modeling is introduced by mapping existing data sets to "a common set of models" that also reveals and identifies the conceptual disparity (linguistic and semantic deviations). - This is where the (EULIS Glossary) approach presented might be useful.

"The fourth and last step will build upon the previous steps and concentrate on completing the common models and on providing the services to fully integrate data from various sources and various levels, from the local to the European level into coherent seamless datasets supporting the same standards and protocols. This step will allow real time access to up-to-date data across the whole of Europe." (http://inspire.jrc.it/ Stepwise approach)

The last step is a major one in terms of modeling efforts, and no doubt appropriate semantic and ontology methods will be required.

3.2.2 Service aspect

In every major system development task, the continuity and lifespan of the service(s) shall be considered. Especially concerning land register and cadastral information this point of view is essential to the market economy, companies and customers at large – including consumers.

Initiatives approaching the topic from different angles, such as Cadastral Domain Modeling, INSPIRE and EULIS, clearly have a different scope or involve different user segments although some overlapping may occur. They also seem to have at least partly different time perspectives in setting up an operational service in different countries, which may enable and accelerate sustainable co-operation. A common and immediate task in all of these initiatives is need for semantic harmonization, an area where we are trying to specify the (common) roadmap forward. Thus the objectivity requirement stated earlier in section 2.5 could be better met considering different services, scopes and by catering to user needs.

Even the continuity aspect would be better served if services on different levels would use the same modeling basis, where reasonable or possible. Hence different user communities have adopted (semantically) different user views. This applies especially to legal conformity, which is of utmost importance with respect to cadastral data, as evident from figures 1-3.

3.2.3 Information community

The current situation with the initiatives mentioned above emphasizes the significance of integration, and the increasing infrastructure involvement of cadastre. The infrastructure is also increasingly dependant on the cadastre, as recent NSDIs (national spatial data infrastructure) developments and the INSPIRE initiative prove. Quality differences on the semantic level cause disintegration and multiple efforts in data updating and maintenance.

The cadastral development has characteristically been incremental in societies. Swift changes are not possible because of legal, structural, financial, information service and other reasons. As a result harmonization need to be of technical nature in the initial stage.

Harmonization and standardization require appropriate technology tools and methods, and there ontology needs emerge as key issues. The information community related to cadastre should agree the use of compatible methods for best results, best benefits and to ensure sustainability of the work for each party since integration should preferably not be made into and fundamentally is not an issue of competition but co-operation.

3.2.4 Modeling and interoperability

Interoperability is achieved by explicitly considering contextual knowledge in the (translation) process of data exchange (Visser, Stuckenschmidt, Schuster, and Vögele 2002 p.7). Here semantic translators come into focus. Even well established methods, for instance UML, have shortcomings as far as semantic integration is concerned.

According to (Visser and Schlieder 2002 p.4) well known modeling with UML have advantages since UML supports both static knowledge and dynamic behavior. A major disadvantage of UML-based modeling is, however, the non-existence of model checking, i.e. consistency checking. It is also not possible to make implicit knowledge explicit. The latter is the main advantage of formal ontologies. If written down in a logic-based language, consistency-checking and the explicit construction of hidden knowledge with the help of inference mechanisms is possible. On the other hand, describing processes, e.g. workflow events, is not possible (for formal ontology methods).

Nevertheless, describing legal entities and processes in different stages of entity-lifespan (with different legal properties) and standardizing legal conformity is difficult even in UML. This applies also to cadastral domain model; the temporal aspect shall be considered: Dynamic view of the registration process (figures 1-3) reveals the different stages in the lifespan of property transaction object, in addition to often rather long time pending from conveyance to title or cadastral registration. The same dilemma seems to appear in ISO/CD 19126 (The impact of BoundAttributes in figures 5-6 on register schemas of CD makes a major complexity. The structural role of BoundAtrributes should be further determined.)

For interoperability purposes there are different ways to employ the ontology. In general, three different directions can be identified: single ontology approaches, multiple ontology approaches and hybrid approaches (Visser, Stuckenschmidt, Schlieder, Wache and Timm 2002 p.1-2). Figure 4 below gives an overview of the three main architectures.

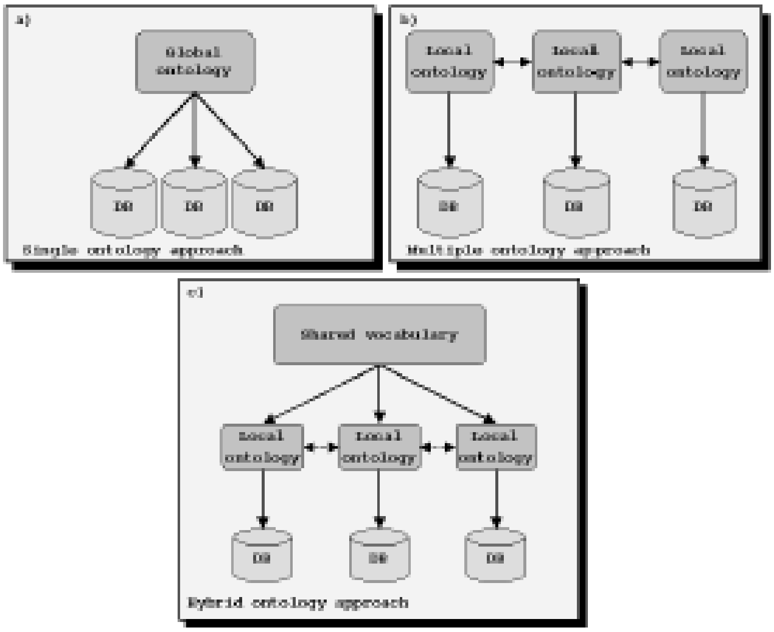

Figure 4: The three possible ways for using ontology for content explication (Visser, Stuckenschmidt, Schlieder, Wache and Timm 2002 p.2 or Stuckenschmidt, Harmelen 2004).

• **Single Ontology approaches**: Single ontology approaches use one global ontology providing a shared vocabulary for the specification of the semantics (see fig. 4a). All information sources are related to one global ontology. A prominent approach of this kind of ontology integration is SIMS.

• **Multiple Ontologies**: In multiple ontology approaches, each information source is described by its own ontology (fig. 4b). For example, in OBSERVER the semantics of an information source is described by a separate ontology.
• **Hybrid Approaches**: To overcome the drawbacks of the single or multiple ontology approaches (e.g. finding the minimal ontological commitment), hybrid approaches were developed (fig. 4c). Similar to multiple ontology approaches the semantics of each source is described by its own ontology. But in order to make the source ontology comparable to each other they are built upon one global shared vocabulary. The shared vocabulary contains basic terms (the primitives) of a domain. In order to build complex terms of source ontology the primitives are combined by some operators. Sometimes the shared vocabulary is also ontology.

3.2.5 Initialization – the necessary steps

The general conclusion about harmonization-standardization issue is that semantic pre-harmonization is needed even for the purpose of standardization. However, to achieve this, first a high-level semantic pre-standardization view, such as the EULIS process-models, must be developed and agreed upon for achieving the necessary objectivity required to compile a shared and harmonized vocabulary as result of the semantic pre-harmonization (respectively EULIS Glossary). This step provides the basis for universal modeling and explication, resulting to possible standardization or (semantic) harmonization whichever the objective may be. We also keep in mind different user communities in the ITC infrastructure, and the obvious need for different user views as regards cadastral information.

In Stepwise approach of INSPIRE the initial semantic harmonization is obviously thought to be achieved by a quantitative method. The other aspects introduced, and relating in particular to the cadastral domain, emphasize preferably qualitative methods to ensure the consistency, and conclude to use of formal methods and ontology explication. The established UML modeling may be used for data modeling after the semantic harmonization steps.

4. ONTOLOGY EXPLICATION

4.1 OGC semantic modeling approach

The essential model for semantics and information communities is defined by OGC using concepts (notions) of information communities, project worlds and sub-worlds, where integrity is achieved by testing (the unambiguity of) properties or property/value pairs (OGC 1999 p.2):

(- Including Abstract Specification of Open GIS Consortium on Topic 14: Semantics and Information Communities):

It should be possible to move information easily and without semantic loss from Project Worlds having naive schema into Project Worlds with more sophisticated and inclusive schema. Moving information the other way requires the truncation and loss of information. A Project World that is more naive than another is called a subworld of the other.

Note that a sophisticated schema should not be denied potential subworlds only because they fall outside the physical extent of its Project as specified in its Project Schema. We ignore the physical extent of projects when comparing them to check if one is a subworld of the other.

Definition: Let S1 and S2 be two Project Worlds in A. Let S2* be the Project World obtained by extending the physical extent of Project S2 (if necessary) until it covers the extent of Project S1. We say S1 is a subworld of S2 if there are three functions, R1, R2, and R3, that behave as follows:

i. R1 is a one-to-one change-of-spatial-reference from the reference system of S1 to that of S2*

ii. R2 is a mapping from the feature instances of S1 into those of S2* such that F is a feature of S1 occupying a point P if and only if R2(F) is a feature of S2* occupying R1(P),

iii. R3 is a mapping from the set of property/value pairs of all features in S1 into the set of property/value pairs of all features of S2* that preserves semantics, and is canonical with R2.

The OGC modeling approach is specified for geographical information, but may be applicable in general, and it should also be suit to the cadastral community well. We find the approach of OGC useful in (high-level) semantic standardization in specifying how to handle different user segments. However it may be good to mention here already that the high-level process-based approach presented in the EULIS context seemed to be necessary as first step of the high-level semantic standardization to create a global domain glossary, which is needed in hybrid approaches presented in 3.2.4.

4.2 Semantic translators

4.2.1 <u>The role of ontology and semantic translators</u>

Visser, Stuckenschmidt, Schuster and Vögele have defined the role of ontology and the process of semantic translation (much resembling the approach of OGC), which are both needed to achieve cross-border interoperability and to promote data exchange from diverse source databases, and the increasing exploitation of GIS, especially in INSPIRE contexts.

The role of ontology is distinguished on three levels: operational information level, ontology level and ontology language level (Visser, Stuckenschmidt, Schuster and Vögele 2002 p.9):

- *On the operational information level* the real task is to determine the concept category an information entity belongs to in a new context, so that it is rather translating type annotations than the information entity itself.

- *On the ontology level* specification of contextual knowledge explicates the intended meaning of terms. Each information source to be integrated is supposed to be specified by such ontologies to enable us to use its contextual knowledge in the translation process.

- *On the ontology language level* properties of concept (defining necessary and sufficient conditions, *see clarification in section 6.2.2*) serve as a common vocabulary used to build the ontologies of different information sources to be integrated.

The process of translation and supporting technologies are described in three stages (Visser, Stuckenschmidt, Schuster and Vögele 2002 p.10-11):

- *Authoring of shared terminology* is to define a common terminology that is general enough to be used across all information sources to be integrated but specific enough to make meaningful definitions possible. Different tools such as ontology editors exist, whether they are appropriate to specific needs of the domain concerned is another matter, and a source or institution independent expert is employed. - Actually this is a stage that has been completed in creating the EULIS Glossary based on system structuring in a high-level service process approach with legal effects and the temporal aspect included, basically *dealing primarily services and service processes*. The expertise needed involves an in-depth knowledge of the application area.

- *Annotation of information sources* can be made once a common vocabulary exists. Annotation means in this context that the inherent concept hierarchy of an information source is extracted and each concept is described by necessary and sufficient conditions (*see clarification in section 6.2.2*) using the terminology built in step one. An annotation tool applicable with different vocabulary repositories according to *different domains of interest* is needed.

- *Semantic translation of information entities*; the existence of ontologies for all information sources to be integrated enables the translator to work on these ontologies instead of treating real data. This is a way of using ontologies as surrogates for information sources. The new concept term describing the type of an information entity in the target information source is determined automatically by a classifier that uses ontologies of source and target structures as classification knowledge. This is possible, because both ontologies are based on the same basic vocabulary that has been built in the first step of the integration approach. (- A very interesting feature here is that a classifier that uses ontologies of numerous possible source structures and the target structure as classification knowledge may be able to determine appropriate information source automatically.)

4.2.2 Semantic translators and continuity

Enhanced semantic translators facilitate interoperability also with existing databases by "using ontology as surrogates for information sources" as stated in (Visser, Stuckenschmidt, Schuster, and Vögele 2002 p.10) without special capabilities.

4.3 Standard views of different user communities

Creating a global vocabulary for the cadastral domain and domain modeling requires sophisticated knowledge about the importance of cadastral information in various needs, present and future, as far as possible. Hence it is a challenging task for ontology study to identify specific user views as universal standards through necessary user surveys.

As lessons learned from EULIS have indicated, it seems to be possible to identify diverse service needs for cadastre, even considering different registration institutions and legislations, since the fundamental functions of cadastre in society are very similar everywhere where there is a cadastre or land registration institution. Service for standard needs could be simplified with a predefined set of selected properties and property values of information entities, and should be taken to objective of further ontology explication and extensions of cadastral information services.

5 QUALITY LABELING

5.1 Quality labeling for cadastral information

For cadastral information the quality or trustworthiness as specified by (Zevenbergen 2004) is of crucial importance. This is, of course, a question that dominates in the case of data exchange and interoperability, too.

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

The examples in table 4 offer only a hint of the possibilities; a very strict semantic study and ontology explication are needed to enable the classification of the quality of properties or property/ value pairs for legal effects and different rights on land, real and subjective.

Concept	Property/value		Concept	Property/value
Mortgage	- No mortgages - Transferable - Priority / 1…n - …		**Owner**	- Not yet registered (buyer) - Registered titleholder - Reg. cad. unit owner / not yet titled, title transferred... - (Registered leasehold / temporal extend of lease, classification for other extend of lease) - …
Parcel (Register unit)	- Not yet registered (transfer of part) - Titled, not yet registered as cadastral unit - Cadastral unit with valid title / not yet valid title / title transferred… - (Registered leasehold unit) - With other holding rights…		**Boundary type**	- General - Boundary marks fixed, coordinate approximation / ISO classification for positional accuracy estimation - Coordinate fixed / ISO classification for positional accuracy estimation - …

Table 4: Properties/values defining the quality for concept items.

For features of spatial representation, topology, coordinate reference system etc. the standards of ISO 19100 (even on ISO 19115 metadata level) may be appropriate as classification.

The next step after quality labeling might be issuing recommendations for quality improvements and adjustments to process technologies when the quality standards are not met, which in itself directs to standardization or harmonization along with the time.

5.2 Quality labeling for information services

Another stage of quality labeling might be giving quality labels for cadastral information services based on the predefined standard views of different user communities or groups according to section 4.3. Table 5 shows an extract of such a predefined standard view.

In this manner the user would be able to determine immediately if a certain logical set of information is available online, through data transfer or some other way.

Parcel (Register unit)	- Titled, not yet registered as cadastral unit, **or** - Cadastral unit with valid title, **or** - (Registered leasehold unit)
Mortgage	- No mortgages, **or** - Transferable mortgages

Table 5: A part of predefined standard data set as combination of selected properties.

6. ROADMAP TO MANAGEMENT OF CROSS-DISCIPLINE SEMANTICS

6.1 Benefits of EULIS approach

There are various ontology explication methods and tools with special features (Visser, Stuckenschmidt, Wache, Vögele p.7, or Visser, Stuckenschmidt, Schuster and Vögele 2002 p. 5-7; 3.2) applicable for semantic harmonization and translations, the end goal being to promote data exchange and the integration of cadastral systems to ITC infrastructure and INSPIRE framework. The hybrid approach for the management of semantic integration seems to be a beneficial strategy that enables the possibilities created by interoperability to be exploited more quickly (Stuckenschmidt and Harmelen 2004 p. 37).

This paper has described the development and the objectives of the EULIS Glossary and compared these with other developments and studies relating to ontology explication and semantics. Some benefits of the experiences from the EULIS Glossary and the approach adopted have been investigated for the purpose of charting the way forward in semantics and integration. As for EULIS Glossary, further formal research of terminology would produce more sophisticated results, should these be needed with respect to the future EULIS service. Widening the terminology contents and adding more detailed levels to the EULIS Glossary would require specific resources were allocated to this work. On the other hand the EULIS approach seems to provide a valuable contribution to cadastral ontology explication and to thus promote the development a global vocabulary needed in the hybrid approach and semantic harmonization in general, particularly in terms of legal conformity. The necessary steps have been defined initially in section 3.2.5 in the beginning of the paper.

The semantic pre-standardization step in the process modeling for the EULIS Glossary is identified to achieve a high-level objectivity needed to create the global vocabulary, and as a prerequisite for harmonization. Joining EULIS will produce the basic standard level in this pre-harmonization to new member countries, as joining is possible only on reference information level including the EULIS Glossary and the knowledge within (and without connection of national information services to the EULIS portal).

6. Roadmap for semantic harmonization

The semantic harmonization process and different approaches are sufficiently described in the preceding chapters, the purpose of the description being to outline a roadmap for harmonization and standardization, respectively. The roadmap is intended as a guideline on principals:

6.1.1 Semantic pre-standardization

A high-level semantic pre-standardization view shall be developed and agreed upon and on sufficiently high objectivity level (meta-model level). The level of objectivity can be improved by high-level standard description of services or the very technology processes. The EULIS process-models are an example of this step. Sophisticated and independent expertise is needed.

6.1.2 Semantic pre-harmonization

As result of the pre-standardization it is possible to compile a shared and harmonized vocabulary in this step (respectively the EULIS Glossary as a simple example). This step provides the basis for universal modeling and explication and may result in the standardization or (semantic) harmonization of data , whichever the objective may be. Independent expertise (and ontology tools in complex domains) is needed.

Some experts, especially from the point of view of semantic web, consider that the shared vocabulary should be according the minimum amount needed. This may depend on the level of conceptualization, and the user community or different user segments involved. In this paper *the necessary and sufficient conditions* as regards modeling are simplified to imply information and features that are, considering the future visions:

- Exploitable *or* indispensable, and
- Trustworthy regarding the process of producing this information.

(Nykänen 2004)

6.1.3 Semantic translation process

A detailed example of the translation process is given in section 4.2.1. This step involves here (Visser, Stuckenschmidt, Schuster, and Vögele 2002 p.10-11):

- *Annotation of information sources*

◆ Annotation means here that the inherent concept hierarchy of an information source is extracted and each concept is described by necessary and sufficient conditions. An annotation tool applicable with different repositories of vocabularies according to different domains of interest is needed.

- *Semantic translation of information entities*

- The new concept term describing the type of an information entity in the target information source is determined automatically by a classifier that uses ontologies of source and target structures as classification knowledge. In this way ontology may be used as a surrogate for information sources.

The OGC semantic modeling approach described in section 4.1 (OGC 1999 p.2) resembles very much these stages of the semantic translation process, and may be used as well, if appropriate. The main difference is that the OGC approach directs to the property level, and if that is the preliminary intention, might be advisable to follow.

6.1.4 Quality labeling for cadastral information

Quality labeling for cadastral information in section 5.1 implies explication for classification of data quality with labels by properties or property values. This is included in the OGC semantic modeling approach in 4.1. User surveys for evaluation may be added.

6.2.5 Quality labeling for information services

Quality labeling for information services in section 5.2 is giving quality labels for cadastral information services based on standard views of different user communities or groups according to section 4.3. User participation and surveys for evaluation may be added.

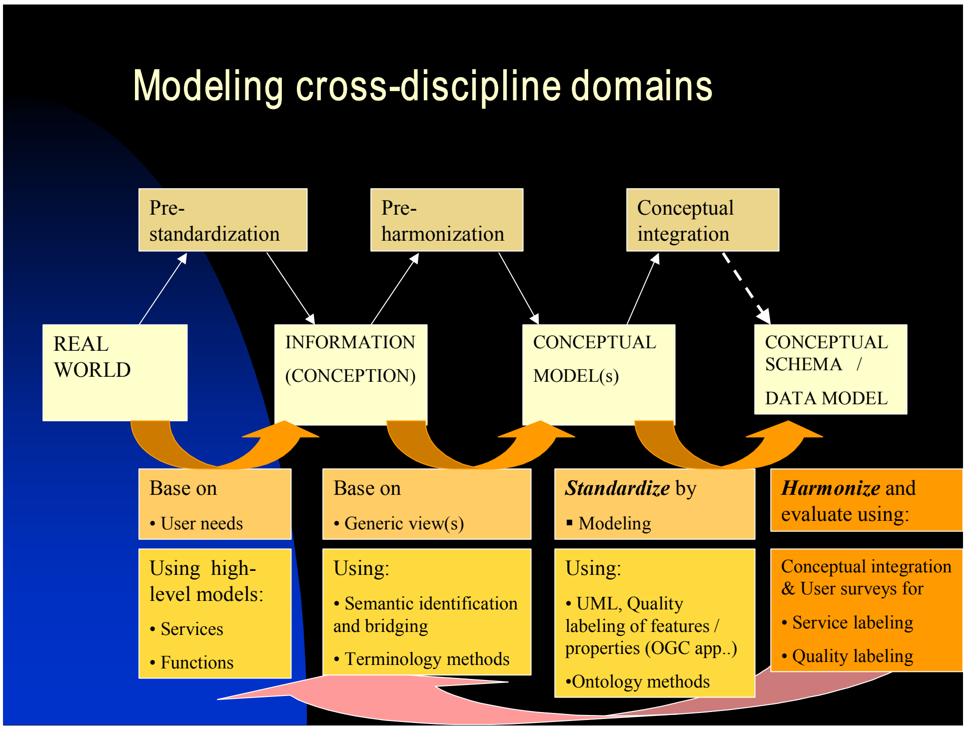

Figure 5: The outline process for semantic integration.

6.3 Possible benefits for EULIS

Further ontology explication could provide EULIS with a more comprehensive and structured terminology to be included in the EULIS Glossary as well as throughout the reference information descriptions. Also, the use of EULIS terms as search words in user interface would be promoted, since present EULIS terms may not satisfy the consistency requirements to be used as search words to a sufficient degree.

Quality labeling stage would significantly improve the services to the benefit of end users, and enable anyone to understand the meaning of property and cadastral information provided.

7 CONTEXTUAL FRAMEWORK FOR SEMANTIC HARMONIZATION AND CADASTRAL DOMAIN MODELING

The experiences and lessons from the EULIS project show that semantic modeling or standardization in the land register and cadastral domain should and is possible to be based on the real world (institutions, rules, functions, processes, diverse user segments and services), not only on existing information systems reflecting that real world in a system specific way, often incomplete and restricted or too simplified. This also implies *widening the extent of investigation* first on a more general level (*pre-standardization*) to achieve a profound unambiquity for terminology and conceptualization, before defining the details. Some approaches are given as examples on how ontology explication and semantic translators can be used as surrogates to connect the existing systems (even with their restrictions) to the ITC infrastructure related. A roadmap with the necessary quality assurance by quality labeling has consequently been outlined. The author's intention has been to review the results presented also with ISO 19100 perspectives.

The requirement for a real world basis is necessary due to the diverse and dynamic dimensions of cadastral and property information; spatial, temporal and legal, even socio-economical as well, and in addition the services must be reality-based. It may even be stated that with respect to cadastre the legal aspects make up the 5th dimension, the four others being established and well-known dimensions in environmental information system domain.

Nevertheless different aspects are possible to assimilate sufficiently based on real world functions and abstractions of them with available semantic methods or ontology explication, using adequate and independent expertise, or more properly, *qualitative* human knowledge or comprehensive user surveys. Accordingly the structuring process is naturalistic, arising from the very acts and functions. It may also be slightly heuristic, searching for most likely choices of the information community, and not necessarily or solely by hierarchical categorizing. Also existing user survey results can be exploited with appropriate methods for quality labeling and amending the domain model in more details (entity properties and property values). The author's insight is that modeling in general should shift *focus more on services or qualitative conditions* and the real world context, instead of information contents only.

Terminology standardization, where the EULIS approach was given as an example in this paper, provide a feasible knowledge basis for further results, following the roadmap given.

Besides legal and procedural views, EULIS reference information includes compilation of core data contents, datasets and product services of various countries, increasing in number, and in a uniform structure for cadastral domain modeling.

Another initiative for cadastral domain is charting the trustworthiness and matching the criteria for quality certification labels consequently as presented and detailed.

The evaluation criteria for a successful progress may be ambiguous whether the main objective is to improve data access and interoperability, to reduce land transactions costs or time spent, raising better security, to improve completeness or integrity of data or services etc. The ultimate criteria might be better services with *better transparency and reliability* of the complex information domain, promoting best practices in technology processes of land registration, the same also being necessary in standardization and harmonization.

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BIOGRAPHICAL NOTES

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Expanding the Legal/Administrative Package of the Cadastral Domain Model – from Grey to Yellow?

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Key words: cadastre, modeling, legal aspects, land rights

SUMMARY

In version 3.0 of the cadastral domain model (Lemmen et al, 2003) we did not elaborate the legal/administrative package very much. We treated the class RightOrRestriction as an association class between Person and RealEstateObject, both of which are 'unpacked' by making them abstract classes with specialization classes in their respective packages.
In this paper some first ideas on how to expand the legal/administrative side of the model are presented. Firstly this is done through no longer treating the class RightOrRestriction as an association class, but putting it in between Person and RealEstateObject. Secondly more attention is given to rights and restrictions that have no direct relation to a person, but where the prime beneficiaries are one or more other RealEstateObjects or are not clearly identifiable. Thirdly RightOrRestriction is made into an abstract class with specialization classes within its package. Attention is paid to the questoin whether derived rights have to be registered as restrictions to one person or as rights to another person. Fourthly a third 'R' (of Responsibilities) is added. Finally it is suggested that certain specializations of RightOrRestriction always coincide with certain specializations of RealEstateObject, and that another way of packaging (only showing such a combination) would be very useful. More work on, and actual UML modeling of, these first ideas will follow soon.

1. INTRODUCTION

1.1 Current model

The core of the cadastral domain model as presented in figure 1 of (Lemmen et al, 2003) is a formalized representation of the often used figure relating the three 'classes' to each other (like (Zevenbergen, 2004) where 'owner', 'right (title)' and 'parcel' are connected, but several variations have been used before). The core model consists of the classes Person, RightOrRestriction and RealEstateObject, whereby RightOrRestriction forms an association class of the relation between Person and RealEstateObject.

In version 3.0 of the cadastral domain model (Lemmen et al, 2003) we did not elaborate the legal/administrative package very much. Whereas the classes Person and RealEstateObject are both 'unpacked' by making them abstract classes with specialization classes in their respective packages, the legal/administrative package only contains three refinements of RightOrRestriction. Firstly the mortgage was made into its own class, that is primarily related to a right or restriction (and through that only indirectly to a real estate object). Secondly a class PublicRestriction was introduced related directly to the real estate object. In both cases no relation is made to the class Person. Finally all three classes just mentioned were related to LegalDocument (like contracts, deeds or decisions), which in virtually all cases are the source of the establishment or transfer of a right or restriction.

In this paper some first ideas on how to expand the legal/administrative side of the model are presented. But before we can do that, we should rethink the roots of the 'parcel' (and the other specializations of RealEstateObject).

1.2 The 'parcel'

Unlike most other geographical objects that constitute what we call geo-information these days, the parcel is not a physical reality (man-made or not), but an institutional creation. A parcel is a part of the continuum of the earth, that a group of people have decided to treat as an identifiable unit. To a certain extent this can be reflected by the use that is made of it, but ultimately it is the legal rights that certain people have that determines the extent of and the boundaries between two parcels.

This also means that the expansion of the core cadastral model in the RealEstateObject package (see paragraph 2.1 of Lemmen et al, 2003) can only be explained by looking at different types of legal rights that relate to different units of the earth (and even other objects). The fact that the RealEstateObject is only an abstract class and different forms of 'parcel' form classes on their own is caused to a large extent by the variety in legal rights and the variety in the types of units their vesting creates.

2. CORE OF THE CADASTRAL DOMAIN MODEL

Based on the above, it is clear that a parcel (or other object) cannot exist on its own, but ultimately finds its definition in the extent of the unit over which a certain person holds a legal right. RightOrRestriction cannot be depicted merely as an association class of the relation between Person and RealEstateObject. In the field of cadastre and land registration, at which the core cadastral model primarily aims, a parcel is totally depending on the legal right (the type of right, the occurrence of the right and the extent of the right). Therefore RightOrRestriction should be seen as a class on its own.

This will also make it easier to deal with the case of rights or restrictions that do not have a direct relation to a person. Now that RightOrRestriction is no longer considered as an association class between Person and RealEstateObject, it would be possible to allow for the occurrence of cases where there is no relation to Person, although introducing a new specialization class 'ImpliedPerson' of the abstract class Person might be a more elegant solution. In any case, this allows for making Mortgage and PublicRestriction into specialization classes of the abstract class RightOrRestriction.

On the other hand in many countries there are certain rights which prime beneficiaries are one or more other RealEstateObjects. This could be simple servitudes, but also party walls (supporting two constructions owned by different persons) and other joint facilities (ranging from common roads, fishing waters to golf courses). Such a right (or the share in the right) is attached to the ownership of (or other strong right in) a certain, neighboring parcel, and can in most cases not be transferred separately from that parcel. An exception to that rule can be found for instance in Sweden with regard to the right to fish in certain water, which can be detached from any parcel in the area. Hence the specialization NonGeoRealEstate.

3. SPECIALIZATIONS OF RIGHTS

3.1 Types of rights and restrictions

In (Lemmen et al, 2003) we emphasized that use is made of 'Literate Modeling', which is very prominently done in section 2.4 with regard to the legal/administrative classes. Even though little is depicted in the class diagram in addition to the class RightOrRestriction, we described four categories of private law rights and restrictions. There is also a difference in the way the different categories of rights and restrictions relate to persons, and the relevant list of attributes is also likely to differ between the different categories. All of this form good reason to expand the legal/administrative package, by making RightOrRestriction into an abstract class and introducing a number of specialization classes along the lines of the categories just mentioned.

The types of legal rights that can be distinguished contain at least:

a. Firstly we have the strongest right available in a jurisdiction, called e.g. ownership, freehold or property.
b. Secondly we have derived rights from the previous category where the holder of this derived right is allowed to use the land in its totality (often within the limits of a certain land use type, e.g. housing or animal farming).
c. Thirdly we have minor rights that allow the holder of it to some minor use of someone else his land, e.g. walking over it to the road. Such rights can be called servitude or easement, and also may include the right to prevent certain activities or construction at some nearby land, e.g. freedom of view.
d. Fourthly we have the so-called security rights, whereby certain of the previously mentioned rights can be used as collateral, mainly through bank loans, in the form of e.g. mortgage, hypothec, lien (paragraph 2.4 of Lemmen et al, 2003).

In addition to the rights listed under c) we have the party walls and other joint facilities (for instance the Dutch *mandeligheid*; also see paragraph 2).
Another type can be restrictions and responsibilities whose beneficiary is less concrete, like for instance a more or less general interest, or a type of servitude that is benefiting for instance a utility company (to let you refrain from undertaking activities that might harm cables or pipelines).

Of course we could expand the core cadastral model by showing these four categories of legal rights as specialization classes of the abstract class RightOrRestriction. We might even try to refine the model a bit more, since not all the legal rights can exist on their own. Usually the strongest right (a.) has to apply to a parcel before rights of categories b., c. or d. can be created. The types b., c. and d. can be depicted as composite associations of the type a.

3.2 Rights minus restrictions

Such derived rights carve something away from the strongest right. This also means that it is not enough to know that a certain person possesses the strongest right. To really know the extent of his right, you also need to know if any of the other rights exist there. The actual legal right a certain person has in an object comprises of his positive rights minus other persons' positive rights with regard to the same object (or a part thereof). The question than remains whether

a) the other persons' positive right is registered;
b) the negative right of the first person is registered; or
c) both are registered

A further complication are the 'responsibilities', negative rights that do not have an (easy) identifiable beneficiary.
The perception on the difference between the strongest right and the derived rights differs between legal traditions. Most continental European countries start with 'ownership' and built derived rights on top of this. Much English literature, however, talks about the bundle of sticks that make up the right(s) in land. The sticks can be freely arranged. This will also affect the decision regarding registration of 'negative side of a right', which is very important in the first case, and not so important in the second.

An interesting way of dealing with the dilemma of positive right minus a negative right is the way the Dutch administrative cadastral database deals with this. When you have the full right of ownership this is registered with the code 'VE' (full ownership in Dutch). Now if someone else gets the right of superficies (right to own a building on someone else's land) not only will that right be added to the registration as 'OP', but the 'VE' will be changed into "right of ownership minus superficies", depicted by flipping the letters of the first right and adding the second right: EVOP. There will be no-one for this object that has a VE recorded, but only an OP and the EVOP. This is only done with the limited rights that imply full use (leasehold, superficies and usufruct), but not with minor restrictions like servitudes in the Dutch implementation.

4. RESPONSIBILITIES

The class for the legal relations shown in the core model used in (Lemmen et al, 2003) is RightOrRestriction. However, current literature on cadastral and land administration isues is often talking about three R's: Rights, Restrictions and Responsibilities. A restriction means that you have to allow someone to do something or that you have to refrain from doing something yourself. Restrictions can both be within private law, especially in the form of servitudes, as within public law, through zoning and other planning restrictions as well as environmental limitations.
Responsibilities mean that one has to actively do something. Not all legal systems allow such mandated activities as property rights (rights *in rem*), and this will also effect the question if they can (and have to be) registered. Obviously their impact can be substantial and their

registration makes sense. Of course it is very important that it is very clear which person is responsible for undertaking the mandated activity. If several persons hold some of the sticks from the bundle of rights, it will not suffice to link the responsibility to the real estate object, but it has to be linked to a specific 'stick', to be able to identify the responsible person. Clearly in a system with a dominant base right, the holder of that base right is the prime addressee of the responsibility. We should make the responsibilities into a class that is in a composite association with other rights, and not relate it directly to RealEstateObject.

5. ANOTHER WAY OF PACKAGING

Now that the definition of parcel (and other objects) is derived from the legal rights that persons have in them, there is a relation between the specializations of RealEstateObject and of RightOrRestriction. If we would model all of them with extensive packages showing a lot of specializations (like figure 2 of Lemmens et al, 2003 for the RealEstateObject package), a model of two (actually three) abstract classes would be shown, each with a whole array of specializations. However, these two sets of specializations are interdependent. Certain rights can only be associated with certain objects, and certain limited rights can not be 'loaded' upon all other types of rights. The question than becomes, what is the use of showing this in the way this would be shown if we expand the legal/administrative side and thus expand the whole core cadastral model. This becomes a hard to read model, which can only be correctly interpreted when an array of constraints is applied (this could be formalized through object constraint languages, but also be verbally given as part of 'literate modeling'). An example of this complication can be seen in the 2003 Greek draft model (Arvanitis et al, 2003) which needs a lot of explanation to be correctly interpreted (the revised 2004 Greek model (Arvanitis/Sismanidis, 2004) does not contain specializations for the class RightOrRestriction, and is more like the 2003 core model).

What we would need is a way to expand from the simple three class core model, not into packages which are based on the disciplinary aspects systems (Zevenbergen, 2002, p. 89-90), but that we would make different models for different types of rights, with only those specialization classes shown for RealEstateObject and for RightOrRestriction for which common instances can be found. This type of packaging seems to be better for using the model as a teaching or comparison tool, and is likely to enhance the spatial awareness of different types of rights for people not used to think that way (like lawyers).

6. FINAL REMARKS

This paper showed some first ideas on how to expand the legal/administrative package of the cadastral domain model. There clearly is room for further work and discussion on what ideas to implement and which ones to leave out. Some indications of at least two main legal traditions with regard to dealing with the derived rights as a right and/or a restriction have been given, which might lead to two cadastral domain models. Finally these ideas should be implemented through actually modeling them in UML. This will also facilitate the understanding of the discussion for much of the audience.

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BIOGRAPHICAL NOTES

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A Legal Cadastral Domain Model

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Keywords: Cadastre, legal cadastre, standardization, land register, modelling, object orientation, real property information,

1. INTRODUCTION

This paper is an introduction to an article submitted for review to the *Nordic Journal of Surveying and Real Estate Research*, expected to be published during 2005. The purpose of this presentation is therefore not to give a detailed approach and analysis of a legal cadastral domain as this will be done in the forthcoming article, but to give a general overview of the model.

2. LEGAL CADASTRAL DOMAIN MODEL

During the last decade numerous attempts have been made to describe and discuss the cadastral domain on both national and international level. In this paper the term "legal cadastral domain" is used as a common term for laws and regulations regulating the content of traditional cadastre, multipurpose cadastre and land register storing legal real property information, regardless of any national differentiation between these registers. A problem towards description of the domain is that real property and cadastre are not homogeneous and standardised terms and different definitions are presented by several authors, see e.g. (FIG, 1995); (Kaufman and Steudler, 1998); (Silva and Stubkjær, 2002). Such standardisation efforts are in addition primarily orientated towards technical storage environment of cadastre and other (software) solutions, but have, in my opinion, minor focus on legal aspects, even if the importance of the legal cadastral domain has been addressed by several authors, e.g. (Lemmen et al, 2003) and (Kaufman and Steudler, 1998). So, surprisingly little has been done to describe the legal issues of standardisation of real property information and cadastre.

Real property rights are special rights that differ from other rights in human society. Many rights in land are not found in goods or differ from those that are; and naturally they often last longer. These rights regulate the access to land. The access can be regulated by means of privately agreed rights or officially imposed regulations.

The access to land can be divided into 3 categories with different theoretical connections between man (subject) and land (object). 1. The direct connection between object and subject, 2. connection through right or obligation and 3 connection through ownership.

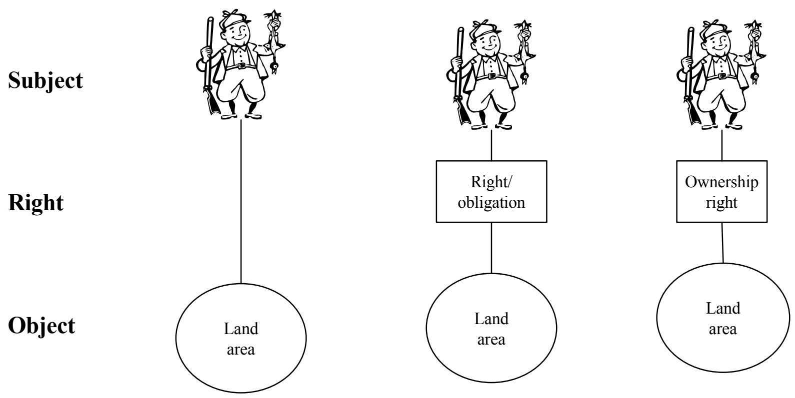

Figure 1: Theoretical connections between man (subject) and land (object) through rights. 1. Direct connection, 2. Connection through Right/obligation and 3. Connection through Ownership right (Mattsson, 2004).

Rights and restrictions are a result of cultural, social and political activities in each country and it might seem difficult to describe the variety of existing rights and restrictions in a common model describing the cadastral domain. The result seems to be that detailed modelling of rights and restrictions has been avoided when producing cadastral models. Rights might even be bundled together with restrictions in a common group, e.g. (Lemmen et al, 2003). However, the legal aspects of rights and restrictions are too complex to be handled as a common group in a legal model. An example is a recent Swedish attempt to model the cadastral domain from a legal perspective, which indicates that a nation's legal cadastral domain is extremely complex and that the legal context of the cadastre is of major importance with regard to standardisation of the cadastral domain (Paasch, 2004).

In conclusion, there is a need for a legal cadastre model which focuses on the right of ownership (to a property) in relation to appurtenances (benefits) and encumbrances (burdens) reducing the extent of the ownership. This presentation will focus on the modelling of real property rights, or to be more exact rights of ownership and granted rights, and including official and private regulations imposed on real property. A better understanding of the legal and logical aspects of property rights might increase the possibilities of producing standards towards the cadastral domain. One of the basic reasons for the employment of logic in law is that it makes it possible to determine criteria for the validity of arguments by means of investigating the form of these arguments.

The legal cadastral domain model outlined here is an abstract model based on the hypothesis that it is possible to classify property rights regardless of their emergence in different legal traditions. The model focuses on the legal classification of the benefits and burdens regulating the right of ownership and not on a detailed classification of the holder of such rights (Person) or the spatial component describing the expansion or geometrical representation and topology of a property (Land). Related objects like "boundary" and "source document" are not described in this first stage of the model. However, a legal description of these and similar objects are important to address all legal perspectives of the cadastral domain.

The legal cadastral domain model is a theoretical approach to the classification of real property ownership. The model is submitted to the Swedish real property legislation in the forthcoming article to see if it covers all legal issues relating to the ownership of real property. However, the model needs to be analysed in relation to other national real property legislation to ensure that it is a general model.
The legal cadastral model illustrated in figure 2 is based on the theoretical model illustrating the connection between subject and land through the ownership right in figure 1. The model is centred round the Ownership right and attached with classes that benefit or limit the right of ownership.

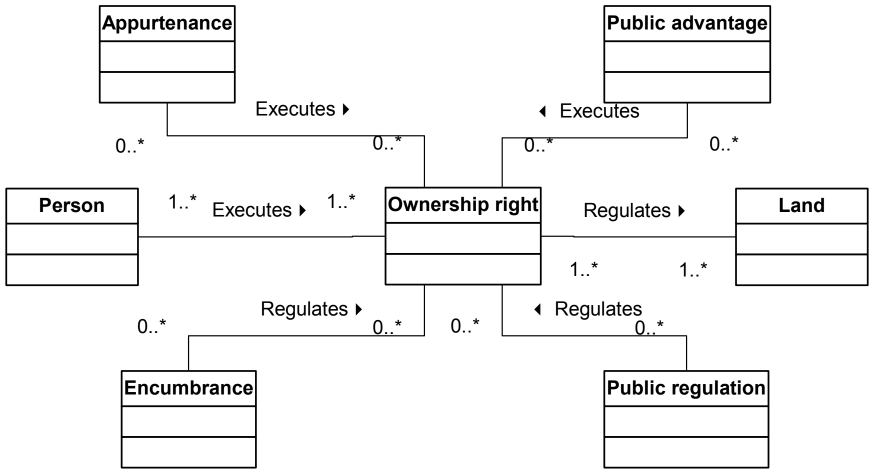

Figure 2: A basic legal cadastre model focussing on ownership right, describing the relation to the Appurtenance, Encumbrance, Public advantage and Public regulation classes (*Paasch, 2005).*

In order to achieve an increased standardisation of the cadastral domain it is necessary to classify of the legal content of a cadastre, focussing on the right of ownership and restrictions connected with ownership. Effort must be taken to focus on the legal aspects and not the technical environment in which the information is stored or processed. Classification of the legal context and discussing the legal ontology and semantics might further the process of establishing a general classification and description of property rights.

Applying object-orientated analysis and design on legislation focuses on the adequate description of the problem domain, e.g. the description of property legislation and cadastre. An adequate description must be based on communication. Any successful communication requires a language that is based on common concepts. However, the description, classification, hierarchy and description of objects and the difficulties of standardisation of a cadastre must not be underestimated. Focussing on the legal aspects and constructing a legal cadastre model is a way of applying ontology to the cadastral domain and can be a step towards a future standardisation process. A better understanding of the legal aspects of property rights might increase the possibilities of producing standards towards the cadastral domain.

If a standardisation of the legal aspects of the cadastral domain has to be achieved, it is necessary to develop a legal core model which can be applied to any real property legislation, regardless of its cultural or historical legacy. The model briefly illustrated in this paper is an attempt to establish a general classification and description of property rights and make a scientific approach towards the construction of a legal cadastral system.

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BIOGRAPHICAL NOTES

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Developing Cadastres to Service Complex Property Markets

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Key words: key words, theme, etc.

SUMMARY

Emerging demands on cadastral design suggest that cadastres as a functional component of land administration are being redesigned to respond to initiatives in technology, government needs and social drivers. The movements in the property market are demonstrating the need to take into account complex commodities. The surge in regulatory requirements affecting land use and building is part of the move to legalise almost all aspects of human behaviour but pose special problems for land administration. How cadastres respond to the multiplicity of regulatory interventions is an open question. This paper considers these issues in the context of building cadastral models. Four case studies are used to illustrate these issues.

1. INTRODUCTION

The experience of building national approaches to cadastres, spatial data infrastructures (SDI) and land administration systems (LAS) in Australia, a country formed by federation of individual states, is similar to the experience of the European Union in absorbing new members and in creating sufficient degrees of commonality among members to extract benefits from organisation. In some ways, the Europeans are advantaged. At least members see value in joining a larger organisation and in making it work. Australia, by contrast, needs a forward vision of sufficient power to advance national solutions in place of the state based silos (ICSM, 1999, 2002).

The Centre for Spatial Data Infrastructures and Land Administration at the University of Melbourne has a nationally funded research project for incorporating sustainable development objectives into ICT enabled land administration systems. The project was predicated on bringing into Australia a clear vision of how integrated cadastres serviced the local economies in Switzerland, Germany, Denmark and The Netherlands. Initiatives of the international community in standardisation and modelling are therefore directly relevant to other nations.

2. CADASTRES

2.1 Dynamic cadastres

Land administration is the key to acceleration of wealth out of land (Wallace and Williamson, 2004b). The administration processes enable market participants to confidently deal in land and to create additional and secondary commodities. In most countries, cadastres are the core or base layer of land information or infrastructure, though many countries successfully run land administration and land markets without them: USA, UK and Canada. Cadastres have broadened beyond the concept in Cadastre 2014: "a methodically arranged public inventory of data concerning properties based on a survey of their boundaries". Though there is scope for debate about where the cadastre finishes and the SDI begins, incorporation of land objects and "land object boundaries" remain basic starting points (Kaufman and Steudler, 1998; FIG, 1995, para 3.18). The problem however lies in the dynamism of cadastres. Cadastral data models specify key types: real estate object, person (subject) and right or restriction (Ploeger and Stoter, 2004; Lemmen et al., 2003). However, even these simple ideas raise issues for consideration given the dynamic changes to the way land is used and recorded. Thus, the problems of settling international definitions for "real estate units" are recognised by the Working Party on Land Administration. Any particular definition must confront situations in which practical land use turns title parcels into properties, and then into areas that concern business entities or corporations who undertake commercial and agricultural uses. The realpolitik of land use therefore builds parcel, property and business activity area layers. As commercial demands grow, these layers are more integrated into the fabric of business. Cadastres must either change in response or atrophy. And models developed for standardisation of approaches to cadastres must be similarly flexible.

2.2 Flexible approaches to standardisation

Following FIG Statement on the Cadastre (FIG, 1995), the focus was on objects of rights restrictions and responsibilities (RRRs), away from parcels associated merely with land rights. The more flexible approach absorbs local variation in cadastres built to reflect unique conditions of the countries which created them. Technology added to local distinctions. When parcel information was digitized to deliver a layer in the form of a digital cadastral data base (DCDB) in a spatial data infrastructure capable of servicing a multitude of needs for land information and land policy, country differences were even more apparent. To reverse this trend towards local systems, the emerging Cadastral Domain Model strives to build in sufficient flexibility to allow cross-border use, and to release the energy of the digital cadastral data bases (DCDB), spatial information, information communication technology (ICT), Internet availability, geo-databases, open systems GIS and web mapping facilities.

Standardisation is particularly driven by information communication technologies along with government imperatives, including the familiar trends to privatize the public sector and to introduce new methods of accountability within government agencies. Efforts to develop shared understandings of basic infrastructure are essential counterbalances of localization trends. Thus the universalisable LAS model in Diagram 1 below reflects local situations within a generic design (Enemark, Williamson and Wallace, 2004).

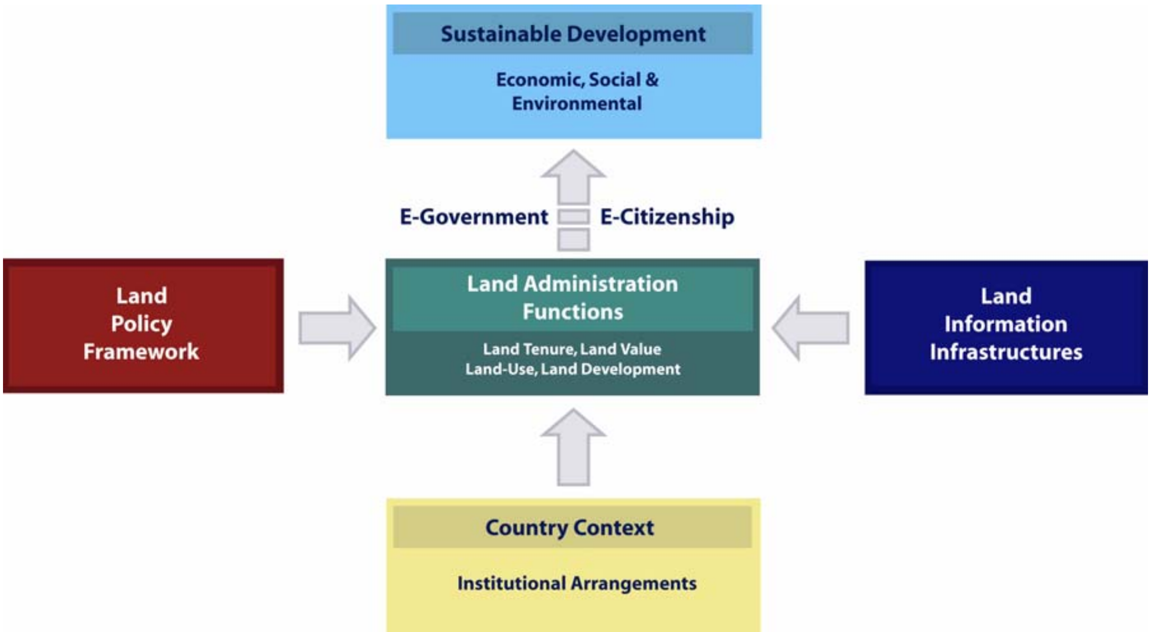

Figure 1: A model of land administration in developed economies (Enemark, Williamson and Wallace, 2004)

3. THE DYNAMIC WORLD OF PROPERTY MARKETS

To understand how dramatically land markets have changed since land administration systems (LAS) were conceived, (Wallace and Williamson, 2004b), two other trends need to be identified. The first concerns development of high levels of sophistication in the capacity of land to support wealth creating activities. The second involves more interesting and problematic trends to commodify property derived from land but unrelated to specific parcels, or even incapable of being related to a polygon or other standard spatial definition. Land administration systems support "simple commodities" – ownership, leases and financial interests (mortgages). Simple commodities provide the foundation for rebundling of opportunities associated with direct access to land, in case of mortgages on default of the loan arrangements. Complex commodities are everything else. They raise the difficulty level to reflect much more refined opportunities of access (multi-occupancy uses), conversion of the built environment into complicated investment opportunities (time shares), abstract interests facilitating investment in land including unit and property trusts and mortgage backed certificates, and even commodities which have no relationship with land at all, which in Australia are being referred to as "new" property.

Three case studies are drawn to illustrate these emerging trends, relying on Australian experience: complex commodities, particularly mortgage backed certificates in secondary mortgage markets, "new" property, particularly water rights objects, and the plethora of restrictions and responsibilities (RRs). The case studies suggest new approaches to parcels and data sharing.

3.1 Complex commodities

A complete comprehensive definition is impossible because new commodities are invented constantly. These commodities cannot exist without sophisticated administrative supports, usually created by government, but not necessarily. To get the most economic energy out of these commodities, a jurisdiction must develop four capacities: abstract conceptualisation (cognitive capacity), administrative rationalisation, corporatisation, and securitisation (Wallace and Williamson, 2004b). Because design of government LAS predates much of the development of these wealth acceleration activities, and because the LAS designs are embedded in legislation and government organisation, public-run LAS are slow to adapt. Much of the administrative structure creating certainties and regularities in these commodities therefore exists in the private sector; for some commodities the infrastructure is entirely provided by the private sector. Developments in complex property markets are illustrated by Figure 2.

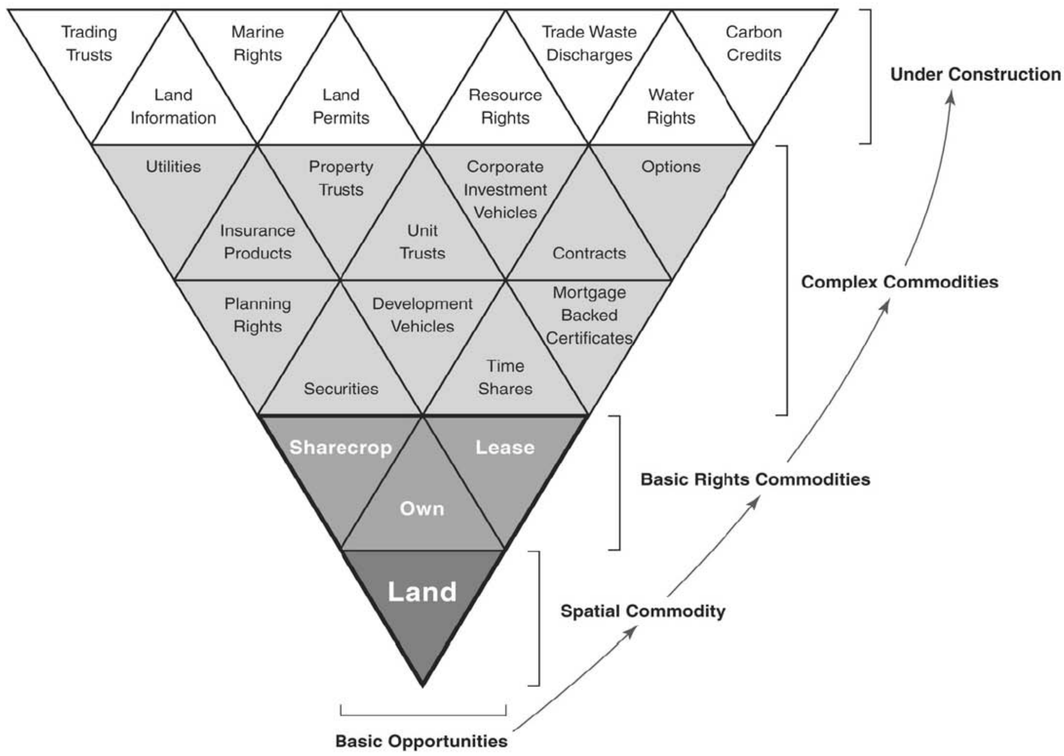

Figure 2: Development of Complex Commodities Wallace and Williamson, 2004b.

A LAS in the modern context must be adaptable enough to assist these derivative and secondary markets, only some of which are appropriately serviced by the primary layers in the LAS - the digital records of activities of the land registration system and the supporting cadastre. These primary layers are expensive to establish and maintain and their smooth administration is the fundamental building block upon which the frenzy of economic creativity depends. The layers therefore serve many purposes. In the developed European economies, the organisation of cadastres is extensive, absorbing large capital, technological and human resources drawn out of taxation and land market activities. Modern democracies now require widening of the functional base of cadastres to support sustainable development, though puzzlement exists about just how to service the policy goal out of a parcel based system. At this point, the international comparisons are significant. European cadastres are much more multi-purpose than are their Australian cousins. They service the land market, support taxation and valuation systems and, more recently, assist coherent land use management; all essential functions for economically successful democracies.

Of particular interest is the development of much more complex land use arrangements (exemplified by attaching corporate responsibilities for unit and common property management to parcels, and building titles demanding three dimensional management of space), conversion of securities into complex and secondary financial instruments (exemplified by secondary mortgage markets), and creation of leveraged opportunities to participate in ownership and profit taking, while facilitating professional building and investment management (through listed property trusts, pension fund investments and other opportunities).

These commodities and activities related to them constitute vast extensions of opportunities for participation in wealth sharing and building through land and ensure economic acceleration. They depend on the smooth, sustained and guaranteed operations of the basic and complex markets in commodities related to land, the public ability to understand (though not necessarily in detail) these diverse activities, and the ability of national systems to attract global investment. An appreciation of the importance of the cadastre as a foundation of these activities is vital: standardisation processes must therefore foresee and even facilitate these trends. Governments need to be especially conscious of how confidence in the LAS and cadastre supports extensive economic activities.

3.1.1 Secondary mortgage market

To illustrate from the construction of the secondary mortgage market. The market is the place where primary residential mortgage lenders, mainly banks, sell their mortgages to obtain more funds to originate more loans. It provides liquidity for lenders. To simplify what is a complex legal structure, the market allows banks to bundle up to, say, 500 of their mortgage loans and submit the bundles to an agency which issues mortgage backed certificates. These are offered for sale to investors for a return. The capital received is returned to the lending banks that place it in the primary mortgage market. In the Unified Modeling Language (UML) suggested for the Cadastral Domain Model, the cadastral parcel base (RealEstateObjects) feeds into associations or classes between objects and opportunities (RightsOrRestrictions) identified with natural and legal persons (Subjects). The linkages envisaged are capable of feeding users diverse information about relationships between land/lenders/borrowers and loans or mortgages.

If its organisation and legal capacity permitted, the land registry could offer a facility for bundling loans from high volume lenders at source as an additional service to secondary mortgage markets. In any event, a service consisting of providing the banking and mortgage lenders with data capable of being integrated into their systems might be developed. Ideally the ability to segregate new loans from "churned" loans (loans replacing existing mortgages in response to the hundreds of new financial products on the market) could be of significant significance to economists looking at land markets. If the mortgages were related to geocoded parcels, and systems were available to allow web access to images or photos of the properties plus to land value data, administration savings and a more robust local secondary market would arise. But, whatever happens, attractive and useful packages or services of a kind well beyond current imaginations could be invented by software suppliers once basic UML models are operative.

3.2 Complex commodities

In Australia, existing LAS, in particular Torrens registries and their supporting cadastres (Australian land registries generally undertake the legal creation of consolidations, subdivisions and boundary changes of privately owned parcels), are being required to facilitate administration of new commodities (biota, water, carbon futures, forestry rights, planning permissions and so on) even where these are separated from land. Characteristics of this "new" property include complex processes of commodification, highly developed administrative and instrumental capacities of governments or private sector agencies, detachment from the parcel based cadastre, and the social and cognitive capacities of participants and organisations.

The continued concentration of land administrators on land and accounting for simple land transactions, particularly changes in ownership, lease and mortgage, fails to account for the frequency with which "new" property is being invented and how more complicated relationships between governments, people and land are developing.

3.2.1 Water

The Council of Australian Governments (COAG) (the Prime Minister, state Premiers and Chief Ministers and the President of the Local Government Association) introduced a framework for water reform in 1994. Since then a great deal of attention has been paid to water trading including a plan to use a Torrens style register or approach to provide water titles separated from use of water on land to underpin water trading (ACIL Freehills, 2004). A much more conservative approach was developed by the Government of Victoria and described in a White Paper (2004) on water policy and related reforms. Even these strategic policy reforms demand a great deal of detailed work to support implementation. The White Paper therefore set out an agenda for focusing research on water policy and institutional reform that can illuminate and help ensure that the reforms achieve their intended goals.

The principal water policy reforms set out in the White Paper are described in outline by Professor John Langford, University of Melbourne:

- Separation of water entitlements into three components namely: a share of the water resource; a delivery capacity entitlement; and a licence to use water on a particular area of land.
- Provision for an environmental reserve that catchment management authorities will be accountable for managing (and potentially trading).

- Reduction of current water ‘sales’ entitlements by 20% and transfer of that 20% of low reliability entitlement to the environmental reserve.
- Separation of water right (high reliability entitlement) from ‘sales’ (low reliability entitlement so that both can be traded independently.
- **Allowing 10% of an irrigation districts bulk entitlement to be disconnected from land.** Currently water entitlements can only be held by irrigators who own or lease land (or by urban water authorities and environment).
- Support for reconfiguration of irrigation channels and delivery systems in response to reallocation of water through trading.
- • Appropriate governance and regulatory arrangements to ensure accountabilities are clearly defined, conflicts of interest are avoided, and the interests of all entitlement holders and the environment are respected.

There are significant legal, hydrological (especially third party effects), registry, accounting, economic, technical, environmental and social questions to be answered. The core question for proponents of water trading of “where is the water?” remains a puzzle in a system which gives titles unsupported by a cadastral or spatial component because the proposal presupposes separation of water from the land on which the resource is used. When water trading is tied to a capacity to use water (traders are both owners and potential users), the system is sufficiently close to existing licensing system; but the intention behind the Australian government design is to have ownership and trading opened up to non-users on the assumption that neo-liberal economics will place the resource with its most efficient user. The proposal to create Torrens titles to water (ACIL Tasman, 2004) seems to depend ultimately on volumetric rather than spatial entitlements in a context of embedded interstate rivalries in resource taking, increasing water shortages and intense contests between agricultural and environmental users. To work commercially, titles to water must never exceed supply. Whether a title system can ensure a connection between water ownership and a supply of water in the right remains problematic.

For cadastral modeling, the class of NonGeoRealEstate could offer itself as an option for a tradeable water right, especially as the concept can embrace a right to fish in a commonly held area (itself depicted as a ServicingParcel) (Lemmen et al, 2003, p 405). However, disconnection of tradeable water from land raises issues of implementation.

4. THE DYNAMIC WORLD OF PROPERTY MARKETS

4.1 Absence of orderly records

Reappraising Cadastre 2014 in the context of world wide land administration system analysis, Paul van der Molen remarked:

“A serious omission in current land administrating systems is the absence of records of encumbrances and restrictions **pursuant to public law**. Government measures can restrict the right of disposal by the rightful claimant (the main element in private-property rights) to a certain and on occasion substantial degree. These restrictions can vary from a very mild form (such as the obligation to accept the presence of a lamppost on the land, or a slight financial burden) to a very severe form (such as a mandatory use of the land and, in the most extreme form, expropriation). … It is important that attention should be devoted to the **retention of up-to-date records of this information**." (2003, pp 11-12) (Emphasis added.)

The solution of retaining records of this information is unarguable. The question is how to achieve a record base which is affordable, practical and compatible with a robust land market given the even cursory version of the issue in Figure 3.

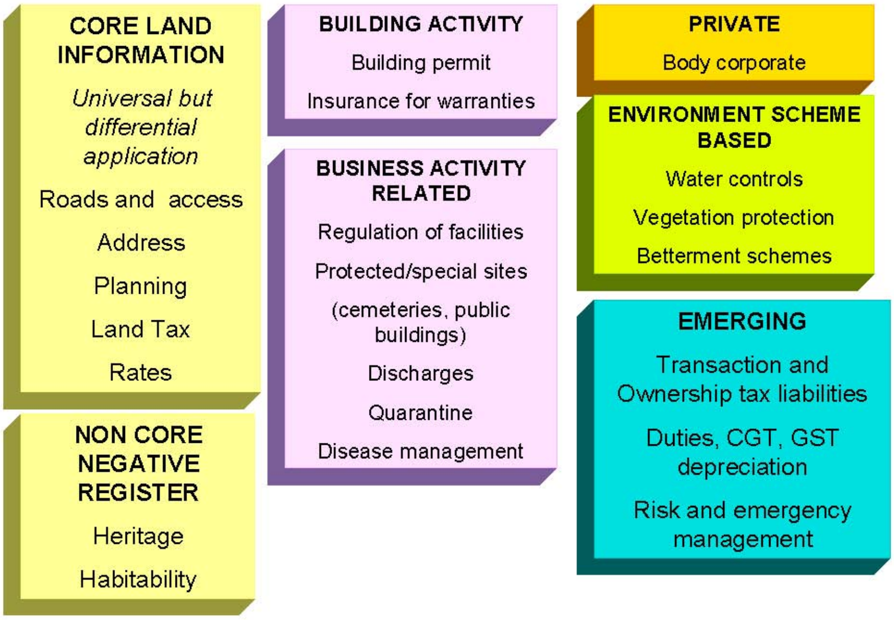

Figure 3: Restrictions and responsibilities affecting land.

Publication of restrictions is essential to their effectiveness. It is no longer sufficient for governments to publish restrictions in separated sources pushing systematic disclosure onto people engaging in transactions (usually sale, mortgage and lease of parcels). The existing efforts in Australia to impose some order on the discovery process are directed to creating web based front ends to the multiply enquiry sources. These efforts fail to meet Van der Molen's agenda which demands a much more robust and integrated approach to RRs.

The emerging issue for land administration is then the conversion of parcel generated DCDB into even more useful information. Most users of land information (including agricultural departments, valuation departments and taxation departments) think in terms of properties or even business entitles, not parcels. The modular standard will therefore make use of legal and administrative classes. But even this is proving inadequate.
Technological opportunities offer different solutions for recording and visualizing core restrictions (road access, gas, electricity, cable, sewerage, drainage and water access and charges, zoning, heritage, contamination, and so on). In the standardisation model, opportunities for including significant restrictions in specialization classes of, say, RestrictionArea and NonGeoRealEstate, are available. The model recognises difficulties with

public law restrictions where the ‘holder of the right is abstract (government or even society at large) and where the area of application is not survey defined except in most advanced systems, a typical issue in areas contained in soil polluted areas, flood plains, tidal zones and so on (Lemmen et al, 2003, p 409).

The most promising and alternative means of access of this kind of information envisages developing a shared land information platform, allowing data custodians who manage the particular restrictions to remain independent, but facilitating the access to and overlay of data through the more traditional web based systems. The shared land information platform (SLIP) of Western Australia’s Department of Land Information is a business activity driven plan to web enable access to and use of significant land information (Western Australian Government, 2004). The core business functions driving the program are emergency management, natural resource management, land development and a register of interests (or, for our purposes, restrictions). This approach recognises significant advances in the spatial information context, including improved GIS systems allowing visual presentation of static data, development of open standards (particularly the Open GIS Consortium, OGC), inter application capacity building and creation of national scale initiatives. In Australia the most important initiative showing exciting opportunities for use in public and private sectors is the geocoded national address file (GNAF).

4.2 Holistic treatment of land and resources

Resource taking activities (particularly forestry and mining) form a significant volume of restrictions on land. For practical purposes then, land administration and resource administration should be treated holistically. Resource taking and use of land by surface occupiers are only capable of being mutually successful if their respective public regulators and beneficiaries are able to synthesise their respective activities. Most owners need to know what mining activities fall within the realm of their parcels. Most miners need to know which parcels are directly affected by mining activities. Despite the need for holistic treatment, administration of land and natural resources has traditionally been divided. Indeed typically two kinds of registries have developed and operated so as to make synthesis of information difficult, and in some parts of Australia, even impossible, often because the registers service different functions (Wallace and Williamson, 2004a).

Traditionally, a land register has two components: text defining the interests and diagrams or, in advanced systems, cadastres, defining spatial identity. Together the text and map or, in developed systems, the cadastre, facilitate answering of the five questions of who, what, where, when and why (policy information) about opportunities related to particular land. Modern land cadastres supporting registration are highly sophisticated, and expensive to design, build and manage. Looked at as a whole, they display three-dimensional boundaries: height, width, depth, plus (when we add the text) a fourth dimension of time (how long the interest lasts for).

Design of resource registers tends to be much more prosaic. The types of registers vary greatly; each was developed on an ad hoc basis in response to immediate needs and perceived future needs related to a particular resource. The systems typically develop where resources are valuable, rivalrous in supply and require state enforced allocation of opportunities to extract resources according to regulated standards. The principle administrative task at the forefront of registry activities is regulation of work related to resource extraction. A secondary driver is the need to create marketable rights or titles to the resource in addition to systematizing physical access to yields.

While the registers are specific and independent, information generated to assist management of harvesting activities ideally should be capable of being translated across information generated by land registration activities through a system permitting incorporation of restrictions and responsibilities irrespective of their sources.

4.3 Activity regulation and standards

Use of the land registration system to manage more bureaucratic controls, permits, licences and regulations is widely used in Australia with substantial negative and unforeseen consequences. In 1999, we foreshadowed co-option of the land registration system as part of the regulatory framework of government and warned that this was inappropriate. Land registration is now used, or is capable of being used, to provide building and planning officialdom with opportunities for enforcement of "controls" over standards relating to chemical hazards; wiring and electricity installations; cable capacity; business compliance; domestic safety standards; plumbing, heating, building permits and certificates; registration of plumbers, builders and electricians and other bureaucratic edifices (Wallace, 1999). This option of loading public regulation management into a Torrens type register appears especially attractive to those who require certificates or installations in premises to be evidenced at the time of sale as a means of enforcement of regulations which would otherwise more likely than not be avoided.

Given the improved capacity of cadastres developed in the intervening five years, the point at which a cadastral model should assist this process of cluttering the register and the cadastre to assist day-to-day enforcement of restrictions and regulations affecting land is a real issue. Governments are making more regulations, not less. Some of the more open-ended or multi-faceted restrictions and responsibilities (RRs) are problematic in the context of cadastral modelling. A key question is then how or why new RRRs might be incorporated into a cadastral fabric when they are remote from physical objects or even spatial identification. One possible approach suggests answers are available from increased technical precision and/or administrative competencies. These problems associated with emerging RRs are emphasized particularly by management of the marine environment where the marine cadastre is only just developing. In the marine context especially there is a clash between cadastral certainty and rigidity (seen in its focus on defined parcels, or on realisable spatial definitions) and management needs, technical capacities and fuzzy, natural and other kinds of boundaries (Wallace and Williamson, 2004a).

Analysis of land administration trends in Australia in 2004 revealed a naïve anticipation in policy makers and planners in the capacity of an LAS, and consequently a cadastre, to service a range of demands well beyond the standard ones. These include opportunities to deliver much more tax equity in the context of development of sophisticated tax liabilities in the realm of capital gains tax and goods and services taxes. Responsibilities of land owners include modifying their activities according to standards that are relatively indefinite. Noise abatement, view retention, maintenance of mountain ridge lines and similar "standards" appear in regulations seeking to balance private opportunities and responsibilities with the public good. In Australia, the issues are squarely on the political table. Efforts to address major national problems of salinity, land clearing, soil quality and water generated complaints about the sheer quantity and quality of government regulation. These complaints were immediately addressed by a national concern about land regulation which sees organisation of these responsibilities through LAS as one of the solutions.

Report No 7 on *Impact of State Government actions on use and enjoyment of freehold and leasehold land in Western Australia* of the standing committee on Public Administration and Finance of the Legislative Council of Western Australia suggested thorough reorganization of the relationship between citizens as land owners and their government through parcel based identification of government decisions, even in relation to "plans, policies and strategies":

> **"Recommendations 35 and 36**:
> In the short term, the Department of Land Information (DLI) continue to implement its aim of establishing itself as a 'one stop shop' database of all interests affecting land as an urgent priority.
> For the long term, the DLI introduce as soon as practical, an electronic 3d CT which records **all interests** affecting the land on the CT."

The most far reaching recommendation was:

> **"Recommendation 37**
> That the Government introduce after a 2 year phase in legislation –
> (a) Any **policy, strategy, plan or other document** impacting on administrative decision-making with respect to land use that affects one or more specific certificates of title, is to be of no effect unless registered with Department of Land Information and
> (b) all policies, strategies, plans or other documents impacting on administrative decision-making with respect to land use that are specific to a certificate of title are to be on registration with the Department of Land Information, cross-referenced with the relevant certificate of title." (page 530) (Emphasis added.)

The genuine and unarguable public concerns that generated this sort of government information chasing exercise are obvious from the consultative processes informing the WA report. However, the recommendations are remarkable for their naïve desire to use certificates of title, rather than generic databases, robust spatial information systems and web enabled access to information as the supply chain. A deeper concern lies with the overall suggestion that it is the business of government to reveal everything about land. The sheer effort involved in determining what pieces of land, rather than what citizens, are affected by policies, strategies, plans and other documents as defined, is enormous. It is not feasible to include all RRs within the realm of orderly administration. The questions are what should be included and how. Thus, on reflection, it is the disorganisation of RRs, not lack of information, that is the real problem.

5. CONCLUSIONS

The emerging demands on land administration and cadastral design suggest two central needs:

A definition of the cadastres supported by reasons for its validity, and
A path for development of LAS using the cadastre as a vital component of a spatial enabled system.

While a cadastre must be reliable and parcel based, it needs to adapt. Our engineering and design of cadastres needs to take account of trends in markets and especially servicing of development of and trading in complex commodities.

Re-engineering is being undertaken at a time when technology supporting the DCDB, parcels and spatial information technology is looking seamless to the web enabled searcher. This capacity is suggesting to policy makers that cadastres can be used for more and more activities. One of the implications for Australia is that the Torrens system is likely to be a victim of its success, and that political demands for it to be used to service activities and administer new commodities fly in the face of much better opportunities offered by GIS, open systems and web enabled management.

At the same time, opportunities for assisting trading in new commodities by building on existing and standard Torrens/cadastral functions, improving their taxation utility, and incorporating trading results into the broader knowledge base for land management and land policy purposes await development. If governments decide trading in new commodities needs no infrastructure support, so be it. So too, if they see the land registry and the related cadastre as the only available vehicles for managing emerging commodities. But at least the decision should be taken rationally rather than as a default arising from failure to examine opportunities and extend the capacity of our cadastres. Neglect should not be the default position.

Our research indicates that change in LAS design is inhibited by limitations of their hardware and software systems, their statutory obligations and restrictions, their inability to retrieve and retain value or funds out of their activities and many other barriers. Though many administrators are excited about the possibilities of new technology and carry a broad interest in improving cadastral services, their ability to convince their political masters of the need to change depends on a convincing case for reconstruction in the context of new ideas and new technology. It is particularly difficult for administrators of any local system to plead for a national or an international vision. In our reality, administrators who see the value of an Open GIS Consortium (OGC) Property and Land Information (PLI) initiative (Lemmen et al, 2003, p 401), find convincing political masters of the need to change remains a hurdle. If we are able to utilise an argument about the movements in land markets and consequential need to move land administration forward, our ability to implement a flexible LAS future is improved. A partnership between land administration designers and the powerful interests behind complex commodities in cadastral reform and modular standards would help governments see the possibilities of building on the remarkable efforts to frame modular and adaptable cadastral standards.

Meanwhile, the emerging Web and Internet opportunities are overtaking the cadastre as the focal point in the delivery of land information to both public and professional users. The need to relate spatial and people data to create knowledge and assist decision makers is driving change. The transportation industry example is illustrative.

> “GIS are moving beyond traditional data models. The distinction between raster and vector will no longer be meaningful from the user’s perspective: GIS will include automated intelligent conversion between these formats as necessary. The collection and storage of georeferenced multimedia, including text, sound, and imagery, are also possible. Georeferenced multimedia can help elected officials, key stakeholders, and the general public understand complex transportation issues, such as proposed changes in transportation infrastructure and services. This can foster a supportive environment for collaborative decision making.” (Transportation Research Board, 2004, p 16)

This futuristic and enthusiastic account of new technological opportunities in transportation management, including Location-Aware Technologies (LATs) and treatment of time as an object, not an attribute, needs distillation in the context of the emerging demands being made on our cadastres.

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Any errors and infelicities are the sole responsibility of the authors.

BIOGRAPHICAL NOTES

Jude Wallace is a land policy lawyer working in legal theory and property law. She researches land tenures, land administration systems, land markets and their supporting infrastructures. Her previous experience includes work in national commercial law, computer support for legal practice, and land policy. Her principal appointments include Law Reform Commissioner for Victoria and regulator of the real estate industry.

Ian Williamson's teaching, research and extensive publications cover cadastral, land and geographic information systems, land administration and spatial data infrastructures, in developed and developing countries. He has undertaken research world-wide including for AusAID, the United Nations and the World Bank. He is a Member of the Order of Australia (AM), a Fellow of the Academy of Technological Sciences and Engineering Australia (FTSE), a Fellow of the Institution of Surveyors Australia Inc., a Fellow of the Institution of Engineers Australia, an Honorary Fellow of The Mapping Sciences Institute and the Spatial Sciences Institute Australia, and an Honorary Member of the International Federation of Surveyors (FIG). He was Chairperson of FIG Commission 7 (Cadastre and Land Management) 1994-98 and Director United Nations Liaison for the FIG from 1998- 2002. He is a member of the Executive of the United Nations sponsored Permanent Committee for GIS Infrastructures for Asia and the Pacific (PCGIAP) and Chair of its Working Group 3 (Cadastre). He is Head of the Department of Geomatics and Director of the Centre for Spatial Data Infrastructures and Land Administration. He was awarded the Centenary Medal by the Prime Minister for service to Australian society in research and geomatics engineering and surveying 2003.

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Assessment of the Core Cadastral Domain Model from a Cadastre 2014 point of view

Jürg KAUFMANN, Christian KAUL, Switzerland

Key words: Cadastre 2014, land rights and restrictions, lean data modeling, simple models for a complex topic

SUMMARY

On the basis of a comparison of the statements of the two papers 'A modular standard for the Cadastral Domain' [Lemmen et al., 2003] and Cadastre 2014 [Kaufmann, Steudler, 1998] the commonalities and differences between the two approaches are analysed.

The result is that there is consensus in view of the importance and usefulness of the standardization of cadastral data with the help of data models and in view of the necessity to have models as transparent and simple as possible.

Differences exist on the level of the concepts. While the Core Cadastral Domain Model follows in principle the traditional 'parcel-centric' approach and tries to open it, Cadastre 2014 stipulates a totally new cadastral system, which might be called 'land object-centric'. A parcel is one certain appearance of a land object.

Cadastre 2014 aims at completeness of the legal information on land. The land object approach makes this possible because a simple model results. The conceptual background of the Core Cadastral Domain Model at the moment needs complex objects to be able to create a correct real property based model. This approach tends to be complex.

This means, that the concepts differ despite both approaches are much in favor of modeling and standardization. So first a discussion on the concepts or the development of an ontology is necessary to resolve the communication problems.

So it is recommended to go on with an open-minded and precise ontology discussion, taking into consideration the efficiency of the possible solutions.

ZUSAMMENFASSUNG

Die zwei Publikationen 'A modular standard for the Cadastral Domain' [Lemmen et al., 2003] und Cadastre 2014 [Kaufmann, Steudler, 1998] untersucht, um die Gemeinsamkeiten und Differenzen zu analysieren.

Die Auffassungen betreffend die Bedeutung von Datenmodellierung und Standardisierung stimmen dabei sehr gut überein.

Differenzen bestehen betreffend das konzeptionelle Gerüst, das in Falle des Core Cadastral Domain Models parzellen-zentriert, im Falle von Cadastre 2014 Landobjekt –zentriert ist.

Die konzeptionelle Diskussion ist so offen und präzis wie möglich weiterzuführen.

1. INTRODUCTION

I was invited to comment the latest (third) version of the core cadastral domain model as published in the report 'A modular standard for the Cadastral Domain' on the occasion of the 3rd International Symposium on Digital Earth in September 2003 – Information Resources for Global Sustainability – by Lemmen et al. from the point of view of 'Cadastre 2014 – A Vision for a future Cadastral System'. I do this with great pleasure, because I see in the development of the core cadastral domain model, that elements of Cadastre 2014 have been included. I am convinced that the Cadastre 2014 approach will help to answer many questions raised in the paper.

The first statement in the introduction to this Joint 'COST Action G9' and 'FIG Commission 7' Workshop on Standardization in the Cadastral Domain is:

'One of the big problems in the cadastral domain is the lack of a shared set of concepts and terminology. International standardization of these concepts (that is, the development of an ontology) could possibly resolve many of these communication problems.'

Such statements are not only valid for the cadastral domain. Often there is a lack of concepts and terminology, although the standardization process can force the stakeholders to clarify the terminology and to come to shared views. But I don't believe, that standardization alone is the 'development of an ontology', which is defined as *'a particular theory about the nature of being or the kinds of existents'.* There is a need to reflect the nature of a phenomenon, before being able to standardize. Cadastre 2014 is the result of reflections on the nature of existing and future cadastral systems. The respective statements and recommendations were intended to contribute to a simple and comprehensive standardized model of the cadastral domain. To have an ontology is a precondition for standardization.

The following discussion will not be about modelling and standardization, but shall contribute to an ontology. The basis for my comments is the report 'A modular standard for the Cadastral Domain' by Lemmen et al. and the Publication 'Cadastre 2014'. I will compare the statements of the reports and comment the similarities and differences.

2. COMPARISON OF THE STATEMENTS OF THE REPORT WITH THOSE OF CADASTRE 2014

The report is an excellent paper and I am very grateful that our colleagues made the effort to carefully document the problems and their proposals to overcome obstacles.

Important statements from the report are compared with statements and principles of Cadastre 2014.

Section of report	View of the report (p 399)	View of Cadastre 2014 (p 20)
Preface	Standardized core cadastral domain model serves to: • avoid reinventing and re-implementing the same functionality again and again • enable involved parties to communicate based on a shared ontology implied by the model	Modelling is substantial for Cadastre 2014 **Statement 3: Cadastral mapping' will be dead! Long live modelling!** The result of this process is a data model of the real world. The modern cadastre has to provide the basic data model.

Comment:

Both approaches emphasize the importance of standardization by modelling the objects belonging to a cadastral system. It is proved that standardized data models avoid duplication of efforts and saves human and financial resources. A Swiss study on 'Reflections on the benefits and potential economies of geographic data standards'. [Kaufmann/Dorfschmid, 2001] tries to quantify the economies obtained by standardization.

Standardized models contribute significantly to the communication on the objects of a certain domain and it is true, that a model implies an ontology. But the ontology must be clarified before creating a model. The report and Cadastre 2014 differ in the ontology. While the report starts from the traditional cadastral systems and develops it further, Cadastre 2014 designs a new system, respecting basic principles of the traditional system.

Section of report	View of the report (p 399)	View of Cadastre 2014 (p 43)
Preface	One of the main preconditions of the model development is to keep the model as transparent and simple as possible in order to be useful in practise.	**4.5 Need for Flexibility and Effectivity** In order to cope with the great diversity of needs, the Bogor Declaration [United Nations, 1996] states that cadastral systems should: • be simple and effective; • ….. Cadastre 2014 with its concept of complete area coverage, with its straightforward information structure, and following the principle of legal independence, can meet these requirements.

Comment:

The issue of cadastre and land information is complex. It is therefore necessary to reduce complexity by simple and straightforward models. There is no difference in opinion between the report and cadastre 2014.

Introducing land objects (p 23), Cadastre 2014 traces back all object-subject relations to the same schema. This is transparent and simple. While based on the principle of legal independence, the Cadastre 2014 is never complete. It moves according to the legislation process in a given jurisdiction.

The report speaks of a 'complete' core cadastral model. When restricting the cadastre to its traditional content, this may be true, but this would contradict the basic idea of Cadastre 2014. Cadastre 2014 is aimed at improving the legal security about land rights as stated in chapter 3.3.2 Mission and Content on p 28. *While legal security in a cadastre-based land registration system is close to or even more than 100% for private law rights, it is near 0% for public law restrictions. Cadastre 2014 must correct this situation, which is becoming more and more precarious. It must document, in a safe manner, all legal aspects of land.*

<table>
<tr><th>Section of report</th><th>View of the report
(p 399)</th><th>View of Cadastre 2014
(p 23, 28)</th></tr>
<tr><td>Introduction</td><td>Cadastral systems are all based on the relationships between persons and land via (property) rights
Land administration systems are not 'just handling only geographic information' they represent a lawfully meaningful relationship amongst people and between people and land.</td><td>A land object is a piece of land in which homogeneous conditions exist within its outlines.
Examples of legal land objects are:
• private property parcels;
• areas where traditional rights exist;
• administrative units such as countries, states, districts, and municipalities;
• zones for the protection of water, nature, noise, pollution;
• land use zones;
• areas where the exploitation of natural resources is allowed.</td></tr>
<tr><td colspan="3">Comment:
For Cadastre 2014 the property right is one example of the different rights on land.</td></tr>
</table>

<table>
<tr><th>Section of report</th><th>View of the report
(p 400)</th><th>View of Cadastre 2014
(p 23, 28)</th></tr>
<tr><td>Introduction</td><td>Land administration systems are not 'just handling only geographic information' they represent a lawfully meaningful relationship amongst people and between people and land.</td><td>Cadastre 2014 is a methodically arranged public inventory of data concerning all legal land objects in a certain country or district, based on a survey of their boundaries. Such legal land objects are systematically identified by means of some separate designation. They are defined either by private or by public law. The outlines of the property, the identifier together with descriptive data, may show for each separate land object the nature, size, value and legal rights or restrictions associated with the land object.</td></tr>
<tr><td colspan="3">Comment:
From the viewpoint of Cadastre 2014 the legal aspect is a basic characteristic of the cadastre. It is the cadastre which documents the legal situation of the land. Land administration work is fulfilled with the help of the lawfully relevant information extracted from the cadastre. The processes can be compared with normal business administration as it was explained 1999 by Kaufmann at the International Conference on Land Tenure and Cadastral Infrastructures for Sustainable Development in Melbourne:
<table>
<tr><th>Business</th><th>Land business</th></tr>
<tr><td>Strategy/policy</td><td>Land policy</td></tr>
<tr><td>Management</td><td>Land management</td></tr>
<tr><td>Administration</td><td>Land administration</td></tr>
<tr><td>Accounting</td><td>Cadastre</td></tr>
</table>
</td></tr>
</table>

Section of report	View of the report (p 400)	View of Cadastre 2014 (p 41, 42)
Introduction	Having a policy is one thing, having instruments to enforce the policy is another. Therefore governments need instruments like regulations concerning land tenure security, the land market, land use planning and control, land taxation, and the management of natural resources. It is within this context that the function of land administration systems can be identified : a supporting tool to facilitate the implementation of a proper land policy in the broadest sense.	**Statement 1 on Cadastre 2014** **Cadastre 2014 will show the complete legal situation of land, including public rights and restrictions!** 4. JUSTIFICATION FOR CADASTRE 2014 4.1 Need for Support of Sustainable Development 4.2 Creating Political Stability 4.3 Omit Conflicts of Public and Private Interests 4.4 Support of Economy

Comment:

Land administration basing on the information from the cadastre is the important tool for 'the implementation of a proper land policy'. But only if the information on the legal situation of land is complete, the land policy can be supported in the broadest sense.

Cadastre 2014 shall give this complete overview.

Section of report	View of the report (p 400)	View of Cadastre 2014 (p 22)
Introduction	Without availability of information systems it is believed it will be difficult to guarantee good performance with respect to meeting changing customer demands.	**Statement 4 on Cadastre 2014 (p 22)** **'Paper and pencil - cadastre' will have gone!** Geomatics technology will be the normal tool for cadastral work. Real low cost solutions are only possible when this technology is used in combination with lean administrative procedures. Developed, developing, and transitional countries need models of the existing situation to resolve the problems of population, environment and reasonable land use.

Comment:

The new possibilities of IT make it possible to design solutions which work efficient and reliable. Only with these technologies the design and implementation of transparent and simple models is possible.

Section of report	View of the report (p 400)	View of Cadastre 2014 (p 33)
Introduction (p 400)	Standardization is a well-known subject since the establishment of cadastral systems. Open markets, globalisation, and effective and efficient development and maintenance of flexible (generic) systems ask for standardization.	Geographic information is sent over the data highways. The Internet and its ability to facilitate worldwide data networks is playing an important role in the exchange of cadastral data. The exchange of data models will become common practice in the distribution of cadastral information.

Comment:
Cadastral data modelling is an essential part of the standardization. It has proved to be the most effective method for standardization.

Section of report	View of the report (p 402, 403)	View of Cadastre 2014 (p 38)
2. Cadastral Domain Model	Core of the Cadastral Domain Model: Person, RightOrRestriction, RealEstateObject One should not look at the whole model at once as the colours are representing UML 'packages' or coherent parts of the model. …. It is likely that more packages will be developed. Besides being able to present/document the model is comprehensive parts, another advantage of using packages could be that it is possible to develop and maintain these packages more or less in an independent way.	Cadastre 2014 puts the legal land object into the center and adjudicates the right to the land object. … The right referring to the parcel, the title, is registered together with the indications about the rightful claimant in relation to the land objects..... The process of adjudication of rights to legal land objects in the case of public law corresponds to the creation of a title in the name of the society as claimant.
Comment: While the report recommends to create individual models for different matters of facts, Cadastre 2014 opens the view by handling all legal land objects in the same manner. The extension of the content of the models is not a new package, but the addition of a new legal independent layer model.		

Section of report	View of the report (p 403)	View of Cadastre 2014 (p 38)
2. Cadastral Domain Model (p 403)	The principles of Cadastre 2014 are integrated in our approach.	The principle of legal independence is a key item in the realization of Cadastre 2014. The principle stipulates that: • legal land objects, being subject to the same law and underlying a unique adjudication procedure, have to be arranged in one individual data layer; and • for every adjudicative process defined by a certain law, a special data layer for the legal land objects underlying this process has to be created. Cadastre 2014 is therefore based on a data model, organized according to the legislation for the different legal land objects in a particular country or district.
Comment: The report concentrates first on real estate objects and tries then to open the focus on restrictions. So there is a need to introduce specialization classes as Parcel, ParcelComplex, Part of Parcel, VolumeProperty, RestrictionArea, ApartmentUnit, etc. All these specializations cause an increase of complexity which is not transparents and resource consuming. Cadastre 2014 does not need these specializations, while working consequently with legal land objects.		

<table>
<tr><td>Section of report</td><td>View of the report
(p 405)</td><td>View of Cadastre 2014
(p 31)</td></tr>
<tr><td>2.2. Surveying Classes</td><td>A cadastral survey is documented on a SurveyDocument which is a legal source document made up in the field.</td><td>One of the most important things was the craft to represent measured objects in a comprehensible map.
With the utilization of information technologies, the process substantially changes. The determination of object co-ordinates becomes easier with GPS and remote sensing methods, and the direct drafting of objects on a map is superseded by the creation of objects in an information system.</td></tr>
<tr><td colspan="3">Comment:
Cadastral surveying is not explicitly treated in Cadastre 2014. But every land object must base on a legal documentation containing also the survey results for the registration of a legal land object in the cadastre system.</td></tr>
</table>

<table>
<tr><td>Section of report</td><td>View of the report
(p 415)</td><td>View of Cadastre 2014
(p 36)</td></tr>
<tr><td>2.5 History</td><td>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 separate entity within the system (with their own identity and set of attributes).
▪ In state based modeling, only the states (that is the results) are modeled explicitly: every object gets (at least) two dates/times, which indicate the time interval during which this object is valid.</td><td>Identical Procedures for Private and Public Land Objects
The procedure of the definition is similar for land objects created under private and public law. After the agreement between land owners about a transfer of rights, a deed or a title are created. The transaction of rights becomes legally effective by the registration of either deeds or titles in an official land register
The determination of public rights and restrictions follow well-defined procedures prescribed by public law. Once the adjudication process is completed, the right normally becomes valid. Cadastre 2014 expects that every right adjudicated to a legal land object will be registered officially.</td></tr>
<tr><td colspan="3">Comment:
The nature of cadastre is by tradition event based. Creation and transaction of land objects are the result of events as signing contracts or adopt laws and regulations. Also future enlarged cadastres have to deal with the events. Cadastre 2014 would prefer event based modelling.</td></tr>
</table>

Section of report	View of the report (p 412)	View of Cadastre 2014 (p 23)
3D questions	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…. In the previous section the volumetricProperty was introduced, but this requires a significant change in the legislation in most countries.	A land object is a piece of land in which homogeneous conditions exist within its outlines. These conditions are normally defined by law. Every society creates the rules for the co-existence of its members. These rules, normally in the form of laws, define how a society will understand the phenomena within the area in which it lives. In the same manner the rights and the duties of the members of a society are defined. These duties are, in most cases, defined by restrictions of the freedom of individuals.
Comment: Cadastre 2014 handles the geometry of an object as an attribute. Technically the objects may be 2D or 3D depending on the rights and restrictions connected with the object. Legally no respective steps have been undertaken. As soon a law defines 3D land objects, they can be taken into consideration in cadastre 2014 by describing them with 3D-coordinates without changing or re-inventing the basic concept. To identify the effect of a law in the 3rd dimension feasible algorithm are to be developed.		

3. CONCLUSION

The basic considerations made in the context of the core cadastral model and those behind Cadastre 2014 do not differ much. Standardization is crucial for both approaches. But beyond, the ontology needs to be harmonized.

The core cadastral domain model initiative, trying to model existing occurrences of cadastres, is confronted in every step with new questions. The development of the core cadastral domain model shows that with every step more elements of Cadastre 2014 are included. A trend in direction of Cadastre 2014 can be identified.

Cadastre 2014 is a totally new approach to cadastre. Including all legal land objects of a certain jurisdiction and according to its laws and handling them according to the proven and successful principles of the traditional cadastre, is a new approach made possible by the development of IT. This new approach makes it necessary to throw overboard some traditional practises as the parcel-centric approach. Thinking in land objects is the future in modern cadastral systems. The nature and the fundamental truths of the cadastre are remaining the same, but its content is changing significantly.

These differences have nothing to do with the modelling, they are in the field of the ontology. The ontology discussion, initiated by the standardization efforts, has to be continued. The important question is: What is the real nature of the cadastre?

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BIOGRAPHICAL NOTES

NAME**:**	Jürg Kaufmann
DATE OF BIRTH:	August 22, 1942
EDUCATION:	Department for Rural Engineering and Surveying of the Swiss Federal Institute of Technology with additional studies in economics and commerce.
PROFESSIONAL APPOINTMENTS:	After many years of surveying practice in Switzerland, he founded his own company KAUFMANN CONSULTING, working for public and private institutions in the field of cadastre and geomatics on a national and international level.
PROFESSIONAL EXPERIENCE:	Among many other involvements in public and private consulting projects, Jürg Kaufmann was a main consultant to the management board of the reform project of the Swiss cadastral surveying system from 1982-1994. Since 1995, he got involved in international projects in Liechtenstein, Belarus, Ukraine, Georgia and Kosovo. From 1994-1997, he was main consultant for the implementation of a modern cadastral system in Belarus, commissioned by the Swiss Federal Office for Foreign Affairs (FOFEA). Since 1998, he is commissioned by UN-DESA as Chief Technical Advisor for the cadastral project in Georgia. Since 1985, Jürg Kaufmann represents Switzerland in the FIG-Commission 7, where – between 1994-2002 – he twice chaired working groups resulting in the publications 'Cadastre 2014' and 'Benchmarking Cadastral Systems'. Since 2003, Jürg Kaufmann is the president of geosuisse, the Swiss Association of Geomatics and Landmanagement. Mother language: German Foreign languages: English, French, Italian (spoken), Russian (basic knowledge)

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

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Key words: Standardisation, Cadastre, Cadastral Domain

SUMMARY

In this paper a series of remarks and observations is presented on the Cadastral Domain Model as published at 'Digital Earth' in Brno 2003, see Lemmen, et al (2003). A substantial part of those remarks and observations is based on the presentations and discussions of the Expert Group Meeting on secure land tenure (new legal frameworks and tools), held in the Nairobi, Kenya, 11-12 November 2004. This meeting has been organised by FIG Commission 7, 'Cadastre and Land Management' in close co-operation with UN HABITAT and the Institution of Surveyors in Kenya. Earlier versions of the Core Cadastral Domain Model, have been developed on the basis of experiences in Europe, the Nairobi meeting provides input from developing countries.
The requirements resulting from this input is analysed with respect to the impact on the core cadastral domain model. It is first discussed what should be considered the scope of the core cadastral model. There is a tendency to include more and more object types and relationships in the model as these are somehow related to the objects in the current model. However, is it better to demarcate the model and develop other core models for the related objects (which can then be accessed via well-defined interfaces of the Geo-Information Infrastructure). The requirements that do fall within the scope of the model are translated into proposals for the new version of the core cadastral model. Finally, the paper is concluded with some final remarks and suggestions to create a new version of the model.

1. INTRODUCTION

In this paper a series of remarks and observations is presented on the Cadastral Domain Model as published at 'Digital Earth' in Brno 2003, see Lemmen, et al (2003). A substantial part of those remarks and observations is based on the presentations and discussions of the Expert Group Meeting on secure land tenure (new legal frameworks and tools), held in the Nairobi, Kenya, 11-12 November 2004. This meeting has been organised by FIG Commission 7, 'Cadastre and Land Management' in close co-operation with UN HABITAT and the Institution of Surveyors in Kenya. Earlier versions of the Core Cadastral Domain Model, have been developed on the basis of experiences in Europe, the Nairobi meeting provides input from developing countries.
Further a number of remarks are included in this paper based on evaluation of the model by the authors. Part of this evaluation is included in this paper where it concerns the system boundary of the Cadastral Domain Model. In section 2 a short overview is given of the

current core cadastral model, the ‘Brno 2003’ version. In section 3 some relevant experiences from a number of countries developing land legislation with attempts to integrate customary land tenure within a formal model. The requirements resulting from this integration are analysed with respect to the impact on the core cadastral domain model in section 4. Before trying to incorporate all requirements in the new version of the model, it is first discussed in section 5, what should be considered the scope of the core cadastral model. There is a tendency to include more and more object types and relationships in the model as these are somehow related to the objects in the current model. However, is it better to demarcate the model and develop other core models for the related objects (which can then be accessed via well-defined interfaces of the Geo-Information Infrastructure). The requirements that do fall within the scope of the model are translated into proposals for the new version of the core cadastral model in section 6. Finally, the paper is concluded in section 7 with some final remarks and suggestions to create a new version of the model.

2. THE CORE CADASTRAL DOMAIN MODEL: A SUMMARY

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

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

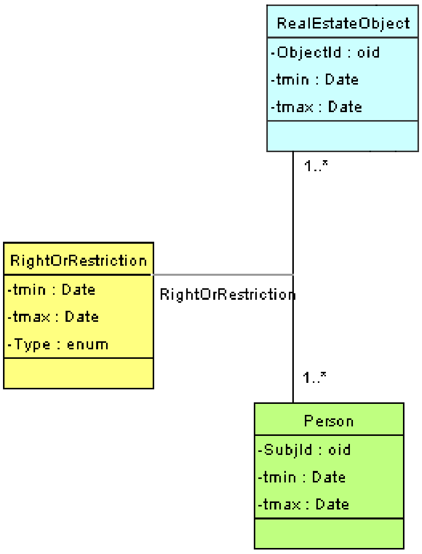

Figure 1: The three central object classes in the core cadastral domain model.

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

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

The proposed UML class diagram for the cadastral domain contains both legal/administrative object classes like persons, rights and the geographic description of real estate objects. This means in principle that data could be collected and/or maintained by different organisations, e.g. Municipality, Planning Authority, Private Surveyor, Cadastre, Conveyancor and/or Land Registry. The model will most likely be implemented as a distributed set of (geo-) information systems, each supporting the maintenance activities and the information supply of parts of the dataset represented in this model (diagram), thereby using other parts of the model. This underlines the relevance of this model; different organisations have their own responsibilities in data maintenance and supply and have to communicate on the basis of *standardised processes* in so called value adding production chains.

One should not look at the whole mode (all packages together as presented in Figure 2) at once as the colours are representing UML 'packages' or coherent parts of the model: green and yellow: legal/administrative aspects, green and blue: real estate object specialisations, blue, pink and purple: geometric/topological aspects.

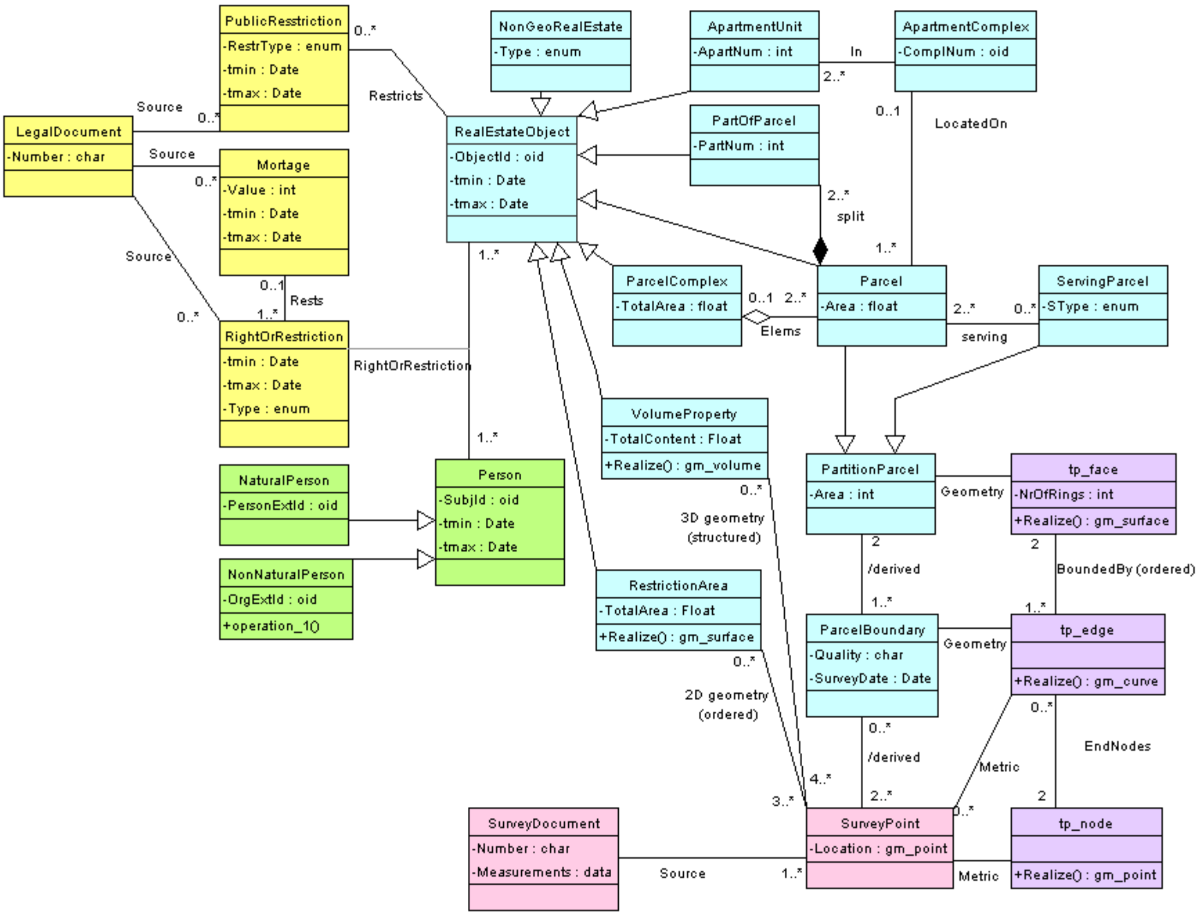

Figure 2: The current 'Brno 2003' version of the core cadastral domain model.

3. OBJECT-RIGHT-SUBJECT

Experience reveals that some countries develop land legislation, which endeavours to integrate customary tenure within the formal system. Bosworth (2002) reports on Uganda where the Land Act enacted in 1998 provides for methods to adjudicate on customary rights and the issue of certificates of customary ownership and occupation certificates for tenants on *mailo* land as well as the establishment of a Land Fund to assist in the market-based transfer

of rights between tenants and landowners. These certificates will be mortgage able. Consequently the Act recognises group rights to land by means of the registration of communal land associations with elected management committees. Quadros (2002) reports on Mozambique, where the new Land Act, 1998, recognises customary rights in the form of co-titling and the need to consult with the local communities as part of the authorisation process for new investments.
In Namibia a new Land Law is pending that will address the broad issues of communal land reform by means of the creation of regional land boards (Pohamba, 2002). A flexible land tenure system has been proposed by Fauerholm Cristensen (2004). A similar approach can be recognised in Tanzania (Kironde, 2004) where residential licenses in urban area's are to be converted to full title later. In Ethiopia a certification in two phases is under development (Abebe-Haile, 2004), in Uganda certificates of ownership and occupancy are used in parallel (Oput, 2004), in Lesotho 3 forms of leases are under development: primary, demarcated and register able (Selebalo, 2004).
Van den Berg (2000) states that under a new Act in South Africa communal titles can be granted to Communal Property Associations.
In Bolivia the INRA Act (1996) (Ley Instituto Nacional Reforma Agraria) provides for the recognition of *Tierras Comunitarias de Origen* (TCOs), i.e. land belonging to indigenous groups (Zoomers, 2000).
The recognition of customary rights also devotes attention to rights of sheep and cattle farmers. In many countries there are serious conflicts between traditional nomadic sheep or cattle farmers and arable farmers about grazing and farming lands (such as Kenya, Tanzania, Rwanda). Tanzania's new village Land Act provides for the sharing of pastoral and agricultural land by sheep and cattle farmers and arable farmers on the basis of adjudication and mutual agreements (Mutakyamilwa, 2002). In analogy with pastoral rights, the problem of *overlapping rights* has yet to be resolved in many countries.

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

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

The conclusion to be drawn from this Section is that the conventional basic concepts of land administration are affected in three ways:
- the subject: group ownership with non-defined membership
- the rights: the recognition of types of non-formal and informal rights
- the object: units other than accurate and established units

4. IMPACT ON THE CORE CADASTRAL DOMAIN MODEL

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

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

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

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

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

- Parcel
- Apartment
- Spatial Unit

could be represented in the Cadastral Domain Model as:

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

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

- Formal Ownership
- Customary
- Indigenous
- Tenancy
- Starter, landhold, freehold
- Possession
- Mortgage
- Usufruct
- Long Lease
- Restriction related to right
- Restriction related to object
- State ownership
- Informal
- Unknown
- Disagreement
- Occupation
- Uncontrolled privatisation

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

Subjects could be:

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

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

5. BOUNDARY OF THE SYSTEM

The current 'Brno 2003' version of the model is organised into several packages. It is likely that more packages will be developed. Besides being able to present/document the model in comprehensive parts, another advantage of using packages is that it is possible to develop and maintain these packages in a more or less independent way. Domain experts from different countries could further develop each package. It is not the intention of the developers of the model that everything should be realised in one system. The true intention is that, if one needs the type of functionality covered by a certain package, then this package should be the foundation and thereby avoiding reinventing (re-implementing) the wheel and making meaningful communications with others possible. The principles op Cadastre 2014 (Kaufmann, Steudler, 1998) are integrated in our approach.

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

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

1. spatial (coordinate) reference system;
2. ortho photos, satellite imagery, and Lidar (height model);
3. topography (planimetry);
4. geology, geo-technical and soil information;
5. (dangerous) pipelines and cable registration;
6. address registration (incl. postal codes);
7. building registration, both (3D) geometry and attributes (permits);
8. natural person registration;
9. non-natural person (company, institution) registration;
10. polluted area registration;
11. mining right registration;
12. cultural history, (religious) monuments registration;
13. fishing/hunting/grazing right registration;
14. ship- and airplane (and car) registration;
15. …

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

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

In several countries of the world we see attempts to harmonise a number of domain model within one country; e.g. Australia (ICSM, 2002), Germany, The Netherlands (Aalders et. al, 2004). But this is not sufficient, as the models should also be harmonised internationally. One could raise the question: 'What is the best order for harmonising: first within a specific domains (at an international level) and then harmonise these different domains, or first within a specific country (including all relevant domains) and then harmonise these different country models?'. Anyhow, it will be an iterative process as our insight and knowledge will keep on refining (and both approaches will probably be applied).

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

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

6. MAIN PROPOSED CHANGES

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

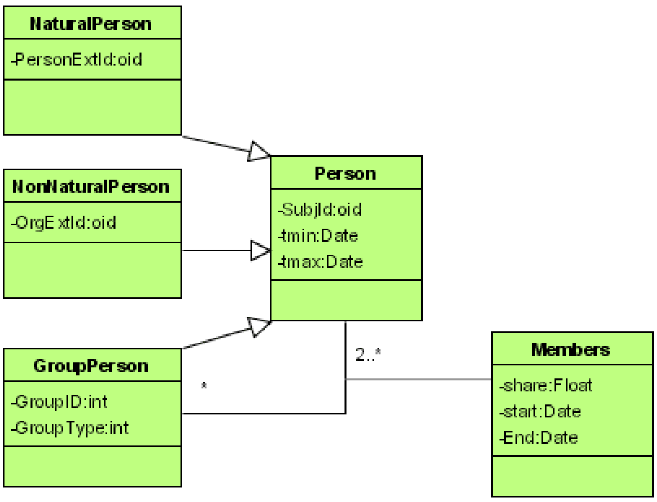

Figure 3: A possible extension of the core cadastral model with a GroupPerson.

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

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

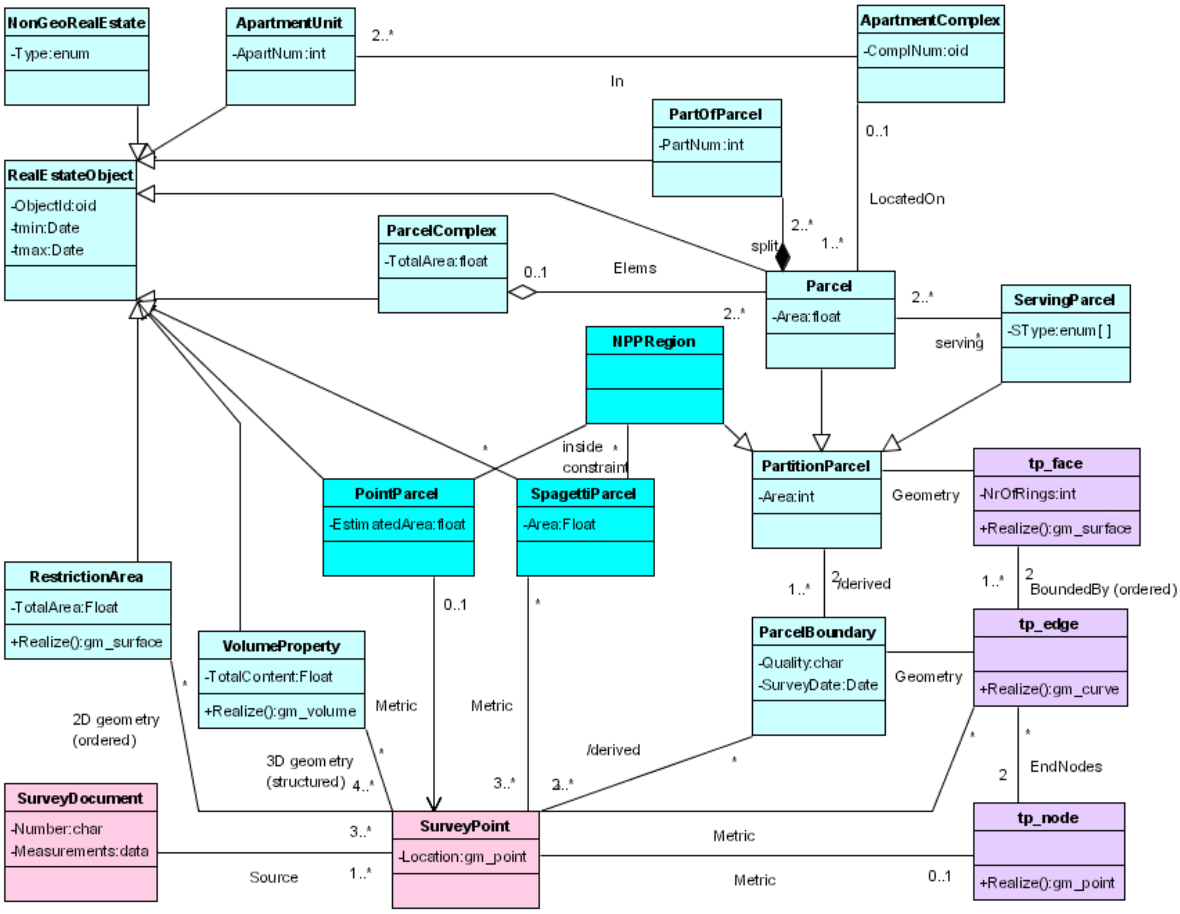

Figure 4: Another possible extension: the introduction of PointParcel and SpaghettiParcel.

The third possible modification to the 'Brno 2003' version of the core Cadastral model is related to what was already discussed in that version: 3D and temporal aspects of the representation (Onsrud, 2002, Mattson 2003, Queensland Government 2003a, 2003b). Until today the (2D) planar partition of the surface parcel is still the geometric foundation of the model (now extended with PointParcels and SpaghettiParcel). The whole 3D column is implied with a surface parcel. So, actually a 3D volume partition of space in implied. The VolumeParcels are an exception to the 3D column representation and they should be extracted from the column (Stoter and van Oosterom 2003, Stoter 2004). The result is then a 3D partition of space represented in a certain (practical) manner in the model and not in a full 3D topology structure. The conceptual model behind is a 3D volume partition (and one can imagine that also over here we have PointVolumeParcels and SpaghettiVolumeParcels).

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

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

It should be noted that this very general version of the model (based on 3D spatio-temporal parcels with fuzzy boundaries) contains all other models as specialisations. If there are no point or spaghetti parcels the model becomes sharp again (special case of fuzzy). When one thus not consider the temporal aspect, the result is a pure geometric parcel. When one is not interested in the 3D situation, everything is projected on the 2D surface and we are more or less back at the traditional model.

7. CONCLUSION

At data collection side modern technology can be integrated with positioning systems. Barodien and Barry (2004) recognise that effective upgrading of informal settlements require accurate and up to date social and spatial information. Home & Jackson (1997) use a point position (collected with hand held GPS) to relate the property identifier number, land cover, crop type, soil condition, and number of structures, etc.. In San Pedro Sula (Honduras) 130,000 parcels, both urban and rural were identified. Montoya (2002) combines Digital Video, GPS and GIS as a rapid ground data capture methodology from a car. Compare the use of the Cyclomedia system in some European cities. A similar approach should be investigated in relation to LiDAR (Airborne Laser Altimetry). Combination of the results with tape measurements (street level) and GPS (inner side of the street blocks) could, in our opinion, result in cadastral maps produced in an efficient way. In general a 'move' from national reference systems to WGS/UTM has to be considered. Further research may be: the relevance of field sketches (could be based on ortho photo's where people identify their properties), the use of cheap laser devices replacing tapes, the use of satellite images (see for example

Trindade, 2003), the development of quality labels related to spatial data representing the level of accuracy and providing information on how many co-ordinates are within this level of accuracy, area calculation (legal and calculated area, allowed difference), link to SDI, mapping of trees (in some area's more important then the parcels), the use of forms for collection of legal administrative data, electronic conveyancing, introduction of postal addresses.

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

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

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

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BIOGRAPHICAL NOTES

Paul van der Molen (54) holds a degree in geodesy of the University of Delft, The Netherlands. He is currently one of the directors of the Netherlands Cadastre, Land Registry and Mapping Agency. During many years the land registrars were within his responsibility. He is part time professor at the International Institute for Geo-Information Science and Earth Observation ITC in Enschede, The Netherlands. He acts as a chair of FIG Commission 7 and as a director of the FIG International Bureau of Land Records and Cadastre OICRF.

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Cadastral Modeling - Grasping the objectives

Erik STUBKJÆR, Denmark

Key words: Modeling, cadastral systems, multiagent systems, requirements analysis, Tropos methodology.

SUMMARY

Modeling is a term that refers to a variety of efforts, including data and process modeling. The domain to be modeled may be a department, an organization, or even an industrial sector. E-business presupposes the modeling of an industrial sector, a substantial task.

Cadastral modeling compares to the modeling of an industrial sector, as it aims at rendering the basic concepts that relate to the domain of real estate and the pertinent human activities. The palpable objects are pieces of land and buildings, documents, data stores and archives, as well as persons in their diverse roles as owners, holders of assets, experts, and holders of authority. More subtle objects are rights and restrictions, which relate persons through enforceable rules and commitments. The objective of this fabric of complex relations is to provide a stable and yet flexible frame for legal-economic dispositions that are related to land.

The paper advances the position that cadastral modeling has to include not only the physical objects, agents, and information sets of the domain, but also the objectives or requirements of cadastral systems.

1. INTRODUCTION

A Cadastral System is conceived, as the call for paper proposes, as the combination of a cadastre with its spatial focus, and a land register with its legal focus, cf. the motivation for this conceptualization in (Silva, Stubkjær, 2002). A fairly high level of abstraction is needed in order to provide for a set of models, which is complete and consistent and at the same time relevant for practice and applicable across jurisdictions within e.g. the European Union.

The COST G9 research activity has achieved some progress in modeling real property transactions. The emphasis has been on stating the activities performed: the actors, the sequence of activities, and the outcome, using UML modeling as the reference (e.g. Vaskovich, 2004). The level of abstraction made it possible to compare the performance of activities across countries. It appeared, however, that it was difficult to explicitly state the goals of the diverse activities, and/or phrase the activities in a way that emphasized the objective of the activity. To illustrate the problem by an example:

Subdivision includes a number of steps, including boundary measurements, and the approval by the Cadastral Agency. What is the objective of this activity? One of the objectives is to make available a cadastral identifier, which unambiguously names a specific parcel on the cadastral map. Another is to specify a the boundaries on the cadastral map in accordance with the legal reality on location, and a third is to specify a property unit, which then makes the base for sale and mortgaging. Who wants or requires this identifier? The geodetic engineer, who made the boundary measurements, and initially defines the parcel? The owner, who requested the cadastral service, because the law requires it? The purchaser, who could not mortgage his property unit without recording in the Land Registry, which again could not be accomplished without the cadastral identifier?

The example demonstrates that to a certain extent, it is a matter of choice to which actor the request should be attributed. The impact of this vagueness may be reduced by stating the requirements of 'all' actors within the domain, and then check, whether requirements are missing or better could be attributed to another actor.

The above mentioned limitations of standard UML modeling has been realized by knowledge engineers as well. The following section 2 refers to recent outcomes of their research, which suggests a more rigorous statement of requirements. Section 3 provides an answer to that call by presenting for each of 10 actors a listing of their supposed requirements from the other actors. Research within the domain has so far stated objectives, functions or features on a more general level. Section 4 analyses these often cited objectives, etc., and relates them to the requirements at actor level. Section 5 presents similar efforts in stating objectives and user needs, section 6 provides a discussion, among others of the idealized government, which was introduced in section 3, and the conclusion in section 7 closes the paper.

2. REQUIREMENT SPECIFICATIONS

2.1 The domain

Cadastral Systems are, world-wide, integrated in societal life in a way that makes it difficult to specify the domain in a way that points out the essentials. By taking a point of departure outside Europe, you might get a better basis for stating, what otherwise would be left unnoticed as truisms.

Hernando de Soto has established the fact that the humbler strata of each of a number of developing countries are in possession of houses, the value of which taken together far exceeds the holdings of the respective government, the local stock exchanges and foreign direct investments, and which is many times greater than the aid from advanced nations (De Soto, 2000). From this perspective he presents a number of effects, which characterize the property rights of the West: They are formalized, written on paper according to rules and norms, through the support of competent professionals and civil servants, who are generally available to owners and prospective purchasers, and the rights are abstracted in carefully maintained databases and archives.

The subsequent statement of requirements is, however, made in the intension to cover the situation only in Europe. This restriction is needed, because some of the main actors described below, the professionals and the public services, are not available, physically or economically, for the transacting parties of the developing countries (BRM, 2001, note 47). The initial adjudication of the country concerned is thus assumed to be completed, and the legislation, expertise, information systems, and practices are taken to be in place. The following may render the cadastral domain in terms of UML 'packages' in a compact way.

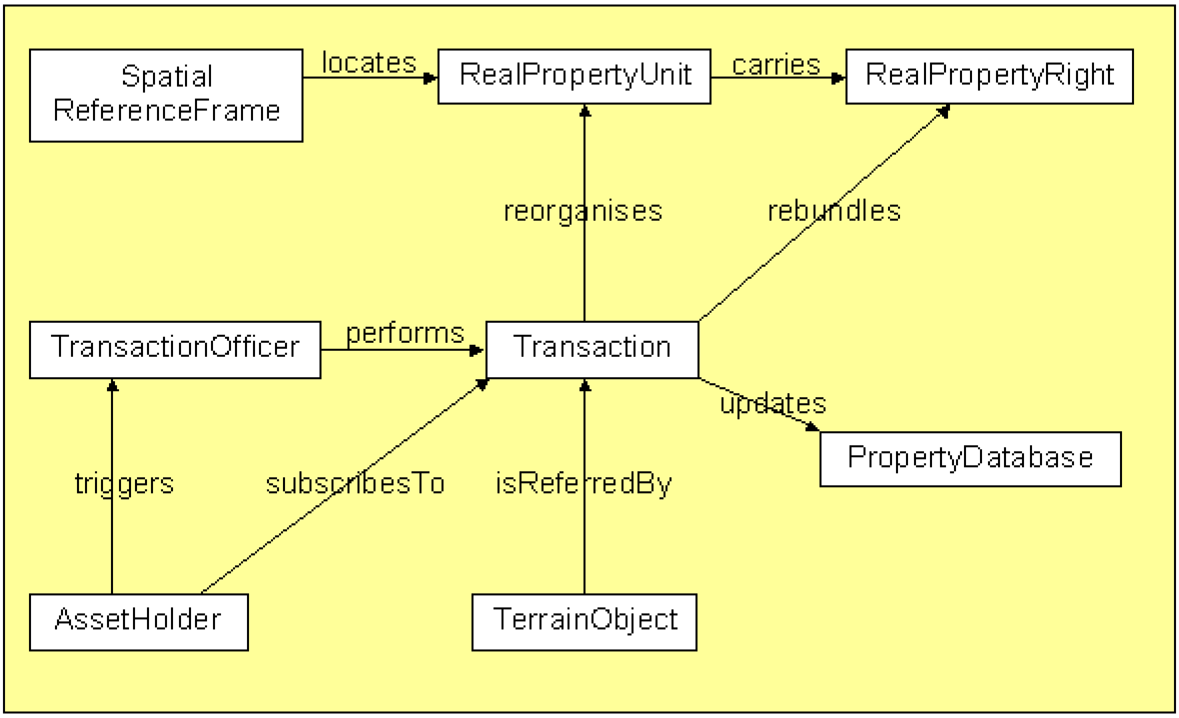

Figure 1: Cadastral Core Packages. Source: Stubkjær, 2003b.

The assumption that the Cadastral System is largely established perhaps implies that a requirement analysis at actor level cannot be used to motivate the establishment of the Cadastral System as such. The statement of requirements at actor level does however contribute to the identification of requirements. The relative importance of the requirements is subject to further studies. The reason for that being that a certain level of, for example legal security in property transactions, may be achieved by a host of combinations of services and measures, which means that the 'most relevant' requirement cannot easily be established.

2.2 The methodology

The limitations of standard UML modeling have recently been realized by knowledge engineers. A framework for requirements engineering is proposed, providing primitive concepts like actors, goals, and actor dependencies (Yu, 2001). The proposal is developed into a specific software development methodology, *Tropos*. The system-to-be is represented as another actor and is related to stakeholder actors in terms of actor dependencies. ('Agent' is a term that includes stakeholder actors, software, as well as other resources. Consequently, 'multi-agent system' is a relevant keyword). The stakeholder actors may draw upon resources or agents, available in their environment as well (Giunchiglia, et al, 2002).

Perini et al (2002) further focuses attention to the interaction amongst stakeholder actors: - behavior may be characterized as lying between extremes of competition and cooperation depending on, to what extent actors try to achieve common goals, or whether their goals are conflicting. Consequently, modeling should reflect the dependency between pairs of actors. Only by modeling this interaction firstly, it becomes possible to keep track of the *why*, the objective of the activities.

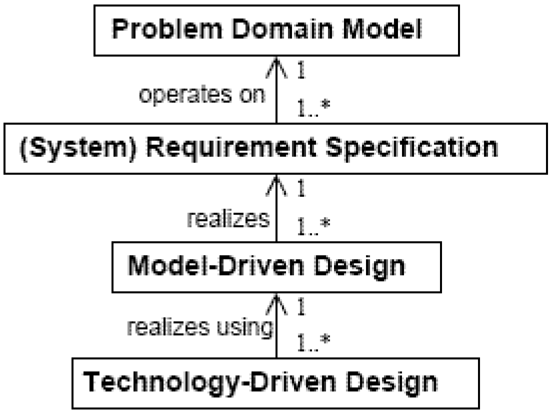

Figure 2: Requirement Specification in context. Source: Astesiano, 2002, Fig 1.

Finally, mention is made of the important suggestion by Astesiano and Reggio (2002) to discern between a Problem Domain Model, the Requirement Specification, and the System, respectively. The latter is specified through Model- and Technology-driven design, as illustrated in Figure 2. This conception of the modeling effort allows for a more explicit description of the system and its boundaries.

3. THE MAIN ACTORS AND THEIR POTENTIAL REQUIREMENTS

The actors charted below are ideal types, fictional models that never the less help us to understand the real world. What is common to the 10 actors is that they are supposed to act in a rational, but not necessarily law conformant, way, maintaining their interests and aiming at reducing their individual costs.

Perhaps, the requirements will be specified in a way, which mentions a specific plan or procedure, rather than stating a goal. This is against the idea of requirement analysis, which should allow for independent treatment of requirements and the subsequent design of plans, respectively. However, the scientific vocabulary of the cadastral domain is yet not developed to an extent, which allows for such 'pure' statement of requirements.

3.1 The Seller

The seller requires from the *Purchaser* an appropriate payment for the sold property unit. Furthermore, as valuable assets are at stake, the trading of ownership rights against money, etc. has to be performed in a way that protects the asset of the seller.

The seller requires from the *Real Estate Agent* the introduce, within reasonable time, of one or more Purchasers, who are able to pay the appropriate sum. Furthermore, the preparation of a sales offer, which accounts for the relevant attributes of the property unit and states a price, as well as guidance on how to market the property unit in an attractive way, and how to establish a mix of cash payment and mortgages that potentially increases the cash sales price.

The seller (and/or Purchaser) requires from the *Legal Advisor* to provide a written evidence of the transaction, have it recorded in the Land Registry, and monitor the related cash flow. Furthermore, to handle the details of receipts and expenditure of the property unit, relative to the day of entering into possession, and to advice on insurances and other appropriate measures to reduce the disturbing impacts of unexpected events of physical or legal nature.

The seller requires from the *Financial Institute* (or the Legal Advisor) the handling of the cash-flow of the transaction in a secure way, and assistance in the possible termination of existing mortgages.

From either of the previous, the seller may require guidance on, how the property transaction might be performed to reduce impact on taxation, as well as advice on the investment of the available capital to maximize rent and accommodate to the future cash-flow needs of the seller.

In case of change of size or shape of the unit and/or change of use category of the property unit, the Purchaser may request a *Geodetic Engineer* to establish the units' new boundaries, and arrange that the unit is functionally viable, e.g. legal access to a public road. The Purchaser then requests from the *Cadastral Agency* an official, unique identifier of the property unit(s).

3.2 The Purchaser

The Purchaser requests from the *Seller* a complete title in the property unit, as well as a fair account of the physical defects and the encumbrances of the unit. The purchaser may request that a part of the purchase amount is settled in terms of a Seller's mortgage in the property unit.

The Purchaser requests from the *Legal Advisor* assistance in specifying all relevant details of the transaction, and recording it in the *Land Registry* as mentioned above. Furthermore, the Purchaser requests from the *Legal Advisor* (and the other professions) that they offer professional indemnity.

The Purchaser requests from the *Land Registry* the provision of correct information on the rightful owner, as well as an account of all encumbrances but the most obvious, e.g. taxes and utility fees.

The purchaser requests from the *Financial Institute* a prompt offer for mortgage, and advice on the various lending options available.

The Purchaser requests information (through *Seller* or professionals) from the *Cadastral Agency* on the location, identification, and boundaries of the property unit.

The Purchaser may request a *Building Survey* in order to reduce the risk in assessing the physical qualities of constructions, etc.

3.3 Real Estate Agent

The Real Estate Agent (and other professionals) requests from the *Seller* (and other clients) to be paid for the service offered, and to be informed on the wishes of *Seller* as regards the conditions of sale, including price.

The Real Estate Agent requests from *Financial Institutes* and/or from *National Statistics* gross information on the real estate market, e.g. the number of transactions of different estate categories within administrative areas, and similar on the mortgage market.

3.4 The Legal Advisor

The Legal Advisor requests from the *Land Registry* an account of the present recordings, in order to assess the validity of the details of the deed.

The Legal Advisor requests from the *Client* to be paid for the service offered, and from the *Real Estate Agent* an agreement on the distribution of tasks as regards the scrutinizing of the conditions of sale, the establishing of rights, the financing of the transaction, and the transfer of money.

3.5 The Financial institute

The Financial Institute (bank) requests from the *Purchaser* that s/he repays the loan(s) and pays interest and charges as agreed.

In case of default, the bank requests from the *Land Registry/Court* that foreclosure action is performed within a predictable period of time.

3.6 The Land registry

The Land Registry requests from *Government* the provision of salaries, office space and equipment, as well as job applicants with sufficient education.

The Land Registry requests from the *Legal Advisor* (on behalf of the *Purchaser*) the settlement of stamp duties, etc, and the provision of deeds, which precisely identify the parties and the property unit transferred, which moreover specify the future owner(s) and the encumbrances and their mutual priority, and which finally state the sale price. The Land Registry furthermore requests that deeds are supplemented with evidence as needed, e.g. to witness the powers of a party.

The Land Registry requests from the *Cadastral Agency* the provision of unique identifiers of all property units, and information on changed (updated) property units.

3.7 The Geodetic Engineer

The Geodetic Engineer requests from the *Seller* (and other *Clients*) to be paid for the service offered, and to be informed on the wishes as regards future boundaries.

The Geodetic Engineer (or other responsible) requests from the *Municipality* (and/or other local authorities) the approval of intended changes of the property unit within a reasonable elapse of time.

The Geodetic Engineer requests from the *Cadastral Agency* relevant maps, including previously prepared boundary map sheets, as well as the documentation and monumentation of a geodetic network.

3.8 The Cadastral Agency

The Cadastral Agency requests from *Government* the provision of basic resources cf. similarly the Land Registry.

The Cadastral Agency requests from the *Geodetic Engineer* a specification of new and existing property units and their boundaries, the remedy of discrepancies between what is recorded and what is the legal situation on location, the recording of previous omissions, as well as the settlement of subdivision duties and fees.

3.9 The Citizen

The Citizen, as a potential buyer, requests from the *Government* a general education in reading and writing, including the use of writing while committing oneself. Furthermore is requested a formation, which enables the Citizen to reflect her assets and other potentials, and invest them in purposeful action. Finally the Citizen requests from the *Government* "to any person within its jurisdiction the equal protection of the laws" (cf. Fourteenth Amendment of the Constitution of the USA, 1868), but also that government and upper strata of society obeys to the law in the same way as the citizens are supposed to do (no dual standards in legal and economic affairs, cf. Collins, 2000: 105f).

3.10 The Government

The Government requests from *Land Registry* and from *Cadastral Agency* a complete and reliable coverage of the jurisdiction, and a reasonably joint conception of the recorded property units, including the use of same or mutually referenced identifiers, and mutual assistance for correction of inconsistencies. Furthermore, that property registration and related procedures contributes to a transparent market in real estate, i.e. that it is accessible to the public, and managed in a technically reliable, timely, and efficient way.

The Government requests from civil servants: *Land Registry, Cadastral Agency,* to behave according to bureaucratic norms of the Weberian, not the pejorative sense. This implies also the monitoring of rules and procedures with a view of reducing complexity and enhancing consistency. Government requests from professionals: *Real Estate Agent, Legal Advisor,* and

Geodetic Engineer, to provide professional indemnity, and behave according to a professional ethics.

The Government requests from *Citizen* the payment of taxes, and from *Buyer* and *Seller* the payment of duties and fees related to the transaction.

The above description of Government may be more idealized than the descriptions of other actors of this section. As announced in the introduction, a discussion is deferred to section 6.

4. REQUIREMENTS IN TERMS OF OVERALL PRINCIPLES AND FEATURES

The cadastral system operates as a whole, while in the previous section we applied the point of view of the diverse actors. In order to complement the above requirement investigation, the following refers to statements on the goals, functions, or features of the system as a whole. It is based on the overview provided by Zevenbergen (2002), which also provides reference details on literature before 1995.

Kurandt (1957), and Henssen (1995) mention the following principles pertaining to the Land Registry (LR) of German tradition:

- The booking principle, that conveyance is effected through recording in LR only
- The consent principle, that only the authorized according to the LR may request change
- The principle of publicity, including that recorded facts enjoy public credibility, and
- The principle of specialty, that the parties and the unit(s) of property are unambiguously identified.

Except for the third principle (enjoy public credibility), the others are means to achieve the overall goal of legal security. The German law demands preconditions and establishes legal effects, which in complex ways relate to the overall goal. The consent principle tends to support the accordance of the recorded with the reality. However, it presupposes a well organized registration system, that is: the principle of specialty must be realized. This principle again depends on the Government's means for identification of persons and on the operation and coverage of a Cadastral Agency, which provide the identification of property units.

Ruoff (1957) mentions three principles often quoted in literature in English:

- The mirror principle, that the recording in LR accurately and completely mirrors the facts that are material to title,
- The curtain principle, that purchasers, etc. need not to investigate legal facts beyond what is recorded in the LR, and
- The insurance principle, that a deficient LR recording triggers compensation to those, who suffered a loss by trusting it in good faith.

The mirror principle is supported by the above mentioned consent principle, and presupposes the specialty principle. Together, the realization of the three principles of Ruoff substantially reduces what in New Institutional Economics is dubbed the measurement costs of transactions. The notion of the mirror principle allow us to restate the request by the Land Registry to the Legal Advisor: The Advisor shall provide the Land Registry with the information needed to maintain the mirror principle.

Fortescue-Brickdale (1914), Kurandt (1957), and the FIG Statement on the Cadastre (1995) offer related sets of features of a (well-functioning) registration system.

Of those, 'legal security' mentioned by all covers the three above-mentioned principles of Ruoff.

'Simplicity' or 'understandability' of registration is mentioned by all as well. The mentioning of this feature seems not weighted against the complexity of the transactions, which suggest the use of professionals, at least until multi-agent systems support the able citizens in a comparable way, cf Arrunada (2004), who states that intervention by lawyers and notaries has become unnecessary for supporting much of private contracting in real property. Anyhow, (a well-meaning) government should strive for reducing the complexity of legislation.

Equitable access, Fairness, and Low cost are mentioned by the FIG Statement. Except for 'legal security', the features mentioned are also requested by the idealized government, which was described above, part 3.10.

Concluding, 'legal security', 'public credibility', and, proposed by Zevenbergen: 'trustworthiness' seems best to capture the overall objective of cadastral systems, while the 'mirror principle' with the 'insurance principle' best explains why credibility is achieved.

5. RELATED RESEARCH: STATEMENTS ON USER NEEDS

5.1 Requirements in the field of artificial intelligence and law

The Dutch Tax and Customs Administration conducts a research program POWER in which methods and tools are developed that support a systematic translation of (new) legislation into the customs' processes. The methods and tools developed are reported to help improving the quality of (new) legislation. Also, the methods support the codifying of the knowledge used in the translation processes in which legislation and regulations are transformed into procedures, computer programs and other designs. To illustrate the aspect of requirement specification, mention is made of a definition of the quality of law enforcement, which is offered by Engers et al (2001): "Quality of law enforcement is defined as the satisfaction of the constituency with the adoption of equality before law, predictability of law enforcement and proper use of law by law enforcing agencies". Here the constituency is taken as the actor, which eventually requests the requirements.

5.2 Requirements in the field of geographic information

A report on Users needs for reference data, (ETeMII, 2001) noted the ETeMII objective to enable better access to geographic information, and consequently stated the intension to tackle the users' needs for reference data (p.3). The report goes on to specify that "Stakeholders are users, data producers, data owners and GI service handlers. For a successful outcome, a European GI infrastructure must involve all of them...". Unfortunately, the user needs are not specified in much detail: "When the question, 'what do you need?' is posed to a specific user, the answer is classically, 'what do you have?' .. .. Nowadays, final users demand much higher data quality and better documentation" (p. 5).

The main ETeMII report includes an Annex C, the purpose of which is to examine existing user requirements (or 'customer requirements') as determined by a wide range of studies and reports from across Europe and the globe. "However, to provide such an analysis has proved to be beyond the scope of this annex ... due to the very large number of competing data requirements arising from GI user groups/sectors". The Annex, however provides economic data, which may be combined with the report's highly relevant structuring of geographic information to provide the following figure:

Visible objects: 33%	**Socio-economic Units: 29%**
Selected topographical themes: • Transport: 5 • Elevation: 7 • Hydrography: 5 • Other environmental: 16	• Units of administration: 2 • Units of property rights: 27 • Addresses: ?
Other: 38% Geodetic framework: 4; Utilities 19; Maritime navigation: 15;	

Figure 3: Geodata groups and their relative economic weight
Source: ANCLIZ Benefit Study, 1995, as quoted by ETeMII, 2001, Annex C.

The figures are surely debatable, but no better evidence appears available. The figures point to the relative importance of the units of property rights, i.e. land registry and cadastre. This may be further illustrated with data from the Danish National Survey and Cadastre (KMS, Årsrapport, 2003). The report reveals that the degree of cost recovery amounts to about 60 pCt on the cadastral activity proper, while only 34 pCt in general for the agency.

An interpretation of the above might be that the agency (and other European agencies?) faces user requirements, which are more determined regarding data on property units, than other, e.g. topographic data.

5.3 Requirements motivating the Lemmen et al standard for the cadastral domain

Governments need instruments to facilitate the implementation of a proper land policy in the broadest sense (Lemmen et al, 2003: 400). The main functions of every cadastral system are 1) to keep the content of the relationships between man, right, and land stored in a database, updated by drawing on legal transactions, and 2) to provide information from this database . The information may be hard to understand. By referring the information to an underlying ontology, expressed as a standardized cadastral core model, the information and communication between parties will be enhanced. This applies especially to communication across jurisdictions.

Open markets and globalisation ask for further standardization. The technology push, as well as the market pull for new services put demands on organisations for change. Cadastral modelling facilitates this development by providing standardized modules . These unspecified references to actors are supplemented with more concrete, namely that GIS suppliers like ESRI similarly offer models for several domains, and the cadastral domain is within its scope.

6. DISCUSSION

The role of government is remarkable. In the countries, which were mentioned by De Soto (2000), governments either have not realized the need for land administration instruments, or have not been able to establish them. Reversely, both the requirements specification of section 3 and section 5.3 above assumes the presence of a (strong) state, in order to make the property market and the implementation of land policy operate.

This is consistent with Giunchiglia (2002) who state that the stakeholder actors may draw upon resources or agents, available in their environment as well. However, the reliance on resources in the environment makes it problematic to transfer a standardized core to other jurisdictions, where the environment may be different, and important resources missing.

The requirement specification of section 3 may well be in need of further development. On the other hand, the specification allows for accumulation of knowledge in a more integrated way than has been possible so far. The statement of section 5.3 on the first function of a cadastral system compares fairly well with the 'mirror principle' of section 4. This is not to say that only one way of expression is appropriate. Rather, the various expressions are more easily compared.

7. CONCLUSION

Standardization of the cadastral domain supports the meaningful exchange of information between organizations and parties, in their dealing with rights in land and other real estate. Standardization is here conceived in the proactive sense, as a kind of legislation or regulation, which is imposed on actors and their future activities within the cadastral domain. Regulation needs to be legitimized. The Parliamentary process is essential in the legitimating of general prescripts, while the legitimating of standards appears to be a more open issue. Nebulous references to 'user needs' may be found.

The relevance of a Cadastral System in its totality is established, not with reference to user requirements, but rater with reference to the historical fact that such infrastructure is needed to enable a market in real estate.

The paper suggests that rational requirement analysis provides the legitimacy in cases, where users are not able themselves to specify the requirements. The approach draws upon recent developments in software engineering methodology, in an effort to state user needs in a way, which is specific enough to allow for empirical testing, and which facilitates a subsequent systems analysis.

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BIOGRAPHICAL NOTES

Erik Stubkjær is professor of cadastral science at the Department of Development and Planning, Aalborg University, Dennmark, since 1977.

He has written numerous research articles and conference contributions with a view to elicit theoretical foundations of cadastral systems.

He is former chairman and member of the Programme Committee of the conference series: Scandinavian Research Conference on Geographical Information Science (ScanGIS), and member of the Scientific Committee of the COSIT series of conferences. During 1996-99, he was co-ordinator of the EU's Phare/ TEMPUS project: Improved Education on Environment and Infrastructure. The project regarded the restructuring of the study programme of the Department of Geodesy, Faculty of Civil and Geodetic Engineering, University of Ljubljana, Slovenia, and resulted in a formally agreed renewal of the study programmes. 1999-2001, he was co-ordinator of a Nordic-Baltic Network on Land Management in Geodetic University Programmes, NorBalt.

Since November 2001, he is elected chairman of the Management Committee of a research project, Modelling Real Property Transactions, which co-ordinates research in 12 European countries, supported by the EU's COST scheme (G9).

In May 2003, he organised a PhD-course in the context of the International Doctoral School of Aalborg University. The course 'Cadastral Development – The Contribution of Scientific Enquiry' attracted 10 participants from 8 countries.

Erik Stubkjær is member of the Danish Association of Chartered Surveyors, and of the IT-section of the Society of Danish Engineers.

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Moving Focus from Organisation to Information

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Key words: Standards, IT, Object-orientation, re-engineering, best practice, co-operation, money

SUMMARY

The public sector is not taking full advantage of IT. The public sector is busy in maintaining existing processes, systems and legal framework, so it is protecting its business, avoiding big changes. IT is used to support existing processes and not as tool to change these processes and move the business forward. In this field the public sector is far behind the private sector e.g. the industry and the financial sector. Money is the driving force in the private sector, there is no such driving force in the public sector. The public sector should introduce the concept of Best Practice in the same way as the private sector.

As a first step systems should be built on a national basis covering the whole sector for land administration, users should not have to turn to a number of systems for getting a complete picture. Co-operation between ministries has been a driving force for building a Common Cadastral Dataset. In Sweden, in what is called the Swedish Approach, co-operation between ministries and other interested parties can't be done without standardisation. Standards are important!

In the next step it is important to exchange data between systems within Europe in such a way that data can be 'understood' by the customer. Coming that far a lot has been achieved; but doing business concerning land in the same way throughout Europe, using similar processes, is the ultimate and may be unreachable step. However for the citizen it would be of great interest as the transaction costs will be much lower.
Data concerning land are of two different types: attribute data and geometric data. The processes for updating and maintaining the geometric are less complicated and more similar but the data itself are a problem. The main reason for this problem is not the complicated model, it is the organisation of the data in the systems that causes the problem. Most of the systems keeping information have to be converted from being organised under data models for producing maps to objects reflecting objects for land administration. Object-orientation is here to stay and a huge task is ahead for coming years.

1. INTRODUCTION

Too much money is wasted on developments in the land administration sector, too many systems are built to preserve existing organisations and processes. Officers in charge of or working with a certain process or function are in general not capable to implement changes. It is related to the human way of thinking that the own job, or area of responsibility, cannot be automated.

Too many authorities (governmental or municipal) have an old-fashioned hymn saying**:**

IT should support our business processes

Already a long time ago that mantra has been changed in the industry and the private sector to:

IT should be a tool for changing our business processes

If IT is only used to support the existing business processes the business will not move forward and the IT will in many cases be an additional cost instead of an investment. The reader couldsay now: ‘oh, this is not happening in my organisation’ and may be you are right. It is a big difference in obtaining new technology to really introduce the technology in really automated the processes, and not just supporting existing processes. Before going into some examples let us look upon the need for standards in system development.

1.2 The Need for Standards in System Development

System development can be divided in three important components:

1. Technology
2. Data
3. Processes

This seminar will focus on the need for standardisation of data. This is without any doubt important, as data will be interchanged a lot as systems will be more integrated. Technically it is more correct to talk about interoperability than integration, as integration is by default synchronous computing. Interoperability opens the possibility for asynchronous computing and this provides better possibilities for flexible solutions. In general too much efforts are made on standardisation too early in IT-projects. It is common that standardisation and modelling activities start even before the requirements on the system are set A consequense could be that non-required data will be modelled.

On the technical a lot of recent developmentshave taken down the costs of system development. Concepts like www, Internet readers, IP-communication, J2EE, .NET etc are very important.

The third component is both developed and undeveloped. On the private side, within the industrial sector and the financial sector, standardisation of processes is well developed. There are many providers for External Resources Planning (ERP) softwares on the market; using ERP software means that only systems with unique business logic have to be developed, the remaining part will handled by standard systems. Organisations and processes will be changed to suit the system.

In the public sector the use of this type of standard systems is minimal, because of unwillingness to introduce changes. In the following a couple of examples will illustrate what is meant here.

1.2.1 Introduction of Monitoring Systems

In my job as a consultant on the international field for nearly twenty years I have seen a number of systems that have burdened the organisation instead of improving it. One organisation had problems with the long time for registration of dealingsat the land registry, the average turnaround time for a registration was more than one month, sometimes even up to three months. The system was manual, paper based, with a central lodgement desk, an enormous archive and registrars approving the dealings. The legal people did not rely on IT and claimed that their job could not at all be automated, not even by a simple work-flow system. The long period of time between the incoming request and the approval made it difficult to serve the search process and this was taken as the reason to build a system to keep track of movements of dealings within the office. Instead of building a system with demand and goal that a dealing should be registered within one to three days, the tracking system was built.

The tracking or monitoring system, called Unregistered Dealings System (URDS), should keep control on where in the process-chain a dealing was. Consequences of the URDS were extra steps in the process, just to inform that the dealing had left one sub-process and arrived at next sub-process. No value at all was added to speed up the registration process and the URDS did not at all improve the situation. A slower process was created for the office. A registration system will automatically tell the status of a transaction.

The organisation got a system that supported the existing business. The problem here is not about good data-models and standardisation on the data, the system should never have been built.

1.2.2 Introduction of Digital Signatures

Nearly every organisation around the world is busy with the introduction of the concept of digital signatures. In many countries this is a part of e-government or 24/7. I have seen systems being designed with digital signatures combined with support to the existing work-flow, this means just changing the status of the document from paper to digital but maintaining all other steps. The concept of digital signatures includes a secure validation of who has signed the document and a completed logging of the whole transaction i.e. there is a minimum of need for a manual checking and the process can be fully automated in many cases. Keeping the manual process is following the concept of 'IT supporting the existing business process'.

1.2.3 The European Market

The next example will be limited to Europe but it is also applicable outside Europe. If you look at a picture of a house it is more or less impossible to see from which country the picture is taken. If you look at the information about land (translated into English) that is available in the registers it is difficult to see from which country the information comes. If you look at a map it is still difficult to see from which country the information comes. Of course I don't take into account that the language can give you some information. The information looks the same and it is more or less structured in the same way. Try to buy the property and you will recognise the difference. Why is it still so that different processes support land transactions in different countries? The question is very relevant as international organisations like FIG, WPLA, Eurographics etc have been in place for so many years.

A big step has been made by EULIS, the European Land Information Service, information from the involved countries can now be retrieved and explained in a prototype environment; but it has taken a long time and the idea was not at all accepted from the beginning. The initial idea about EULIS was drawn up May 1997 in Sweden, and the idea was communicated to a number of other countries. The answers were both positive and negative, from "What a great idea, we will take part" to "Not interested, the information is for internal use", one answer was "Good but only interested as long as it stays with the data and not looking into the processes". EULIS is up running after a very long time-to-market, it has gone through a lot of compromising and it is only about data.

1.3 The Concept of Best Practice

In the IT-sector, which is very young compared to the land administration sector, we have worked with the concept of **Best Practice** for the last thirty years. If you as a consultant don't follow that concept you are out of business. The industry has adopted the concept and a comprehensive system concept has been introduced in big companies operating world wide. Systems like SAP, Baan take care of all processes within a company, the organisation of the company has to change to follow the system. In the same way the processes have to be changed, taken away the existing ones and new ones being implemented. The system is built with a focus on information and not with a focus to the organisation. The process from an order to delivery and payment looks the same independant of the business.

The driving force for the private sector is money and efficiency. If information concerning land looks the same in different countries, who is protecting the processes for land transactions? What is the driving force for any change? The legal system can't be changed over one night, not even over a year is the normal answer, but on the other hand there is the question: are you interested of any change that will jeopardise your position? It is an establishment of organisations that depends on existing processes for land transactions that is protected and the normal citizens just have to pay.

2. A SMALL STEP

In every country I have looked into, a number of ministries is responsible for different areas when it comes to land administration. The consequence of that situation is that a number of systems have been developed within one country serving just a part of the total business of land administration and the external users have to use a number of systems to get a complete overview. Sweden has an approach of a comprehensive system built with information in focus and giving the external users one single point of information provision.

3. THE SWEDISH APPROACH

All land in Sweden is divided into property units. Changes to the division of property units is a continuous process - lots are amalgamated or sub-divided and other cadastral procedures are carried out. Lantmäteriet (National Land Survey of Sweden) is responsible for guaranteeing legal security for individual property owners and also participates in measures to improve and formulate legislation in this field. Lantmäteriet is also responsible for the register and for land registration system which shows ownership, mortgages, encumbrances etc, the custodian for that system is the National Court Administration. These two registers are the basis in the Swedish Land Data Bank System (SLDBS).

The development of the SLDBS started in beginning of the 1970s as a common system for the management of the 'textual part' of property- and land-information. It started as an internal system, developed in-house, with internal demands and serving internal users but the SLDBS has over time grown to an open system used in land administration and in the financial sector throughout Sweden with more than 25.000 users connected. The number of users might look not too big; but it has to be remembered that Sweden has a population of nine million and around three million properties.

In Sweden, like in many other countries, different ministries have responsibilities for different data on land. To facilitate design and construction of a common system for the land register and the property register a project was set up by the involved ministries, at that time the Ministry of Justice and the Ministry of Housing. The project was formed as a governmental authority: The Central Board for Real Estate Data (CFD) with its own huge task to build a common automated system for information regarding land and property. Of course CFD also got the responsibility for the data collection and operation of the system. When the last area was completed, the task given to CFD was completed, it disappeared as independent organisation and merged with Lantmäteriet.

One of the success factors in the Swedish approach by the formation of a separate organisation was to built an organisation that could fully concentrate on its task. Another big advantage was the balance between the demands on the system from the two Ministries: the Ministry of Justice (National Court Administration), responsible for the land register, and Ministry of Housing (National Land Survey), responsible for the property information system.

3.1 External User Demands

The SLDBS was, from the beginning of its perations, an open system being met with big interest from external users, as the private sector (banks, financial institutes, brokers etc.), municipalities and other governmental authorities, i.e. everybody dealing with information on land. The external users soon started to put demands on the system, they were not fully satisfied with what they got and wanted more information . A good thing can easily be improved while a poor system can seldom meet new demands. The customers were satisfied with having one single point of access to get information on land and property, but still the had to turn to the municipalities for information on buildings and addresses, to the National Taxation Authority to get information on taxation and valuation. CFD took the initiative to add a number of additional registers to the SLDBS and made proposals to its Ministry.

CFD got approval to go ahead and a number of additional registers have been added as time went on and today the comprehensive register is named The Real Property Register, including:

- Address Register

- Building Register
- Co-ordinate Register
- Plan Register
- Property Assessment Register
- Sales Price Register
- Owner Associations Register
- Housing Credit Guaranties Register

CFD and Lantmäteriet merged when the task to collect and convert all information from the land and property register was completed 1996. From that date Lantmäteriet is responsible for running The Real Property System and from that date the integration of two other big registers begun:

- The Geodata Bank System, including digital maps of different scales and for different usage, and:
- The Digital Archive, including digitised documents on dealings and historical maps.

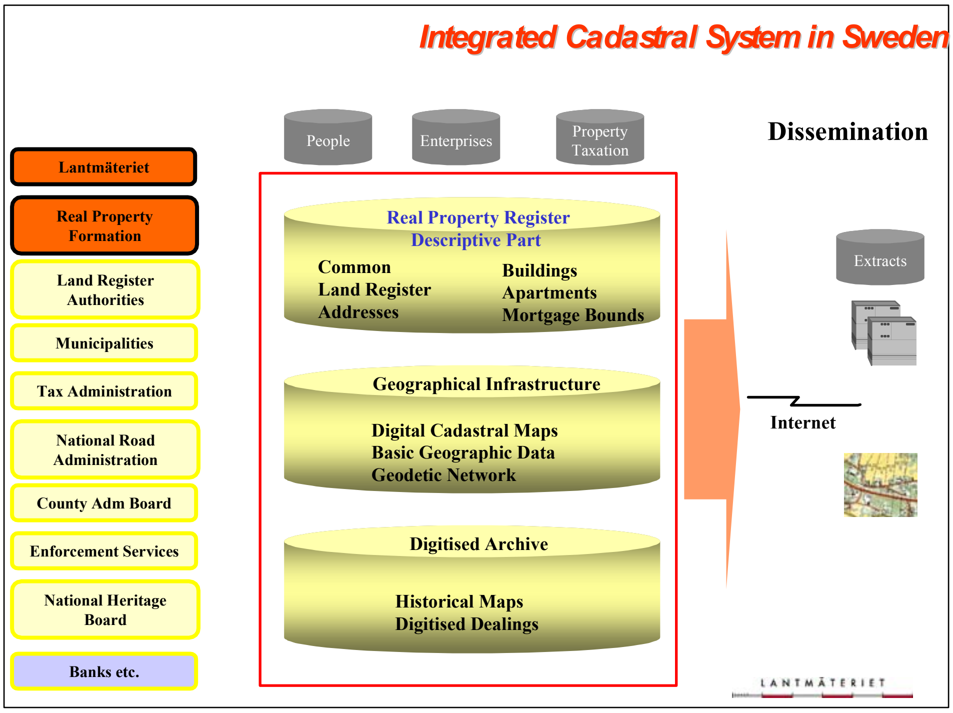
In the role of being responsible for operations, maintenance and enhancement of a comprehensive system concerning land information Lantmäteriet had to do a lot of co-ordination, as many other organisations are responsible for the their data and standardisation on data became even more important.

Integration of registers with geometric and descriptive information is complex, from technical perspective there is a big difference between interoperability and integration. The systems have been working on an interoperability basis for a number of years now and applications have been in place just for performing the conversion. The main problem is that almost every geometric or geographic database today is stored under a data model suitable for the noble art of map production. Until recently every tool in the market worked with moving lines, drawing arcs, connecting information to dots etc. just for the purpose of producing a map.

The databases for the descriptive part of the information are stored under a data model with objects like properties, owners, rights, encumbrances, plans etc. It is obvious that there are different identifiers in the two databases and the databases containing geometric data has to be changed following the principle that reflects the business of land administration.

The management tool for property formation has also been using the tools for drawing maps e.g. in a subdivision the surveyor has to draw lines and do a lot of checking. Lantmäteriet has together with ESRI developed a new software called ArcCadastre. This software puts the information in focus and a work-flow engine guides the user through any process. ArcCadastre will work against a data model based on the business of land administration, the users will have checks built into the work-flow.

Lantmäteriet is going to be fully object-oriented for all information in the Integrated Cadastral System. The objects will contain information from all databases regardless if it is descriptive or geometric information. A huge task is ahead to convert the geometric models from mapping objects to land administration objects. XML is used for handling the formats.



3.2 Lantmäteriet (The National Land Survey of Sweden)

The task of Lantmäteriet is to contribute to an efficient and sustainable use of Sweden's real estate, land and water. The organisation has three divisions:

1. The Division Land and Geographic Information is responsible for the generation, management, development and distribution of geographic and real property information. Real property information comprises information from the Real Property Register, including the digital cadastral index map, the Land Register and the central registers for buildings, apartments, addresses, mortgage certificates and real property prices. Geographic information comprises basic geographic data such as co-ordinates, terrain elevation data, aerial photographs, vegetation cover data and place names. The Division is also responsible for standardisation questions and for R&D in the fields of geodesy, cartography and geographic information systems.
   The Division's main clients are credit institutions and banks, public administrations, municipalities, estate agents and property management companies.
2. The Division Cadastral Services is responsible for Lantmäteriet's cadastral activities including decisions concerning the formation of new properties, changes to existing properties, joint-properties, easements, utilities and common facilities. Land ownership rights are determined and registered in the Real Property Register. Our clients include private property owners, forest companies and companies and organisations in the energy, telecommunications, road and railway sectors and the municipalities.
   The main activities are carried out within 21 Cadastral Authorities, one in each county. At the headquarters there are units for development, marketing and management. The division has a total staff of approximately 850 of whom 800 are working at the Cadastral Autorities and 50 at the central level.In 38 of the municipalities there are also Cadastral Authorities within the local administration.

3. The Division Metria carries out a broad programme of repayment services in the land survey sector and also produces basic landscape information for the Division of Land and Geographic Information. Other services and products supplied by Metria include consultancy services in surveying and mapping and geographic information techniques. Through Kartcentrum Metria is responsible for the publication of the national map series and other map products, as well as a comprehensive cartographic work on a contract basis. Metria's clients are to be found in both the private sector, such as forestry and telecommunications companies, and in the public sector.

As Lantmäteriet is one organisation all needs for co-operative functions are managed in one Department called Co-operative Functions. The biggest department within Co-operative Functions is the IT-Department, with of 85 system developers and 65 staff responsible for Computer Services. Around twenty consultants are contracted for system development.

4. CONCLUSION

Lantmäteriet is a governmental authority responsible for a number of registers including all basic relevant information concerning land in Sweden: descriptive information, maps and archived instrument, dealings and historical maps. The information in the registers is open for use and can easily be accessed if you are authorised. The use of the information is regulated in two laws, the Swedish Data Protection Act and a special law about the Swedish Real Property Register. It is up to Lantmäteriet to look after the customers and how they fulfil these laws.

The registers are structured as one common database but with many suppliers, there are a number of different technical solutions but they are transparent for the users. The users have one single interface for accessing the database. Comprehensive standardisation and data modelling exercises have accomplished a single database concept. The most important factor is the use of common identifiers and definitions in each register throughout the database, e.g. a building is described in the same way, regardless if it is on a map or in a register for ownership.

The information in the database is updated and maintained by the organisation that is responsible for the data, which means that municipalities update e.g. property addresses, banks update mortgagors, the National Tax Board updates the assessment value etc.

The openness and accessibility of basic land information leaves the field for application open for competition, Lantmäteriet does not have a monopoly on applications for land information. However Lantmäteriet is responsible for the contents, the maintenance and the dissemination. As noticed from the examples above, Lantmäteriet does have relevant and essential knowledge in the business so they are the natural partner for co-operation, also for applications.

The concept of object-oriented databases is fundamental in future developments, we cannot go-on treating the geometric information as just being important for map production.

The Swedish system is built with the information in focus. Systems built with organisations in focus will not facilitate for the external users, as they have to turn to a number of systems to get a clear picture of land information. The external users are the real users as they are representing the society, internal users are just concerned about support to internal processes.

Even if the Swedish system is built with information in focus it is still a long way to go to have a system based on the model of best practice to facilitate for doing transactions in land between countries. The willingness to improve existing law is maybe a bit better in Sweden compared to other European countries, but still it is a long way to go. As systems for land administration will continue to protect its own business area full advantage of IT is not taken.

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Swiss Cadastral Core Data Model – Experiences of the last 15 years

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Key words: cadastre, core data model, data modelling, INTERLIS, Switzerland.

SUMMARY

In Switzerland, the need for a standardized data exchange format for cadastral data has already been expressed in 1987. The requirement for a clearly defined data model that can be adaptated in flexible ways leads to the concept of a specific data description language, with which the whole cadastral core data model was defined. The data description language was named INTERLIS, while the data model for cadastral surveying became known as AV93, enacted in 1993 with a Federal ordinance.

The requirements for the core data model as well as the data description language evolved since. INTERLIS has been complemented and became INTERLIS2 in 2003. In 2004, a new revised core data model has been adopted, taking many of the discovered drawbacks into account. The revised core data model was named DM.01.

The concept of the data description language INTERLIS is very similar to the GML/XML concept that is in full development on the international level. This paper describes the experiences made with INTERLIS and the cadastral core data model in Switzerland over the last 15 years with the perspective of possible lessons learnt that might support international developments. The paper also includes two case studies illustrating the practical applications.

ZUSAMMENFASSUNG

Das Bedürfnis nach einem systemunabhängigen und normierten Datenaustauschmechanismus für Katasterdaten wurde in der Schweiz bereits 1987 ausgedrückt. Dies führte schliesslich zum Konzept einer spezifischen Datenbeschreibungssprache – als INTERLIS bekannt geworden – mit welcher das Datenmodell AV93 der Katastervermessung formuliert wurde, welches 1993 per Verordnung in Kraft gesetzt wurde. Die Beschreibungssprache wie das Datenmodell wurden seither den Anforderungen angepasst und sind nun unter INTERLIS2 und DM.01 bekannt.

Das INTERLIS-Konzept ist dem sich auf internationaler Ebene durchsetzenden GML/XML-Konzept sehr ähnlich. Dieser Artikel beschreibt deshalb die Erfahrungen, die in der Schweiz während den letzten 15 Jahren gemacht wurden im Hinblick auf heutige internationale Entwicklungen.

1. INTRODUCTION

Data modelling, interoperability, spatial data infrastructure, OpenGIS and GML/XML are important key words in the context of efficient and transparent data access and eGovernment developments for cadastre and land administration activities. The role of geo-referenced information is crucial not only for cadastre and land administration themselves, but for many other decision-making processes that are related to land in one way or another.

The integration and sharing of geo-referenced data becomes more and more crucial, and there is an increasing need for efficient and reliable data exchange standards. In order to provide long-term security, these standards have to be independent from any specific hard- or software systems on the one hand, while for reasons of flexibility, they also need to provide a model-based approach. The following sections describe the experiences that have been made in Switzerland, where such a standard has been introduced more than ten years ago and where there already is a variety of experiences.

2. HISTORICAL BACKGROUND

In Switzerland, the need for a data exchange standard for digital cadastral data has already been expressed in the detail concept for the reform of cadastral surveying (Eidg. Vermessungsdirektion, 1987). In the light of the evolving digital technology, traditional cadastral maps on paper were not flexible enough and not suitable for the needs of the emerging information society. A project for the reform of cadastral surveying has been started in the mid-1980's, in which the conclusion was drawn that the need for a standardized data exchange mechanism arises out of four prerequisites:

- out of the need to transfer data from older to newer software systems;
- out of the tendency of devolution and networking, which leads to the situation that different problems require different solutions and systems;
- out of the fact that users prefer digital data in standardized ways;
- out of the high value of the cadastral data, which – for data security reasons – have to be kept on different systems and transferred back and forth.

A problem at that time was that software packages provided exchange standards that were proprietary, static and format- rather than model-based. Vendors had a certain vested interest to keep their software systems "closed" to any transfer of data into another system. As long as there were no cross-platform data exchange standards, it was possible to "lock" data into their specific system. Experiences from the late 1980's suggested that the costs for the transfer of geospatial data from one software system to another were nearly as high as the whole data acquisition process itself. This was of course not tenable for the maintenance of cadastral data that have to provide long-term guarantee – potentially much longer than the life span of hardware and software.

An expertise in 1985 (Messmer, 1985) suggested a bi-level approach for the future data exchange standard in cadastral surveying, which then was further developed by Dorfschmid (as described in Dorfschmid, 1996). He proposed a data description language to describe data models in an orderly and precise way, while the data model itself had to be decided by the respective authorities. This proposal was based on the following thoughts:

- precision and flexibility in data description;
- data archiving according to principles of data and information security;
- formal and automated data quality control.

This proposal satisfied the expectations and was accepted by the steering committee. A detail concept was commissioned and led to the creation of the data description language INTERLIS and the data model for cadastral surveying.

The model-based concept has further advantages. It allows data exchange without information loss – as opposed to the format-based exchange standards – and thus provides a system-independent data exchange mechanism for the protection of the high financial investments in data acquisition. The principle of method and system independency was also the basis for the introduction of tendering projects because it became possible to define the final product rather than the method or the system.

3. CADASTRAL DATA MODELLING BASED ON DESCRIPTION LANGUAGE

The INTERLIS language has been developed in such a way that it can easily be read by human beings. The interpretation of INTERLIS models is nevertheless precise and unambiguous. The language is textual and well-suited to complement the graphical description language Unified Modelling Language (UML), but goes well beyond that. The INTERLIS concept also includes a transfer service, which can automatically generate the transfer file from the conceptual model.

INTERLIS has been designed for the interaction between information systems, in particular land information systems. It therefore is a conceptual description language with which the data model of the real world can be described. Such a description is called a "conceptual model". Properties and relations of real world objects are being described with clearly defined expressions and terms. Furthermore, INTERLIS makes a clear distinction of the description of the real world objects and their graphical representations.

INTERLIS is not geared towards a particular application. It is based on object-oriented principles and while coordinates, lines and areas are basic constructs, there are many others to describe other properties of the objects, enabling INTERLIS to also deal with non-geographic data and applications.

Data modelling in conjunction with system independent interface services is called model-based approach or model-driven architecture. Models can be defined on the basis of a common concept and standard, which is crucial from the perspective of semantic interoperability. For example, data can be transferred from a municipality to a higher administrative unit (cantonal or Federal level) without effort and without loss of semantic, topologic, and geometric information. It suffices that a common data model is at the basis and that each administrative level builds its model on the basis of the next level above.

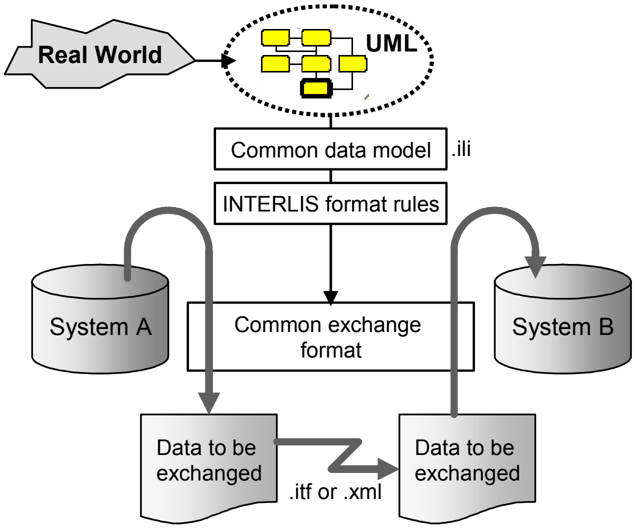

Figure 1: Data transfer between different information systems through a common datamodel defined through a common data description language.

The core data model for cadastral surveying data – initially called "AVS" then "AV93" – was defined with the data description language INTERLIS and became an integral part of the new legal basis for digital cadastral surveying introduced in 1993. The data model consists of eight information layers; the distinction into different information layers had mainly a data management purpose, namely to be able to assign distinct stakeholders and to separate and distinguish data acquisition for each layer.

The two new ordinances that were introduced in 1993 were "VAV" ('Verordnung für die Amtliche Vermessung' or Ordinance for Cadastral Surveying) and "TVAV" ('Technische Verordnung für die Amtliche Vermessung' or Technical Ordinance for Cadastral Surveying). The objective was to renovate the cadastral surveying system and to introduce the digital data format. Due to the versatility of data in digital form, the 'raison d'être' of cadastral surveying data had been extended from a sole legal purpose to multi-purpose, serving not only for land registration but also for "any kind of land information system". The data description language INTERLIS is a crucial element for this extension of purpose because it is well suited as basis for the definition of data models in any other domains (compare also Figure 3).

The cadastral map in digital format consists of eight information layers. By definition, the two layers "land cover" and "ownership" cover the whole territory in a complete way, i.e. without overlaps nor gaps, while other layers have different structural definitions. Buildings are part of the "land cover" layer. The separation of the data into the eight information layers has the advantage that the layers can be acquired independently from each other. Each of the information layers is object-oriented and defined by an entity-relationship diagram, representing the data model and basis for the translation into the INTERLIS data exchange format (Figure 2).

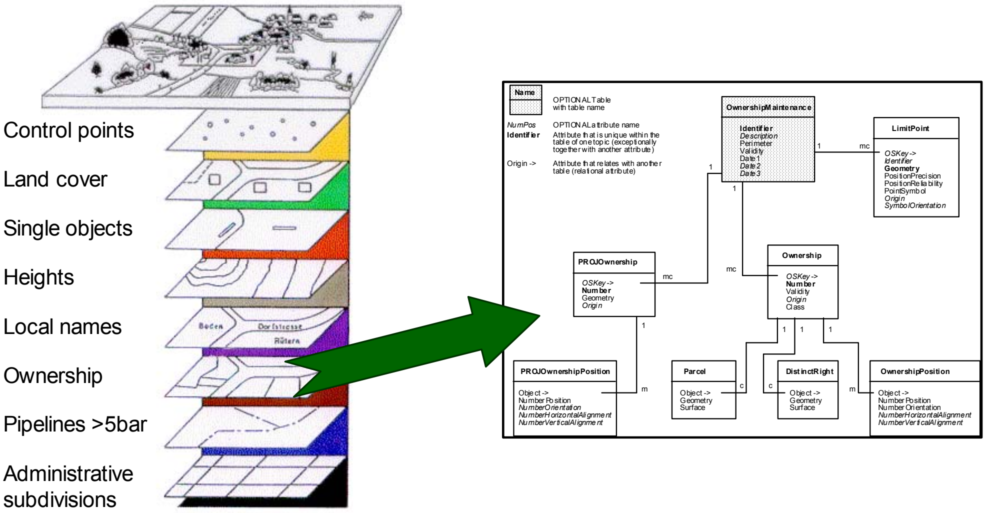

Figure 2: *The eight information layers of cadastral surveying and example of entity-relationship diagram for layer "ownership".*

The following example intends to illustrate how the entity-relationship diagram resp. the data model is being translated into a machine readable file. It shows an extract from the "ownership" layer of the data model DM.01 for cadastral surveying. It also shows the hierarchical structure of INTERLIS with the main constructs MODEL–DOMAIN–TOPIC–TABLE.

```
TRANSFER INTERLIS1;

!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
!! Datenmodell 2001 der Amtlichen Vermessung "Bund" (DM.01-AV-CH)
!! beschrieben in INTERLIS Version 1 (SN 612030)
!! Version: 24 deutsch
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!

MODEL DM01AVCH24D

  DOMAIN
    LKoord = COORD2 480000.000   70000.000
                    850000.000  310000.000;
    HKoord = COORD3 480000.000   70000.000   -200.000
                    850000.000  310000.000   5000.000;
    Hoehe = DIM1      -200.000    5000.000;
    Genauigkeit = [0.0 .. 700.0];  !! in cm
    Zuverlaessigkeit = (
      ja,  !! genuegend
      nein);  !! ungenuegend
    Versicherungsart = (Stein, Kunststoffzeichen, Bolzen, Rohr, Pfahl, Kreuz, un-
versichert, weitere);
.........

  TOPIC Liegenschaften =
    DOMAIN
      Grundstuecksart = (Liegenschaft, SelbstRecht, Bergwerk);

    TABLE Grenzpunkt =
      Entstehung: -> LSNachfuehrung;  !! Beziehung 1-mc
```

```
      Identifikator: OPTIONAL TEXT*12;
      Geometrie: LKoord;
      LageGen: Genauigkeit;
      LageZuv: Zuverlaessigkeit;
      Punktzeichen: Versicherungsart;
      ExaktDefiniert: (Ja, Nein);
      HoheitsgrenzsteinAlt: (ja, nein);
    IDENT Geometrie;
    END Grenzpunkt;

    TABLE GrenzpunktSymbol =
      GrenzpunktSymbol_von: -> Grenzpunkt;  !! Beziehung 1-c
      Ori: OPTIONAL Rotation // undefiniert = 0.0 //;
    IDENT GrenzpunktSymbol_von;
    END GrenzpunktSymbol;

    TABLE Grundstueck =
      Entstehung: -> LSNachfuehrung
        // Gueltigkeit = gueltig //;  !! Beziehung 1-mc
      NBIdent: TEXT*12;  !! Beziehung 1-m zu Nummerierungsbereich
      Nummer: TEXT*12;
      !! Elektronisches Grundstueckinformationssystem
      EGRIS_EGRID: OPTIONAL TEXT*14;
      !! abgeleitetes Attribut: muss streitig sein, falls Liegenschaft,
      !! SelbstRechtvoder Bergwerk streitig;
      Gueltigkeit: (
        rechtskraeftig,
        streitig);
      !!unvollstaendig, falls z.B. das Grundstueck
      !! teilweise ausserhalb des Perimeters liegt.
      Vollstaendigkeit: (
        Vollstaendig,
        unvollstaendig);
      Art: Grundstuecksart;
      GesamteFlaechenmass: OPTIONAL DIM2 1 999999999;
    IDENT NBIdent, Nummer;
    END Grundstueck;

    TABLE Liegenschaft =
      Liegenschaft_von: -> Grundstueck // Art = Liegenschaft //;  !! Beziehung 1-mc
      !! NummerTeilGrundstueck ist fuer Teil Grundstueck noetig
      NummerTeilGrundstueck: OPTIONAL TEXT*12;
      Geometrie: AREA WITH (STRAIGHTS, ARCS) VERTEX LKoord BASE
        // Geometrie nur LFP1, LFP2, LFP3, Grenzpunkt oder Hoheitsgrenzpunkt //
        WITHOUT OVERLAPS > 0.050
        LINEATTR =
          Linienart: OPTIONAL (streitig, unvollstaendig);
        END;
      Flaechenmass: DIM2 1 999999999;
    NO IDENT
    END Liegenschaft;

  END Liegenschaften.

END DM01AVCH24D.
```

As mentioned above, the new ordinances introduced in 1993 required that the cadastral surveying data are to serve not only for land registration, but for any kind of land information system. The idea behind that stipulation was to integrate and share spatial information of public interest and to avoid double data acquisition. With the introduction of the INTERLIS data modelling concept, this demand became technically feasible. Spatial data can be integrated and shared in one information system only when they have a common geodetic reference framework and a common data modelling concept. As illustrated in Figure 3, data ownership and responsibility can still be retained without interfering in stakeholder interests and data acquisition and maintenance processes.

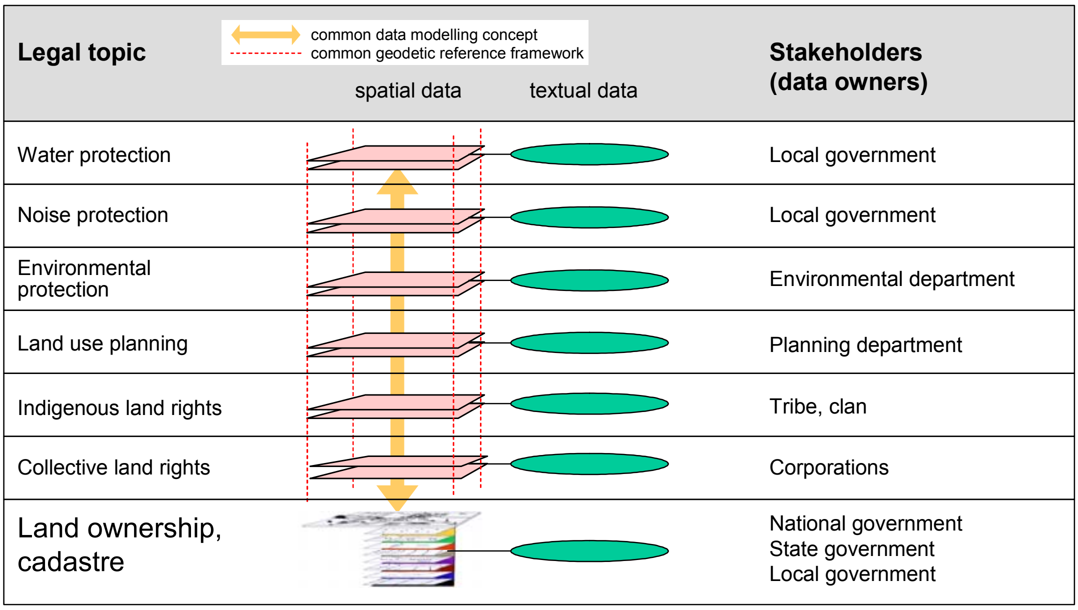

Figure 3: Concept of shared land information through common geodetic reference framework and common data modeling technique.

Data modelling plays a similar role as the geodetic reference framework. Both are not an absolute necessity for data integration and sharing, but they both provide the required ease of use for land information systems to work. This concept is at the core of spatial data infrastructures, which are very important in sharing information and ultimately the set-up of eGovernment services.

4. DEVELOPMENT OF INTERLIS2 AND COMPARISON WITH GML3

At the time when the data-modelling concept has been introduced, there were only few international standards available that were able to support it. One was the data description language EXPRESS, which however does not seem to have overcome the initial problems for practical implementation for geo-information.

INTERLIS was adopted as the description language in Switzerland and it also went through a difficult period at the beginning. However, after some initial problems, it was accepted in practice and was supported by the inclusion in several software packages. It became widely used in the cadastral surveying community as well as for the description and definition of many other municipality-based data sets.

Due to several minor, but important restrictions, INTERLIS had to be extended and complemented in 2003. It became INTERLIS2, which now offers new possibilities such as incremental updating, the definition and transfer of graphical representations, data views, and the description of units and coordinate systems. Also terms of the language have been altered for better readability and compatibility. For instance TOPIC has been altered to CLASS, OPTIONAL is replaced by MANDATORY, and IDENT by UNIQUE.

Instead of the specific INTERLIS file transfer format .itf, it is possible with INTERLIS2 to encode the data for transfer directly with the "eXtensible Markup Language" .xml. XML is expected to become the international standard with a large number of compatible software tools to be developed in the near future.

Users acquainted with INTERLIS will not have to face many changes when working with INTERLIS2. Various tools such as the commonly available INTERLIS2 compiler will facilitate the adaptation to the new version. Software producers who already had implemented flexible configuration possibilities in their systems with INTERLIS will find that their past investments will retain their value. Open accessible program libraries will support the full integration of INTERLIS2 into their systems.

In summary, INTERLIS2 does not replace the initial INTERLIS description language; it rather provides complements that facilitate new possibilities. The most important changes were:

- INTERLIS2 offers new extensions such as data types, constraints, data views, graphical descriptions, description of units, descriptions of coordinate systems, and user-specific extensions, such as e.g. line geometries.
- Possibility of incremental updating. Incremental updating requires that both the primary and secondary data bases support the transfer format (XML) and that new object identifiers be introduced.
- Instead of the .itf-format that INTERLIS used, encoding of the INTERLIS2 transfer format will be done with the eXtensible Markup Language (XML). This ensures that the national standard is compatible with internationally accepted standards.

In a recent study, Nebiker (2004) compares the concept of INTERLIS2 with GML3. His findings can be summarized that INTERLIS2 is an established 'de jure' standard with rather slow, pragmatic development pace and a mainly national basis. The pace of development for GML is much faster and through an international, mainly US-based industry consortium. With the integration of GML into the ISO standardization process, the pace of development will however be slowed down and thus the integration into practice being improved. Both INTERLIS2 and GML offer constructs for the description of spatial objects including their properties and mutual relations.

The way of modelling is very similar with both languages. INTERLIS is slightly superior in the modelling of overlaps and the specification of plausibility checks, while GML offers some functionality not available in INTERLIS2, e.g. modelling of 3-dimensional objects or the support of different coverage types. GML bases its XML schema on a well known IT standard, which is being supported by a large collection of software tools. Models in XML can very easily be checked against errors with these software tools, however are not easily readable by human beings.

	Strengths	Weaknesses
INTERLIS2	• precise and lean • version 1 already passed the test of practice • evolution rather than revolution • many software tools • UML and text	• only modelling and transfer • 'island' solution (national solution) • too good version 1 • yet unclear role of XML (schema) • how to deal with further extensions?
GML3	• large basis in market • pragmatic modelling language • part of a standard family • application language	• flood of versions • large and complex • restrictions of the XML schema • cryptic model descriptions • lack of practice • lack of producer support

Table 1: Strengths and Weaknesses of INTERLIS2 and GML3 (Nebiker, 2004).

Nebiker (2004) also lists the commonalities between INTERLIS2 and GML3. They are both model-based and object-oriented and they both support domain specific application schemas and data transfer with XML. Differences are: different modelling languages; INTERLIS can create three different representations of the data model; INTERLIS can separate model description and data transfer description; INTERLIS is tested in practice for several years now and has a pragmatic and somewhat slower standardization pace; INTERLIS is readable by human beings while GML is difficult to interpret.

The objective of the study was to evaluate the further advancement of INTERLIS2 in view of the technical developments around the UML, GML and XML standardizations. The recommendation was that Switzerland should continue to use INTERLIS2 for the description of data models, mainly for the following reasons:

- there is a well established industry to deal with INTERLIS2, while GML – although an accepted international standard – is still in rapid development
- many software tools are available for INTERLIS2 (parser, compiler, checker)
- data described with INTERLIS2 are compatible with the .xml format
- the compiler for INTERLIS2 has been extended and now provides the basis for the generation of GML application schemas and XSL style sheets for data transformation
- data services can easily be set up on the basis of OGC
- INTERLIS2 supports incremental updating
- there are control tools in INTERLIS2 that do not exist for XML yet
- INTERLIS2 can describe graphic representation, which is not possible in GML

The GML and XML developments will of course be closely monitored. The suggested continuation with INTERLIS2 provides the required stability for the industry. The Swiss geoinformation community has a tool that provides the required services and it has the privilege not having to rush into a new standard.

5. CASE STUDIES

5.1 Cadastral Surveying Data Model DM.01

The initial data model AV93 of cadastral surveying was very successful in its implementation, but due to the developments and experiences over the first few years, it had to be adapted to newer requirements. The new version of the data model was named "DM.01" and it was enacted in early 2004. DM.01 takes many of the earlier discovered shortcomings into account.

One of the crucial shortcomings was that AV93 contained too many "cantonal options", which were sort of political requirements at the beginning. Cantons were given the choice of optional data or to include specific data in their cantonal data model. This however had a diverging effect and led to– although very similar – different cantonal data models. The amalgamation of cantonal data sets into a national one became more and more difficult.

The revised core data model DM.01 is more restrictive and defines one clear Federal model; Cantons – in their political autonomy – are still permitted to maintain their own data models, but are required to provide data in the format of the Federal model. This concept now allows a hierarchy of data models, which is well-suited for the federative and decentralised political and administrative structures of Switzerland.

Other changes in the revised data model concern the improvement of the suitability and homogeneity of data. Additional attributes have been defined that were required by on-going projects such as agricultural areas (grazing land, pasture), interface to land registration (additional identifiers for use in new information system; new relation between entities 'parcel' and 'property'), provisional products (new quality standard), and address data (more precise and nationally unified attributes) (Eidg. Vermessungsdirektion, 2004).

The Cantons are not required to use INTERLIS2 for the revised data model DM.01, the older version 1 of INTERLIS is still functional and accepted. It is however recommended that Cantons switch to INTERLIS2, because it provides more and better possibilities for data management. The full data model including commentary and entity-relationship diagrams can be viewed on the Internet at http://www.interlis.ch/mo/index.php?language=d (in German, French, Italian).

With the introduction of the new data model DM.01, the Federal Directorate for Cadastral Surveying (Eidg. Vermessungsdirektion) also introduced a new web service, which allows to automatically check data sets. The possibilities are:

- check service with INTERLIS1: Federal data model DM.01 + data
- check service with INTERLIS2: any data model + data

These new possibilities also demonstrate the advantage of using standardized data description languages.

5.2 Interface with land registration offices

Land registration and cadastral surveying offices are operating separately in Switzerland. In spite of this institutional separation, there is a close cooperation between the two organizations and data are being shared readily. While cadastral surveying has defined the digital format of its data, land registries were slower to adapt. Over the last few years, however, digital data have become standard in land registration as well and since 2001 there is a project going on to get access land registration data through an information system. A first subproject embarked upon the definition of the interface between land registration and cadastral surveying data to facilitate the transfer of data. The relevant entities that are being transferred are 'landowners', 'parcels', and 'mutations'.

There are several software and database systems that are being used in land registration and cadastral surveying. The transfer of data however had to be independent from any system and it therefore was decided to take the same data modelling approach as in cadastral surveying. The data model was therefore described with INTERLIS, also taking benefit from additional advantages such as for example incremental updating. It was also important to have a future-oriented solution.

The data model was divided into four sub-models in order to separate the legally valid data from projected data and to respect the independence of the two data stakeholders. The four sub-models are 'ownership circumstances', 'parcel description', 'mutation table' and 'execution matter'. The four sub-models reflect the procedures for typical transactions (BJ-EGBA and Swisstopo-V+D, 2003):

- *ownership circumstances:* information from land registry to cadastral surveyor for finding owner of a property (compare Figure 4);
- *parcel description:* information from cadastral surveyor to land registry describing the property respective to its legally valid situation;
- *mutation table:* information from cadastral surveyor to land registry describing the properties before and after the mutation, illustrating the provisional, projected and definitive situation;
- *execution matter:* information from land registry back to cadastral surveyor confirming the closure of the mutation (e.g. the definitive parcel number).

The concept report for the interface between land registration and cadastral surveying (BJ-EGBA and Swisstopo-V+D, 2003) lists the data models of those four sub-models in file format.

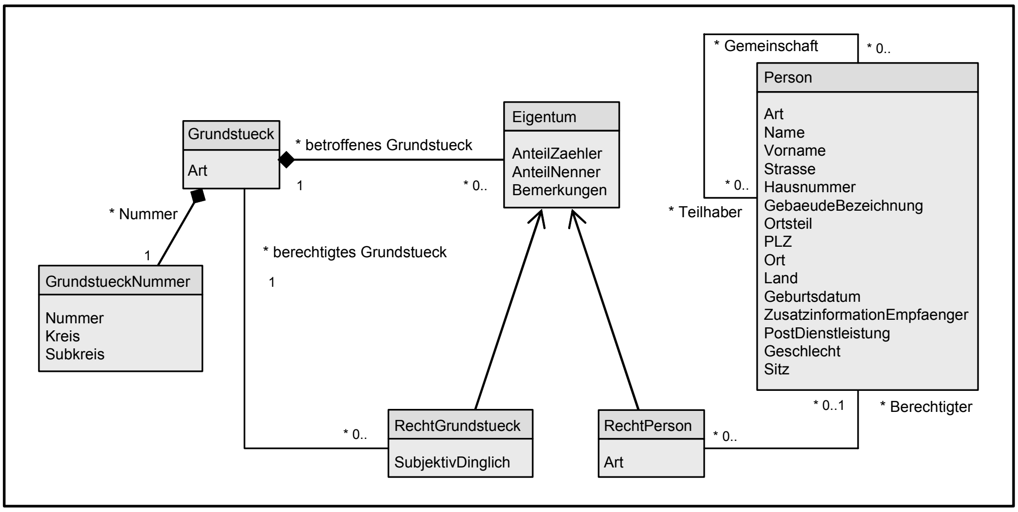

Figure 4: UML respective data model of ownership circumstances.

6. IMPORTANT LESSONS LEARNT

During the preparatory and implementation phase of the INTERLIS concept from the late 1980's until today, there were important lessons to be learnt. They were the following:

- The constant dialogue between authorities and the private sector software producers were crucial and important during the development. This helped to find a feasible solution.
- The fact that data are the most expensive element in cadastre – as in any geo-information project – and therefore have to be protected against the fast hard- and software system changes was a strong and crucial political argument in the decision for this concept.
- Although the development of the INTERLIS concept has been discussed extensively with private sector companies prior to its introduction, the acceptance in practice was not very high initially. The concept by itself, although considered a valuable one, was not enough to convince the surveying community and to guarantee its use. Only the development and provision of software tools made a difference and produced tangible benefits.
- The creation of a competence centre for data modelling and data exchange provided the crucial support for the INTERLIS concept. The competence centre became a platform and contact point for data modelling in general and it initiated and supported the development of software tools, which finally were the breakthrough from a mere "nice concept" to practical application.
- The supervising body for cadastral surveying on the Federal level – the Federal Directorate for Cadastral Surveying, who initiated the reform for the digital format and who had the responsibility to carry it out – used its subsidy system to put financial pressure on the implementation of the INTERLIS concept. This was crucial for the implementation of the INTERLIS concept.
- It was important to recognize and to communicate that the data model as well as the description language are in constant development; the first revisions have now been made with DM.01 and INTERLIS2. Even when it again takes some time for the industry to

digest such development steps, they receive better acceptance with clear and transparent communication.

7. CONCLUSIONS

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

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BIOGRAPHICAL NOTES

Daniel Steudler graduated from the Swiss Federal Institute of Technology (ETH) in Zurich in 1983, earned the Swiss license for cadastral land surveyor in 1985, and did his M.Sc.Eng. degree at the University of New Brunswick, Canada from 1989-91. Since 1991, he is working with the Swiss Federal Directorate of Cadastral Surveying with the responsibilities of supervising and consulting Swiss Cantons in organizational, financial, technical, and operational matters in cadastral surveying. Since 1994, he is involved in the activities of FIG-

Commission 7, of which he became the official Swiss delegate in 2003. In March 2004, Daniel received a PhD degree from the University of Melbourne, Australia, under the supervision of Prof. Ian P. Williamson. The main research topic was to develop a framework and methodology for evaluating cadastral systems in the context of land administration.

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A Modular Standard for the Cadastral Domain: Application to the Portuguese Cadastre

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Key words: Cadastral Reform, Cadastral Domain Modeling, Real Estate Register, UML, Real Property Transactions.

SUMMARY

Following recent worldwide developments and initiatives by FIG (Cadastre 2014) and UN, an object oriented, conceptual model for the Cadastral Domain, adapted to Portuguese Cadastre and related Real Estate Register is presented, based on a previously proposed standard. After a brief description of present Cadastral and Land Registration situation in Portugal, UML (Unified Modeling Language) literate modeling was used to describe the top level classes by using a structured mix of UML Class Diagrams and natural text[1]. Important contributions of this paper are the evaluation of the FIG core cadastral model by applying it to Portugal. It turns out that a limited number of the classes of the core model are currently not needed (but some of them might be used in the future) and that other classes were added specifically for the situation in Portugal. This is anticipated use of the core model and in case similar patterns occur in several countries, the new version of the core model should be adapted accordingly within the FIG. In addition to these static model aspects, Activity Diagrams were used to model dynamic behavior concerning a number of chosen Cadastral Update tasks. Currently, the dynamic aspects are not yet present in the FIG core cadastral model, but in case similar dynamic patterns occur in several countries, then they should be added to the core model.

SUMÁRIO

No seguimento de recentes iniciativas globais (FIG, Cadastre 2014; UN), é apresentado um modelo conceptual para o domínio cadastral adaptado ao Cadastro Português e ao Registo Predial, baseado num normativo previamente definido. Após breve descrição da actual situação em Portugal, Modelação UML, documentada com texto de apoio, é usada para descrever as principais classes do modelo conceptual proposto. Um contributo importante deste artigo reside na avaliação do Modelo Cadastral Fundamental da FIG, através da sua implementação ao caso Português. Resulta deste exercício que um número restrito de classes do Modelo Fundamental não são correntemente necessárias (embora possam vir a sê-lo) e que outras classes não previstas foram adicionadas tendo em conta especificamente a situação Portuguesa. Tal poderá vir a traduzir-se numa adaptação do Modelo Fundamental da FIG. Adicionalmente ao Modelo Estático, são mostrados Diagramas de Actividade que modelam o comportamento dinâmico para um número de tarefas cadastrais.

[1] Notation: in this article, all class names appearing in the text are written in *Italics*, while the names of class methods are written in ***Bold Italics*** and names of attributes are in the in default text style. Where it exists a correspondence with the standard model, the original English name is referred within brackets.

1. INTRODUCTION

The main goal of this article is to present a generalized conceptual model for the Portuguese Cadastre, developed upon the modular standard presented in the article "A modular standard for the Cadastral Domain" (Christiaan Lemmen et al, 2003). For the Portuguese Cadastre, both the Geometric and Legal components will be considered. Strong relationships between these two components are already considered in the legislation, but they are not yet fully implemented in actual practice.

To achieve the stated goal, in a first stage, for all the object classes presented in the original (standard) diagrams, a local equivalent was identified, where it existed. For some classes presented on original diagrams, however, there was no equivalent in the Portuguese Cadastral System. Where the authors assume that those classes could, sometime in the future, be necessary for an eventual implementation of the proposed data model, those object classes were indeed maintained in the packages presented.

The contrary was also verified, that is, certain classes existing in the Portuguese Cadastre had no counterparts in the original modular standard. In those cases, they were inserted in the most logic place, and associations with already identified equivalents were created. If during further investigation it becomes clear that these classes are also relevant for other countries, then the core Cadastral model should be extended.

With this process, the proposed model intends to answer all the main requirements already defined, while others are foreseeable in the near future and were also considered. The aggregation of classes into packages follows the one presented in the standard model, because they reflect well functionality that can be assumed by different existing Portuguese institutions.

As already verified on the modular standard, the consideration of a UML literate modeling process presents the advantage of communicating a complex model in a clearly organized and standard form, more easily interpreted by the several professionals involved, from surveyors to registrars ("conservadores") to cadastral experts.

The following sections include a number of class diagrams showing the static or "entity" view of the proposed data model, that is, the components which would originate the spatial database in a possible implementation. The last diagrams present interactions between several classes previously identified, modeling the dynamic behavior of the data model for a few typical functions of the Cadastre. It should be further investigated whether these dynamic models are indeed generic, that is, also applicable to other countries. Until now the dynamic aspects are lacking in the core cadastral model, but if generic dynamic behavior can be modeled, then this should also be included in the core cadastral model.

This paper continues in section 2 with the presentation of the current situation of the Portuguese cadastre as this is the starting point and (legal) context for any further development or re-engineering and re-modeling. Section 3 then presents the new (static) data model for the Portuguese cadastre based on the standard core cadastral model; extensions and modifications are presented. Correct implementation of the modular standard, extended for the most relevant Use Cases, including modeling some dynamic behavior of the system, can answer more effectively to legislative demands for a closer integration between the geometric and legal components of Cadastre. A few proposed communication channels between the Real Estate Register and the Geometric Cadastre can be seen on the Activity Diagrams on section 4. The dynamic aspects of the Portuguese cadastre are then presented in section 4 in the form of UML activity diagrams augmented with natural text. The paper ends with conclusions, recommendations and future work in section 5.

2. THE PORTUGUESE CADASTRE: PRESENT SITUATION

Before presenting a brief description of the evolution and present situation of Cadastre in Portugal, a word must be said concerning the scarcity of documentation dealing specifically with the Geometric Cadastre, or its relations with the Legal Register. Until recently (Silva, M.A., 2002) this subject received no focus at academic level, although some studies exist concerning related subjects, such as Socio-Economic aspects of Land Tenure or Land Administration. Considering its relevance for further studies, a list of Portuguese bibliography about Cadastre and related legislation is included in the bibliography of the paper.

In its beginnings in the XIX century, the Cadastre had mainly a fiscal purpose, managing the application of taxes to rural property and related agricultural income. Its focus was then the inventory of all rural land parcels, in what has been known by "Cadastro Geométrico da Propriedade Rústica", that is, a Geometric Cadastre of Rural Property.

Systematic land (at first) and aerial surveys were conducted far into the XX century, with this aim, and eventually more than 50% of territory was covered. Besides a survey on parcel boundaries, that cadastre also included a procedure for valuation of property and the identification of land use, both data serving fiscal purposes, although statistics produced upon it were most valuable to Ministry of Agriculture services (Coelho, 1989; Pinto, 1986).

The legal component was also secured in those municipalities were the geometric cadastre was completed, and legislation was created turning mandatory the legal registration of parcels under the regime "Concelho em Regime de Cadastro". All transactions involving parcels should be certified by rigorous identification on the existing Cadastral Plans. Eventually, this Cadastre began to face multiple problems due to lack of timely update procedures (Veigas, 2002).

Following decades of almost stagnation, the nineties brought new digital technologies to the Cadastre, involving the definition of a Cadastral Plan Data Model, already implemented on 5 municipalities. The main focus has now changed from a fiscal to a legal cadastre, in which new planning and management issues are being also considered. This new form of Cadastre[2], called "Cadastro Predial", includes now the inventory of all immovable property, being it rural or urban parcels (IPCC, 1995).

The legal counterpart, the Real Estate Register ("Registo Predial"), which can be considered as a system based on titles (Mendes, 2003), by its turn, is just making its first steps into the digital realm. At present, however, there is no Data Model equivalent as to what exists in the Geometric component. Also, the adaptation of digital data and procedures is facing serious difficulties, due to differences in the development stage of Geometric and Legal components.

In view of the present situation, it seems as indeed necessary an involved discussion on a future integrated Geometric and Legal Data Model, for which the authors assume this article can contribute as a systematic, upgradeable and scalable solution, based on state-of-the-art modeling techniques. In subsequent developments the presented (static and dynamic) models are to be implemented in a distributed environment (using state-of the-art information and

[2] The Fiscal Role is only foreseen in the future “Real Property Cadastre National System”.

communication technology) in which the different organizations each have their own responsibilities.

3. CADASTRAL DATA MODEL

In this section the static part of the model is presented, that is, the data model of the Portuguese Cadastral domain. This is done on the basis of the UML class diagrams of the core cadastral model (Lemmen, et al. 2003). This model is subdivided in a number of packages and in the subsequent subsections the adoptions of the packages to the Portuguese situation is described. First, subsection 3.1 discusses the three core classes of the model (RealEstateObject, RightOrRestriction, and Person). In subsection 3.2 the classes from the core cadastral model related to the geometric side of the cadastre (Parcel, geometry, topology, and surveying) are placed in and modified according to the situation in Portugal. Also, a number of new classes, not present in the current core cadastral model, but needed in Portugal, are presented in this subsection. Finally in the last subsection, the more legal classes of the model are evaluated.

3.1 Core of Cadastral Domain

The fundamental relationship between real estate objects and persons (natural or not) via legal rights (or restrictions) as the core of the cadastral domain, is a basic relationship that serves as core for the proposed Portuguese Cadastre model as well. Additional notes on Fig.1 diagram reflect the distribution of the cadastral responsibilities between different Portuguese institutions.

Thus, real estate objects are included in the super class *ObjectoCadastroPredial* (*RealEstateObject* in the standard model) whose specializations should be implemented and maintained by the Portuguese Geographical Institute (IGP), although some collaboration with the legal register is expected. The specialization classes include all geometric objects collected in the Cadastral Plans. This package is further elaborated in section 3.2.

The Persons super class is here called *Titular* (*Person*) reflecting the legal basis of the proposed model and also the fact that it is a system based on title. According to the Titular nature, different departments of the General Directorate for Registries and Notaries (DGRN) should implement and maintain this component of the model.

Finally, the *DireitoOuRestrição* (*RightOrRestriction*) association class, also a super class, should be implemented and maintained by the Real Estate Register, also belonging to DGRN. Again, some collaboration is expected with the Geometric counterpart, IGP. These last two super classes will be further developed on section 3.3.

Regarding the cardinality of the association, the diagram on Fig.1 preserves the original ones, although some additional attention is in place for a number of specializations of PartitionParcels, which do not have any identifiable *Titular* to associate with (e.g. a ServingParcel in the core cadastral model). This question is further elaborated on section 3.2.

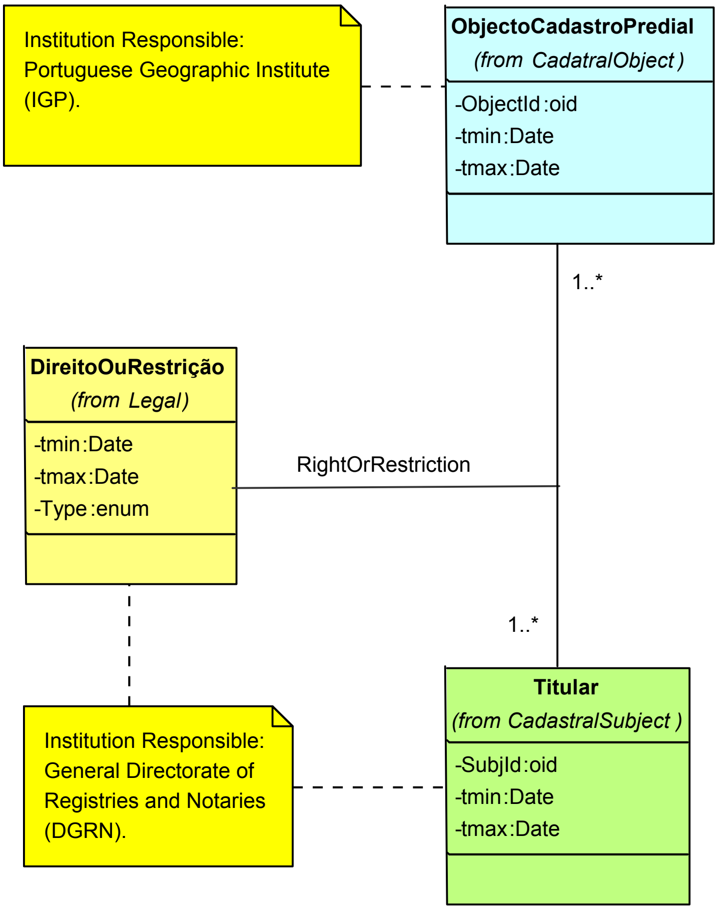

Figure 1: Cadastral Model Core.

3.2 Geometric Cadastre Class Diagrams

3.2.1 <u>The Parcel Component</u>

Following class diagrams show the specialization (and associated) classes of the *ObjectoCadastroPredial* (*RealEstateObject*). A total of four (partial) class diagrams (in Figs. 2-5) were created, due to the complexity of the model, each showing different functions and components for the geometric component of the Cadastre. 3D objects were not considered, but some other classes from the core cadastral model that were not considered in the present Portuguese Cadastral Data Model were included (for future use).
In the first diagram (Fig.2) all the specializations derived from the *ObjectoCadastroPredial* have in fact an identifiable relationship with one or more *Titular* (meaning owners of Title). The *Prédio* (*Parcel*) is the fundamental legal unit in the 2D partition of space called here *PlantaCadastral* (*PartitionParcel*), from which it represents a specialization, together with *ÁreaSocialDeFolha* (*ServingParcel*), that is a Social Area identified in each Cadastral Section. Typical instances of *ÁreaSocialDeFolha* are Public Roads serving several Parcels, or other areas of Public Domain (and with no identifiable *Titular*). It can also represent community pastures or other forms of communal land known as "Baldios".

By its turn, each cadastral area unit included in the *PlantaCadastral* (*PartitionParcel*) is derived from a set of one (closed boundary case) or more parcel boundaries, here named with the Portuguese expression *Estremas* (*ParcelBoundary*). These objects can in fact be associated with all four specializations of the *PlantaCadastral* object class, as we will see on Fig.4. All these four classes exist already in the Portuguese Cadastral Data Model, but they are not implemented as shown because current system is not based on an Object Oriented Data Model (IPCC Public Tender 7/96, 1996).

Also existing is the class *Fracção* (*ApartmentUnit*), meaning an apartment or horizontal property, located on one *LoteUrbano* (*ApartmentComplex*). A *LoteUrbano* should have at least 2 *Fracção*, otherwise both these classes are not considered. The main difference to the standard model is that each *LoteUrbano* should belong to just one *Prédio* (*Parcel*) object, which is an additional constraint to the standard core cadastral model as this allows an AppartmentComplex to be related to one or more Parcels. The *Fracção* class has no graphical representation in the present system; it exists only in the associated database.

The following classes, shown also on Fig.2, do not exist in the present system, but they should be considered for future implementation based on this proposal: *Subdivisão, Loteamento, and ÁreadeRestrição*. First, we have the class *Subdivisão* (*PartofParcel*), which is important to consider regarding update procedures to be adopted. It can represent: (a) one annex to be merged (see subsection 4.1), or (b) a split from a *Prédio* (*Parcel*), or (c) a split due to inheritance (Portuguese: Partilha) or (d) a special case of *Loteamento* (*ParcelComplex*) where just one departing *Prédio* is involved.

Regarding *Loteamento*, also important for cadastral update procedures, it is an aggregation of two or more *Prédio* objects, although is not mandatory. There are plans to change the Real Estate Register Code to ease and accelerate the legal procedures involved in such a case.

Current legislation forces each Titular of a Parcel, part of an Urban Lot project, to register an individual permit[3], which by its turn can involve annexations or detachments. The situation can be further complicated if the different Titular involved pretend to exchange parts or the totality of Parcels they own in the Urban Lot project area. A common solution to this question has been to constitute a collective or Non-Natural Person, which will own the entire project area.

At last, we have the *ÁreadeRestrição* (*RestrictionArea*), representing planning areas defined, for instances, in the Municipal Master Plans, and that typically would overlap with a set of *Prédio* and other *PlantaCadastral* objects. These areas are not under the jurisdiction of IGP, but they should be considered in a future Cadastral National System, through database linkages to several other state agencies. There is however a proposed specialization of this class, termed *ÁreaSocialPrédio*, described in Section 3.2.3, which exists in the current system and is acquired by IGP.

[3] The "individual permit" means that each Titular involved in a Loteamento must request a building permit and must also register any possible detachments and/or annexes. As this procedure involves at least 2 Titular (often much more), the legal workflow implies a heavy burden both to Titular and Registry Services.

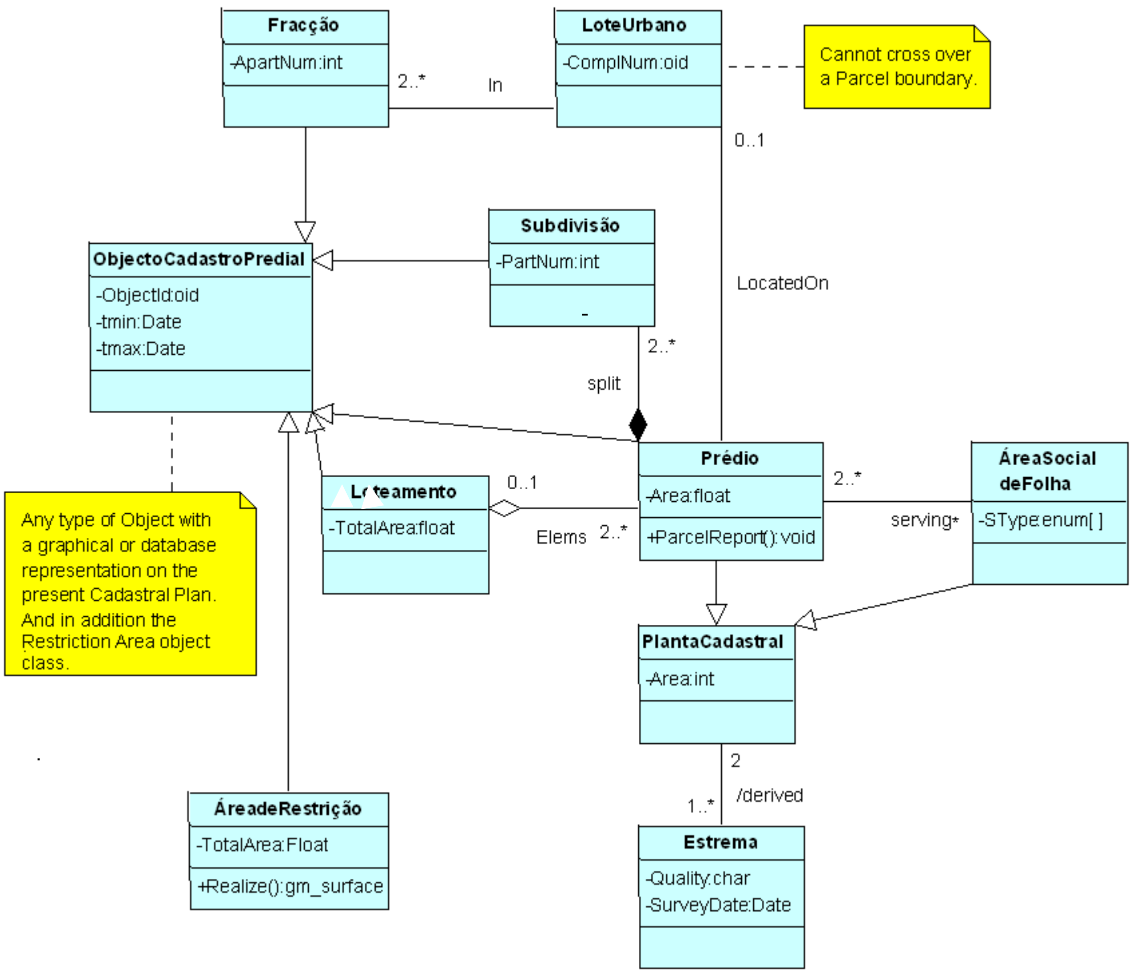

Figure 2: Geometric Cadastre - Parcel Component.

3.2.2 Geometry and Topology

This part of the model shows no fundamental differences with the one presented in the standard model, except for some class names. However, it must be stressed that the present Portuguese Cadastral Data Model does not store explicit topologic classes as shown in Fig.3 by classes *tp_face*, *tp_edge* and *tp_node*. Instead, extensive tests and verifications are conducted, ensuring that the graphical elements have correct topology; e.g. all PartitionParcels are closed areas and they do not overlap.
The advantage of having topologic classes, however, can overcome the disadvantage of increased processing time (and costs), namely by ensuring the correctness of future updates or facilitating certain types of queries and spatial analysis. Also redundant storage of the shared parts of the boundaries (in left and right Parcel) is avoided and boundaries can have there own attributes (not belonging to the Parcels), such as survey date and quality.
In the Portuguese Cadastre, we can assume a *tp_node* (see Fig. 3) to be an end node of an *Estrema* on which the *PlantaCadastral* (and all its specializations) are based. This corresponds to an end node of a *ÁreaSocialDePrédio* (ASP), *ÁreaSocialDeFolha* (ASF), *ÁreaCadastroDiferido* (ACD), or *Prédio* (in the form of a parcel corner/cornerstone, or a passage mark), as described in subsection 3.2.3 and Fig.4. Each pair of end nodes will then

form a *tp_edge* (with a one-to-one association to *Estrema*), and if it forms a closed figure, a *tp_face* (with a one-to-one association to *PlantaCadastral*).
However, in the present data model in Portugal, if the object is a Parcel, one should have in fact a minimum of three *tp_edge* to form a *tp_face*, because currently a cadastral edge must be a straight line between two cornerstones or end nodes or passage marks. No intermediate vertices are allowed at this moment in Portugal, in contrast to the core cadastral model, which allows intermediate vertices (we keep the multiplicity "1..*" at the side of *tp_edge* as in the FIG core cadastral model, though current practice in Portugal implies the more strict multiplicity of "3..*").
Another advantage of topologic classes is that one can consider enclaves of a *Prédio* within the area of another *Prédio*, a situation that occurs rarely but poses some questions on the present Data Model. Associations with the purposed surveying classes are not show here. Read subsection 3.2.4 for an explanation on how to bring survey field data to the Cadastral Model.

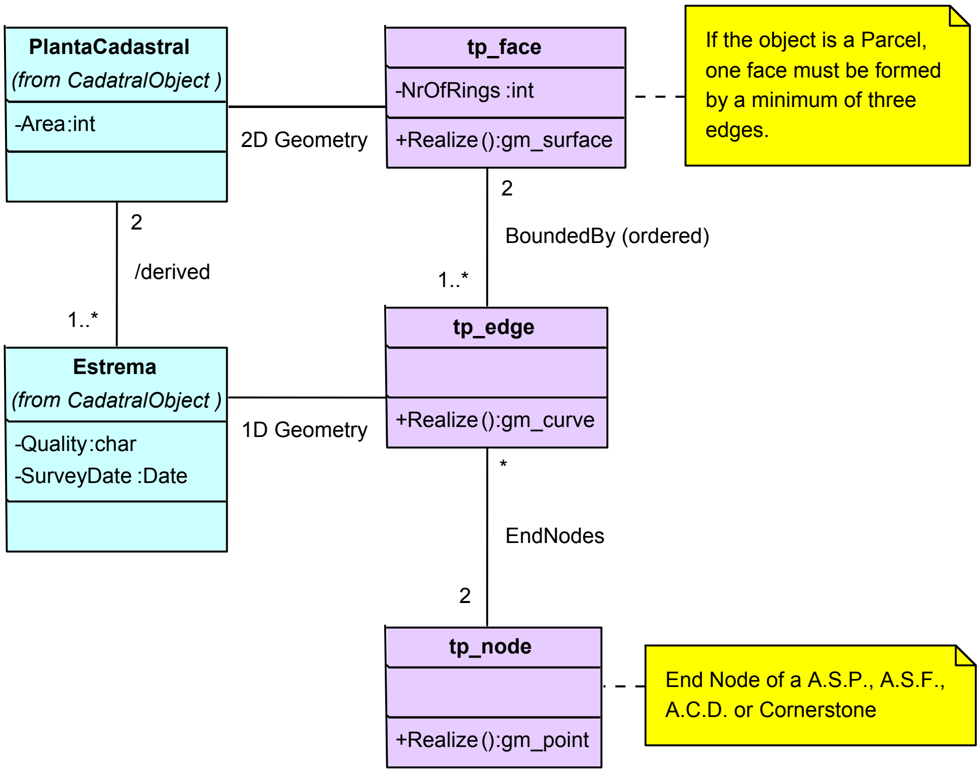

Figure 3: Geometric Cadastre - Geometry and Topology.

3.2.3 <u>Additional Cadastral Plan Objects</u>

Certain classes of objects belonging to the present Portuguese Cadastral Data Model were not available in the standard core cadastral model, or in the adaptation shown on Fig.2. To overcome this, a number of new classes are created, as shown on Fig.4. Most of those classes are new specializations of the *PlantaCadastral* class, thus implying some new form of partition of 2D space.
The *ÁreaSocialPrédio* however, is a specialization of *ÁreadeRestrição* (*RestrictionArea*), abbreviated to ASP hereon, and should overlap the area of at least 2 *Prédio*, although a given

Prédio could show no ASP overlapping it. One typical instance of such a class would be a Right-of-Way ("Serventia de Passagem" is the Portuguese term), which can overlap more than one Parcel.
In the cases of *ÁreaSocialDeFolha* and *ÁreaCadastroDiferido* (a Deferred Cadastre Area), there cannot exist any overlap between them, nor with the areas of parcels, nor with *ÁreaSocialDePrédio*. Thus, no association is defined here. These areas should participate in the same topology structure as the *Prédio* (and therefore, first two are considered as specializations of *PlantaCadastral*). The classes *ÁreaSocialDeFolha*, *ÁreaCadastroDiferido* and *Prédio* form the 2D Partition of space, filling the whole area of any given Cadastral Section. The new class *Construção* (a Building) should be related to a given *Prédio*, where several buildings can exist. The association is not obligatory, meaning a *Prédio* can also have no buildings (*Construção*) within it. However, a building is always in exactly one *Prédio.* A *Construção* is not embedded in the same topology structure (as all *PlantaCadastral*); it has therefore its own geometry.
Furthermore, a new aggregation class was defined, representing a set of *PlantaCadastral* objects included in a certain bounding box area, thus forming a printable *FolhaCadastral*. The method ***SectionReport()*** answers to one of the deliverables of the present Cadastral Model, as well as the method ***ParcelReport()*** considered in the *Prédio* object. The newly formed classes represent the following real world objects:

- *ÁreaSocialdePrédio* (ASP): as referred above, it can represent a right-of-way or other type of area part of a given Parcel where the *Titular* has some form of restriction to its rights. Another example is an irrigation channel serving a neighboring Parcel.
- *ÁreaCadastroDiferido* (ACD): sets of parcels were their Titular and / or their boundaries could not be defined during cadastral execution, or an area subject to legal litigation.
- *Construção*: any construction of permanent nature on a Parcel. It is only surveyed above a certain dimension of its projected straight on the ground.

Note that ACD could also be modeled with a specifically coded Titular, and therefore no extension to the core cadastral model would be needed. However in order to emphasize these important situations in Portugal they are shown in the conceptual UML class diagrams (but later on they might be implemented with the standard FIG core cadastral model with a number of 'specific Titulars').
Concerning the methods ***SectionReport()*** and ***ParcelReport()***, they can simply present a set of Administrative and Cadastral attributes read from the objects and inserted in a formatted document, as occurs in the current system, or they can represent a step ahead in a future implementation, presenting at the same time spatial information concerning the *FolhaCadastral* or the *Prédio* objects.

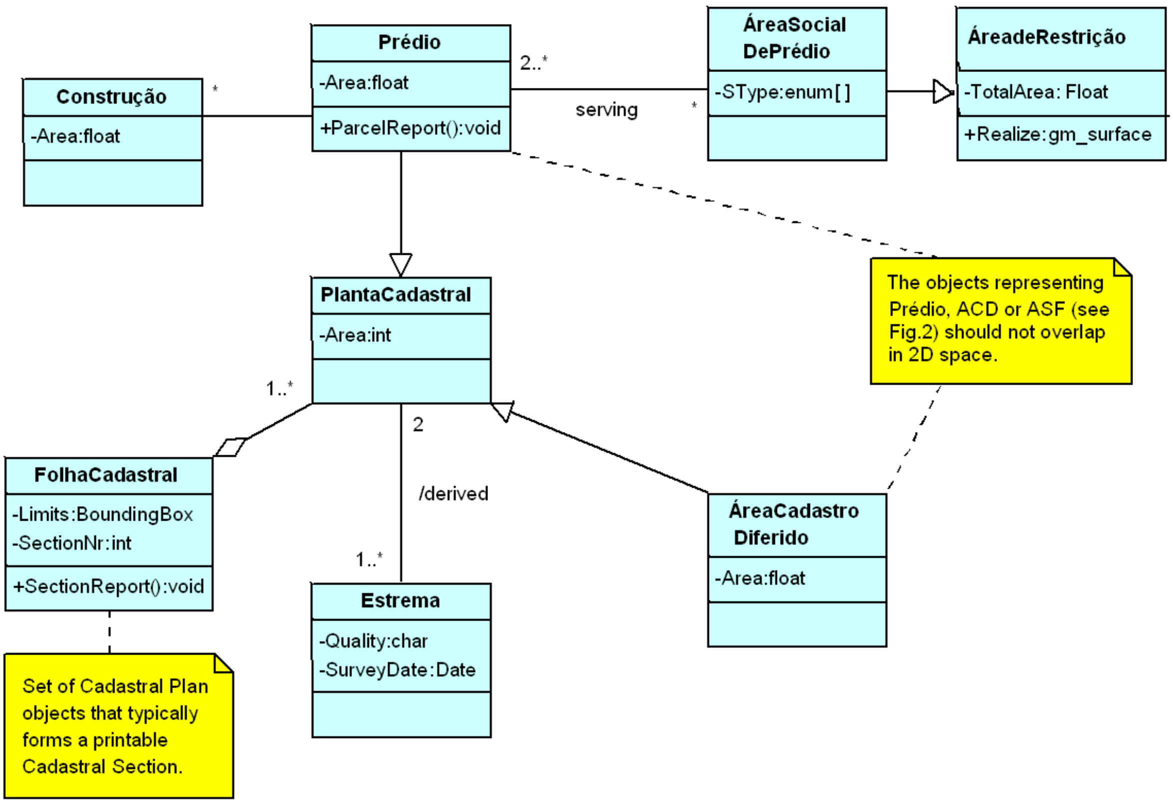

Figure 4: Geometric Cadastre - Other Objects.

3.2.4 Surveying Classes

The present Portuguese Cadastral Data Model does not explicitly store any component of the surveys carried out in order to complete a Cadastral Plan. Instead, they are archived as separate Plans and Computations, together with the material used to produce the Cadastral Plan. It is a great advantage, however, especially if one considers a system that should be constantly updated, to implement classes of survey data and associate them with the geometric components of the Data Model. Based on some actual survey information and on the standard model diagram, Fig.5 shows a possible implementation of Cadastral Survey classes.
The source of all survey data is the *DocumentoDeLevantamento* (*SurveyDocument*), which can exist both in printed form and as a digital archive, and should be done by a chartered surveyor (Portuguese: Perito Cadastral). In fact, this information represents typically a set of three types of files, as follows:

1. A survey data file, with field observations;
2. A graphic archive, which can store also the computations;
3. Descriptive text and commentaries.

To the *DocumentoDeLevantamento*, a class is associated, called *PontoLevantado* (*SurveyPoint*). This class has a PointType attribute, which differentiates between Auxiliary Survey Points and Cadastral Points, that is, points that will belong to the Cadastral Plan. One auxiliary point will not make, in principle, part of the *PlantaCadastral* nor its specializations.

It can be a Station in a Traverse or an offset point, or other kind of point useful for the Survey, but with no Cadastral meaning. A *PontoLevantado* represents the end node of a cadastral object like an *Estrema*, so it defines the metrics of a *tp_node* object.
Two connected survey points are required to define the metrics for a tp_edge, but an object *LinhaLevantada* (a directly surveyed linear object), which is a linear object defined by an aggregation of at least two *PontoLevantado* objects can also directly form this object. The *LinhaLevantada* object should be obtained from the *PontoLevantado* object upon verification of its chain and survey codes, that is, alphanumeric attributes stored in the field data by surveying equipments like Total Stations or connected Field Collectors. It can represent a straight-line segment, with end nodes, or a line with a series of intermediate points and the end nodes.

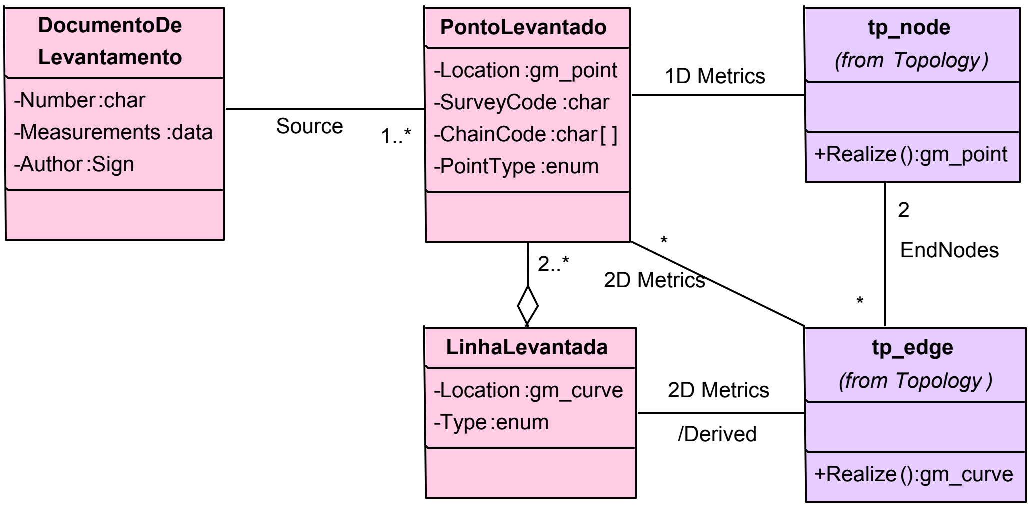

Figure 5: Cadastral Survey Classes.

3.3 Legal Component Class Diagram

This diagram further develops on the *DireitoOuRestrição* (*RightOrRestriction*) and on the *Titular* (*Person*) superclasses of the core model. It represents the legal and administrative components of the system, and presently is managed by three branches of the DGRN. As traditionally the legal and geometric components have worked in an autonomous fashion, some overlapping occurs in data that is stored in present systems (digital or not).
In particular, it should be noticed that the legal description of a parcel is stored nowadays in the Register ("Registo Predial") but is in fact data about the *Prédio* (and also *Fracção*) objects in the Geometric component. A future implementation should take care of this in the form of a shared edition of such objects by both Institutions (IGP and "Registo Predial"). This further implies that there will be certain attributes of the referred objects that will be maintained by IGP (like its Area), while other attributes of the same objects will be maintained by the "Registo Predial" (like the Legal Classification of the Parcel: Rural, Urban or Mixed).
The source of all the information regarding rights or restrictions on a given Cadastral object is the RealEstate Register, which in fact represents a combination of two classes, the

DireitosOuRestrições and the *Hipoteca* (*Mortgage*) object classes. Other data presently stored by the Register will be stored directly on certain *ObjectoCadastroPredial* objects, as explained above following "Shared Edition" (that is, objects in part maintained by both Institutions: IGP and "Registo Predial"). By its turn, the source of information for the register is a *RequisiçãodeRegisto* containing three types of documents, typically supplied by an Owner who wants to register a Title, or any interested party in some form of Transfer of Rights. These three types of documents could have been included in the conceptual model in UML class diagram, but we omitted this because these documents will not be stored (reflected) in the digital version of the system (just paper documents).

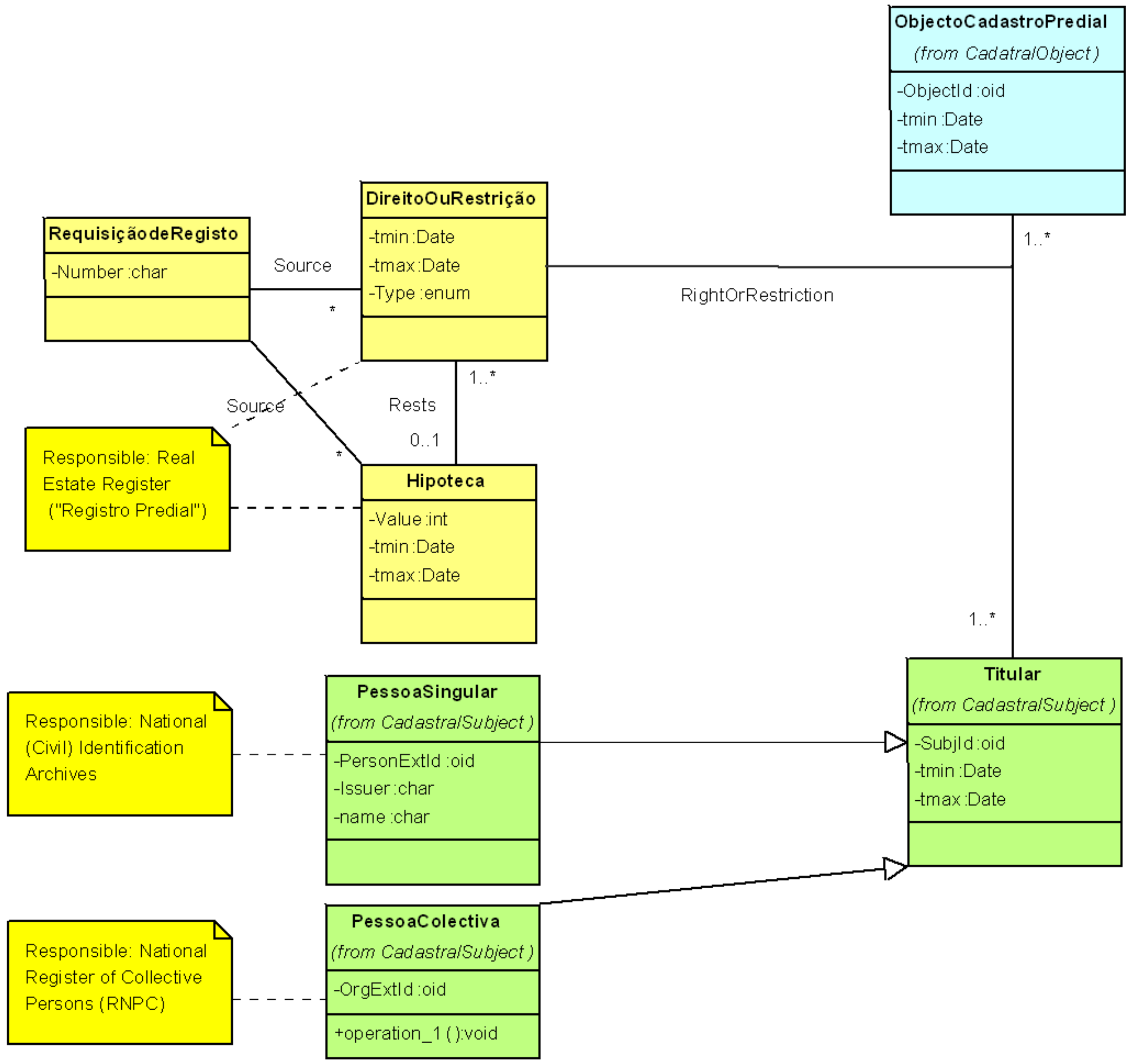

Figure 6: Legal and Administrative Registers.

Each request should have at least a Principal Declaration and one (or more) Legal Documents to support it. In certain types of request, namely in a first inscription in the Real Estate Register, a Complementary Declaration is also needed. Those three types of documents, as said, are not shown as Classes in the Diagram, because they are solely intended to serve as a

base for data input into the above mentioned object classes, although they can also serve as a sort of analogue backup to the Real Estate Register.
Each record of the Real Estate Register should have at least one registered right (typically, ownership), although it can store several *DireitoOuRestrição* objects. Furthermore, additional information will update some attributes of the *Prédio* (or eventually *Fracção*) objects. Several tenths different types of Rights or Restrictions are mentioned in the legal code. At a given time, there can also be a *Hipoteca* upon the Parcel or a part of the Parcel. In the Portuguese Civil Code, one can constitute a mortgage over rights of ownership, a long lease (provided it respects public domain parcels) or rights of superficio.
Following is a list of possible Rights or Restrictions currently stored in the files of the Real Estate Register. This list is, of course, far from exhaustive. Its intention is to give a broad picture of the kind of legal inscriptions associated with a given *Titular* and *ObjectoCadastroPredial*. An unofficial classification is given, grouping items in the list into Means of Acquisition (of Rights and Restrictions), Legal Rights and Restrictions (the last term is not common in Portugal, where the terms onus and incumbency are used, which makes a difference between restriction (what not to do) and responsibility (what you have to do).

- **Means of Acquisition**
  - Acquisition: a Titular gets its Ownership registered;
  - Donation: a free Transmission of Rights from a registered Titular to a new one;
  - Financial Location[4]: legal contract between the Titular and a third party. Assumes that a building or habitation permit already exist;
  - Concession (long lease): legal contract that allows a third party to use the Parcel for an extended period in time (typically, several years);

- **Legal Rights**
  - Ownership: the basic Right. It must be registered for every Parcel;
  - Usufruct: a Right for someone (not the Titular) to use facilities within a Parcel;
  - Time Share: the Titular has the right to use this particular type of Fraction for a defined period in time throughout the year;
  - Urbanization Lot Permit: a Permit to split a Parcel for Urbanization, typically issued by a Municipality;

- **Legal Restrictions**
  - Servitude: a Restriction to full private ownership of a certain part of a Parcel, like in a right-of-way. There are several different types of Servitude;
  - Pledge of Receivables: the Titular assumes to pay a certain rent for the Parcel (which can be a factory, for instance) to a third party;

[4] It is a type of leasing which can involve movable or immovable goods. E.g. a Titular can preserve his Superficio rights while allowing a firm to build a new building on its Parcel, according to a Financial Location contract.

– Economic Rent: details of the Rent to be paid under state controlled residential building construction, and related subsidies.

- **Can work both as Rights or Restrictions**

  – Legal Action: Register of a Legal Action taking place, which can modify existing Rights or Restrictions. If a Legal Action is pending in Court, over a certain Parcel, then it should be referenced in the Registry.

Every Right, Restriction or Mortgage, by its turn, is associated with one or more *ObjectoCadastroPredial* and one or more *Titular*, a super class with two specialization classes: *PessoaSingular* (*NaturalPerson*) and *PessoaColectiva* (*NonNaturalPerson*). While the Real Estate Register is taken care by the "Registo Predial", the *PessoaSingular* class should be addressed by the Civil Register, which National Archive is in digital form already for several years. It typically stores data used to issue the personal identification card. The National Register of Collective Persons (RNPC), also in digital form, addresses the *PessoaColectiva* class.
Although the *PublicRestriction* object class was included in the standard model, it is not included in this article, mainly because such type of areas are not under the jurisdiction of the Legal Registers, but can belong to several different types of state agencies or ministries, like the Ministry of Agriculture or the Ministry of Environment. Examples of Public Restrictions are certain types of Agricultural or Ecological areas, or rights-of-way and protection areas related to State owned facilities.

4. DYNAMIC ASPECTS OF THE CADASTRAL DATA MODEL

The previous UML class diagrams described a static or "Entity Objects" view of the data model. Next two subsections show procedure flow and involved class interaction for a few typical update types to the Cadastral Data Model, which involve both the Geometric and Legal components. Currently, the standard core cadastral model does not cover these aspects. Therefore the presented dynamic aspects are modeled from scratch. The first procedure being modeled is the annexation (and detachment) of a part of a Parcel (see subsection 4.1). The second procedure is ‘Transformation of a rural into an urban parcel’ (see subsection 4.2).
It must be stressed, at this point, that the presented procedures were drawn from existing tasks performed within Portuguese Cadastre (Real Estate Register and Geometric Cadastre), as a possible implementation based on the static data model. They should not be interpreted as a description of generic behavior of the standard model.
Included at the end of each procedure description are some preliminary comparisons between the proposed Portuguese implementation and the dynamic modeling of Property Transactions presented for some European countries such as Slovenia and Sweden (Sumrada, 2004) and Denmark and England&Wales (Vaskovich, 2004).

4.1 Annexation (and detachment) of Part of a Parcel

In this process, it is assumed that a part amounts to a small fraction of a Parcel area, always far less than half of its area, unless we would have an actual split of Parcel, originating a new

Parcel. In the law, however, there is no definite number (in terms of relative area) regarding the distinction between an annexation and a split.
In descriptive terms, one can say that this process involves the purchase of a small part of a neighboring Parcel by a Titular, whose Parcel area will increase through this annexation. This transaction involves modification of both the Legal and Geometric components of Cadastre, as explained in the following paragraphs. It does not involve, however, the deletion or creation of new Parcels (it is just a boundary change).
To begin, lets assume Titular A sells a small part of its Parcel to Titular B (that is, both have its Parcels registered) who will make the annexation. Titular B wants to register this new situation, so it presents a request to the Real Estate Register, consisting namely of a notary deed of transfer, and a declaration where the Parcel's Register numbers and both Titular ID's are shown. Let's further assume that Titular A is the owner of Parcel 1, and Titular B is the owner of Parcel 2 (that will see its area increased through annexation). The following modifications should be done to the *ObjectoCadastroPredial* object, through the Real Estate Register:

1. Legal Description of Parcel 1 must be changed, stating its new area (original area – annex area) and value;
2. Legal Description of Parcel 2 must be changed, stating also its new area (original area + annex area) and value

The new acquisition through annexation must be registered as a new Right in the *DireitoOu Restrição* component of Parcel 2, were an association to the previous owner of the annex (Titular A) must be included. The added Right means that there should be equally an update to the Geometric component of Parcel 2.
Above steps do not contain any references to the Geometric component, although it is necessary to modify it in order to derive new area figures, and present an updated Cadastral Plan with the new Parcel's shape. A possible procedure is as follows:

1. After Titular B makes its request to the Real Estate Register, this institution sends a Subdivision Request to the Geometric Cadastre;
2. The Subdivision Request goes to a queue accessible to all licensed Cadastral Experts and eventually is addressed by one of those professionals, who will then write and send a Survey Document to the Geometric Cadastre;
3. The Geometric Cadastre updates Geometry and Topology of Parcels 1 and 2, while preserving old data that becomes "historic" information. The *Subdivisão* object (see Fig. 2) is then destroyed, and an update notification is send to the Real Estate Register.

The process termination will occur when Titular A and B receive notifications in the form of updated Parcel Reports for Parcels 1 and 2. Nowadays, this could be achieved through the implementation of a Web Service, were the Titular would have a Login and could know in which phase the process would be at any time.
The following Activity Diagram represents a complex task used in both processes (that is Annexation (and detachment) of Part of a Parcel and Transformation of a Rural into an Urban Parcel), namely involving an update to the geometry of a Parcel. This complex activity is thereon referred as "Cadastral Geometric Update".

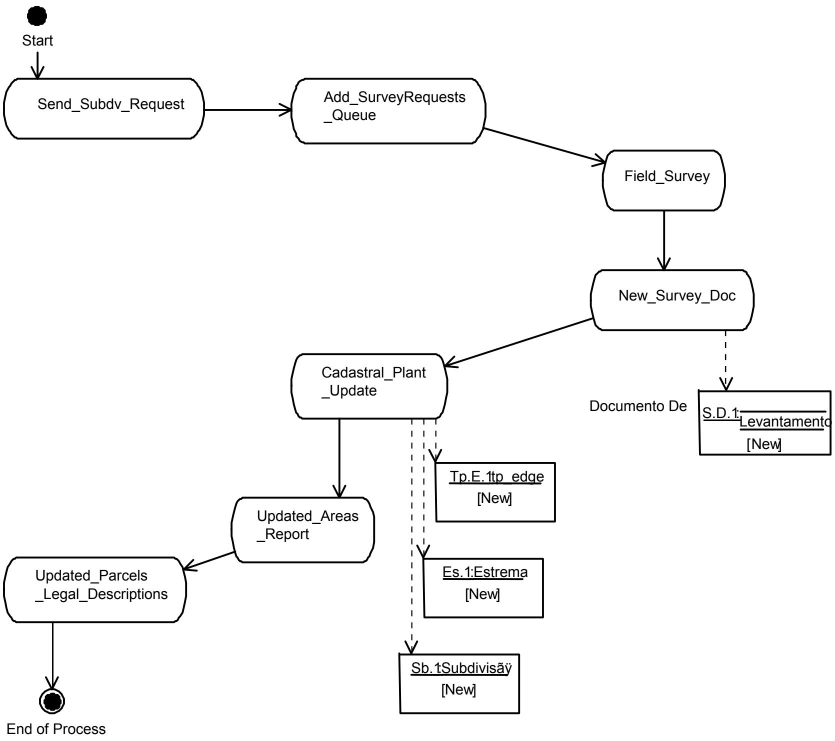

Figure 7: Cadastral Geometric Update (UML activity diagram); see Fig. 10 for overall UML Activity Diagrams with the involved actors indicated.

A comparison of the presented activity diagram with the subdivision or "Parcelling Out" transactions as documented for Denmark and England&Wales (Vaskovich, 2004), although the described procedure is not a true subdivision, indicates both a different modeling approach and different procedures between these countries.

Regarding modeling approaches, clearly the documented case for the Portuguese annexation procedure did not take into account tasks done before the annexation request, although it was referred that this request is preceded with a notary deed of transfer. Notaries' role is not shown in any of the diagrams, but the Solicitor role as described for England&Wales is roughly equivalent to current situation in Portugal.

The Surveyor's role, absent in England&Wales (and also in current Portuguese practice), plays a fundamental part in Danish Cadastre. In the proposed implementation, surveyor's tasks do not include Land Policy Control neither the Treatment of Rights. Both tasks should be done by a Solicitor or under the Titular initiative.

Decision and registration phases are described in greater detail in the present article. As in the Danish situation, two institutions are involved: Geometric Cadastre (Danish "Cadastral Authority") and Real Estate Register (Danish "Land Registry"). The main difference here lies in who initiates the registration procedure: The Real Estate Register in the proposed implementation; the Cadastral Authority in Denmark.

The subdivision activity diagrams for Slovenia and Sweden (Sumrada, 2004) show significantly different approaches for cadastral activities in both countries. Swedish situation has many differences to the proposed implementation, mainly because of the rather extensive role of the Surveyor, which has even more responsibilities than in Denmark. The Surveyor

does the majority of tasks, delivering at the end information to the Titular and Land Registration Authority.
Slovene situation is very interesting, once it shows many commonalities with the proposed implementation. In particular, the Surveyor's role is almost identical.
There is, however, one difference between the proposed implementation and four other countries: the registration process begins with the Land Registry and not with the Cadastral Authority. Furthermore, the proposed implementation considers a provisional register with the Real Estate Register (also for procedure in section 4.2), only mentioned in the Danish Parcel Sale activity diagram.

4.2 Transformation of a Rural into an Urban Parcel

In this second process, very frequent nowadays due to intensive urbanization pressures especially in the cities located near the Littoral[5], there is also no creation or destruction of the Parcel object, but a different and more complex modification of its description, both legal and geometric.
In textual form, one can tell this most repeated story as follows: A Titular (A) of a registered Rural Parcel now lying in a zone open to urbanization, sells the Parcel to a Real Estate Firm (becoming Titular B), which requests a building permit to the Municipality. After receiving the permit, construction of a new urban lot begins, but the Municipality annexes a small portion of land to rectify a neighboring service road.
After the urban lot is finished, a residential permit is issued upon inspection and the building Fractions identified with letters A to F are bought by Titular C to G, and Titular A (the 1st owner) receives also an Apartment (*Fracção* Object) as part of the original deal.
Let's identify, step by step, the modifications that should be made to the Real Estate Register during this process:

1. The acquisition of the Parcel by the Real Estate Firm is registered, making it the new Parcel Owner. The reservation of one future Fraction for the previous Titular is also registered as part of the acquisition contract. Both inscriptions will update the *DireitoOuRestrição* component of the Real Estate Register;
2. The Real Estate Firm submits a building plan, including the constitution of horizontal property (Apartments) to the Municipality. This part of the process does not belong to any of the institutions directly related to the Cadastre, so it is not shown here. After some time, a building permit is issued by the Municipality, and the Real Estate Firm requests a new update of the *DireitoOuRestrição* component of the Parcel, stating that it has now an authorization to constitute Fractions A to F. As part of the deal with the Municipality, a small portion is detached for the Municipal Domain. This last action requires also an update of the legal description component of the Parcel object;
3. After the building is completed and receives a residential permit (again from Municipal Services), acquisition of Fractions by different Titular will be eventually registered in subordinate registers, associated with the main Parcel Register in the same way *Fracção* are associated with a *Prédio* (through an *Lote Urbano* object).

[5] In all the main cities located on the Atlantic Shore of Portugal, there are tremendous pressure for Urbanization in the rural areas adjacent to them.

And now the related modifications to the Geometric Cadastre:

1. Step 1 on the Real Estate Register process does not involve any modification on the Geometric component. Step 2, however, involves a permanent change in Parcel boundaries, due to the detachment of a small part for the Municipal Domain. This process implies a resurvey and the update of Parcel's boundary (through a new *Estrema* object) and of the neighboring *A.S.F* object. The building permit plan, as a temporary object recorded by Municipal Services, could be referred through a hyperlink, at this stage;
2. After construction is completed and the Municipality issues a residential permit, an "as built" survey records the definite layout of the *Lote Urbano* object. This concludes the update of the Parcel Geometric component, as Fractions do not have a graphic depiction.

Due to the complexity of this process, there were two groups of tasks which are shown as complex activities, each having their own Activity Diagram, as presented in Figures 8 and 9.

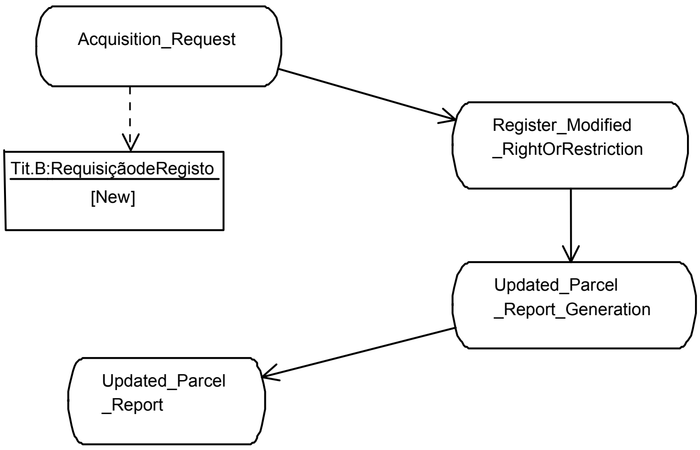

Figure 8: Parcel Change of Ownership (complex activity).

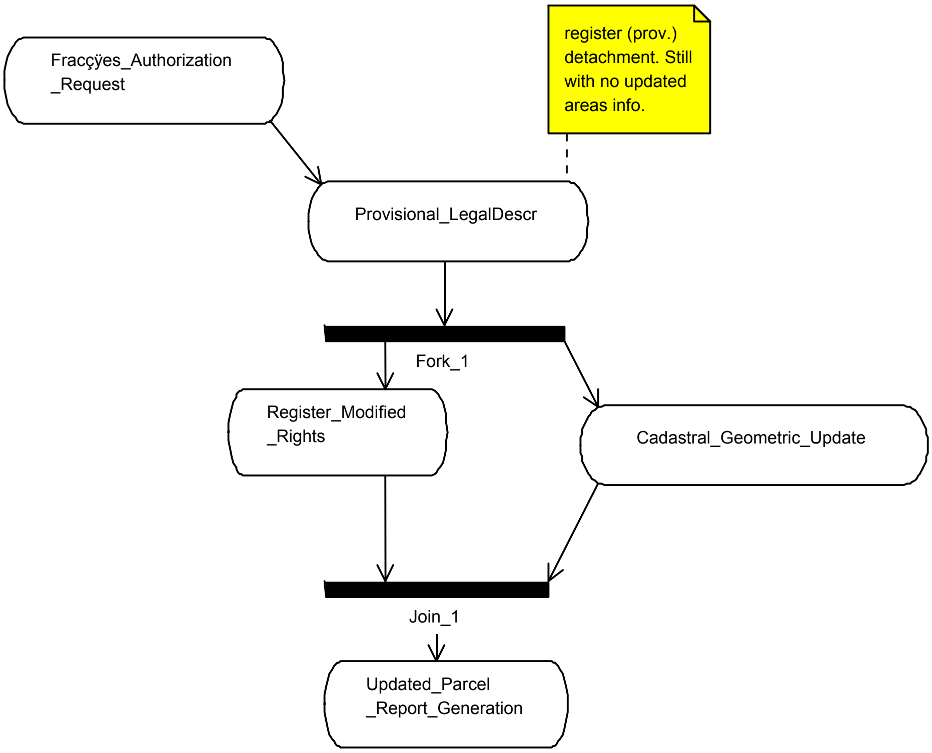

Figure 9: "Fracções" Constitution w/ Boundary Change (complex activity); see Fig. 11 for Activity Diagrams.

Presented Activity Diagram does not include any mention to externally imposed restrictions and regulations, identified in recent Property Transactions studies (Sumrada, 2004; Vaskovich, 2004) as the "Land Policy Control" phase. So, although this phase also exists in Portugal, the examination of master plan zones regulations or others at National level, like those respecting the Waters Public Domain, are not shown.
It must be said, however, that there is a commonality present in all 5 countries (Portugal, Denmark, England&Wales, Slovenia and Sweden), which is the presence of three common actors, namely the Owner (Titular), the Land Registry (Real Estate Register) and the Municipality.

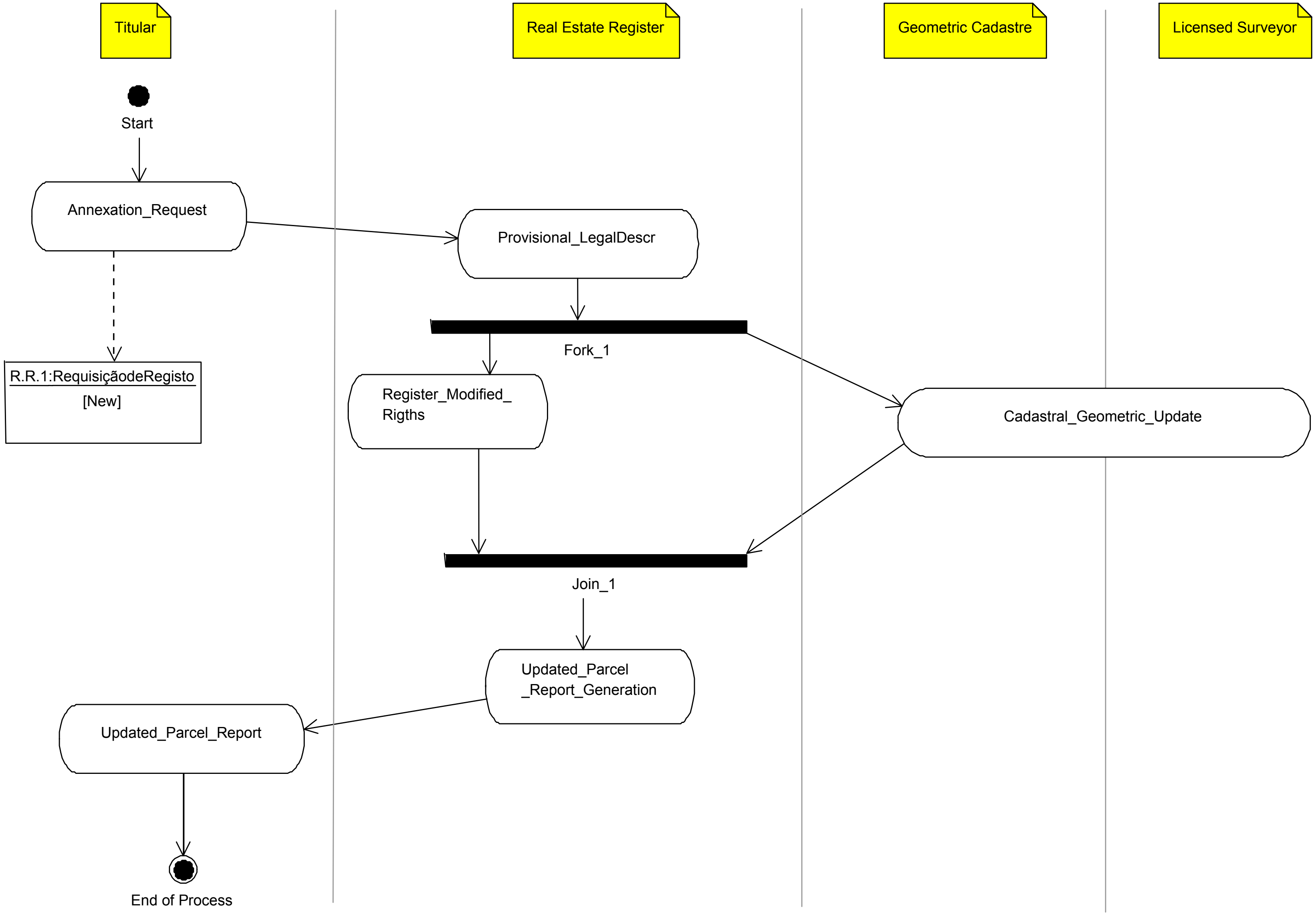

Figure 10: Annexation UML Activity Diagram.

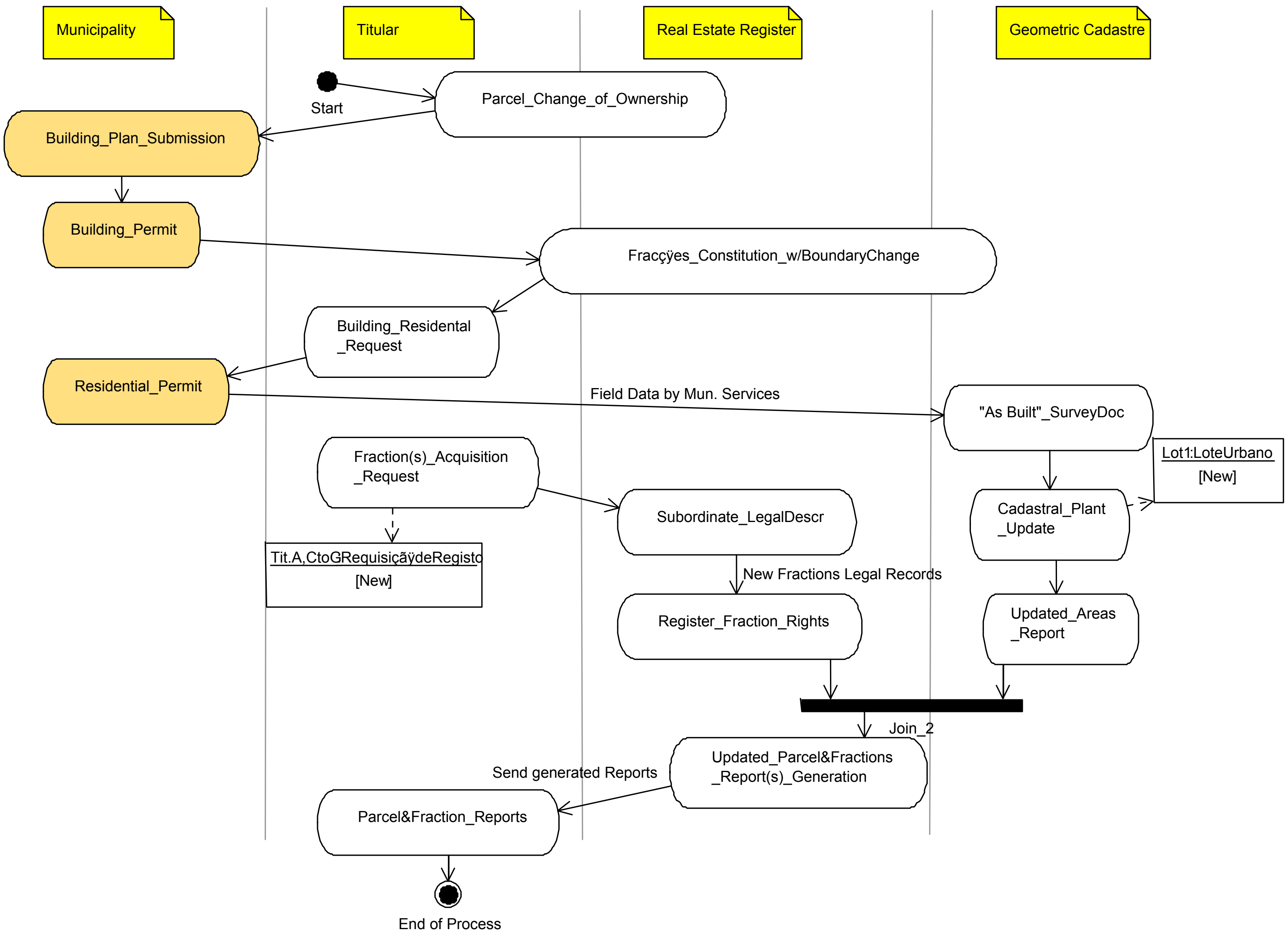

Figure 11: Urban Lot creation w/Detachment.

5. CONCLUSIONS AND RECOMMENDATIONS

The Modular Standard where the present article is based upon builds on the FIG Core Cadastral Domain Model that integrates Land Registration and Cadastre, so it shows the same development path Portuguese Cadastre aims at.

Through the different sections presenting a possible implementation of the Modular Standard to National Data, one can conclude that most of the classes and its associations were preserved, although some adaptations have been made.

Generally speaking, modifications increase from the Core to the more specialized diagrams, a natural consequence of particular solutions adopted in Portuguese Cadastre. The more conceptual, top level view of the Cadastral Domain Model, however, reflects a fundamental relationship that seems to be widely applicable.

More important for any other implementation work to be developed, is the way the Modular Standard was modified to suit particular (National) needs and existent Data Structures.

For that purpose, each original Class Diagram was carefully examined, paying special attention to each class description and its associations with other Classes. From that data, a possible National equivalent was identified, and the Class Name and its description adapted accordingly. Although some Classes had an almost immediate equivalent identified, with nearly 100% overlap in description and associations, there were cases that involved modifications in associations and Class contents (Properties and Methods).

After the first phase above explained, the result was again examined for global consistency. At that stage, the lack of certain Classes existing in National Data Structures immediately pop up from the Diagrams, so they were added, and new associations were established between them and the already existent Classes. Comparisons with other countries will be important to decide whether these extensions are specific for Portugal or are more generic (and in that case should be included in the future version of the FIG core cadastral model). Other future work includes the development of a prototype system based on the proposed model, in order to further evaluate the appropriateness in a realistic (distributed) setting in which the system has to be used.

Last phase involved the consideration of the methods to implement in each Class, considering namely the dynamic modeling cases presented. Currently, the dynamic modeling is not a part of the FIG core cadastral model. In case similar dynamic models (or at least parts of the dynamic models) can be identified in other countries, then the FIG core cadastral model should also be extended with these dynamic aspects (as they carry an important part of the semantics). For this purpose, the initial dynamic models from Portugal are compared to models of a number of other countries that have been described and compared as part of the ongoing COST Action G9 'Modeling Real Property Transactions', esp. Denmark, England&Wales, Slovenia and Sweden. It is too early to draw conclusions whether significant similarities can be found, because the 'modeling style' of the researchers involved may be different (though their reality could be the same). Only in discussion between researchers and experts of the country being modeled and a researcher from another country, the (dynamic) models can be questioned and refined enough to be able to come to real comparison, as was learned in COST Action G9 (and reported in e.g. Zevenbergen, 2003). Thus, further discussion is needed between these researchers in order to make a definite decision concerning the (un)equality of the modeled dynamic aspects (processes).

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http://www.otb.tudelft.nl/uk/onderzoek_advies/geo_information/text.php

Standards and new IT developments in Hungarian Cadastre

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Key words: Standardization, Cadastre, Land Registry, Real Property Registry, Cadastral Information Systems

SUMMARY

During the last ten years there were many successful and unsuccessful developments in the Hungarian Cadastral Domain. The base of them is the National Standard of Digital Base Map (Cadastral Map), which was accepted by the Hungarian Standardisation Body in 1996. The standard defines a relational database scheme based on CEN pre-standards. A new cadastral base map instruction system (called DAT) has been developed by the Institute of Geodesy, Cartography and Remote Sensing (FÖMI), which has been operative since 1997. In the National Cadastral Program of Hungary, new cadastral maps (databases) have been created for 500 thousand hectares (5% of the whole territory of the country), based on the standard and instruction system.

The paper outlines the former developments, describes the legal circumstances that belong to cadastre and land registry. The main characteristics of the above-mentioned standard are described. The new, DAT based cadastral data model is outlined in the next section. The similarity and differences are stated between our model and the modular standard for the Cadastral Domain. The real property transactions executed by the new system are detailed

1. INTRODUCTION

During the last ten years there were many successful and unsuccessful developments in the Hungarian Land Management Sector. At first, the conversion of real property registry from paper based to relational database form had been accomplished (Complex Decentralized Real Property Registry System). After the completion of this system, the development of a new, integrated cadastral information system has been started, called TAKAROS.

TAKAROS system contains an integrated real property registry with the digital cadastral maps. The project was financed by PHARE funds. The real property registry part of the system has been finished in 2000, and from this time, it is operating in the 116 District Land Offices of Hungary. The digital cadastral map part of the system was unfortunately an unsuccessful development, and up to now, there is no real integrated cadastral IT system at the District Land Offices which solves the principles of the uniform Hungarian Land Registry.

For better public access to the real property registry data, an intranet-type network has been built-up called TAKARNET (network of TAKAROS system). TAKARNET network connects all the members of the Hungarian Land Management sector, and there is a public, but limited access to the system via Internet, too. By this year, the number of the public queries to the system exceeded the 1 million. All the registered users of TAKARNET have admittance to any data of the uniform real property registry.

Beside the elaboration of TAKAROS system, which was carried out by private companies, new developments have been started in the Land Management Sector, mainly in the field of GIS standardization.
The first standard was the Hungarian GIS Data Exchange Standard (MSZ 7771 or HUNEX) which was accepted by the Hungarian Standardization Body in 1995. This standard defines an EXPRESS language scheme for GIS data exchange. HUNEX has an important role in the IT system of the County Land Offices (META).
From cadastral point of view, the most important standard is the Digital Base Map Standard (MSZ 7772-1 or DAT standard), which defines the conceptual model of the Hungarian Cadastral Maps. The Hungarian Standardization Body has accepted DAT standard in 1996. Based on DAT standard, a new instruction system has been developed for the creation, maintenance and updating of DAT based cadastral maps. The Institute of Geodesy, Cartography and Remote Sensing (FÖMI) has developed the standard and the instruction system.
In the National Cadastral Program of Hungary, DAT standard-based cadastral databases have been created for 500 000 hectares (5% of the whole territory of Hungary). The success of the National Cadastral Program of Hungary shows that standardized cadastral databases are the future.
Beside these developments the management of the new cadastral databases at the district land offices has not been solved yet. Therefore FÖMI developed a new cadastral data model (based on the DAT standard and instruction system) for the Land Offices' IT system, TAKAROS. The new data model completely covers the data managed by the Land Offices (cadastral maps, real property registry etc.) and procedures belonging to the Land Offices' activity (real property transactions, land use registry etc.). The new cadastral data model completely achieves the tasks of the uniform real property registry, since the two parts (cadastral maps and the land registry) are using the same functions, constrains and modules in the operative work.
In this paper the DAT standard, the new data model, procedures and the cadastral IT system are outlined.

2. LEGAL FRAMEWORK

For the understanding of our cadastral developments the reader must know the legal background of the Hungarian Cadastral System.
There are two Acts which mainly influence the cadastral activities in Hungary:

- Act on Surveying and Mapping Activities (Act LXXVI., 1996.) and
- Act on Real Property Registry (Act CXLI., 1997.).

Act on Surveying and mapping activities defines that cadastral and large-scale topographic mapping (scale 1:10 000) is in the responsibility of the Land Management Sector of Hungary. This means that the cadastral maps must be registered and managed at the Land Offices (20 County and 116 District Land Offices). The Act divides the cadastral map data into two parts. The **state base data** are the data, whose production and maintenance is financed by the central governmental budget, and **base data** are the data, whose production and maintenance is financed by other (e.g. local governmental) funds. The objects belong to state base data or base data defined in the DAT standard. [1]

Act on Real Property Registry regulates the principles and procedures of the real property registry of Hungary. Production and maintenance of the real property registry is the task of the Land Offices Network (including FÖMI). The Act determines that the cadastral map is a part of the real property registry which defines the geometric characteristics of a land parcel (area, boundary etc.). From real property transactions point of view the principles of the real property registry are very important. The principles of real property registry are the following:

- Inscription (any right in the real property registry arises from its registration on the property sheet),
- Publicity (anyone has access to view, to copy or to note any data from real property registry),
- Authenticity (any rights and facts in real property registry are authentic),
- Bond of application (any modification in real property registry must be based on an application),
- Ordering (the order of any registration based on the time of application registration),
- Principle of deed (any registration of rights or important facts must be based on a deed). [2]

Our new cadastral data model completely satisfies these requirements derived from the legal regulations.

3. DAT, THE HUNGARIAN CADASTRAL BASE MAP STANDARD

The role of the DAT standard is to determine the objects to include in the cadastral database, to define their geometric properties, connectional and qualitative characteristics and principles of their integration and their metadata. [3]

The data model of DAT standard is in accordance with prEN 287001:1995, Geographic Information — Reference Model European prestandard. The standard's reference system is the Hungarian Geodetic Datum (HD-72), projection system is EOV (Uniform National Projection System) and the height datum is Kronstadt (Baltic system).

The objects are classified into object-classes, object-groups and objects according to the hierarchical level. Classification of object classes and objects groups is the following:

A	**GEODETIC POINTS**	
	AA	**Horizontal and 3D geodetic control points**
	AB	**Vertical control points**
	AC	**Vertexes**
B	**BOUNDARIES**	
	BA	**Administrative units**
	BB	**Administrative subunits**
	BC	**Land parcels (public)**
	BD	**Land parcels (private)**
	BE	**Subparcels and land use**
	BF	**Soil-quality categories (for arable land)**
C	**BUILDINGS, FENCES AND TERRAIN FEATURES**	
	CA	**Buildings, houses**
	CB	**Building attachments**
	CC	**Fences, abutments, and earthworks**
	CD	**Terrain features**
	CE	**Statues, memorials**
D	**TRANSPORTATION**	
	DA	**Characteristic points of transportation**
	DB	**Transportation in built-up areas**
	DC	**Transportation in rural areas**
	DD	**Railroads and other fixed-way transportation**
	DE	**Airline infrastructure**
	DF	**Transportation structures I.**
	DG	**Transportation structures II.**
E	**SPAN-WIRES, TELPHERS**	
	EA	**Axes of span-wires and telphers**
	EB	**Structures of span-wires and telphers**
F	**WATER AND WATER STRUCTURES**	
	FA	**Rivers and lakes**
	FB	**Public utilities**
	FC	**Water structures**
G	**RELIEF**	
	GA	**Contour lines**
	GB	**Features of relief**
	GC	**Digital Elevation Model**
H	**OTHER AREAS**	
	HA	**Surveying area**
	HB	**DAT database handling unit**
	HC	**Expanses**

Objects are geometrically separated into three categories: point, line and polygon type objects. The geometry of an object stored in 2D, the third dimension (height) is stored in attributes. The thematic structure of DAT is shown on Figure 1.:

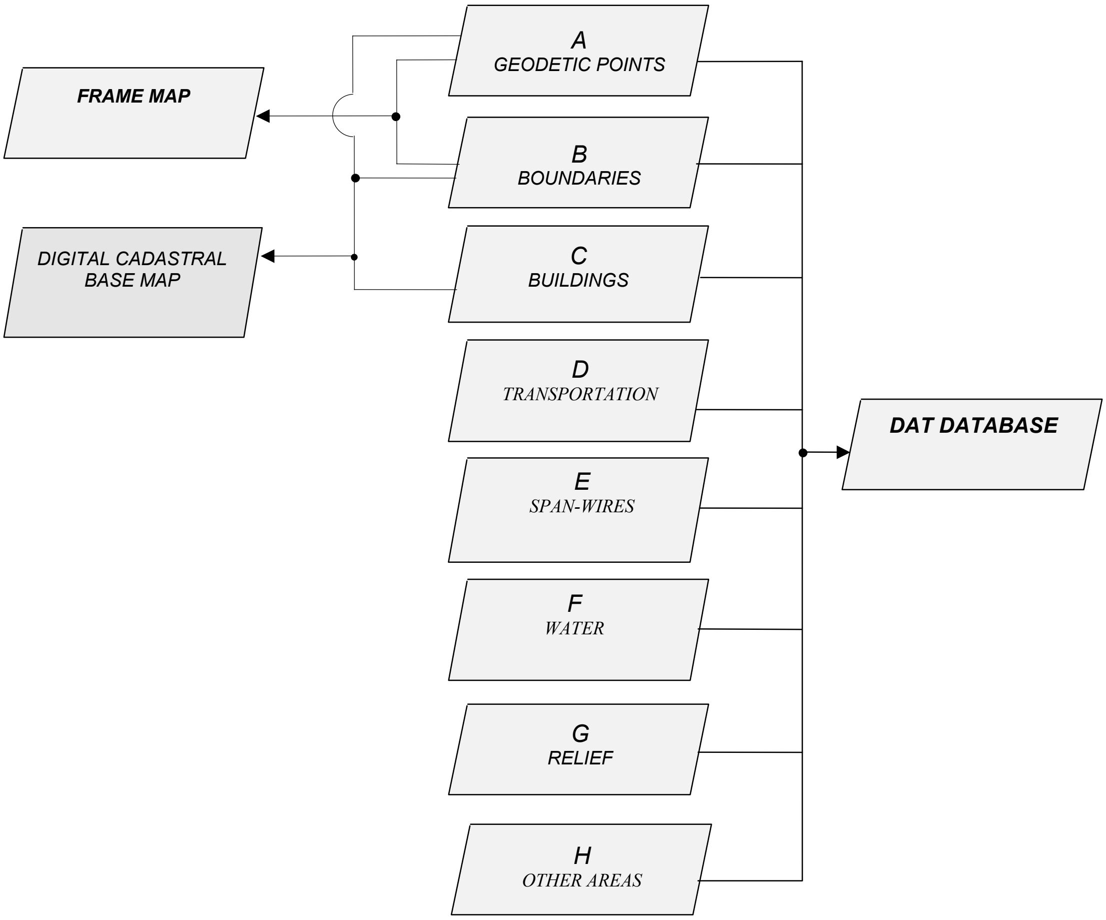

Figure 1: Thematic structure of DAT standard.

As shown on Figure 1, DAT standard contains much more objects than a cadastral map needs. During the elaboration of the DAT standard, there have been many harmonization discussions among the different sectors of the Hungarian economy. It is the reason why there are so many objects in the standard. But as Figure 1 shows, the cadastral base map contains only 3 object classes. These 3 objects classes are defined as state base data in the standard. In the National Cadastral Program, only the objects of these 3 classes are determined and organized into a cadastral database.

3.1 Geometric and topological elements of the standard

The standard contains the following geometric and topological elements, which is in accordance with the prEN 287007:1995, Geographic Information — Data Description — Geometry, European prestandard.

Geometric elements

Point: 0D geometric element, described with one pair of coordinates.
Line: 1D geometric element, described with two or more pairs of coordinates, can be opened or closed.
Polygon: 2D, closed geometric element, with one or more outer and zero or more inner boundaries.
Boundary: 1D closed geometric element, which is bordering a polygon.
Boundary line: 1D geometric element, which is a part of a boundary.
GRID points: Points, which are the parts of a grid.

Topological elements

Nodes: 0D topological element, related to a point. There are three types of nodes:

- Isolated node: which is not connected to any edge,
- Connected nodes:
    - End node: which is bordering an edge,
    - Intermediate node: which is on an edge, but not bordering it.

Edge: 1D topological element, which connects two end nodes directionally.
Ring: 1D closed topological element, which is described by connected edges.
Face: 2D topological element, which is described by one outer and zero or more inner rings.

3.2 Data quality

In DAT standard the data quality elements are in accordance with the prEN 287008:1995, Geographic Information — Data Description — Quality European prestandard. The data quality groups are the following:

- Origin of data,
- Amount of data use,
- Quality of geometric data,
- Quality of attribute data,
- Actuality of data,
- Completeness of data,
- Consistency of data,
- Technology of data collection,
- Data protection,
- Authenticity.

Data quality groups can be connected to the following data level:

- DAT database or a part of a DAT database,
- Object classes and object groups,
- Objects,
- Attributes.

From data quality groups we want to outline the geometric quality and data actuality requirements, since these factors shows dominantly the quality of the new cadastral databases.

Tolerance classes:

For the distinction of different geometric quality, the standard classifies four different tolerance classes, based on the data collection method and surveyed area:
T11 — digital new surveying on the field in built-up areas,
T12 — digitization of existing analogue maps in built-up areas,
T21 — digital new surveying on the field in rural areas,
T22 — digitization of existing analogue maps in rural areas.

The vertices are also clustered into four groups:

R1: marked dominant vertices of administrative units, subunits and land parcels of built-up areas
R2: other vertices of administrative units, subunits land parcels of built-up areas and marked vertices of land parcels of rural areas. Dominant vertices of buildings, wires etc.
R3: Other vertices of land parcels of rural areas, buildings, wires etc.
R4: Other vertices, which cannot be clustered into the three above groups (e.g. vertices of subparcels).

Identification RMS value of vertices (cm)

	T1		T2	
	T11	**T12**	**T21**	**T22**
R1	3	20	5	45
R2	5	25	7	50
R3	6	30	10	60
R4	8	45	19	90

Table 1: Geometric accuracy of vertices.

Data actuality

Data actuality is one of the most important data quality factor. In DAT standard the two main data actuality factor are the following:

Map rectification periods

Geographically demarcated database	Period of map rectification	
	Recommended	Acceptable
Built-up areas of towns, resorts and industrial areas	10 years	30 years
Built-up areas of villages	15 years	30 years
Rural areas of settlements	15 years	40 years
Areas of land consolidation	Depends on claim	

Table 2: Map rectification periods.

Map rectification is the procedure, when the changes between an earlier cadastral status and the present one — which are not documented in deeds — are working into the database. Other changes, which are documented in deeds, can be characterized by the updating period of data.

The other important actuality factor is the updating period of data in the database. DAT standard defines the following data updating periods depending on the type of data:

Updating periods of data

Type of data	Updating period	
	Recommended	Acceptable
Registrations in Real Property Registry	Immediately	1 day
Changes in land parcels	Immediately	1 week
Dominant structures	1 month	3 months
Other state base data objects	1 month	3 months
Other base data objects	2 months	6 months

Table 3: Updating periods of data.

3.3 Metadata

Metadata of DAT standard are in accordance with the prEN 287009:1995, Geographic Information — Data Description — Metadata European prestandard.
DAT standard defines metadata, which are required for the description of DAT database or datasets derived from DAT database.
The main groups of metadata are the following:

- Identification of dataset,
- Overall data of dataset,
- Quality of dataset,
- Reference system,

- Geographic and temporal dimension,
  - Operativeness of dimension,
  - Horizontal dimension,
  - Vertical dimension,
  - Temporal dimension,
- Determination of data content
  - Description of objects,
  - Description of attributes,
  - Description of relations and constrains,
- Description of classification
  - Orderliness of classification,
  - Elements of classification,
- Data administration
  - Organization and its role
  - Contact person and his role
  - Turning over
- Actuality of metadata.

In this section we wanted to give a short outline about DAT standard which is the base of the new cadastral data model at the Land Offices of Hungary. As the above-mentioned tables show, there are very rigorous quality requirements against the objects stored in the DAT database. In the National Cadastral Program, half a million hectares have been transformed into this relational database format with these rigorous requirements. But unfortunately, there is not yet any map manager system in the Land Offices which can handle these cadastral databases. Therefore the databases are losing their actuality which is one of the most important factors in the case of cadastral systems (see Table 3.: Updating period of data).

FÖMI — like the developmental, operational respond of TAKAROS system — decided to develop a new data model and application for TAKAROS system, which completely integrate the cadastral map and the real property part of the Land Offices IT system. [3]

4. DATR, THE NEW CADASTRAL SYSTEM FOR THE LAND OFFICES

DATR (DAT standard based Mapping System) achieves all the integration, and legal requirements defined in the DAT standard and the Acts mentioned in section 2.

The main vision in the development of DATR has been that the cadastral map is the geometrical representation of objects stored in the real property registry in accordance with the Act on Real Property Registry. The system must provide the authentic updating of real property registry and the cadastral map together. [3,4]
These requirements conducted us to the following decisions:

- There is no need to replace any modules or functions operating in the existing real property registry system called TAKAROS, the new system must use from administrative point of view the same functions, procedures like the older one.

- The DAT standard based cadastral database must be stored in the same database as the real property registry, therefore we need only one database scheme and we are able to enforce the database integrity.
- The internal database of the cadastral map must be compatible with the database defined in the DAT standard and instruction system.
- There is no need to have any map editor or modification function in the new system, all the changes must be carried out within a database transaction. This unfunctionality provides the authentic updating of cadastral maps.
- Only the use of standard functions of the graphic operation system can solve the graphical representation of cadastral map data, therefore we do not need any commercial GIS software. It is very important from financial point view.
- The system must support the real-time queries of TAKARNET network, so the on-line cadastral map service will be available.

Main characteristics of DATR [5]:

- Total integration with TAKAROS system
    - Database structure,
    - Ability system,
    - Transactions,
    - Data service,
    - System administration,
- Uniform database structure:
    - One scheme,
    - Administration of changes,
    - Enforcing of database integrity,
- Tracking of temporal changes:
    - Archiving,
    - Displaying any arbitrary status of cadastral map,
    - Updating in background procedure,
- Real-time queries via TAKARNET network:
    - Integrated search with the real property registry,
    - Real-time map generating,
    - Minimizing network weighting,
- Modular, self-calibrating architecture
    - All the functions are in modules,
    - Explicit and implicit communication among modules,
    - No client side configuration needed to insert any new module,
- Easily extendable
    - Uniform calling interface and protocol
    - Usable base modules,
    - Opened module API
- Operation system and RDBMS
    - Windows NT 4.0 or Windows 2000 server and client,
    - ORACLE v8.05 RDBMS (because it is operating at the Land Offices, but the functions are compatible with the higher version ORACLE RDBMS too.)

4.1 Core data model of DATR

The core data model of DATR is very similar to the core model defined in Cadastral Domain Model [6]. In DATR we are using the following core data model (see Figure 2.)

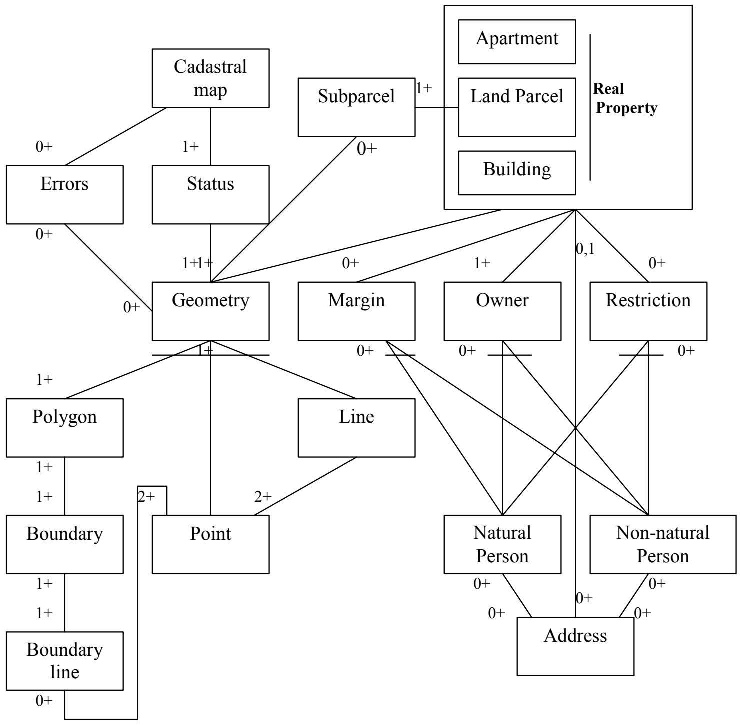

Figure 2: Core data model of DATR.

As shown on Figure 2., there could be three types of real property: apartment, building and land parcel, but a real property must be one of them. In our real property registry, the apartments have no geometric representation, only the land parcels and buildings have one.

In the part of geometry, an object can be point, line or polygon type object. Therefore if a cadastral map object has no connection to the real property registry (e.g. railroad), there is no relation between the real property and the geometric tables (0+ indicates, that there are zero or more relations to the tables). Structuring of geometric tables is unambiguous.

The object called Margin has a very special role in the real property registry. Margin provides the ordering principle of real property registry. If the Land Office receives any application related to the real property, the Land Office must register it and Margin shows the flag of the application on real property. Of course there could be zero or more margins on the real property (0+). The margin also register the person who made the application, therefore there is a link to the natural or non-natural person.

The role of the owner is unambiguous. One real property must have at least one owner (1+), which could be a natural or non-natural person.
The real property could have an address or not (0+).
There could be rights (e.g. easement, mortgage) and restrictions related to the real property. The Restriction object makes for this purpose. The Restriction can be connected to a person too.
Each person (natural or non-natural) — who has any connection to the Land Office — is registered in the database with his address, too.
This core data model has been physically achieved in DATR system and is able to manage the cadastral map data and real property registry in an integrated way.

4.2 Real property transactions in DATR

Real property transaction is one of the most important procedures in the Land Office's activity. Its legal and surveying relations must be handled very rigorously in an integrated cadastral system. The real property transaction in DATR contains the following steps (see Figure 3.):

- Application registration in order to map data service,
- Allocation of affected real properties,
- Generating of changing area,
- Data service for changing (map and real property),
- Closing of affair (end of data service for changing),
- *Changing data in an other system (e.g. ARC/INFO),*
- Application registration for uploading map changing
- Uploading changed map data to the work map,
- Automatic and manual checking of changed data,
- Adding a clause,
- Closing of affair (end of changed data uploading),
- Application registration for changing real property registry,
- Transactions in real property registry,
- Deed and updating (legally valid map and real property),
- Closing of affair.

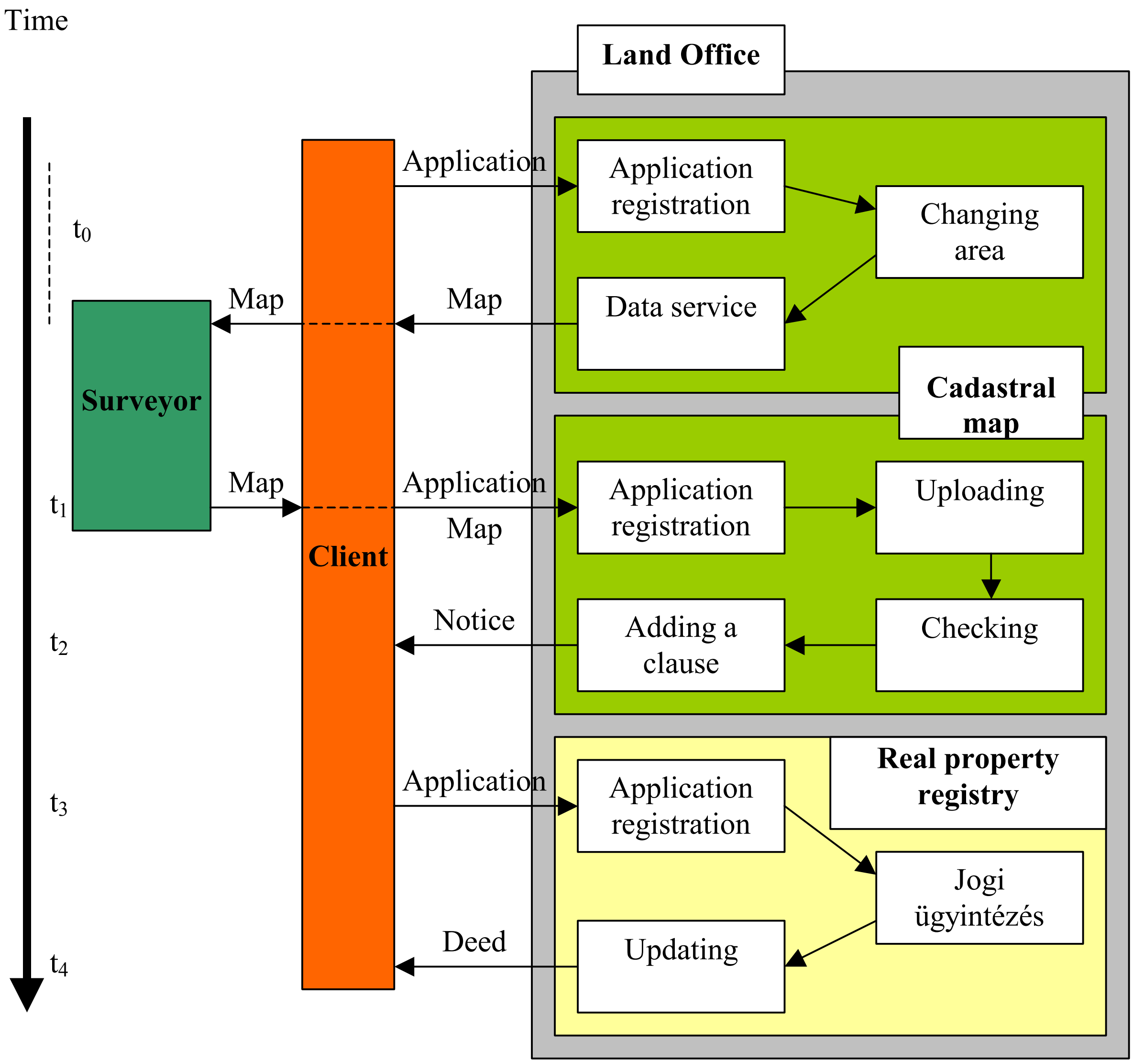

Figure 3: Real property transaction in DATR.

Application registration in order to map data service
This procedure is carrying out by the application registration module of TAKAROS system or in DATR, but physically the result is the same in the database.

Allocation of affected real properties
Allocation can be executed by three ways:

- Listing of lot numbers of parcels,
- Selection of real properties and other objects on the map,
- From the selection of the real property registry.

Generating of changing area
DATR generating changing area with the boundary of the area, land parcels and objects belongs to the land parcels and other objects within the changing area.

Data service for changing (map and real property)

The client receives the map and real property registry data. Data service is available in different forms (e.g. ESRI SHAPE, DXF etc.).
Closing of affair (end of data service for changing),
Changing data in an other system (e.g. ARC/INFO),
Application registration for uploading map changing
Same as in the case of data service
Uploading changed map data to the work map
Work map is a distinct area of the database.
Automatic and manual checking of changed data
Checking contains the following tasks:

- Formal and syntactical checking,
- Checking of inner consistency (e.g. links),
- Checking of geometrical consistency (e.g. topology),
- Temporal consistency checking (e.g. coincidence to the map data service)
- Checking of integrity (e.g. integrity with the real property registry).

Adding a clause
During the addition of a clause, the following procedures are executed:

- Objects of the changing area will be erased (only logically),
- The objects of the working map will be uploaded to the legally valid map (flagged with clause)
- The new real properties will be uploaded to the real property registry (flagged with preliminary)

Closing of affair (end of changed data uploading)
Application registration for changing real property registry
Same as in the case of data service
Transactions in real property registry
Deed and updating (legally valid map and real property)
This task finalizes the changes consistently both in cadastral and real property database. In the case of the cadastral map it means:

- The erased objects will be deleted physically,
- The clause-flagged objects will become legally valid.

Closing of affair

5. CONCLUSIONS

In this paper we wanted to give a short outline about the new IT developments related to cadastre in Hungary. We dealt with the Digital Base Map Standard (DAT standard) which has a very important role in the Hungarian cadastral activities. In the last sections, we introduced our new IT development DATR which completely achieves the legal and technical regulations and requirements of Hungarian Real Property Registry.
The data model of DATR is very similar to the data model that has been evolved in the modular standard for the Cadastral Domain [6]. In the case of DATR, we wanted to build an operating cadastral map based on the real property registry system and now it is working. This fact shows that the modular standard for the Cadastral Domain is a good way to "provide the "common ground" for data exchange between different systems in the cadastral domain"[6]. Our DATR solution is not as flexible as the Cadastral Domain, because of the

specific requirements of our legal system. For the further needs of our clients, such an opened, flexible standard (mentioned in [6]) is recommended in every cadastral information system.

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BIOGRAPHICAL NOTES

Szabolcs MIHÁLY: Director General of Institute of Geodesy, Cartography and Remote Sensing (FÖMI). He is the author of DAT standard and co-author of DAT instruction system. He is heading the Geographic Information Technical Committee of the Hungarian Standardization Body. He is the representative of Hungary in FIG Commission 3, Spatial Information Management.

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Gábor SZABÓ: Leader programmer and system architect. He has participated in the development of TAKAROS, TAKARNET system as system architect and programmer. He is leading the development of DATR system.

Gyula IVÁN: Head of department of GIS at FÖMI. He is a co-author of DAT instruction system, GIS and DAT expert in National Cadastral Program. He is leading the GIS team in the development of DATR system. He is the co-author of Digital Topographic Database Standard (MSZ 7772-2).

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Modelling of Land Privatisation Process in Belarus

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Key words: Land privatisation process, the Republic of Belarus, modelling, Unified Modelling Language (UML), class and activity diagrams, the core cadastral domain model.

SUMMARY

Land privatisation is at the moment regarded as the main tool for land distribution in Belarus. Obviously, the process has to function smoothly and effortlessly from the user's point of view. The paper addresses the land privatisation process in Belarus with aim to identify its drawbacks and pitfalls. It therefore assumes that land privatisation is overcomplicated as well as time-consuming and not adapted to the user's needs process. Hence, there is an urgent need for simplification and, thereby, making the property market active and efficiently functioning.

The paper moreover analyses modelling of privatisation process and mostly the developed models with application to further formalisation of the core cadastral domain model. In particular, two types of modelling, namely static and dynamic, or process modelling, are employed in the paper and two respective models in UML notion are used as basis for this analysis. It also raises a question about initial harmonisation of the main cadastral processes by applying the land privatisation process in Belarus as a testing example.

The paper employs 'Literate Modelling' approach when the diagrams alternate with explanatory text.

1. INTRODUCTION

Cadastre and land registration are internationally recognised as spatial and legal/administrative components of an integrated system whose aim, among others, is to ensure sustainable development. Such integrated system is identified by different names such as, for example, land administration system (Williamson and Ting 2001), system of land registration (Zevenbergen 2002), cadastral system (Bogaerts and Zevenbergen 2001, Silva and Stubkjaer 2002), and cadastre (Navratil and Frank 2004). This paper in turn applies the term 'cadastral domain' to cover the whole area of cadastre and land registration. Development in the cadastral domain is directly influenced by global drivers such as sustainable development, globalisation, economic reform, and technological reform (Ting and Williamson 1999). Globalisation as the result of free market economy requires establishment of international standards within both national jurisdictions and different problem domains including cadastral. At present the main attention of surveying professional organisations and academia is also paid to the process of standardisation (FIG, COST, etc.) and its results of it (Greenway 2002, Lemmen et. al. 2003, Stubkjaer 2003). Unified Modelling Language (UML) is used as a primary tool for this process.

The overall objective of this paper is to address the land privatisation process in Belarus with the aim to identify its drawbacks and pitfalls, i.e. to uncover controversies and to study the deficiencies. The developed static and dynamic models in UML notion are used as basis for the analysis. The complementary objective of the paper is to find out how modelling privatisation process and mostly its developed models could help in further formalisation of the core cadastral domain model.

The paper applies modelling of one specific cadastral process (i.e. privatisation of land) within the legal jurisdiction of one specific country. The models developed here are not final and contain several simplifications and generalisations in comparison with the reality. Model is considered here as 'a simple description of the object' (Cambridge Dictionary 2003) and it is 'nothing more than the way of describing some activity, phenomenon, or problem area' (Rudwick, 1979).

The two developed models (viz. static and dynamic models)[1] shall highlight specific features of privatisation process. Particularly, a static model describes the process through classes, objects, and their relations and how they work (Eriksson et al. 2004), while a dynamic model illustrates the formalised and structured activities performed by different actors as well as the sequence of activities in the course of the process. The process modelling within the cadastral domain is also behind the modelling of core cadastral data. The initial attempts to model property transaction processes (mainly property subdivision and transfer) are being undertaken by the COST Action G9 'Modelling Real Property Transactions' (Stubkjaer 2002). See also presentations within the COST Action G9 framework in Szekesfehervar (Hungary) and Riga (Latvia) for the recent development[2].

The first assumption of the paper is that the land privatisation process in Belarus is overcomplicated as well as time-consuming and unadapted to the user's needs. It has remained as a relic of the Soviet time. Hence, there is an urgent need for simplification and, thereby, making the property market active and efficiently functioning. There are several activities that may be abolished without any negative consequences in terms of quality, time, cost, etc.

The other assumption is that investigation of a specific case is of great help not only for further development of the presented core cadastral model (Lemmen et al. 2003) but also for movement to initial harmonisation of the main cadastral processes within the EU. Logically, harmonisation of cadastres shall be in line with harmonisation of land registry and property regimes (van der Molen 2002), even if the Treaty Establishing the European Community (1957) leaves the system of property ownership to national governments. Obviously, this will be brought to the agenda of the European community in the future. In support of this statement, the Bologne Process[3] can be given as a good example of harmonisation of the educational process on the European arena that is also regulated by national legislations.

Next assumption is that static and dynamic models of cadastral processes are mutually supplemented and both useful for scientific purposes. It is rather incorrectly from scientific point of view to analyse the process without taking into consideration the results both of static and dynamic modelling. Furthermore, standardisation of the cadastral domain is

[1] Static and dynamic modelling are described in detail in the section 4
[2] http://costg9.plan.auc.dk/
[3] http://europa.eu.int/comm/education/policies/educ/bologna/bologna.pdf

reasonable through standardisation both information sets maintained by different databases and the activities of cadastral processes themselves.
The paper employs 'Literate Modelling' approach when the diagrams alternate with explanatory text.

2. CADASTRAL PROCESSES

Property rights are established, abolished or rearranged by different cadastral processes. Therefore, analysis of these processes will be incomplete without considering the concept of property rights. It is not the goal of the paper to address this concept (for that see, e.g., Demsetz 1967; Alchain and Demsetz 1973; Libecap 1989, etc.). It should only be mentioned here the three modes through which persons can be related to land, namely open access (i.e. none is connected to land), limited access, (i.e. some single rights/obligations are imposed on land), and, finally, complete transfer (ownership right connects a person with land) (Mattsson 2004). The paper omits analysis of the first two connections and concentrates only on discussion of the third one.

Mattsson (1997) distinguishes three forms of property-related change applicable to land held in ownership (Figure 1), namely:

- Transfer of property rights (the most common case is property transfer)
- Property formation measures (e.g., subdivision, amalgamation, etc.)
- Alteration of land use (through planning and environmental regulations).

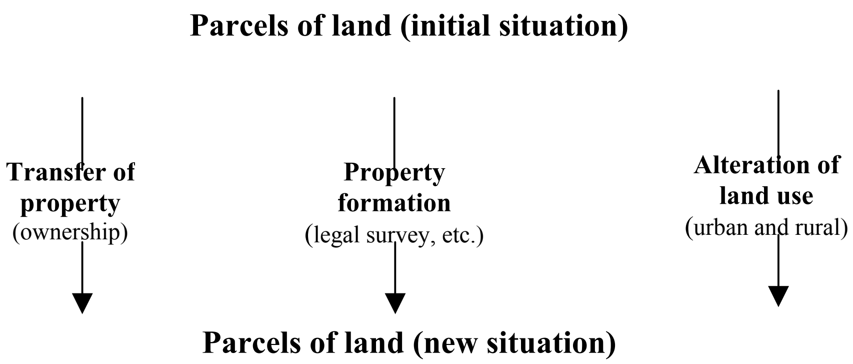

Figure 1: Necessary procedures in land law for change (Mattsson 1997).

This paper regards property formation measures as cadastral processes. Such processes as subdivision, allocation/consolidation, and adjudication are widely considered as the general and important ones within cadastral domain. For example, the comparative work on subdivision in several countries is presented by Zevenbergen (2002). In this paper, land privatisation as a particular case of subdivision is modelled and discussed.

2.1 Land privatisation

Land privatisation is a specific case of subdivision when land in state ownership is transferred into exclusive possession of a private owner or company. The process itself can be separated into a series of activities that are undertaken in order to achieve a result. In our particular case, in Belarus, the result is state owned land transferred to private ownership. So, both transfer and property formation measures are involved. Privatisation, according to the Law of the Republic of Belarus on privatisation of state property (1993) is the process of acquisition of the ownership right on state property by natural or legal persons. The state property can be acquired free of charge or by purchase.

Land privatisation in this paper means transfer of land plot for specifically designated land use. In Belarus private ownership on land is limited by four types of land use (Land Code 1999). It should also be mentioned here that agricultural land is in exceptional state ownership and, thus, privately owned land is mainly used for single family and summer houses (i.e. construction is normally included in the process of acquiring land in private ownership).

Two types of modelling, namely static and dynamic, or process modelling are employed in this paper. To express land privatisation in ontological way, two types of UML diagrams, namely: class and activity diagrams have been developed (Figure 3 and 4).

3. THEORETICAL FRAMEWORK

The developed activity diagram (Figure 4) presents the land privatisation process divided into several general successive activities that in turn consist of actions[4]. Every activity ends with results (e.g., application, map, etc.) that are expressed in documents. Even any intangible result of an activity like, for example, decision about granting land plot is to be documented

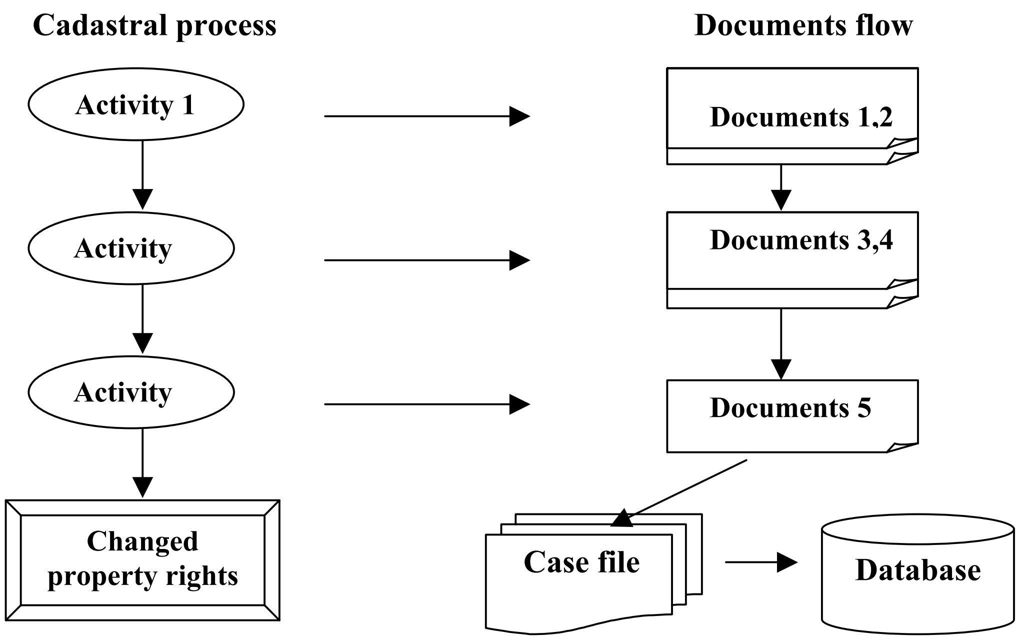

Figure 2: Interrelation between activities within a cadastral process and corresponding documents.

[4]Actions as elementary particles of an activity are not discussed in this paper

(especially in CIS countries due to the historical development). Thus, every activity ends up with one or several documents that exist in the reality and represent the data (compare Navratil and Frank 2004), which has to be stored in the register (i.e. database). Figure 2 graphically illustrates this situation. In application to Belarus it means that in the end of any cadastral process a case file consisting of several documents (e.g., decisions of municipality), cadastral map/plan, etc is to be composed. Then the collected information is converted in digital format and stored in database. Summing up, the results of the process are, among others, the changed property rights on land, information represented in the databases and case files stored in archive.

4. MODELLING

By modelling the cadastral domain is expressed in a formal way. Cadastral modelling is on the agenda at least since the FIG Congress in Washington in 2002 and the subsequent Workshop on Cadastral Data Modelling in Enschede in 2003. Since then the progress is mainly made in modelling of the cadastral domain in the form of UML class diagram.

Generally speaking, modelling is the process of making a model and, therefore, models are the desirable results. Two types of models can, among others, be distinguished, namely: static and dynamic models. Static models describe static characteristics of the system (in our case of the process), while dynamic models describe respectively dynamic ones. Zevenbergen (2004) states that both are useful for describing land registration[5]. Thus, a static model accentuates on the structure of a system and, thereby, information kept, while a dynamic model describes processes that bring changes.

A simplified static model of cadastral system (with some modifications) can be found in Hanssen (1995), Mattsson (2004), Zevenbergen (2004) where a property right connects owner (i.e. subject) with land (object).

In this paper static modelling of land privatisation is regarded as development of a model that describes and structures information (by means of classes and associations) produced during the process. Dynamic modelling of land privatisation implies in turn development of a model that takes the time component into consideration. Therefore, the main focus of this model is not on structure but on the consecution of the process activities and respective changes. The detailed discussion of these two models by the example of land privatisation process follows below.

4.1 Static modelling of land privatisation

This section is aimed at describing static modelling of privatisation process. Following the modern trend of development in the cadastral domain and gradual move of land information service to full cost-recovery (Kaufmann and Steudler 1998), land privatisation can be considered as a business and simultaneously as an open system, as it interacts with the social environment by means of laws, regulations, stakeholders involved, etc. For example, in Belarus an applicant enters a system by applying to municipality and exits it by getting the

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[5] Land registration is equivalent here to cadastral system

State Act on land registered by the state cadastral authority[6] and endorsed by the respective municipality. From another point of view, land privatisation can be described as a ‘black box’ with input and output (Zevenbergen 2004), or with the objective to transform an input into output (Rudwick 1979). Thus, the input, in our case, is the existing tenure situation on land in state ownership and the output is land held in private ownership and prospective positive changes in terms of, e.g., development of property market, efficient land use, etc.

Figure 3 presents the Belarusian privatisation process in UML notion, i.e. UML class diagram that employs classes, objects, and their relationships to describe particular components of the process and how they interact with each other. In particular, the privatisation process begins with submission of application to municipality, namely applicants shall come in person to municipality and fill in the application. It is impossible to begin the whole process just by applying to a surveyor through phone as, e.g., in Denmark. Moreover, application shall be supported by additional documents and calculations (e.g., proof of required land area, etc.). Therefore, it is clearly seen that the privatisation process in Belarus is very formalised, bureaucratically structured and under the strong state control.

The detailed step-by-step description of the whole process is not a subject matter of this paper. However, it is worthy to emphasise the specific circumstances of the process as well as its advantages and drawbacks as well as particular features of static modelling.

Many associations are omitted from the developed class diagram in order to keep the model as simple as possible and not to overload with details. There are several *drawbacks* in analysing the situation in Belarus with this model and they are stated below.

First of all, it seems to be impossible to present the whole process in detail on class diagram. The process is very extensive and some steps in the process are repeating several times (e.g., application to different organisations). Moreover, if all stakeholders have been included into a diagram, it would be overloaded without reflecting an essential core of the process. To reach this goal, development of several class diagrams mirroring a particular state of the process at specific moment of time is probably needed.

Furthermore, it is obvious that class diagrams are not useful for revealing the time component of the process. This type of diagram is probably useless for identifying the moment when the process starts and when it is complete or when different classes are changed.

Due to clarity of visual presentation, specialisation class ’InterestedParties’ is used instead of dividing it into several classes like, e.g., ’Neighbours’: ‘Natural/NonNaturalPersons’, different municipal departments, other authorities (e.g., environmental protection, etc.).

Advantages: class diagrams clearly identify specialisation classes, especially stakeholders and different documents to be prepared and stored in case files. Class diagrams mainly answer in the clear way on two questions, namely: who? (stakeholders) are involved and what? (documents) are prepared. For improvement of the process in Belarus it might be reasonable to propose decrease in a number of documents needed to be prepared and approved. The detailed research in this direction is further needed.

Is it necessary to show on diagram all documents prepared during the whole process? It might be necessary as ‘documents provide [this] presentation because they exist in reality and are objects describing cadastral data’ (Navratil and Frank 2004).

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[6] It is single governmental authority performing both cadastral and registration functions

Concluding, class diagrams seem not to be suitable for describing different property rights and regulations treated in the process. Moreover, they do not emphasise or have difficulties with identifying the moment of change of property rights that is considered as one of the most important result of the whole process. The changes take place at the moment when land is transferred to an applicant who is recognised by the third parties as the rightful owner and, for example, when state ownership is transformed into private one. As it was mentioned above, property rights are an intangible concept, but they are materialised through documents.

The land privatisation process is discussed more in detail in the section 4.2.

4.1.1 Comparison to the core cadastral domain model

The class diagram of land privatisation process can in outline be compared with the core cadastral domain model (Lemmen et al. 2003).

The developed class diagram statically presents dynamic process, while the core cadastral domain model standardises information kept in database (i.e. register). Therefore, different nature of two phenomena can clearly be noticed. Moreover, these two diagrams intersect only in one point - register (in the case of Belarus it is the Unified register) as land privatisation process produces information (i.e. data) that should afterwards be stored in register.

The core cadastral model identifies and standardises the information (i.e. data) maintained, while the privatisation process model mainly describes documents and stakeholders involved. For correlation between documents and data see Navratil and Frank 2004.

Some more details shall be mentioned, e.g., class ‘Fee’ depicted on the diagram is not reflected in the core model. Simultaneously class ’RightsOrRegulations’ of the core model ought to be divided into two classes, namely ‘Rights’ and ‘Restrictions’ (Paasch 2004).

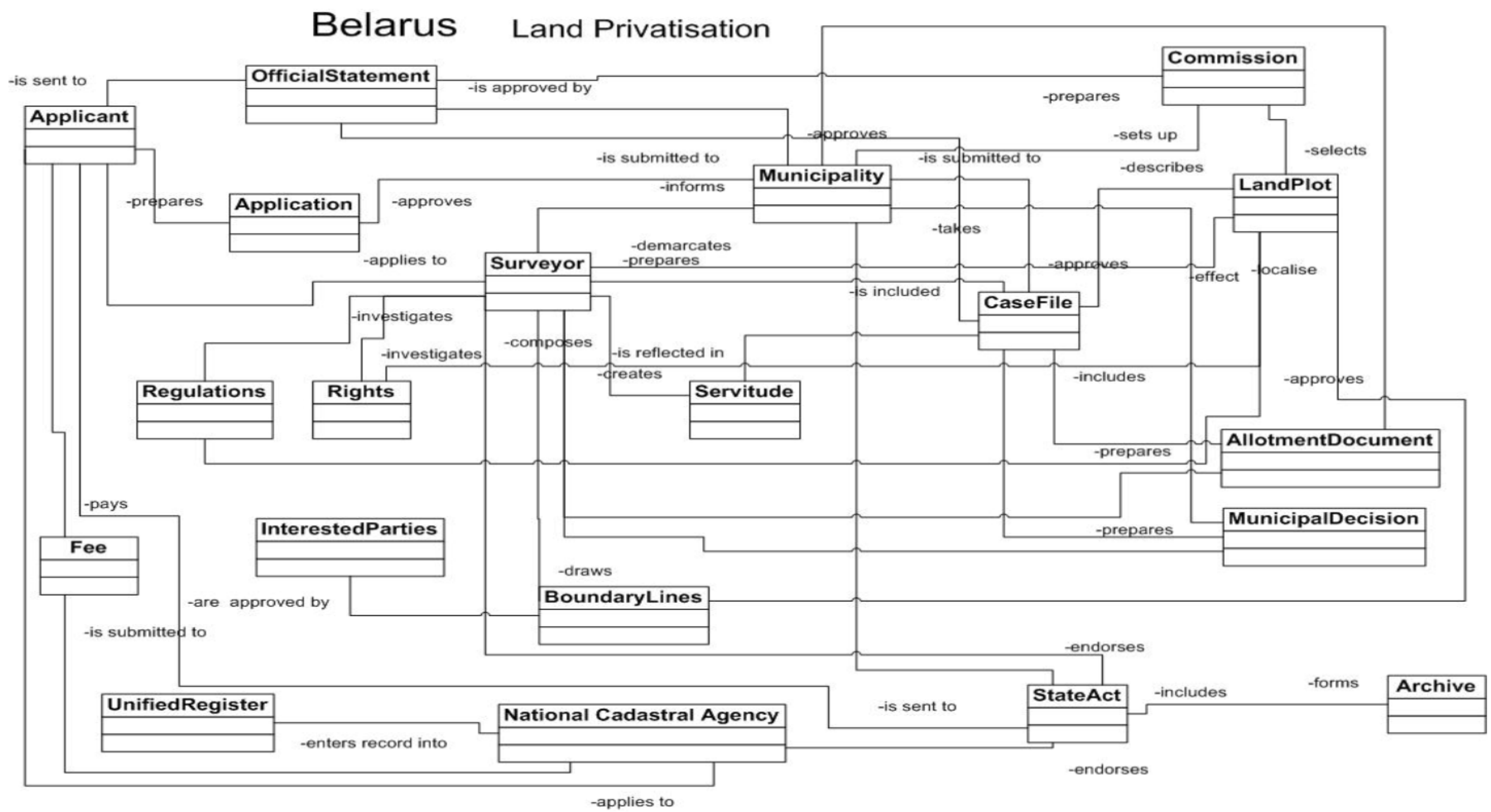

Figure 3: Class diagram of land privatisation process in Belarus.

4.2 Dynamic modelling of land privatisation

Formalisation of the privatisation process is done with help of activity diagram in UML notion presented in Figure 4.

As we have discussed, land privatisation is a specific case of subdivision that is regarded as one of the three main functions of the cadastral system (Zevenbergen, 2004). It must be mentioned that the existing activities of land privatisation have been generalised in Figure 4 for better visualisation and understanding of the process.

Activity diagrams are of great help for analysing a sequential flow of activities performed by different stakeholders. So, in our particular case, four main stakeholders are involved in land privatisation such as applicant (i.e. potential owner), surveyor (including surveying organisations and private surveyors), municipality as a governmental body on local level, and cadastral and registration authority that is the single authority in Belarus.

Looking at the diagram, it is easy to understand that municipality plays an important role in the course of the whole process as the same documents return to municipality several times for approvals or decisions. It proves the statement formulated previously that the privatisation process in Belarus is bureaucratically structured and under the strong state control.

To facilitate analysis of land privatisation, the process has been divided into three phases, namely: the land policy control, preparation, and registration phases, where each of them is aimed at accomplishing a specific goal. For example, the goal of the registration phase is to guarantee security of tenure. The main activities for each phase are also identified. This is the very beginning of another type of standardisation within the cadastral domain, namely: standardisation of processes. Generally speaking, the process is divided into several general phases that may exist in different countries. The problem is to clearly identify phases and then to name the activities, which are to be correctly understood outside the national jurisdictions. It in turn helps to compare them with similar ones in different countries. For the complete overview in this direction, see Ferlan, Mattsson and Sumrada (forthcoming).

A two-year gap between the land policy control and the preparation phases may be applicable in Belarus. It means that during this period the applicant has to prepare an architectural plan of the building. If the time limit is exceeded, the applicant shall restart the whole procedure from the very beginning.

According to the described process, the applicant has to apply to different organisations several times. First, to initiate the process, secondly, for development of a case file including the following data: area of granted land plot, soil data, value of land (for compensation purpose, if applicable), type of land use including arrangement of property rights. The third application is to municipality for taking decision about granting a land plot, while the fourth is to the cadastral authority for cadastral and ownership registration. It is remarkable, that in the course of the process several approvals and decisions are taken by both municipality and the cadastral authority but only two possibilities to appeal are stated by the legislation in action (i.e., the Land Code 1999 and the Law on state registration of real property 2002), namely: in the very beginning of the process when municipality approves initial application and the second time – during registration. Appeal procedures against other approvals and decisions of municipality are not mentioned by the main legislative Act concerning land privatisation (i.e. the Decree of the President 2002). Therefore, it sounds logically to question the necessity of these two approvals for which appeal procedures are not prescribed by law.

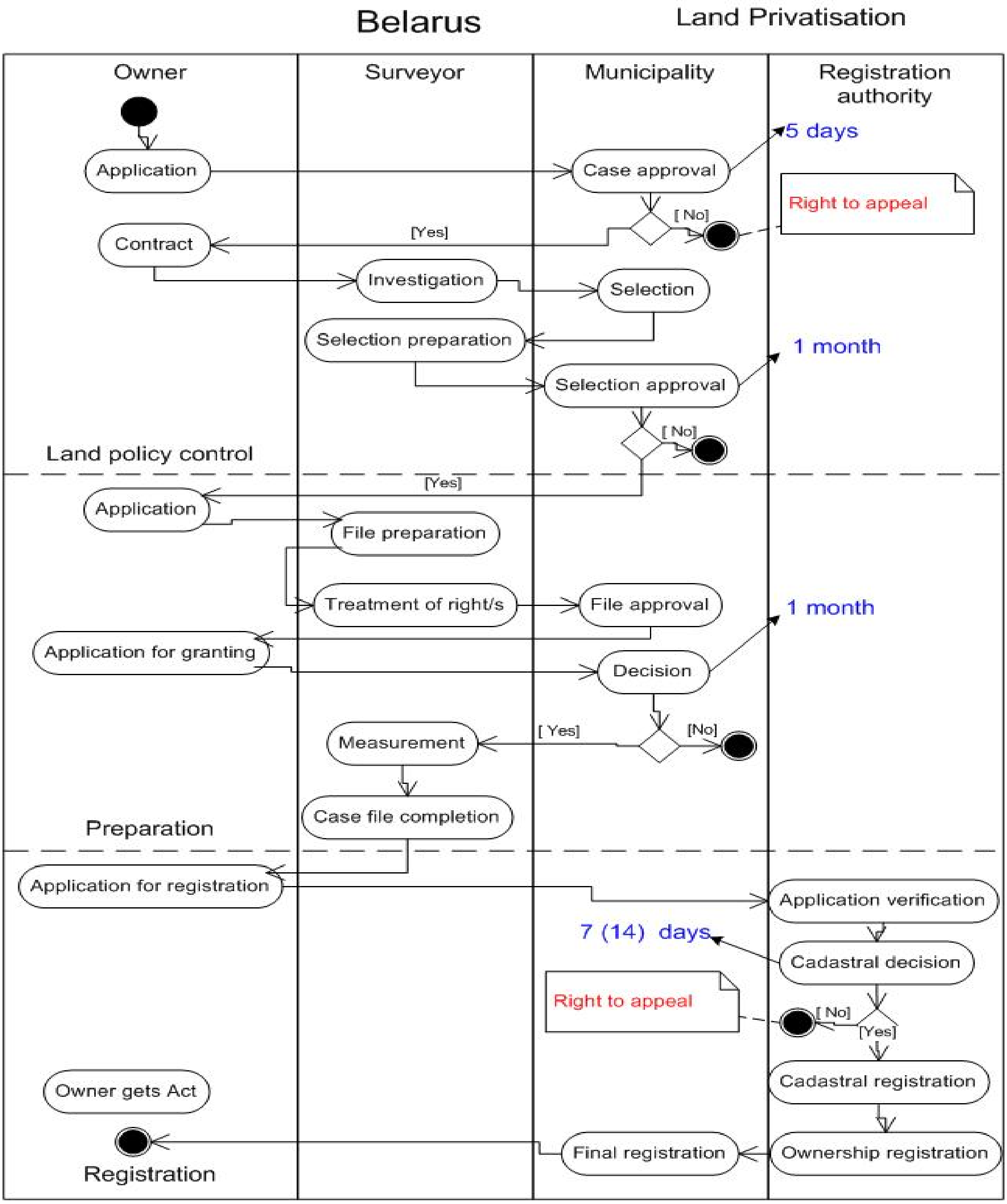

Figure 4: Activity diagram of land privatisation process in Belarus.

The technical (i.e. surveying) measurement is undertaken during the last step of the process, just prior registration, when all approvals and decisions are taken and collected by the applicant. Surveyors just perform simple geodetical measurements and demarcate the boundaries in the field. This would be interesting to compare with some Western European countries where technical measurement is normally performed prior of the final decision about subdivision (e.g. Denmark, Sweden, Finland). It reflects the differences among countries and administrative framework of the society.

Furthermore, the diagram also depicts the prescribed time limits for taking decisions or approvals by municipality (the Decree of the President 2002) or by the cadastral authority (the Law on state registration of real property 2002). It is seen that they vary from 5 days up to 1 month.

As I see it, process modelling helps, to some extend, to further standardise the core cadastral domain model as it identifies activities, which usually end with the results (i.e. information) that shall be stored in database. Improvement (i.e. betterment) of the process (i.e. decreasing the number of activities and their rearrangement) can be useful for decreasing the amount of data in the database. In other words, the less activities are performed, the less of documents are produced, and therefore, the less data is to be processed, stored, and maintained. But of course, all changes shall be reasonable and well-founded. Thus, static and process modelling supplement each other and can be considered as interrelated. And, therefore, process modelling shall also be taken into consideration during the discussion of the core cadastral domain model.

5. CONCLUSIONS

Formalisation of the particular cadastral process with help of Unified Modelling Language provides the strong basis for analysis. A lot of questions based on this analysis can be formulated. But is it possible to answer them with help of UML diagrams? For example, can approvals be abolished without any negative consequences for the process? Or what is legal power of approvals if appeal procedures are not prescribed?

The accomplished analysis lets us conclude that land privatisation in Belarus is an overcomplicated process including many iterative activities. These activities can probably be skipped without decreasing quality of the whole process, as it is difficult to see any functions of them. It is, therefore, soundly to propose abolishment of some activities for the process simplification. It is desirable to re-organise the process as simple as possible, with reasonable number of activities, to make it less time-consuming and less costly. This is vital for further development of property market, increasing the efficiency of land use, as it is widely recognised that land in private ownership is used more efficient than land in state ownership. But the possibility of oversimplification of the process must be kept in mind as not to endanger the legitimacy of public society (Mattsson 2003).

Modelling of land privatisation helps to reveal weaknesses and shortcomings of the process and, thereby, to convince decision-makers in necessity of its revision and redesigning. Moreover, the government in the country ought to be willing to implement comprehensive changes of relevant policies. The developed models are illustrative examples for convincing government to introduce changes and overcome well-known ‘resistance to change’. It does not mean that government will accept the recommended changes but it starts at least thinking about it.

UML modelling can be regarded as a tool providing solution for improvement of organisation of land information service and, thereby, reducing costs and increasing profitability. UML is a useful tool not only for technical specialists but also for surveyors and legal experts to analyse cadastral processes for their further improvement and revision.

To choose 'the right' diagram for analysis, researcher should clearly realise the final goal of research. Class diagrams better identify classes and their relationships, while activity diagrams are useful for visual presentation of succession of the activities and their logical framework. The interrelations between two types of developed diagrams are not sharply identified in the paper. It must also be noted that none of two diagrams emphasises the moment of change of property rights, i.e. the moment of transformation from one legal situation to another. Certainly, to discover it, other methods shall be applied or the used method shall be revised. The developed models of land privatisation are, however, both useful for scientific purposes.

The models enrich and deepen the ongoing discussion about further formalisation of the core cadastral domain model and simultaneously raise a question about initial harmonisation of the main cadastral processes by applying the land privatisation process in Belarus as a testing example.

The paper also states the possible future research issues whether it is possible to standardise the main cadastral processes or to distinguish any general components within a process that are present in many countries? Is it realistic to develop the core model of main cadastral processes?

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BIOGRAPHICAL NOTES

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SUB WORKING GROUP SESSION THEMES

The **specific goals** for the workshop are to bring together the different communities, publish the results and standardize the cadastral domain model, with emphasis on: 1. legal aspects, 2. formalization, 3. testing in countries, and 4. industry involvement. The workshop uses two types of sessions to obtain the results: 1. presentations and discussion sessions (the normal type of session at workshop, symposium or conference) and sub working group sessions (SWG). During the SWG sessions smaller groups are working on a specific topic and try to make a list of relevant questions (the 'research agenda'), and next try to answer a number of these questions (or try to describe approaches to answer the questions, in case of larger open research problems). Every SWG has a chairperson, trying to organize and structure the SWG sessions (two parallel sessions on each topic). At the plenary closing session, the SWG chairpersons will present the main results related to their SWG theme.

1. LEGAL ASPECTS

Chairperson: Yerach Doytsher

The current FIG core cadastral domain model puts a lot of attention to the geometric side of the model. To get the model back in the right balance also the legal/administrative side of the model should be further developed. This covers aspects such as: rights of persons to lands, customary and so-called 'informal rights', 3D aspects, legal and survey based source documents. Some of the open questions for the sub-working group are:

1. Is there one general legal model (which can be used in every country, of course with applying specialization and adding some specific local classes/attributes/associations) or are the two or more fundamentally different general legal models?

2. Has the electronic of digital conveying of property ownership documents (both complete parcels or parts of parcels to be transferred) any effect on the model?

3. Should the focus be on the static side of the legal model (UML class diagrams) or should it also include the dynamic side of the model (e.g. UML activity diagrams)?

4. If complete groups of rights (or restrictions) have the same model structure (that is, the same attributes, associations, and constraints), but within a group clearly reflect a range of different rights, should there be an attempt to make an enumeration of the right types (one overall list or per country)? How is any meaning/semantics attached to a certain right type in this enumeration (text document with description)?

5. Very often a RightOrRestriction is both positive ('Right' side) and negative ('Restriction' side), do both sides have to be mentioned explicitly in the model (with the danger of

inconsistencies) or is one side (positive 'Right' side) sufficient (and the other side can be derived from the model structure)?

6. Same type of question for a 3D cadastre situation: assume the basis is a 2D surface partition with parcels (representing infinite 3D columns) and bounded 3D parcels are then created as individual objects, should this space then also explicitly be removed from the infinite 3D column (or implicitly)?

7. What is the effect of having several legal actors involved in the process (surveyor, owner, buyer, the public, financial bodies, notary, municipality, land registry, cadastre), all allowed to perform certain steps (that affect the content/status of the model) in a kind of distributed systems (service/web-based) architecture? Should the model reflect this by indicating which actor is allowed to update which class (or attribute thereof)?

8. The common cadastral ownership model is "from the center of earth up to heaven". What about other models? What are the pros and cons regarding the different models? In view of developing nowadays the 3D cadastre in many countries, what are the legal limitations caused by the common cadastral ownership model "from the center of earth up to heaven" and how can it be solved?

9. In many countries there is a separation between the cadastral mapping and the legal ownership rights – in terms of two different agencies or governmental departments: a cadastral mapping unit handling the cadastral surveying and preparing the cadastral maps; and the registry unit handling the registration of cadastral ownership). Few countries are trying to define a different model and merge them into a unified department/agency being responsible both for the aspects of cadastre as well as the ownership rights. What are the pros and cons of these two models? Is it realistic to develop standard recommendations on the matter? Can they be adopted by different countries and societies?

2. FORMALIZATION

Chairperson: Christoph Schlieder

The current FIG core cadastral model is described in UML class diagrams (static model only). This implies certain formal semantics, but it has also its limitations. Specific formal ontology languages have been developed, which try to catch more semantics in machine-readable manner. Some of the open questions for the sub-working group are:

1. The first step of refinement of the UML class diagrams could be adding formal constraints to the model in the form of OMG's Object Constrain Language (OCL). Would this be applicable to the cadastral model (evaluate, show a number of OCL examples added to the model)?

2. How can this OCL-refined model be used in knowledge engineering based tools (e.g. to compare two different models and identify their differences and correspondences)?

3. What would more specific ontology languages (such as W3C's Ontlogy Web Language, OWL or OMG's Ontlogy Definition Metamodel ODM) add to the current core cadastral model?

4. What type of machine reasoning could benefit from having a more formal description of the model?

5. The current core cadastral domain model is limited to the static aspects; a lot of knowledge is also attached to the dynamic side of the model (the processes). What formal tools should be applied to the dynamic side of the model (and how is this related to the formal description of the static side)?

6. Would a more formal model (and the use of knowledge engineering tools) help in making the cadastral registrations in the different countries of Europe be more transparent, e.g. would it be possible to have 'one interface' fro information retrieval? The same for data (instances within the model) maintenance (both legal and geometric side)?

7. Assume that beside the core cadastral model, a number of models in related domains have been developed and formalized (e.g. topography, addresses, person registration, organization/business registration, subsurface mining registration, spatial development/planning, cultural history or monument registration, etc), what should (and can) we then do with knowledge engineering tools)?

8. Is it possible to check the related (other) domain models on overlap, (in) consistencies, and completeness? Should we try to harmonize these models (and perhaps adjust some of the individual models in order to make them fit)? Where and when does this harmonization stop as there may always be more remote (slightly related) domain models to consider?

9. Could knowledge engineering help in a distributed web environment (during the use and maintenance of the data within a formal model). E.g. certain constrains may be known at the source of the data, but what happens when a remote actor is updating a part of the model (in his local environment) and unaware of all constraints (at the source)?

3. TESTING IN COUNTRIES

Chairperson: Robert Dixon-Gough

The development of the current FIG core cadastral model has been based on the experiences of several persons in different countries and, in addition, several rounds of remarks (from different) countries in the world have been processed. However, this is an on-going activity and there is a difference is making remarks on the basis of a model described in a document or really trying to apply the model in a (prototype) implementation in a real world situation. Some of the open questions for the sub working group are:

1. When applying the model in a certain country (or developing a specialized model for a country), how much effort should be put into making this country model as similar as possible to the core model? For certain situations, two solutions might be possible. Firstly, with a 'little adjustment' the core model could fit. Alternatively, an alternative model could be proposed, which intuitively and more effectively fits the current thinking within this specific country, but possibly detracts from the emphasis of the core cadastral model. Which is the preferred approach?

2. In all probability, certain classes (attributes, associations, methods, constraints) will not be used in all countries. At what point should the decision be made that those classes be removed from the core model (since the core model should not be unnecessarily complicated).

3. Conversely, it will also turn out that certain classes (attributes, associations, methods, constraints) are missing and that this may be true for several countries. At what point should the decision be made that that these extensions do belong to the core cadastral model?

4. How should the maintenance of an (international) core cadastral model be organized (by ISO, FIG, OGC …)?

5. Besides COST G9 meetings and FIG Comm. 7 meetings, should there be a structured set of meetings where experiences with applying the core cadastral model (and related tools from industry) can be exchanged?

6. Should the model be structured in different modules (as is now already the case). Furthermore, are the current modules practical or should these be defined differently?

7. In order to become the reference standard in as many cadastral situations as possible, and not be too large and complicated, the modular approach could also be interpreted in the following manner: there is a set of obligatory modules (without which it could not be a true cadastral model) but, in addition, there may be some extensions which are not needed in all countries which, should they be required, are similar. These could be the

optional modules, ensuring that a certain kind of information/functionality is available. Can we define and describe these modules?

8. Is there a need to formalize the dynamic elements of the model? What are the expectations of this and are they feasible?

4. GEO-ICT INDUSTRY

Chairperson: Oscar Custers

Having a very nice model and even very well defined in a formal manner is one thing, but if this model is not used (applied), it is close to having no value at all!. Crucial in making it possible to apply the model is having tools available supporting this model in the environments of the users. For this purpose the role of the standardization institutes and industry is very important. For the industry it is also nice to have a situation that a cadastral solution (set of tools operation on the model) is not (too) specific for a certain country, because that would be an expensive development (for one customer). Having a shared model and implementations helps to lower the cost per actual implementation. Of course there will be different industry players competing, but when they base the solutions on the same model, it is better possible to meaningfully interface these tools form different vendors (e.g. during information exchange between different countries, or within different countries using tools from different vendors). Some of the open questions for the sub-working group are:

1. How can the relationship with OGC be seen within a Cadastral Environment (LandXML, LandGML, activities, domain models in other application area's)?

2. Supporting OGC standards for exchange of data is a different kind of level compared to the support of Models. What is the industry's view on supporting one generic Cadastral Model? If the industry player supports a certain Cadastral model, what rational is behind for the choice of this specific model? How does the core cadastral model fit in the product line of the relevant industry players, somehow the FIG core cadastral model assumes a 'model driven approach' (OMG's MDA). Are the tools from industry ready for this?

3. What is the need of an actual (interoperable) testbed environment; e.g. in the European context of EULIS (and INSPIRE in general)? Would one Cadastral Model be sufficient to service all Cadastres worldwide and how specific can such a model be? E.g. one country could be focusing on building up all information in a more 'basic' 2D environment where for other countries, Information Management and Publishing up to Cadastral Portals is of highest importance. To what extent should the Model be specified according to the industry as different strategies are taken by the specific companies? E.g. ESRI offers solutions around an SDE environment, Bentley around the Managed environment and InterGraph with a focus on InterOperability and Land Information Management. Is the

industry growing into solutions with great similarity? If so, (we should avoid a Sales Story/Functionality comparison in detail) it is important to discuss to what extent the model is to be defined or can be defined (and how these can fit within the future plans, 1, 3, etc. years).

4. Industry implementations of the model, what is the current status and what are the future plans of these in 1, 3, 5, or 10 years timeframe?

5. What would the Maintenance implications be of the model in case of changes to n the core model (role of OGC, FIG, ISO, …)?

6. What are the relationships to other related/overlapping domain models and how to keep the different related domain models consistent (harmonized)?

7. What is the vision of the companies versus to other related and (potentially) overlapping models? How important is it to be compliant with these models? Are the current or past implementations accordingly to these models?

8. How would a Cadastral Model integrate with Municipalities, internal and external Operational Systems e.g. tax operation/legal ownership, etc.

A Modular Standard For The Cadastral Domain

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SUMMARY

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

1. INTRODUCTION

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

In many global documents (Agenda21, Habitat, Johannesburg) land is considered as being an important issue. Main political objectives such as poverty eradication, sustainable housing and agriculture, strengthening the role of vulnerable groups (indigenous, women), are one way or another related to access to land, and to land-related opportunities. This definitely impacts on the policy of donor agencies (e.g. the English policy on 'better livelihoods for people', the German policy on 'land tenure in development cooperation', and the Dutch policy on 'business against poverty'), and on Poverty Reduction Strategy Papers for the Worldbank. How with this respect governments deal with the land issue, could be defined as 'land policy'. Having a policy is one thing, having the instruments to enforce the policy is another. Therefore governments need instruments like the regulations concerning land tenure security, the land market, land use planning and control, land taxation and the management of natural resources. It is within this context that the function of land administration systems can be identified: a supporting tool to facilitate the implementation of a proper land policy in the broadest sense.

The UN Land Administration Guidelines (UN/ECE, 1996) speak about land administration as the 'process of determining, recording, and disseminating information on ownership, value and use of land when implementing land management policies'. If 'ownership' is understood as the mode in which rights to land are held, we could also speak about 'land tenure'. A main characteristic of land tenure is that it reflects a social relationship regarding rights to land, which means that in a certain jurisdiction the relationship between people and land is recognised as a legally valid one (either formal or non-formal). These recognised rights are in principle eligible for registration, with the purpose to assign a certain legal meaning to the registered right (e.g. a title). Therefore land administration systems are not 'just handling only geographic information' as they represent a lawfully meaningful relationship amongst people, and between people and land. As the land administration activity on the one hand deals with huge amounts of data, which moreover are of a very dynamic nature, and on the other hand requires a continuous maintenance process, the role of information technology is of strategic importance. Without availability of information systems it is believed it will be difficult to guarantee good performance with respect to meeting changing customer demands. Organisations are now increasingly confronted with rapid developments in the technology, a *technology push*: internet, (geo)-databases, modelling standards, open systems, GIS, as well as a growing demand for new services, a *market pull*: e-governance, sustainable development, electronic conveyance, integration of public data and systems. Cadastral modelling is considered as a basic tool facilitating appropriate system development and re-engineering and in addition it forms the basis for meaningful communication between different (parts of the) systems.

Standardization is a well-known subject since the establishment of cadastral systems. In both paper based systems and computerized systems standards are required to identify objects, transactions, relations between real estate objects (e.g. parcels) and persons (also called subjects in some countries), classification of land use, land value, map representations of objects, etc. etc. Computerized systems ask for even further standardization when topology and identification of single boundaries are introduced (Van Oosterom, Lemmen, 2001). In existing cadastral systems standardization is limited to the territory or jurisdiction where the cadastral system is in operation. Open markets, globalisation, and effective and efficient development and maintenance of flexible (generic) systems ask for further standardization. In (Van Oosterom, Lemmen, 2003) an overview is given of the following initiatives and developments:

1. Land Title and Tenure SIG: first initiative of the OpenGIS Consortium (OGC) in 2000.
2. Several standardization initiatives and developments in Cadastral Organizations
   - Introduction of ISO Standards in Germany (Seifert, 2002)
   - US National Integrated Land System (FGDC, 1999, Meyer, von *et al.,* 2001)
   - Initiatives from Australia and New Zeeland (LINZ, 2002, LandXML, 2002, ICSM 1999, 2002)
   - Initiative from Sweden: The EULIS project (Ollén, 2002)
3. COST Research Activity Statement
4. The International Federation of Surveyors, FIG (Greenway, 2002)

Further initiatives can be recognised in Europe: INSPIRE is “an initiative to support the availability of spatial information for the formulation, implementation and evaluation of Union policies” . 60 spatial data components, grouped around 17 theme’s have been identified as important data-sets, among others topography, *cadastral properties,* geographical names *administrative area’s, postcodes, buildings and addresses,* terrain elevation and orthophoto’s. INSPIRE ‘intends to set the legal framework for the gradual creation of a spatial information infrastructure’. INSPIRE can be considered as an outcome of the 6th Environmental Action Program 2001-2010 of the EU. (www.ec-gis.org/inspire).

After the ‘false start in 2000’, the OGC now seeks sponsors for Property and Land Initiative as announced in a press release of March 25, 2003: ‘The Open GIS Consortium, Inc. (OGC) is issuing a Call for Sponsors for a Planning Activity that may support future development of an OGC Property and Land Information (PLI) Initiative. This planning activity will seek interested sponsors to provide input on technology requirements and concepts to foster development of next-generation interoperable networked architectures and capabilities to enable broader sharing and application of property data and land information between collaborating organizations’. And: ‘The ultimate goal of the OGC Property and Land Information Initiative is to promote increased understanding of the application of OpenGIS® Specifications to the challenge of cross-organizational and cross jurisdictional access to critical information. The Initiative would seek to design, test and operationally validate open architectural frameworks for distributed property and land information networks. As part of the growing “Spatial Web”, these networks will allow information to be easily exchanged between consumers, governments, and businesses for many different purposes. This information would be accessible online through OpenGIS Interface Specifications and other standards consistent with best practices defined as part of National and Global Spatial Data Infrastructures and E-Government initiatives. This initiative will demonstrate how standards-based distributed networks of databases and information services can help consumers and citizens to access vital data, businesses to offer premium customer services, and governments to provide more effective service to citizens’.

This paper continues in Section 2 with an overview of the progress made so far in the development of a standardized Cadastral Domain Model based on the geographic standards from ISO and OGC (OpenGIS). This cadastral model is developed in cooperation with the FIG, the research is also related to the framework of the COST (Co-ordination in the field of Scientific and Technical Research) Action G9: ‘Modelling Real Property Transactions’. Alternatives for 3D Cadastral modelling are discussed in Section 3 and the dynamic nature of Cadastral systems is elaborated on Section 4. The main conclusions and future work are finally described in the last section.

2. CADASTRAL DOMAIN MODEL

The core of the cadastral domain model as depicted in Figure 1 is the central part of the model as was already presented at the FIG working week in April 2003, Paris (Lemmen, Van Oosterom 2003). It shows the Unified Modeling Language (UML) class diagram, which represents the result of the previous work. The relationship between real estate objects (e.g. parcels) and persons (sometimes called ‘subjects’) via rights is the foundation of every land administration. Besides rights, there can also be restrictions between the real estate objects and the persons. The figure shows that RightOrRestriction is an association class between the classes Person and RealEstateObject. Note that this an n-to-m relationship, with the conditions that every persons should at least be associated with one RealEstateObject and vice versa every RealEstate object should be associated with at least one Person (indicated in the UML diagram with the multiplicity of ‘1..*’ at both ends of the association).

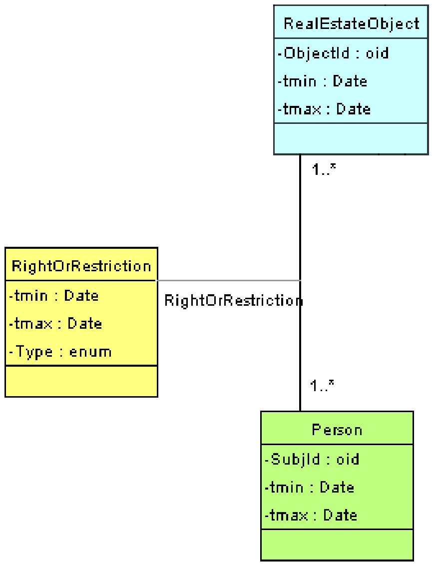


Figure 1: Core of the Cadastral Domain Model: Person, RightOrRestricton, RealEstateObject.

When presenting or trying to describe a model, one always faces the question 'how to describe this model for domain experts (non-technical end-users, managers, but not modeling experts)?'. This question reappears in every context where models are developed. Textual descriptions alone are difficult to understand, as the model structure may not be visible. For this purpose all kinds of diagrams have been developed with 'boxes and arrows'. However, every time the 'boxes and arrows' did have a different meaning, which made general understanding, even by modeling specialists, difficult. Therefore, the Object Management Group (OMG, see Booch, Rumbaugh, Jacobson, 1999) standardized the main types of diagrams and the meaning of 'boxes and arrows'. In this paper we will mainly use UML class diagrams to describe the cadastral domain model. There are several other types of UML diagrams. Normally the modeling starts with the development of use case diagrams (for this work we refer to the COST Action G9 'Modeling Real Property Transactions'). In this paper we start with the class diagrams as these are the most 'stable' and independent of organizations and actors. UML class diagrams are reasonably well suited to describe a formal and structured set of concepts, that is an 'Ontology' (Gruber, 1993). This is one of the main results from our attempt to develop a Cadastral domain model. Experiences (in other domains) show that it is still not easy to read these diagrams. The solution used in this paper is to use 'Literate Modeling', that is UML diagrams embedded in text explaining the models. More details and discussion on Literate Modeling, with examples from British Airways, can be found in (Arlow, Emmerich and Quinn, 1998).

A UML class diagram describes the types of objects and the various kinds of structural relationships that exist among them like associations and subtypes. Furthermore the UML class diagrams show the attributes and operations of a class and the constraints that apply to the way objects are connected (Booch, Rumbaugh, Jacobson, 1999). The proposed UML class diagram for the cadastral domain contains both legal/administrative object classes like persons, rights and the geographic description of real estate objects. This means in principle that data could be maintained by different organizations, e.g. Municipality, Planning Authority, Private Surveyor, Cadastre, Conveyancor and/or Land Registry. The model will most likely be implemented as a distributed set of (geo-) information systems, each supporting the maintenance activities and the information supply of parts of the dataset represented in this model (diagram), thereby using other parts of the model. This underlines the relevance of this model; different organizations have their own responsibilities in data maintenance and supply and have to communicate on the basis of standardized processes in so called value adding production chains.

One should not look at the whole model (all packages together as presented at the end of this section) at once as the colours are representing UML 'packages' or coherent parts of the model: green and yellow: legal/administrative aspects, green and blue: real estate object specializations, blue, pink and purple: geometric/topological aspects. It is likely that more packages will be developed. Besides being able to present/document the model in comprehensive parts, another advantage of using packages could be that it is possible to develop and maintain these packages in a more or less independent way. Domain experts from different countries could further develop each package. It is not the intention of the model that everything should be realized in one system. The true intention is that, if one needs the type of functionality covered by a certain package, then this package should be the foundation and thereby avoiding reinventing (re-implementing) the wheel and making meaningful communications with others possible. Furthermore basic packages could be implemented by software suppliers, e.g. GIS suppliers like ESRI are providing models for several domains like agriculture, topographic mapping, biodiversity/conservation, defence, energy utilities, environmental regulated facilities, forestry, geology, historic preservation, hydrograpic/navigation, marine, petroleum, pipeline, system architecture, telecommunications, urban, water utilities, water resources. One domain of interest for ESRI is Cadastre 2014 (Kaufmann, Steudler, 1998). The principles op Cadastre 2014 are integrated in our approach. In the following subsections the different packages will be described in more detail.

2.1 Specializations of RealEstateObject: object detail classes

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

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

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

Parcel's are defined by ParcelBoundaries and have a geometric/topological description (Oosterom, van, Lemmen, 2001). The class ParcelBoundary always has two neighbour PartitionParcel's, where territorial ParcelBoundary's have one 'zero-Parcel' as neighbour, representing the external territory. There can be more then one ParcelBoundary between two neighbour PartitionParcels, depending on attributes and the geometric configuration. Exclaves and enclaves from territorial perspective can be managed in this approach. In general this approach implies that individual PartitionParcels, and therefore also the derived classes Parcel and ServingParcel, are not explicitly represented as 'closed polygons'. Attributes can be linked to individual boundaries; this allows for example classification of individual boundaries based on the administrative subdivision of the territory. In this way double, triple or multiple storage of the same boundary can be avoided, thus avoiding all kind of 'gap and overlap' problems, which don't have a meaning in reality.

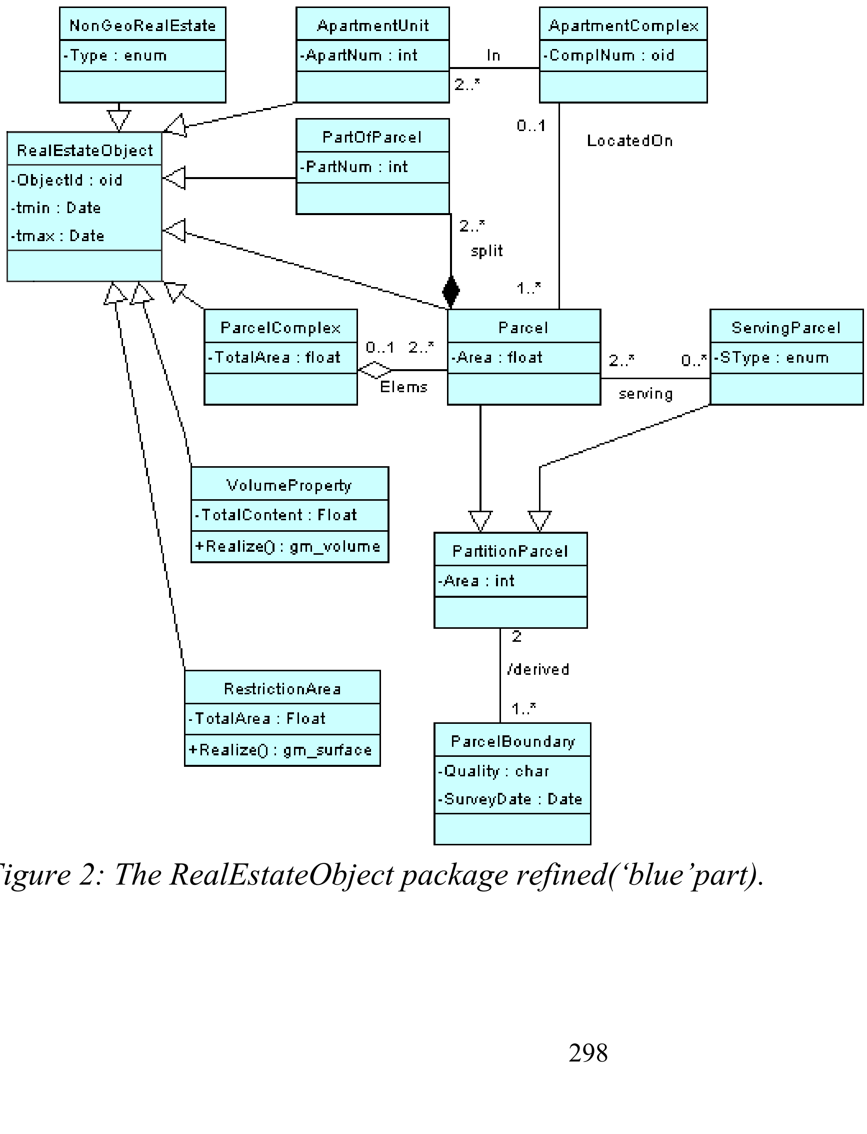


Figure 2: The RealEstateObject package refined('blue'part).

In most cadastral systems a restriction is associated to a complete RealEstateObject (Parcel) and this is also reflected in the presented model: a Person can have a (RightOr)Restriction on a RealEstateObject (there are also PublicRestrictions; see section 2.5). However, this may be inconvenient in some cases: one 'thing' may cause the restriction on many RealEstateObjects and in such a case this information has to be repeated many times (with all possibilities for inconsistencies). Further, a restriction might also cover/affect only a part of the RealEstateObject, but it is not (yet) registered which part this is. A better solution for this situation is to introduce a new layer (in addition of the planar partition of the PartitionParcels) with RestrictionAreas (comparable with 'Cadastre 2014', Kaufmann and Steudler 1998, Kaul and Kaufman, 2003). These can be considered as a kind of RealEstateObjects 'overlapping' other RealEstateObjects, from which they 'carve out' a part of the associated rights. We would suggest to maintain only the 'positive' rights, that is not explicitly store (for one Person) that another Person has a part of the rights, in the cases where the 'positive' right holder is known (see also section 2.4). This can be obtained via inspecting all rights associated with the RealEstateObject and the overlapping RestrictionArea's. Note that RestrictionArea's are modelled as closed polygons (and obtain their coordnates from SurveyPoint's, see section 2.3) and there is no explicit topology between RestrictionArea, that is, they are allowed to overlap (and it is expected that they will not often share common boundaries as Parcels do).

Because of the high pressure on the use of space, more and more situations occur which can best be modelled in three dimensions. Normally a (2D) Parcel represents the whole 3D column from the center of the Earth, trough the surface out into the sky. Explicit 3D VolumeProperties 'carve out' a part of this space in favour of another Person (the buyer of a 3D VolumeProperty). It is possible that one VolumeProperty overlaps with many Parcels (again this can be obtained via spatial overlay). In the same manner as suggested for RestrictionAreas, we suggest that it is best only to register the 'positive' side of the registration without redundancy. VolumeProperties are modelled without external topology, but with internal topology by referencing several times to the same SurveyPoint, when this is shared between the different faces of a polyhedron. VolumeProperties should not overlap in 3D space. However, their projection in 2D space may overlap. It is expected that it will not happen often that VolumeProperties will share faces with other explicit VolumePropties (as is the case in 2D with the PartitionParcels). Might this assumption turn out to be wrong, then a 3D topological structured model should be introduced. More background and discussion on alternative 3D cadastral modelling can be found in section 3.

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

2.2 Surveying Classes

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

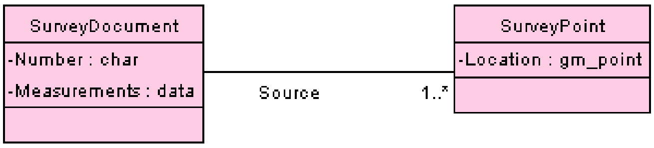


Figure 3: The Survey Package, 'pink'.

2.3 Geometry and Topology: imported OpenGIS classes

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

Parcels have a 2D geometric description. A Parcel corresponds one-to-one to the tp_face in a topological structure (as defined by ISO TC 211 and OpenGIS Consortium). A face is bounded by its edges in 2D. An edge is related one-to-one to a ParcelBoundary, which may contain non-geometric attributes as explained in 6.2. Every edge has exactly two end points, represented in tp_nodes. In addition, an edge may also have several intermediate points. Both intermediate points and nodes are associated with SurveyPoints. The topological primitives tp_face, tp_edge and tp_nodes, have all a method ('operation') called 'Realize' which can be used to obtain a full metric representation.

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

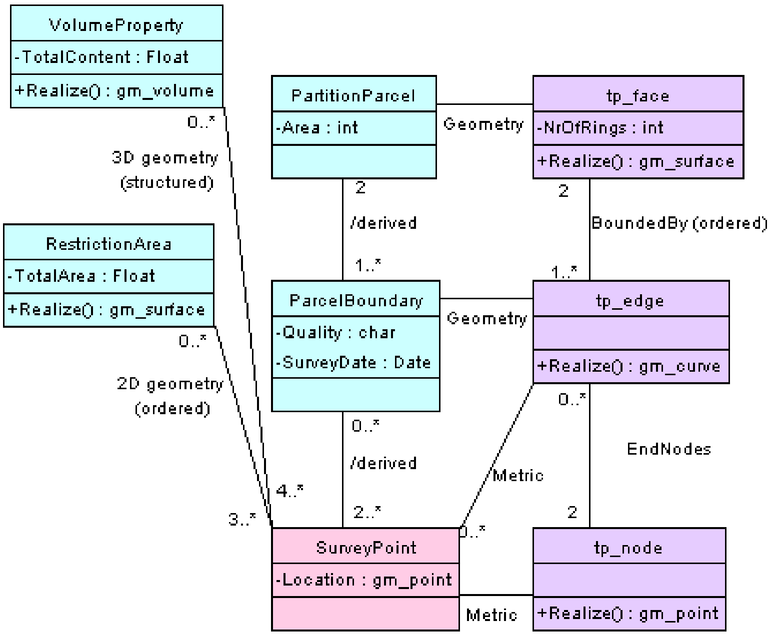


Figure 4: The Geometry, Topology and some related packages, purple.

2.4 Legal/Administrative classes

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

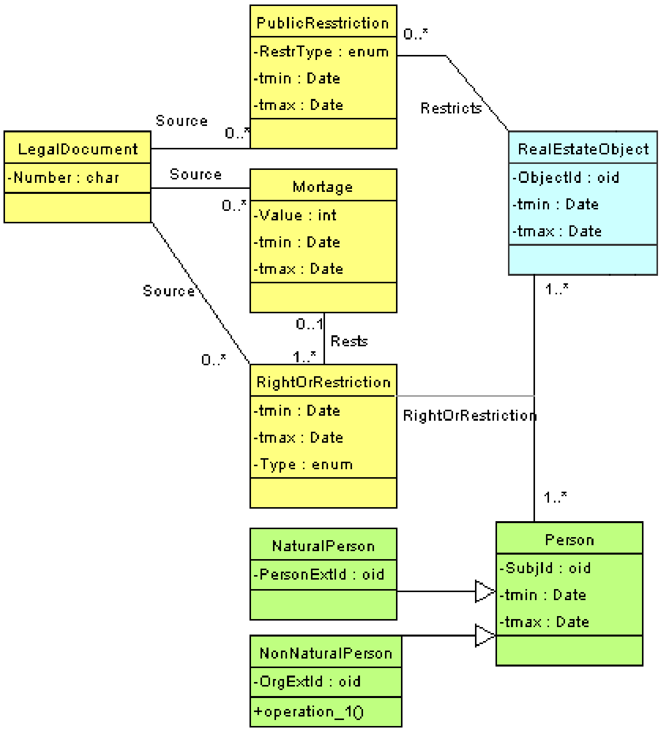


Figure 5: The legal/administrative classes (yellow) and person classes (green).

Each jurisdiction has a different 'land tenure system', reflecting the social relationships regarding rights (and restrictions) to land in that area. The variety of rights is already quite large within most jurisdictions and the exact meaning of similar rights still differs considerably between jurisdictions. Usually one can distinguish between a number of categories of land rights.
Firstly we have the strongest right available in a jurisdiction, called e.g. ownership, freehold or property.
Secondly we have derived rights from the previous category where the holder of this derived right is allowed to use the land in its totality (often within the limits of a certain land use type, e.g. housing or animal farming).
Thirdly we have minor rights that allow the holder of it to some minor use of someone else his land, e.g. walking over it to the road. Such rights can be called servitude or easement, and also may include the right to prevent certain activities or construction at some nearby land, e.g. freedom of view.
Fourthly we have the so called security rights, whereby certain of the previously mentioned rights can be used as collateral, mainly through bank loans, e.g. mortgage, hypothec, lien.

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 losing something (who sees his right restricted by the newly created right). The rights and restrictions we are concerned with here usually remain valid, even if these persons change after the right was created (and registered). This is called a right *in rem* in many jurisdictions. There is a difference between legal systems and registration approaches in whether rights, other than under a), are formulated and recorded primarily as the right of the holder, as a restriction to the right (or object) they are 'carved' out from, or both. The last solution is of course risky from data management point of view, since inconsistencies can arise.

Because property and ownership rights are based on (national) legislation, ‘lookup tables’ can support in this. E.g., the right of ‘ownership’ might be ‘Norwegian Ownership’, ‘Swedish

Ownership', etc. etc. 'Customary Right' related to a region or 'Informal Right' can be included; from modelling perspective this is not an item for discussion. Of course, for the actual implementation in a given country or region, this is very important.

In addition to 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 abstract (either "the government" or "society-at-large") and usually they are primarily seen as restrictions. Some of them apply to a specific RealEstateObject (or right therein) or a small group of them. E.g.. most pre-emption rights, or the duty to pay a certain tax for improvements on the road, or the duty to repair damage or perform belated maintenance. Others have their own area of application, like whether there is soil pollution present, flood plains, (re) zoning of areas (esp. when urban development is made possible in a rural area).

Each restriction type has its own place in the cadastral domain model. Public restrictions with their own areas can be recorded via the RestrictionArea class, not being linked to a specific holder. Obviously the documents on which they are based need to be included. Public restrictions, which apply to RealEstateObject's but have no clear beneficiary, are recorded as PublicRestrictions. Other restrictions should be recorded as well as possible as rights in the name of the holder, but in certain countries some types do not state the holder (or the holder is a neighbouring RealEstateObject, regardless of who holds that RealEstateObject). In such cases the restriction as such is recorded on the RealEstateObject, often without a person connected to it. Nevertheless, the most vital rights are usually in the name of a person, like ownership, leasehold or usufruct. Security rights differ between jurisdictions. Sometimes the holder of the right (e.g. bank) is recorded, in other cases there is only a restriction recorded, informing others someone already has a security right on this RealEstateObject (often only a defined, and often recorded, amount of money is secured, and a second or third mortgage could be created). For every RightOrRestriction it is important that it is made clear how it is recorded. In all cases the relevant source LegalDocument(s) should be associated. One should finally be aware that in most jurisdictions certain use rights and certain security rights can exist totally outside the registration system. These so called 'overriding interests' are valid, also against third parties, without registration. Examples can be rent contracts for shorter periods, certain agricultural tenancy agreements, and 'liens' by tax authorities.

The abstract class 'Person' (that is again a class without object instances) has as specialisation classes NaturalPerson or NonNaturalPerson like organisations, companies, co-operations and other entities representing social structures. If a Person is a NaturalPerson it cannot be a NonNaturalPerson and the other way around. That is, NaturalPerson and NonNaturalPerson are mutual exclusive.

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

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

2.5 History and dynamic aspects

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

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

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

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

Besides the data modelling aspect of the dynamic processes within the Cadastral Domain, one could question how are the functions and processes related to each other? Focus of the work until now has been on the UML class diagram, that is, the structural aspect. The UML class diagram should further be completed by diagrams covering other aspects, e.g. via state (use case, sequence, collaboration, state or activity) diagrams. Figure 6 shows a state diagram of the splitting of a parcel. Activity diagrams show how processes are related to the information (data) and how one 'flows' from on to the other. In all the other mentioned types of UML diagrams, actors or organizations play an important role and this may be quite dependent on that (national) set-up. The introduction of different 'stages' of a parcel (one-point, image, surveyed), a right (start, landhold, freehold) and a person could further reflect the dynamic nature of the system. More background discussion related to the dynamic aspects of a cadastral system can be found in section 4.

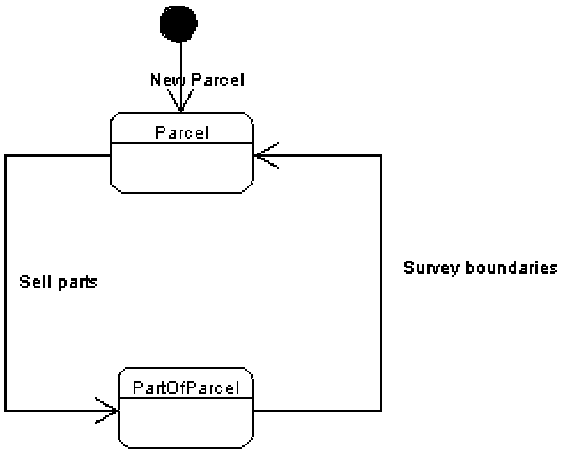


Figure 6: State diagram of splitting a PartionParcel. If a part of a parcel is sold, the parcel is split into several PartOfParcels, which become regular parcels again only when their boundary is surveyed.

2.6 Further developments

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

GeodeticReferencePoints, could be a specialization of SurveyPoint. This will make SurveyPoint an abstract class with CadastralSurveyPoints and GeodeticReferencePoints as its specializations. Further specialization could be CadastralCentroidPoint, in case only one point of a Parcel or NonGeoRealEstate is observed, see Jackson 2002.
Higher level administrative units (aggregations: sections, municipalities,...) and the relationship to the lower level units. If possible redundant storage of the geometric and topological data should be avoided.
Land consolidation/reform, urban development, urban and rural cadastres
Links to external registrations could include:
Persons (e.g. via fiscal person identifier, or other approved identifiers)
Companies/organizations (e.g. chamber of commerce)
Addresses and zip codes, related to objects *and* subjects
Buildings or more general, topographic data, in relation to core cadastral data.

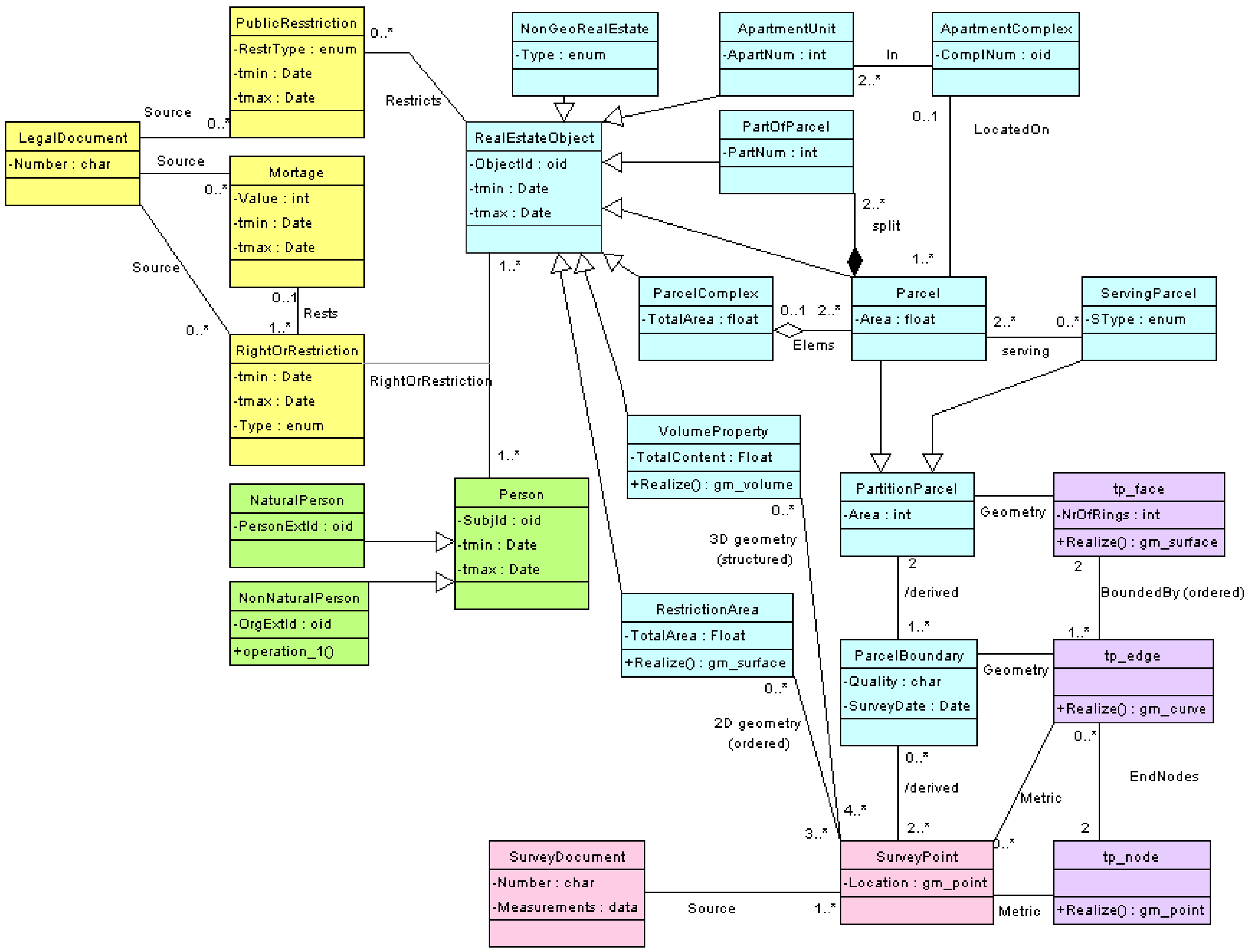


Figure 7: the 'complete' cadastral core model, version 3.0.

3. THREE DIMENSIONAL ALTERNATIVES/EXTENSIONS

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). In the previous section the VolumentricProperty was introduced, but this requires a significant change in the legislation in most countries. Therefore in this section some alternatives (with less legal impact and based on the well known concept of the 2D parcel) for 3D situations are presented together with their UML class diagrams. In addition to the 3D legal volumes, the 3D constructions themselves cannot be queried in current cadastral registration systems, for example it is not possible to perform a query such as 'who is the owner of this tunnel?'. To overcome these limitations, the 3D aspect should be incorporated in the core cadastral data model. Two alternatives to the VolumetricProperty of the core cadastral data model have been introduced in the 3D cadastre research (Stoter and Ploeger, 2002; Stoter and Ploeger, 2003). These will be described in this section.

3.1 Registration of the 3D extension of rights

The first alternative is just a simple extension of the core model: the introduction of a 3D right-object. The 3D right-object is the 3D representation of a right that is established on a parcel for a

3D construction (Stoter and Ploeger, 2002). The 2D extent of a 3D right-object is the actual parcel-boundary. The upper and lower limits of the 3D right-object are the upper and lower limits of the space where the right applies (Stoter and Ploeger, 2002). The 3D right-object gives insight in the vertical dimension of the rights established. For example when a railway tunnel crosses a parcel and a right of superficies is established on the parcel, the 3D right-object is the 3D description of the space where the right applies. This example is illustrated in figure 9. For this example new (fictive) parcel boundaries were created in order to avoid that parts of parcels that do not overlap with the tunnel are affected with a right of superficies. With the 3D right-objects it is possible to see that the rights are established for an underground construction, also the depth and height of the construction is visible, which is not visible on conventional cadastral maps. The UML class diagram of 3D right-objects is shown in figure 8. For every right that is established on a parcel and that concerns a complex situation (one parcel is used by more than one person) a 3D right-object is maintained. This contains the 3D representation of the right, which is also maintained in the DBMS.

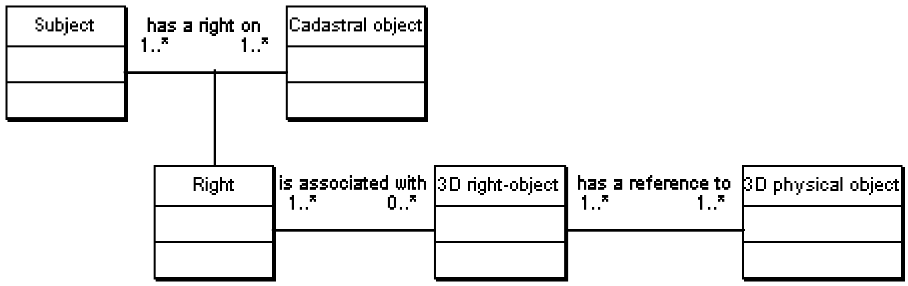
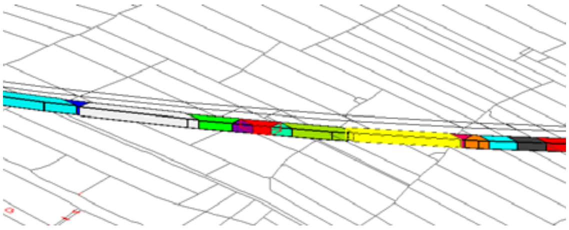


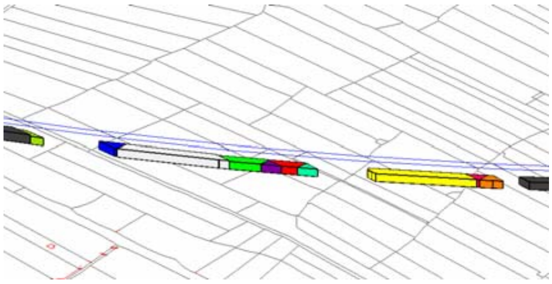
Figure 8: UML class diagram of 3D right-objects.

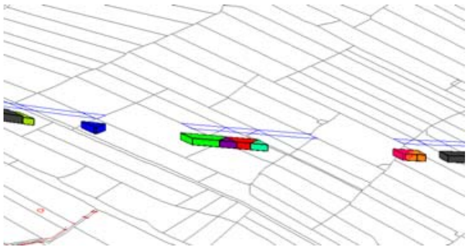
One 3D right-object can be associated with more than one right, e.g. if a tunnel is held by two subjects. One 3D right-object can have a reference to more than one physical object. For example when two tunnels held by one subject cross a parcel and only one right is established for the two tunnels. All 3D right-objects belonging to one physical object can be found since they refer to the same 3D physical object. The factual ownership of a volume of space can be found by tracing the subject(s) that has/have the right that is associated with the 3D right-object. The data model needs some adjustment compared to the current cadastral model, but the principle of the 2D parcels as basic objects remains the same. The registration of a 3D right-object will not take place if only one subject has the complete right on a parcel. For the tunnel the registration of 3D right-objects will not take place, when the Ministry of Transport and Public Works owns the intersecting parcel. This leads to 'gaps' in the 3D registration. This is clearly illustrated in figures 9b and 9c. Figure 9b shows the situation when new parcels are created and some of these parcels are in full ownership with the Ministry. For those parcels a 3D right-object will not be created (the Ministry owns the whole parcel column). The situation is even less clear in figure 9c. This will be the case when both new parcels and the original undivided parcels are in full ownership.



(a, left)

(b, right)





(c)

Figure 9: 3D right-objects representing the 3D extent of rights established on 2D parcels for a railway tunnel owned by the Ministry. Figure a: all the parcels are encumbered by right of superficies, new parcels are created for all intersecting parcels. Figure b: as figure a, but now three newly created parcels are in full ownership of the Ministry. Figure c: three newly created parcels are in full ownership, two parcels that are not subdivided are in full ownership. All the other (new) parcels are encumbered with a right of superficies.

3.2 Legal space of object is registered

How to know the actual location of the tunnel and to avoid the 'gaps' in the registration? The only solution is the registration of the complete construction itself, as is shown for the railway tunnel in figure 10. This would be the most optimal solution to register 3D situations and is the second alternative proposed: registering the 3D physical object itself together with a spatial description of the legal space of the object. The legal space 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). Note that this solution does not introduce the possibility to register 3D physical objects as real-estate objects. The cadastral registration of the legal status of real estate is still based on 2D parcels.

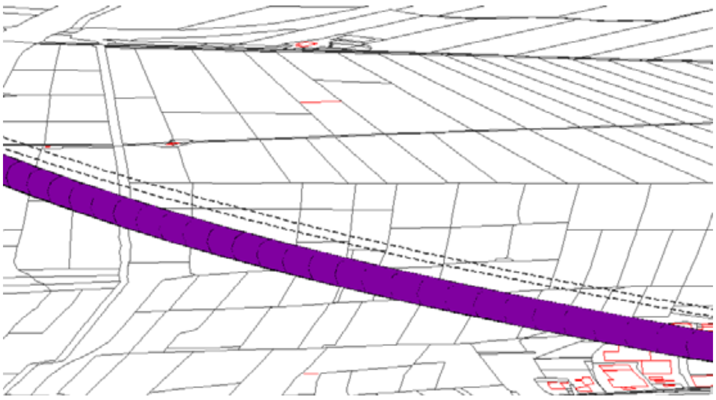


Figure 10: Registration of the legal space of the railway tunnel. The dashed line is the projection of the tunnel on the surface. Note that the parcels are not divided into smaller parcels.

The UML class diagram of this registration is shown in figure11. Apart from parcels (cadastral objects), 3D physical objects are also registered. The holder of the 3D physical object is a subject with a right on the intersecting parcels established for the 3D physical object (factual ownership, which is not the same as the juridical ownership). This can be right of superficies, but also complete ownership. In general the holder of a 3D physical object is the person or organization who is responsible for the 3D physical object, and uses the object as if he were the owner. Rights and limited rights are still registered on parcels. The only right that a person can get on a 3D physical object is that he can become the holder of this object. Therefore, a 3D physical object is not a subset of cadastral objects: 3D physical objects are maintained in addition to 2D parcels.

The juridical relationship between the legal space of the 3D object and the intersecting parcel(s) is stored implicitly, because the holder of a 3D physical object is maintained. This is the same (non-natural) person who has a right on the intersecting parcels. The solution of registering the legal space of 3D objects compensates many limitations of current cadastral registration. The intersecting parcels still need a right referring to a 3D construction, but the parcels need not to be divided into smaller parcels. The spatial relationships between parcels and the (legal space of the) 3D physical object can be maintained with spatial functions in the DBMS.

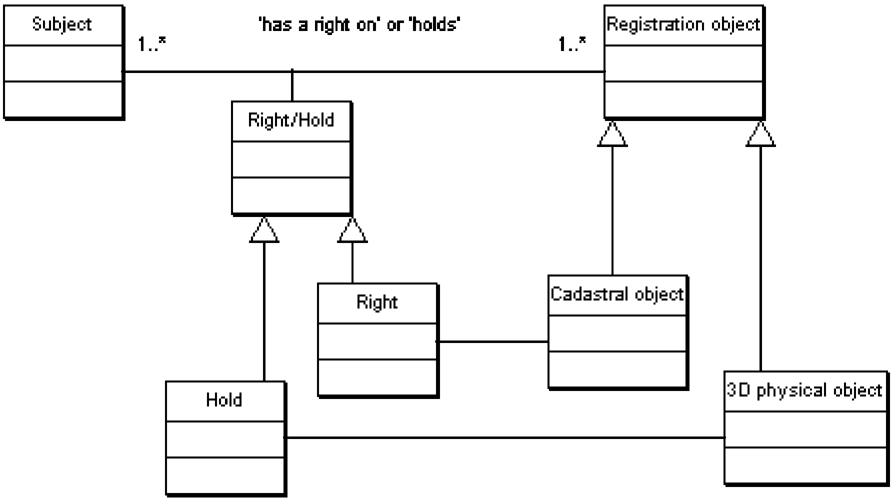


Figure 11: UML class diagram of 3D physical objects.

4. DYNAMIC ASPECTS OF THE MODEL

The dynamic nature of land tenure is a major challenge for cadastral modelling. In section 2.5 we discussed some structural aspects of the dynamic cadastral systems, mainly at an overview level in the model. In this section some more details and considerations are presented. In the first place there is variety of forms of tenure (Toulmin & Quan, 2000), (Zoomers & Van Der Haar, 2000) and it is possible to switch between these forms, and 'upgrade' of the right. Regarding private tenure there are for example rights to land with an unlimited duration (like freehold, ownership, mulk), rights with limited duration (like leasehold and miri), condominium and strata title, rents, derived rights like usufruct, superficies, easements, mortgages, and forms of adverse possession. Regarding public forms of land tenure we observe crown lands, state lands, parastatal lands, and various forms of public interest in land (like encumbrances pertaining to land use regulations, pre-emptive rights, expropriation). Also land rights within the customary law and tradition are more and more considered as being 'legal' moreover it they are recognised explicitly by statutory law. Without such a recognition however one could assume they within the jurisdiction of the customary tradition they are as valid as written law. Various forms are tribal lands, collective lands, individual use rights, secondary rights (right to collect firewood, grazing after harvest, water rights, berry picking etc.), and pastoral rights (grazing lines, corridors, reserved grazing areas). The dynamic nature of land tenure does not pertain to the normal land market and land development (land reform) only, it reflects also the evolving rights to land in countries where adjudication and cadastral boundary survey that results in the issuing of full fletched titles to land (freehold) is considered as being much too expensive and too demanding. New right top land are evolving, such as native title (Australia, USA, Canada), Maori title (New Zealand), certificates of customary ownership and occupation certificates (e.g. Uganda), co-titling (e.g. Mozambique), starter and landhold title (e.g. Namibia), cadastral certificates (Albania), village titles (e.g. Tanzania), to name a few. Also quite a few countries are attempting to integrate their customary tenure in the statutory environment, such as the new land laws in Uganda (1998) and Mozambique (1998), Namibia (pending), South Africa Communal Property Bill (pending), Bolivia INRA-law (1996), Ghana Constitution (1992).

Similar innovative concepts (Fourie et al, 2002) are observed for the geometric component of land administration, where a well known guiding principle for the cadastre 'specialty', requires an good identification of the land parcel that is subject to the execution rights, normally by the survey of its boundaries. Apart from the dynamics of the land parcel as the result of the land market and land development (subdivision, consolidation, redistribution, restitution etc.) new forms of identification are mentioned such as midpoint co-ordinates only, topographic visualisation (similar to the application of the general boundary rule in e.g. in England and Wales) and alike (Jackson, 2002). All these examples might provide some evidence that the creation of core cadastral domain models might be of a complex nature, and is a challenge. However the driver for the development of a core cadastral domain is the basic concept of a relationship between people and land, whatever right holders, whatever rights, and whatever land object. The here presented dynamic aspects could be represented in the proposed model, further research is required to verify this.

5. CONCLUSION

A core cadastral data model should serve at least two purposes:

Enable effective and efficient implementation of flexible (and generic) cadastral information systems based on a model driven architecture (as argued in this paper), and
Provide the ‘common ground’ for data exchange between different systems in the cadastral domain.

The later one is a very important motivator to develop a core cadastral data model, which could be used in an international context; e.g. the EULIS project. The OpenGIS Consortium ‘Property and Land Information Initiative’, as announced in March 2003, underlines the relevance of standardisation. We would again like to emphasize that the current (third) version of the Core Cadastral Domain Model is just a proposal; it is incomplete and may even contain errors. We would like to encourage everybody to participate in the further development of this model in order to make this standardization effort really work. Worldwide many efforts can be recognized related to standardization in the cadastral domain. It is again proposed here to join forces between FIG and OpenGIS (ISO TC211) and to establish an OGC SIG for the Cadastral Domain. The activities of this SIG could be organized in close co-operation with the FIG. The introduction of a de facto standard on the cadastral domain, which is OpenGIS compliant, is a substantial effort. In any case there should be sufficient support world wide.

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