ArcGIS Cadastre 2014 Data Model Vision

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This document describes the Cadastre 2014 vision and a high-level approach for implementation using modern GIS software.

ArcGIS Data Models

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1 Introduction

Cadastral systems have a long tradition. Egypt has had such an institution since about 3000 BC. The Romans, particularly under Emperor Diocletianus in the 3rd century AD, introduced land inventories in occupied territories. Also in China a taxation system was developed for land. Spain introduced its first cadastre for taxation purposes in 1714. The colonialists in the late 19th and early 20th century introduced systematic inventories on land in the colonies to enforce their power. The purpose of the cadastres has changed over time. Initially, taxation was the main purpose, later on juridical cadastral systems for land use control were established; and after private land ownership became more common, the systems were providing security and reliability and became a basis for land markets.

For more than 100 years the cadastre has played an important role in the development of land markets and thus strengthened the economies in the Western countries. This role was a successful one. The positive effects of functioning cadastral systems within stable formal property systems have been described by Hernando de Soto in 'The Mystery of Capital' - Why Capitalism triumphs in the West and fails everywhere else. [de Soto, 2000}.

After the radical changes in the former communist countries, the cadastre has gained importance to secure the newly created private land rights and to support the emerging land markets in the transition nations.

But also in all countries where private land ownership or even land use rights of the citizens exist, cadastre is an important issue. Without a reliable documentation on the legal situation concerning land, economic development is hampered. Cadastres together with the land registries help to transform the land rights and resources into tradable assets. Cadastres and land registries document and localize pieces of land, which are objects of ownership or land use rights, which are defined in the constitutions and laws in many countries of this world. The guarantee of these rights proved to be a source of economic growth and social welfare.

The concept of private right documentation can be considered a big success, despite of some insufficiencies in some countries. Hernando de Soto has described the economic and social importance of a functioning cadastre and land registration in his book [De Soto, 2000]. A long time has passed since the cadastral and land registration systems have been introduced. And the issue has not lost its importance. There are many cadastral projects and reform projects going on, based on traditional and successful concepts.

But the context of the resource 'land' has changed during the last century. A growing world population, an increasing mobility of people, an impressive economic growth in parts of the world, an increasing resource consumption, and globalisation all contributed to a need for regulations to organize the cohabitation of more and more

people, to protect the environment from being destroyed by the activities of humankind, and to balance the social situation.

Especially after World War II a growing number of legal regulations concerning land use, environment protection, resource management, etc. were created.

The arrangements of these new legislations have effects on the traditional exclusive power given to the landowners by the modern institutions and the land or civil codes. Additional restrictions and also more rights concerning the resource 'land' which often includes other real property assets, were created.

The absence of a systematic, well-defined and public documentation system about these additional rights and restrictions creates an increasing legal insecurity. Landowners, investors and administrations are therefore confronted with additional efforts to find out what legal situation they have on their properties or in areas, where they intend to invest in. Politicians have taken up the issue and are asking for systematic registration of restrictions and rights on land. They imagine to enlarge the content of the land register and to enter there the information about restrictions. This solution proves not to be feasible, because land registries focus on the documentation of ownership and possession rights. The objects of the registration are in principle the land parcels, often connected with further real estate object as buildings and apartments. This means that legal information can only be represented in tion to a certain land parcel or a piece of it. But the arrangements which result in additional rights or restrictions, exist independent from individual parcels. So heavy work would be created to link everything to the parcels and the maintenance would be nearly impossible because of the cumbersome procedures necessary to keep clean ownership records. Cadastre 2014 is a concept to create a systematic documentation of the legal situation of land, using the possibilities of the GIS technology combined with the procedures used in the traditional cadastral and land registration systems.

The realization of the Cadastre 2014 concept requires efforts in the fields of technology and legislation. ESRI as a leading provider of GIS technology intends to provide the technical basis with the "ArcGIS Cadastre 2014 Data Model". This model represents the basic legal framework for land matters with an open and flexible object-based data model. While the model is general and flexible, the unique needs of a variety of land administration and land management users can adapt it easily to the legal environment of their jurisdictions.

The author of this report and ESRI encourage all decision makers and GIS professionals to engage in a coordinated effort that will lead to standardized best practices and land record modernization as well as a solid foundation of digital land records and parcel infrastructure that will carry us into the future.

2 Essentials of Cadastre 2014

2.1 The Cadastre 2014 publication

It was the task of a working group 7.1 of Commission 7 of FIG (International Federation of Surveyors) to reflect on the future development of the Cadastre. The initial terms of reference were:

> *Study cadastral reform and procedures as applied in developed countries, take in consideration automation of the cadastre and the role of cadastre as part of a larger land information system, evaluate trends in this field and produce a vision of where cadastral systems will be in the next twenty years, show the means with which these changes will be achieved and describe the technology to be used in implementing these changes.*

The working group was commissioned in 1994 and delivered the result in form of a booklet [Kaufmann, Steudler, 1998] at the XXI. FIG Congress in Brighton, UK. (see Figure 1)

Figure 1 Title page of booklet.

The term Cadastre 2014, meaning 1994 + 20 years = 2014, has first been created as a working title and became in the end the booklet's title. The booklet has since been translated into more than 20 languages, among them Arabic, Russian and Spanish.

The result of this study is not limited to the 'developed countries' as mentioned in the terms of reference. The principles found for modern cadastral systems can be applied in every country and situation, even when no private property rights are introduced yet or where mixed systems of rights to land, namely private property, possession and land use rights and state property, etc exist in parallel.

Because the Cadastre 2014 concept is based on the formal and informal laws existing in a jurisdiction and therefore takes into consideration all types of rights to all types of land objects, it can be applied generally.

2.2 Traditional cadastral systems

The definition of the traditional cadastre used in this documentis: *a methodically arranged public inventory of data concerning **properties** within a certain country or district, based on a survey of their boundaries.*

Traditional cadastral systems can be characterized as illustrated in Figure 2. They consist normally of a mapping part and a textual part.

The mapping part is the result of a survey of the property boundaries and objects being part of the property (e.g. buildings, etc) according to the legal situation. The textual part consists in many cases of a register arranged according to parcels, a register according to proprietors and some auxiliary registers for easier handling. The central focus of traditional cadastral systems is the parcel, which is defined as: *a piece of land with defined boundaries, on which a property right of an individual person or a group of persons or a legal entity applies*. The holders of the rights in the Cadastre 2014 concept are denoted the rightful claimants.

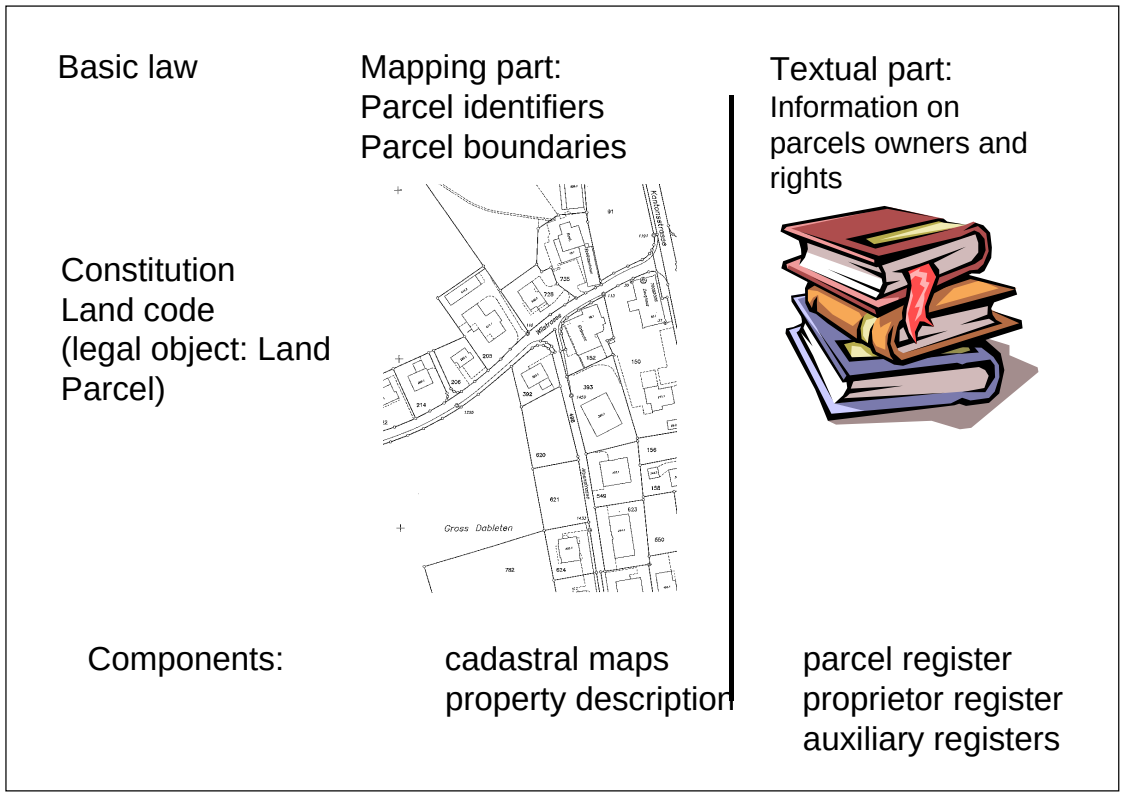

Figure 2 Components of a traditional cadastral system

2.3 Modelling traditional cadastral systems

In any case a parcel is at least a piece of the surface of the earth The respective model is very simple.

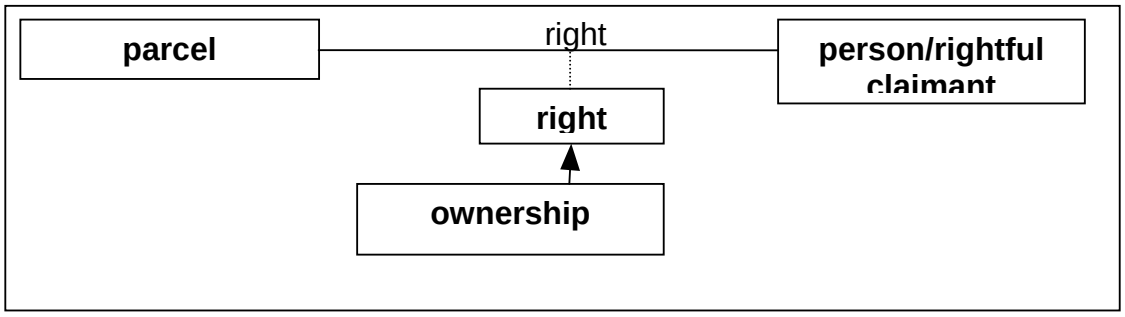

Figure 3 Relation between parcel and rightful claimant

Depending on the different laws in different jurisdictions the right to a parcel can include objects on the surface and objects beneath and above the surface. In most cases these additional objects are buildings on a parcel. The parcel and the buildings on it form a real property. There are different possibilities to model this situation, i) to link the buildings directly to the parcel as an attribute ii) to link the building to the parcel as a geographic object or iii) to consider the building as an individual object, which is not linked directly to the parcel. The link between the parcel and the building in the latter case is made geographically based on the fact that the two objects are located more or less in the same place.

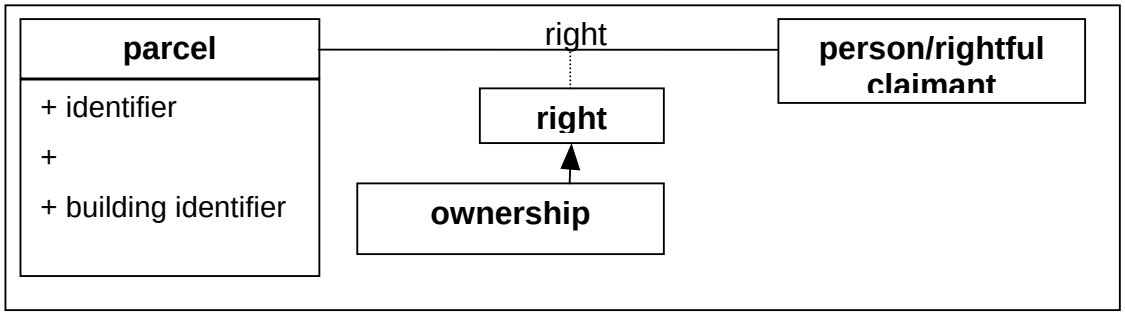

Figure 4 Basic model with buildings as attributes

The first solution allows to establish the traditional property registers and records. The fact, however, that the building has its own individual geographical characteristics is neglected. From the traditional register's point of view this is sufficient because only the fact is relevant that one or several buildings belong to the same parcel. This solution is simple, straightforward, and has successfully been applied for a long time (compare Figure 4).

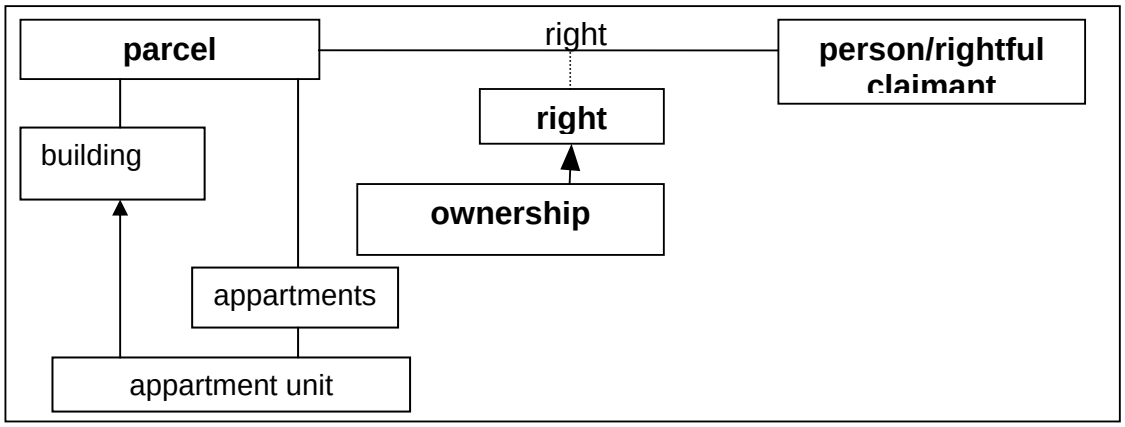

Figure 5 Complex data models

The second solution takes the geographical characteristic of the building into consideration. It links the building directly to the respective parcel. The model for this solution is more complicated because it does not take into consideration that buildings

have their own existence. The building, in reality an object on the parcel, is replaced by apartment units which become components of a real estate .

The third solution considers the buildings as legal objects, something which they are in fact.

The buildings have their own legal definition, which is similar to that of the parcel although not necessarily the same. The third solution takes advantage of the capabilities of modern GIS systems, which provide tools to detect if two objects are linked by their geographic position (see Figure 6).

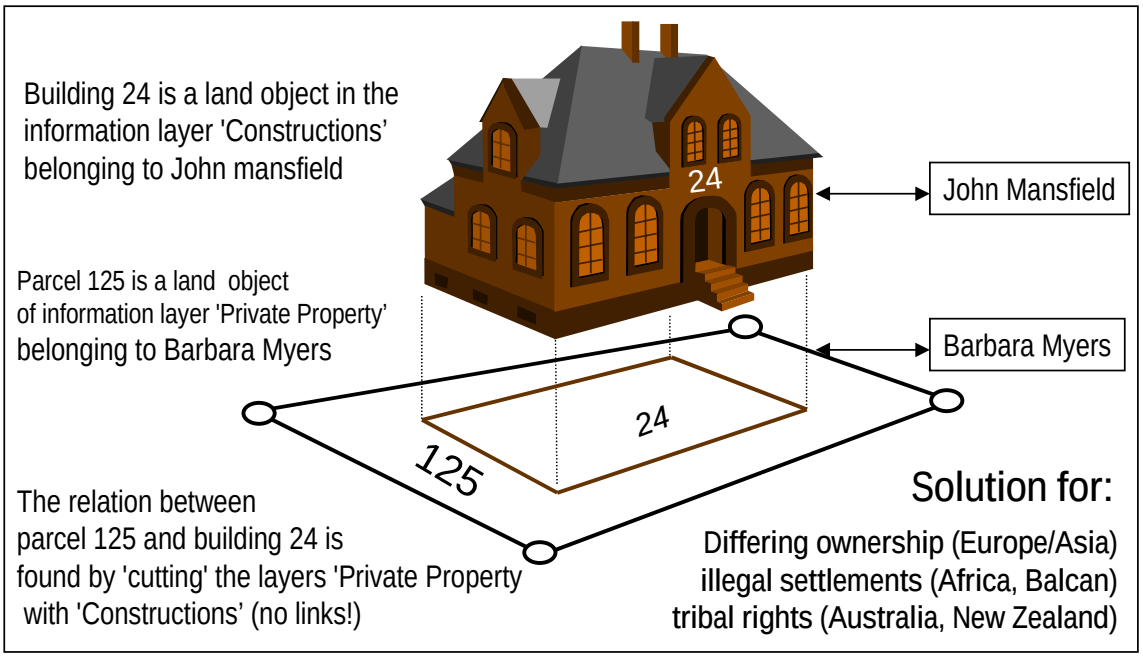

Figure 6 The building is an individual object situated on the parcel

This solution works as well, if the building is represented only by a single point with a coordinate, eventually referring to the address. If in a jurisdiction the outlines of buildings are not necessarily to be represented on a cadastral map, they are not to be measured in detail. The location by a coordinate allows the automatic attribution of a building to a parcel, while not having to be located with a high accuracy. This is a real low cost approach corresponding to the principles of Cadastre 2014.

Of course a geographical relation can only be successfully identified, if the respective objects are defined in a common reference system (see Cadastre 2014, chapter 3.4.7). It is the special capability of surveying professionals to find the appropriate way to transform objects into a common reference system. In the worst case, where a transformation is not possible e.g. due to missing parameters or to insufficient quality of the localisation of the objects, a re-survey with the most efficient and least expensive method may be a more sustainable way to get an adequate result. To adapt the models to questionable information from a professional point of view is a

deceit of the society, which has a right to know objects in a position corresponding to its needs and rules. From a economic point of view it is also to be mentioned that in the never ending activities of the cadastre over a long time, the cost for maintenance of expensive models may be higher than the cost for a re-survey and the maintenance of simple and straight forward models. Of course a geographical relation can only be successfully identified, if the respective objects are defined in a common reference systems (see Cadastre 2014, chapter 3.4.7). It is the special capability of surveying professionals to find the appropriate way to transform objects into a common reference system.

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With this approach 2 basic models result, one for parcels (figure 7)

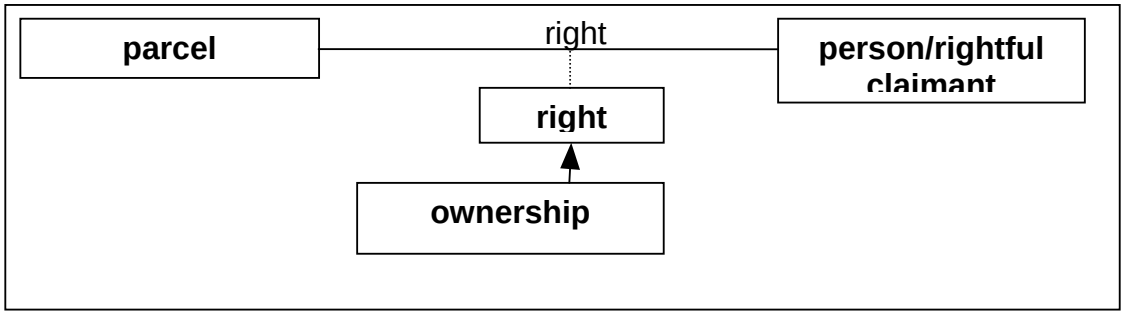


Figure 7 Model for parcels

and one for buildings (figure 8)

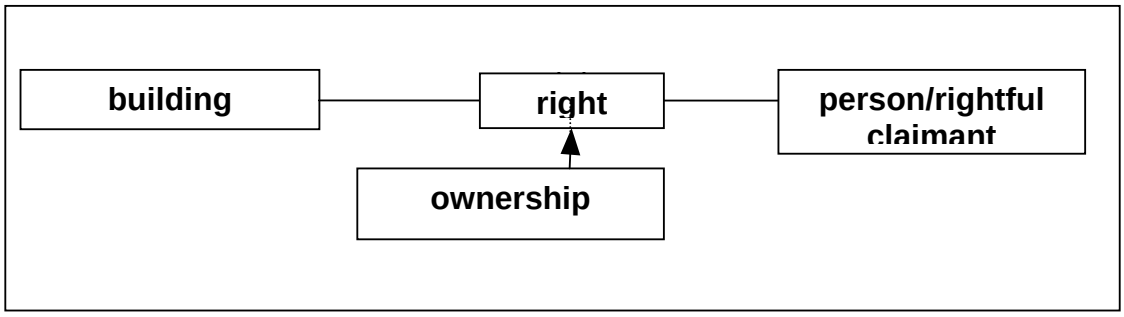


Figure 8 Model for buildings

This modelling concept makes use of the polygon overlay technique to detect if two objects are geographically linked to each other If the owner of the building is the same as the owner of the parcel, we have the case of a real estate property, which has been implemented in most Western countries. For condominiums, however, the owner of the land parcel may differ from the owners of the apartments or of the common parts of the building.

In other jurisdictions, the existing legal situation is different. In the states of the former Soviet Union the owner of the land is often different from the owner of the building standing on it. This situation is based on the fact that in the former socialist system, citizens were allowed to own buildings while the state remained the owner of the land. This diverging ownership is nowadays continued at least as long as the land privatization process is not concluded.

This third solution corresponds exactly to the principles applied by Cadastre 2014. The use of IT facilitates simple and comprehensive data models.

2.4 Shortfalls of the traditional cadastral systems

It has to be acknowledged that the traditional cadastral systems, where they exist at all, have played an important and successful role in the economic development of the respective countries. But the environment of the cadastre has changed significantly since their implementation. At the beginning, the rights to land were the ownership rights of natural and juridical persons, nothing more.

The situation of the traditional cadastral systems is characterized in Figure 9.

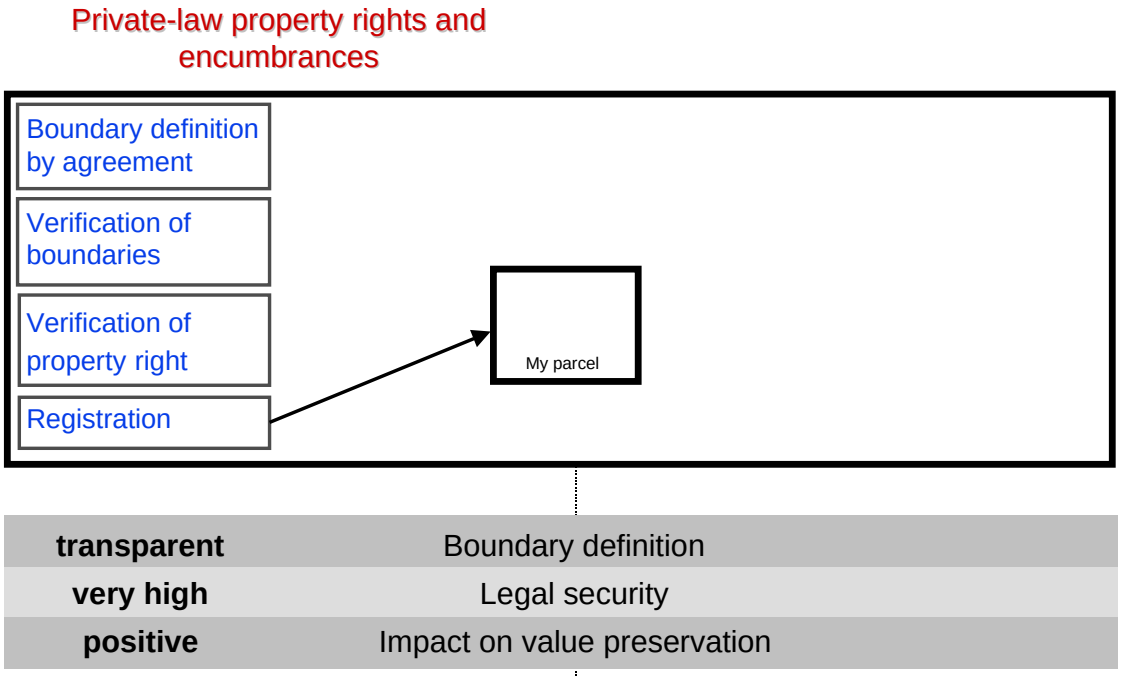


Figure 9 Traditional cadastres document the property rights perfectly

In the meantime the different societies were forced to regulate the land use due to the growing population and the need to protect the environment and the natural resources from being polluted and wasted.

These arrangements have an impact on the land ownership rights, because they become increasingly restricted and these restrictions are so far not documented in an appropriate way. The restrictions are documented normally on maps with scales different from the cadastral maps and are not publicly and easy accessible. Land owners, investors and administrations can get reliable and guaranteed information about the boundaries and the ownership of land, but the search for additional information such as restrictions can be a cumbersome and time consuming process. Even when successful, there always remains some uncertainty if the found information is complete and reliable.

In the Cadastre 2014 booklet this situation is illustrated in a diagram (compare Figure 10).

This situation is not only unpleasant for the players in the land and immovable property market, it is increasingly becoming a risk factor for the economies. The trustworthy documentation of objects and property rights by the traditional cadastral systems are a crucial basis to turn real estate properties into tradable assets.

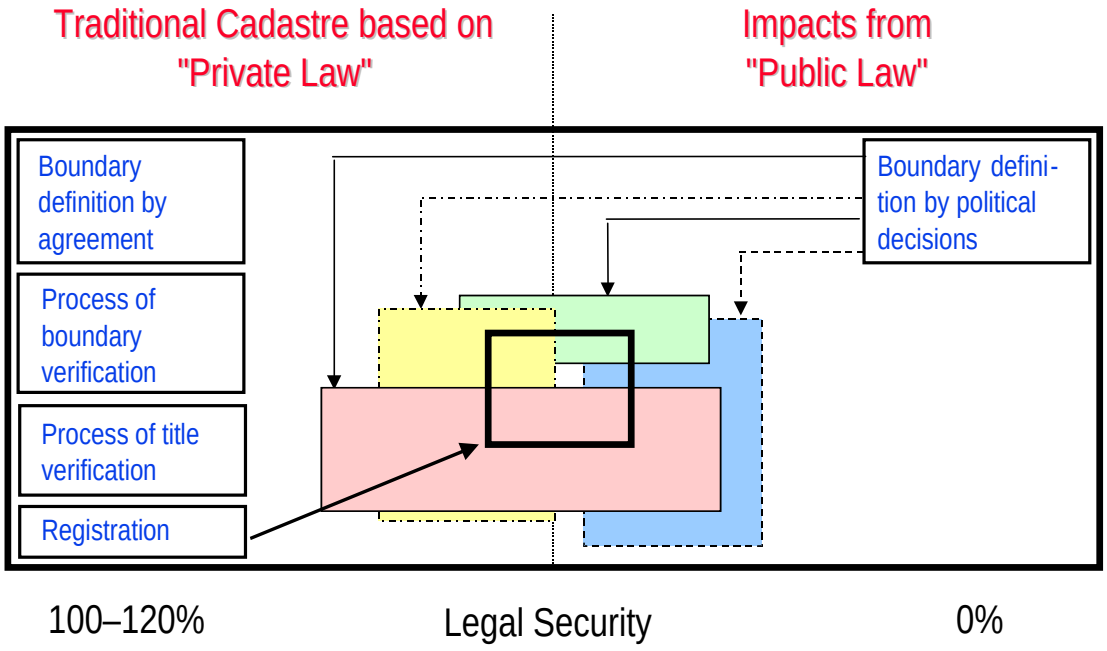


Figure 10 Impacts of legislation on the land

These tradable objects are often used as collateral in order to get loans from banks in form of mortgages. If the cadastral system and therefore the legal security of these assets is weak and unreliable, banks and loan institutes would hesitate to provide loans. This would create significant problems for national economies and of course the respective businesses and the citizens.

3 Cadastre 2014

3.1 Aim of Cadastre 2014

One of the major aims of the Cadastre 2014 proposal is to improve the information about the legal situation of land and thus to strengthen legal security.

The laws on spatial planning, environmental protection, etc. describe geographically defined objects, mostly in the form of zoning areas where something is allowed or forbidden to do. Cadastre 2014 names such objects 'legal land objects': *A legal land object is a piece of land in which homogeneous conditions, defined by a law or regulation, exist within its outlines* Typical legal land objects are defined by zoning areas. Even when the legislation mentions lines or distances, they have the character of zone areas, e.g. distance lines along roads are a boundary between an area where it is allowed to construct buildings from an area where it is forbidden.

Cadastre 2014 also talks about other aspects of cadastral systems, namely about organizational aspects, data modeling, use of IT, Public Private Partnership (PPP) and cost recovery aspects. Cadastre 2014 gives some recommendations as well how these aspects should be handled in future cadastral systems.

Even though all aspects carry significant weight, the data modeling aspect can be singled out as the most crucial one, which has the potential to make or break the implementation of all recommendations. Data modeling influences the way how data and information is acquired, administered, handled and distributed, which then also impacts on the organizational and institutional structures.

3.2 Principles of Cadastre 2014

3.2.1 Principle of land objects

Cadastre 2014 builds upon the established principles of traditional cadastres but extends the definition of the basic cadastral unit – the land ownership parcel – to also include land objects such as e.g. zoning areas. The cadastral system therefore would include and administer all land objects, which have some legal or economic relevance, the land ownership parcel of course being the most basic one (compare Figure 11).

Land Parcel	Land Object
A land parcel is a piece of land with defined boundaries, on which a property right of an individual person or a legal entity exists	A land object is a piece of land in which homogeneous conditions exist within its outlines. Legal land objects are described by the legal content of a right or restriction and the boundaries which demarcate where the right or restriction applies.

Figure 11 Definition of 'land object'

Cadastre 2014 proposes that future cadastres shall comprise not only the land ownership parcels and other real property assets, but all legal land objects in a certain area. This means that future cadastres not only include land or real estate ownership rights, but also all other restrictions and responsibilities. (Figure 12).

Cadastre	Land Object
Cadastre is a methodically arranged public inventory of data concerning properties within a certain country or district, based on a survey of their boundaries.	Cadastre 2104 is a methodically arranged public inventory of data concerning löegal land objects within a certain country or district, based on a survey of their boundaries. the right or restriction applies.

Figure 12 Definition of a modern cadastre

3.2.2 Principle of title registration

In consequence, Cadastre 2014 operates with the geographically located land objects and relates the real rights, mortgages and restrictions and responsibilities of physical or juridical persons to these objects. (Figure 13)

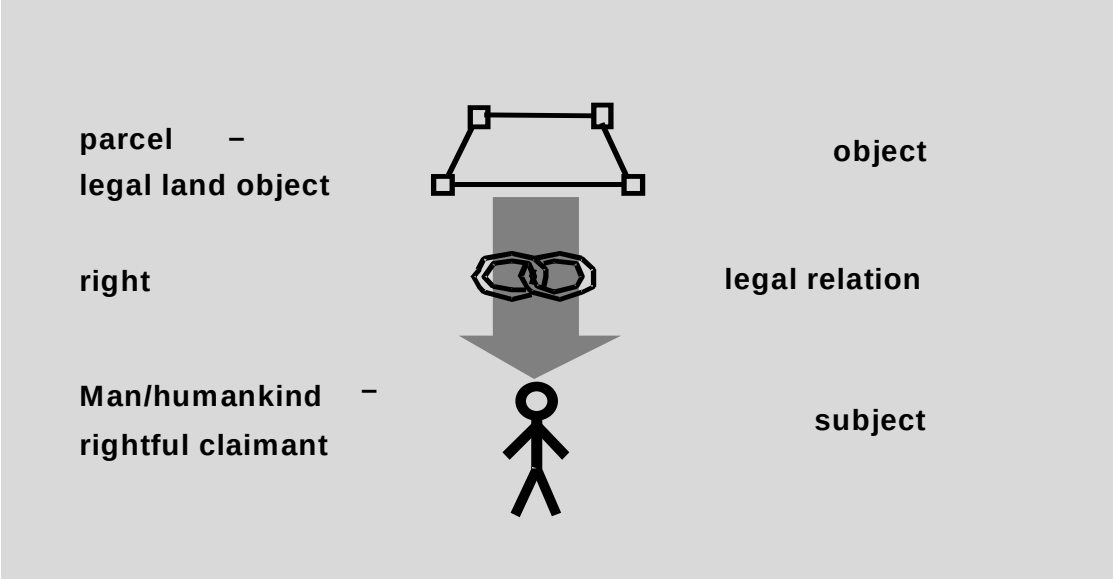


Figure 13 Titles to land are related to rightful claimants

Cadastre 2014 is therefore title-oriented. A land object to be included in Cadastre 2014, is based on a title which describes the object and the related rights and/or restrictions For the private property rights, the title results from a parcel description. Often this title is a map like a land use map, a map about protected areas, etc, stamped and signed by the government. To serve the societies best, these maps are to be elaborated in a quality which make them comparable with parcel boundaries. If this is not the case, a professional will verify the content and decide about the location

of land objects with the help of any information available, like indications on measurements, sketches, descriptions, etc.

3.2.3 Principle of the documentation of private and public rights and restrictions

The most important statement on Cadastre 2014 is statement 1, shown in figure 14:

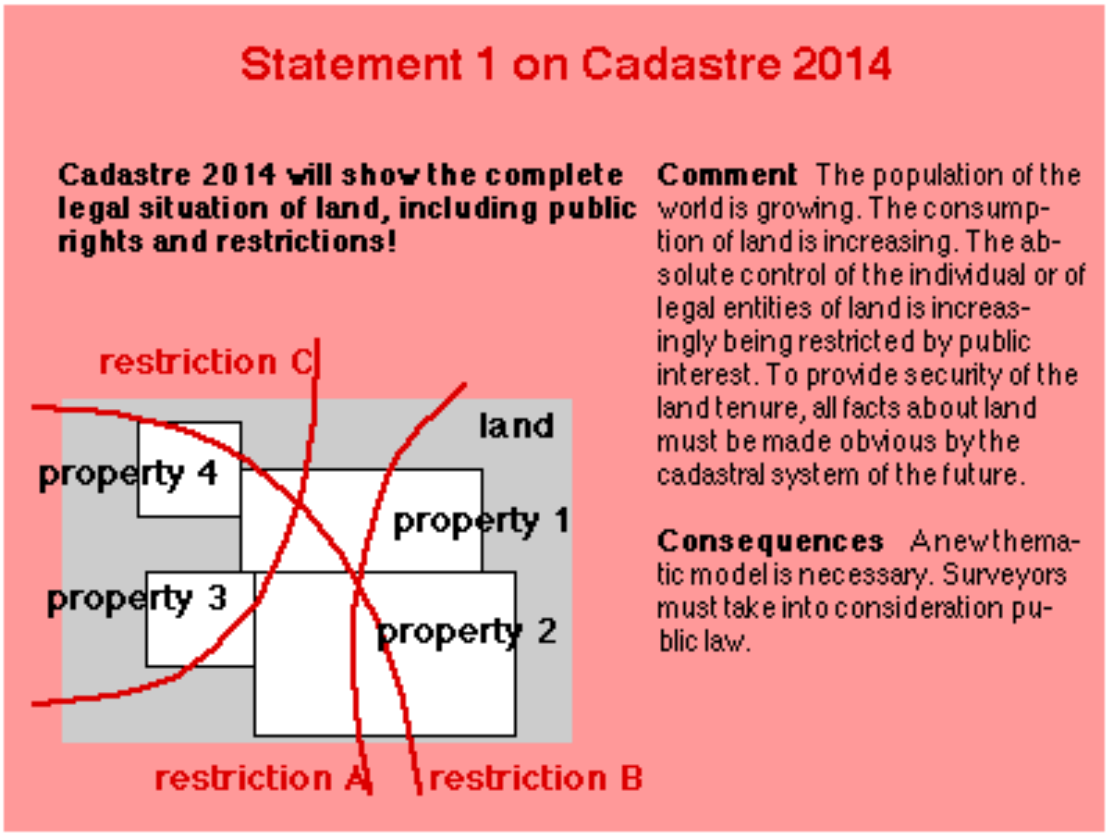


Figure 14 Documentation of the legal situation of land

This statement means, that not only property or possession rights will be documented, but also the rights established by the different legislations having an impact on land shall be registered properly. The realization of this statement is only possible when modern IT is used.

The procedures necessary to achieve a valid registration of the additional rights and restrictions are the same as they are used for the ownership, property and possession rights in the traditional cadastres.

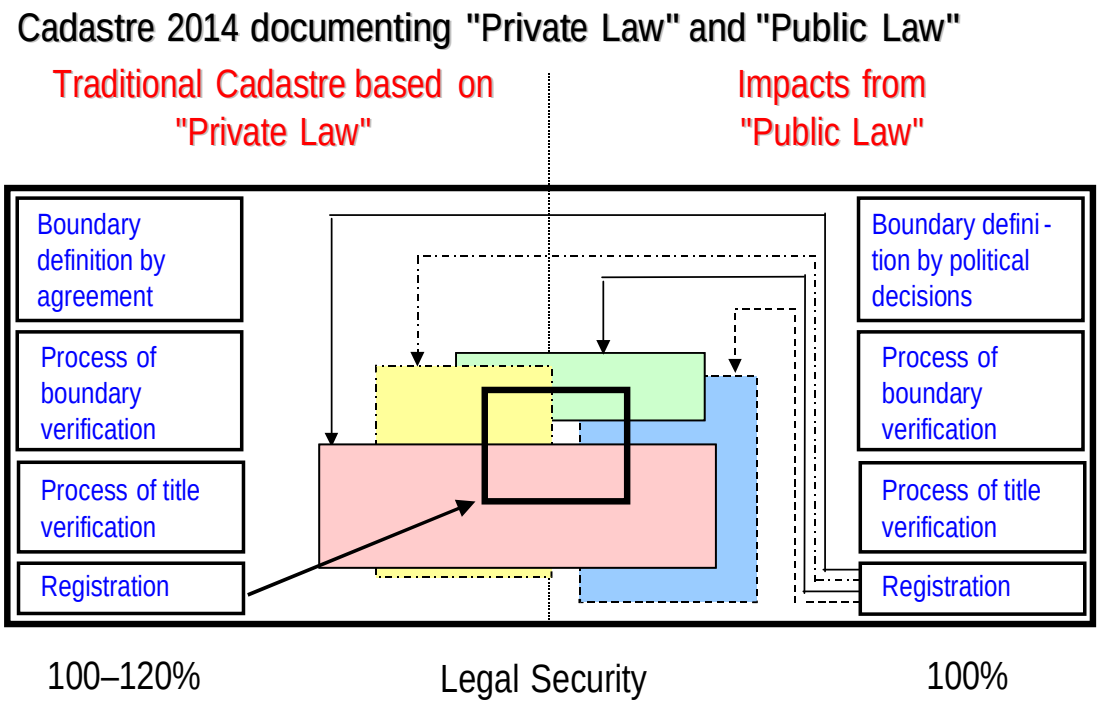


Figure 15 Need for verification of titles and boundaries

To achieve a sufficient legal security, the additional information has to undergo boundary verification and 'title' verification processes before it is validated (see Figure 15).

The procedure of the verification of boundaries contains the following checks

- is the boundary configuration corresponding to the respective legal prescriptions;
- are the boundaries defined in the correct reference system;
- are the boundary-points defined unambiguous;

In the title verification process the checks have to answer the following questions:

- do the types of objects correspond to the legal prescriptions;
- are all defined objects corresponding to the legal prescriptions.

All land objects emerging from a law – and not only the land parcels as objects describing the property right - are to be carefully defined, verified, and kept in a public register.

Future cadastres shall improve and correct this insecure situation by applying the principles of cadastral systems on all legal land objects.

3.2.4 Principle of legal independence

The future complete documentation of the legal situation of land must respect the principle of legal independence, which is shown in Figure 16. Land objects are defined by different laws describing the types and effects of rights or restrictions and

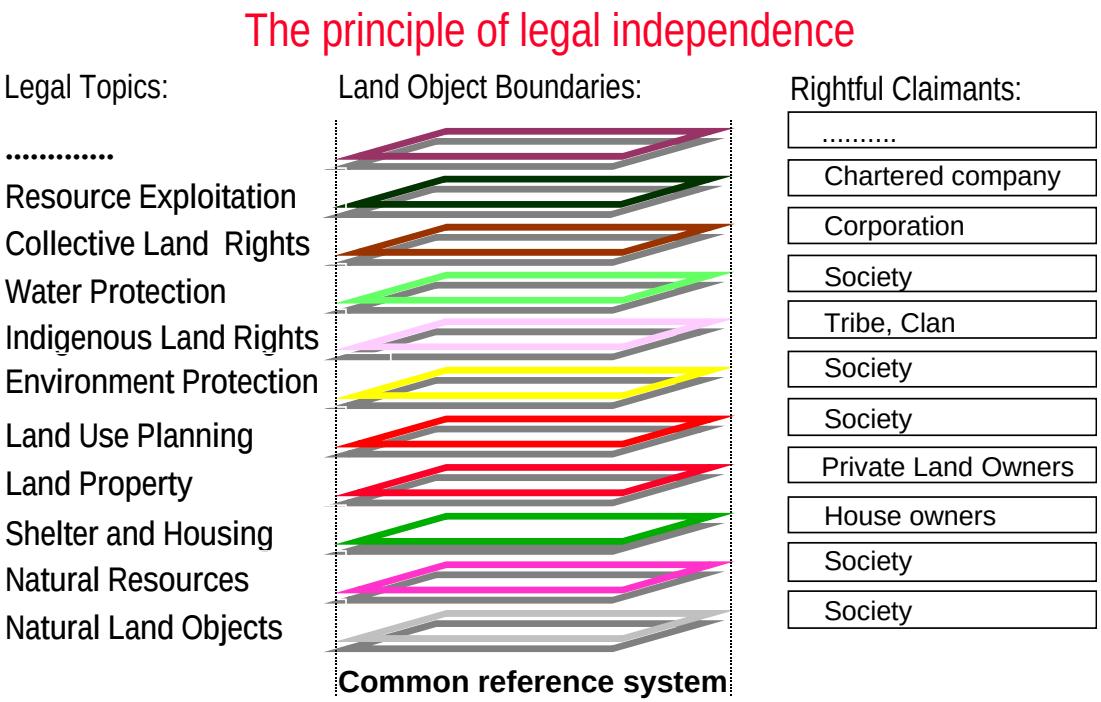


Figure 16 The structure of cadastre 2014 is defined according to the legal framework

the area where a right or restriction is effective. The area of effect is often drawn on a map or, in informal situations, it is known to the people concerned. To be able to build a modern cadastral system, it is necessary to investigate the laws in a jurisdiction and to identify those with an effect on land.

The different legal land objects are to be arranged according to the laws by which they are defined. This structure allows the immediate adaptation of the cadastre to the development of the legislation. It is not necessary to rearrange the information. New legal topics can simply be added by including a further information layer. If a law is cancelled, the respective information layer can be removed without reorganizing the other layers.

This process can be compared with the bookkeeping system. A new account for the administration of the new Land Objects is introduced because a law defines a new category of assets being part of the Land Business. An abrogation of a law would mean the removal of an account in the system. This happens unfortunately not to often.

Cadastre 2014 can also deal with facts which are not formally written down in a law. Such informal and customary rights exist where tribes or clans are obeying unwritten rules. These legal entities may have living, hunting and fishing rights within a defined territory from which the boundaries are known, but not documented formally. The rightful claimants are certainly able to localize the outlines of their rights and the respective land object can be included into the cadastral system.

A form of occupation 'rights' exist in the informal settlements in many areas of the world. Even when the occupation of the land may be contrary to the formal law , the rights of the involved settlers are informally defined by an unwritten code. In such case one should not speak of rightful claimants but better of informal claimants. The boundaries resulting from these informal arrangements can be localized and documented according to Cadastre 2014 principles. So the Cadastre 2014 concept can show also overlapping rights and serve to formalize the situation, to regulate transactions, to monitor and to improve the ambiguous situations.

Indigenous rights, e.g. in Australia and New Zealand, normally overlap with a formal property right system concerning the crown land. The rights and the boundaries where they are in effects are well known and can be documented properly and formally correct in Cadastre 2014. On the base of the reliable documentation of the legal situation, conflicts may be reduced and cohabitation improved.

In these cases no exaggerated precision is required, but reliability and completeness of the information is crucial.

3.2.5 Principle of linking objects by geometry

The realization of the principle of legal independence results in a structure of independent topics. Land Objects are arranged in legal topics. There is no link between Land Objects in different topics, Links between Land Objects are not stored in the system but created when needed using the fact that the Land Objects are located in the same area.

According to Cadastre 2014, the links between land objects are created with the help of the polygon overlaying technique when needed.

Cadastre 2014 can resolve the problem when land and houses are no immovable unit. This situation occurs often in the countries in transition, where the land used to belong to the state and the houses belong to the citizens. Even when land privatization is intended, this process takes time. Cadastre 2014 documents the rightful claimant of the land parcel independently from the rightful claimant of the house. If both objects have the same owner, the parcel and the house may be considered as an immovable property.

Cadastre 2014 can stabilize the situation where conflicting legal arrangements exist

This technique is very favourable from the point of view of updating. There are no crosslinks between land objects evolving from differing legal prescriptions to be administered and kept up-to-date. Relations are created when needed

Using this principle means to say goodbye to the parcel-based cadastral systems of the past. The future cadastral systems are therefore no longer parcel-based.

3.2.6 The principle of unified Cadastre and Land Registry

The second statement in figure 17 of Cadastre 2014 says:

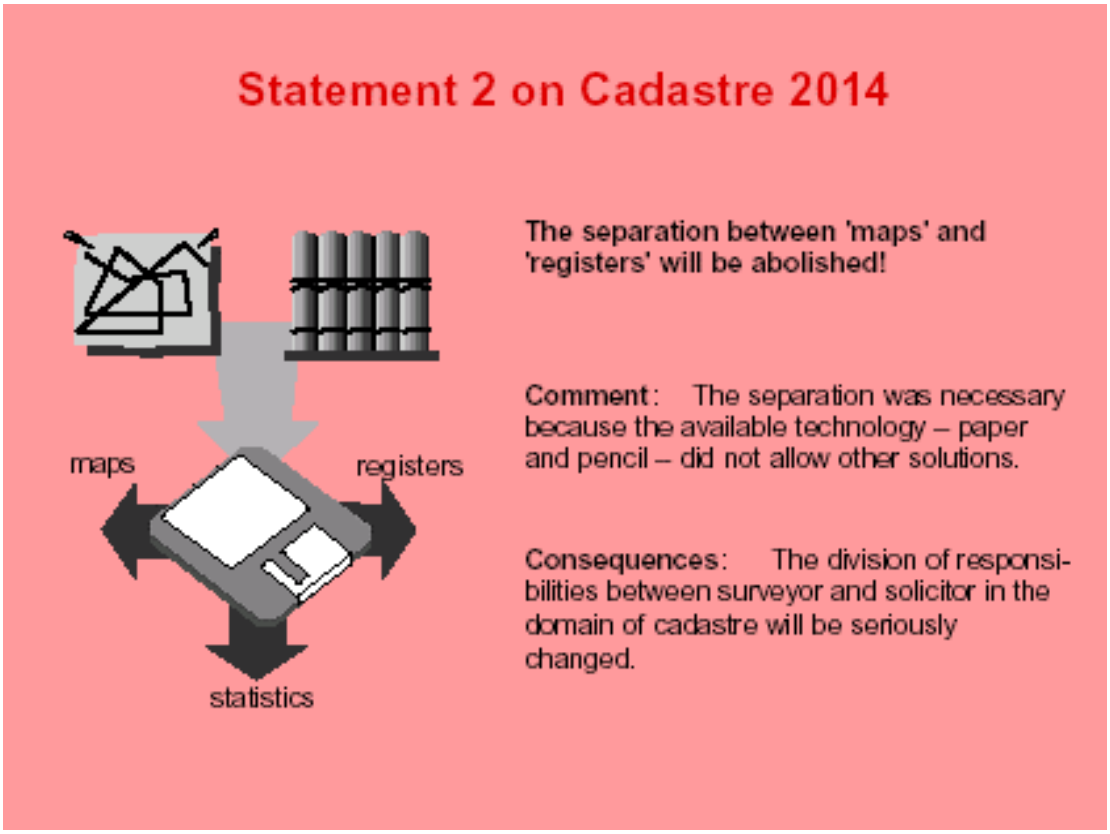


Figure 17 Cadastral maps and registers not separated

The establishment of separate organizations for map production and land registration was often necessary because the two operations used to require different skills, and the available technology did not allow for other solutions. With modern technology (IT) it is possible to link land objects directly with the information needed for registration. The often practiced separation of the physical and organizational structure will become defunct.

From the point of view of modelling, this statement is of minor significance.

3.2.7 The principle of Cadastral Modelling

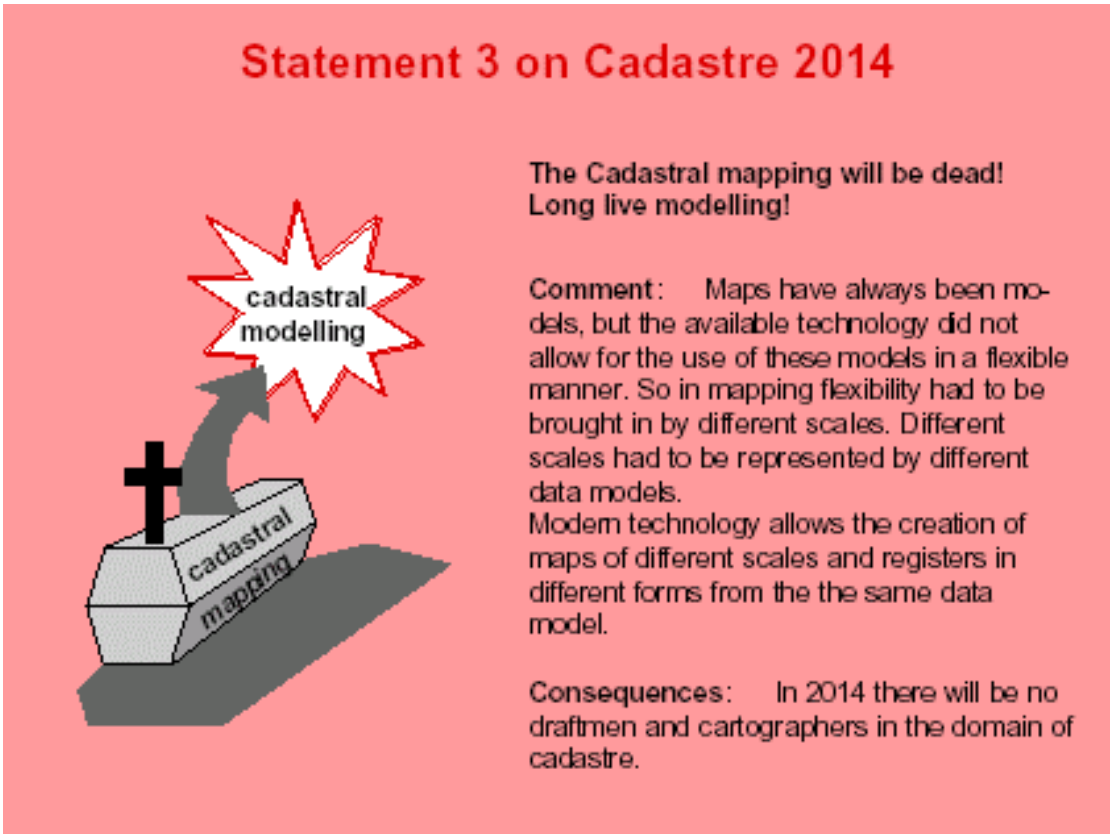


Figure 18 Cadastral modelling is most important

The idea to replace the good old paper maps by virtual models is a mental challenge for professionals who are used to think in graphical categories. Information technology operates with digital data and provides the ability to model objects of the real and legal world. Maps as analogue representations will lose their function as information repositories; their only purpose will be the representation of information. In future we will have increasingly different graphic representations as extracts of the cadastral model tailored to the needs of the individual customer. To store maps on a computer as pictures is therefore an archaic operation.

When working with data models, the data descriptions have to be precise and there is also a need for a description of data representations. In Switzerland such a data modelling language has been developed during the reform of the cadastral surveying laws in the years 1975 to 1993; it has been named INTERLIS.

INTERLIS1 was the first operational geoinformation standard and is widely used for precise data modelling (Figure 19), secure data exchange

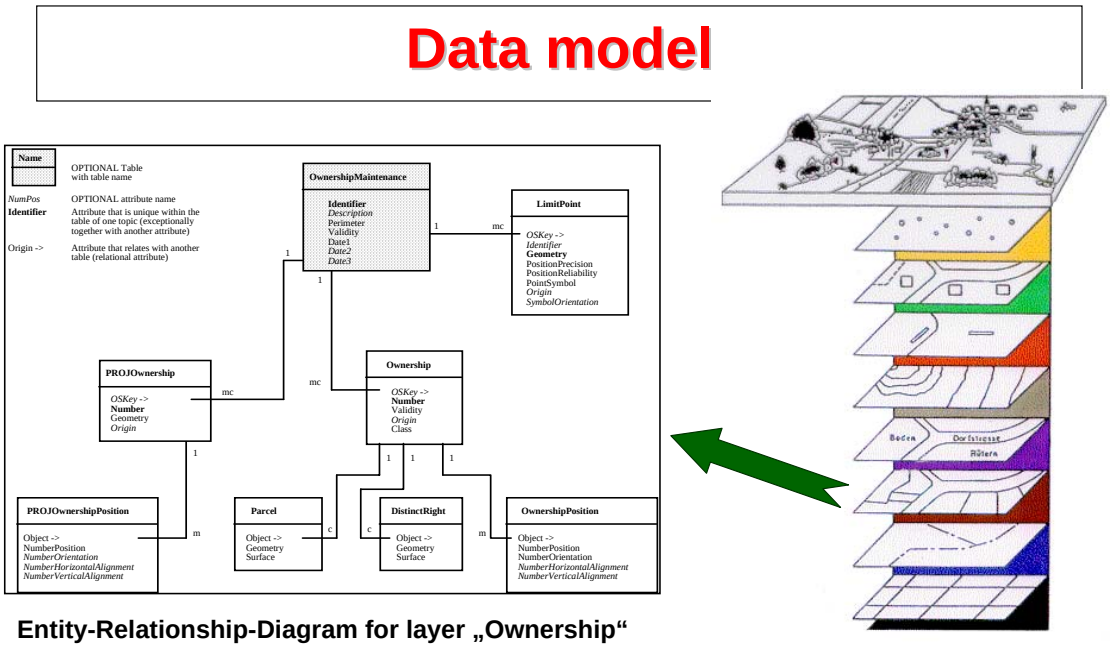


Figure 19 Example for formal data modelling

and sustainable insurance of long-term data availability. INTERLIS1 creates automatically an ASCII data exchange format and respective files.

INTERLIS2 with additional possibilities for incremental data updating and the description of representation models will replace INTERLIS1 in the near future. INTERLIS2 is compatible with UML and is able to create XML- or GML-files automatically.

Considerable work in standardisation is presently done by a group of cadastral specialists. The intermediate results have been published under the title 'A Modular Standard for the Cadastral Domain' [Lemmen et al., 2003].

3.2.8 The principle of IT application

This statement (figure 20) implies that the best technical tool for bookkeeping is IT. One can see the automation of business processes all over the world and one cannot find any cadastre project in the world where information technology is not involved. IT makes work easier and is the only way to achieve, what nowadays is called a low-cost cadastre.

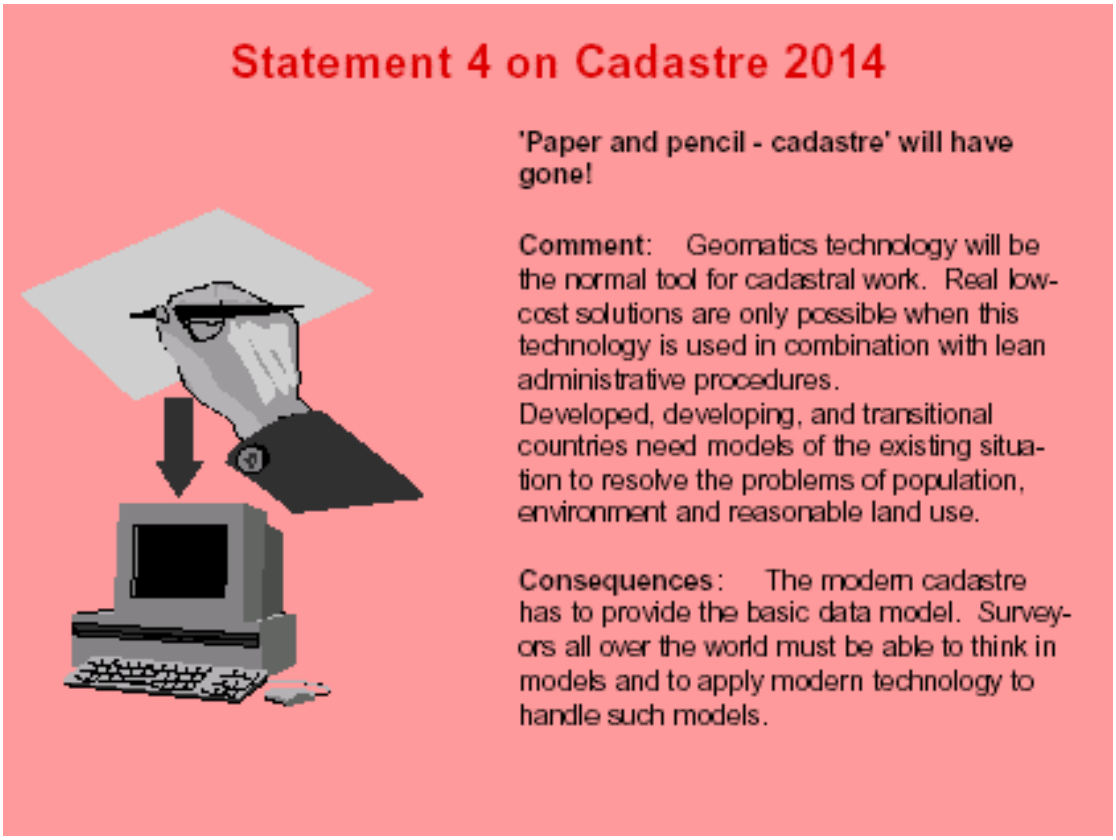


Figure 20 Future cadastral systems are IT-based

IT application especially for geodata with a long life cycle asks for data modelling to secure the value of data over long periods.

3.2.9 The principle of Public Private Partnership

The trend to privatise the operational work to be executed in the field of cadastre is reflected in statement five (figure 21).

This is a fundamental trend. The public domain will have to provide secure land titles and therefore concentrate on supervision. Operational work can be outsourced to the private sector.

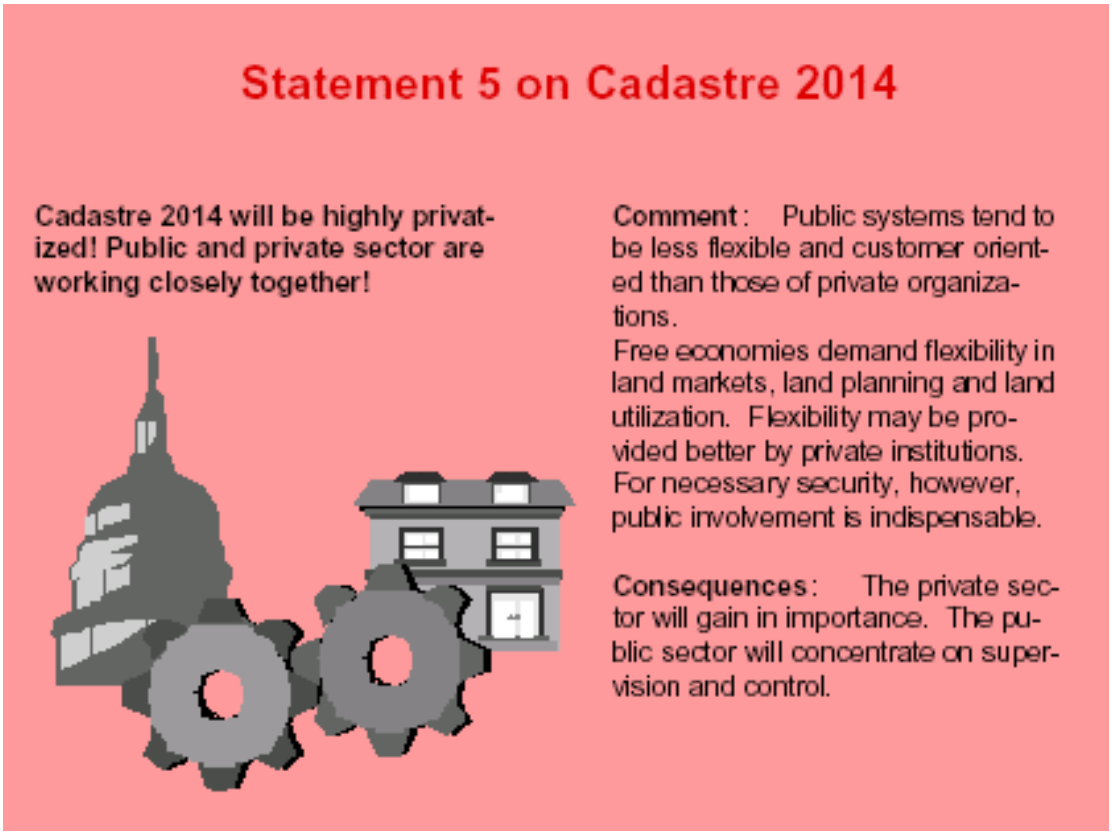


Figure 21 Private-Public-Partnership is the key for success

Data modelling has a significant effect to make public private partnership working successfully. On the one hand the modelling following the principle of legal independence, makes it possible to distribute the work to allocate the work to the authorities responsible to enforce a certain law and to the respective specialists defining and maintaining the land objects resulting from the laws. In any case the verification processes are to be carried out to secure the necessary quality of the information and the responsibility for the verification are to be defined clearly. It is essential that the verifying body is independent from the one producing the land objects. On the other hand a clear definition of the data by a formal data model allows correct mutual understanding between the contraction entity and the contractor of data acquisition and data maintenance tasks and between data producers and data users.

3.2.10 The principle of cost recovery

Finally, in statement 6 the aspect of cost recovery which is another international trend, is expressed (figure 22).

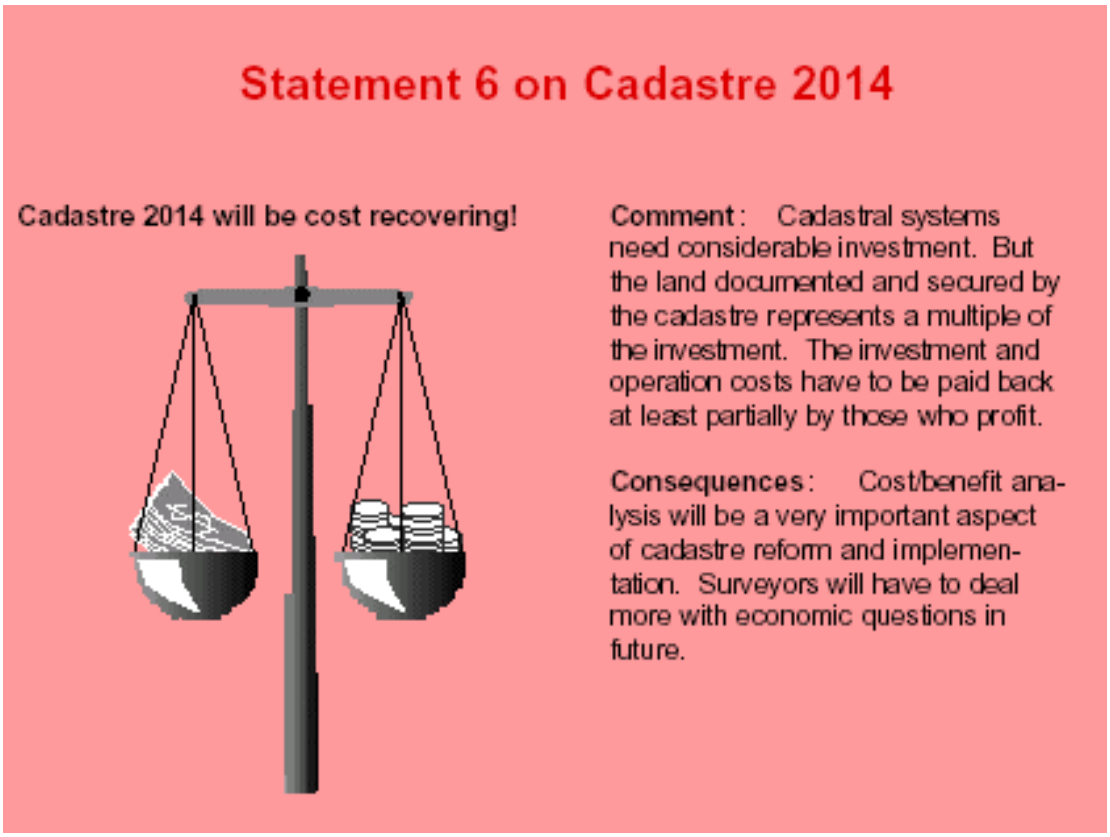


Figure 22 Cost-recovery will be a key issue for modern cadastres

A functioning cadastral system represents a considerable value for a society. The awareness that public and private sectors have to cover their cost, leads to efforts to implement cost covering fees in the field of cadastre. Because the cadastre is a long-term investment the depreciation period for the initial investment can be longer than for normal goods. Correct data modelling is an important tool to prolong the life cycle of data and therefore to diminish the yearly depreciation rates for the investment in data.

4 Cadastre 2014 and the 3rd Dimension

When elaborating Cadastre 2014, the aspect of the 3rd dimension was not of primary interest. Maybe first ideas were existing. Meanwhile the issue has gained a certain importance in the discussions in professional circles.

From the point of view of Cadastre 2014, the introduction of the third dimension is depending from the legal framework. If a law defines land objects with 3 dimensions,

it is represented in the Cadastre 2014 concept simply with its three dimensional coordinate values.

If the effects of the right or restriction have a spatial significance, the three dimensional objects defines clearly the space of impact, describing the outlines of the effect of a right or restriction. If spatial impacts are to be evaluated, functions of spatial exploitations are to be developed and used for analysis.

Normally the effects even of three dimensional objects have planar impacts as shown in figure 6 where the vertical projection of the tree dimensional building is used to compare the location on the land parcel.

5 Consequences for modelling

Cadastre 2014 is basically a legal and organizational concept, which can only be implemented successfully, when modern ICT technology is applied.

Every law defining land objects that have an impact on private property rights or other legal arrangements valid in certain areas, creates a new data set with the rather simple structure shown in figure 23.

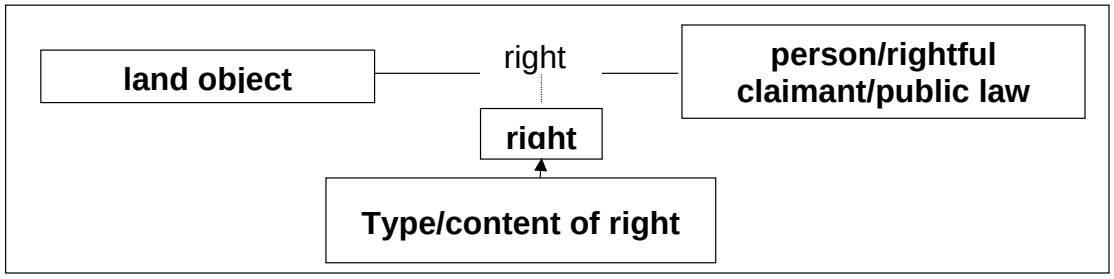


Figure 23 The basic structure of Cadastre 2014

Using this simple data structures and the possibilities of object overlaying to identify the geographic location of the objects and to detect if delimitations of rights interfere with other legal impacts, the complexity of a modern and complete cadastral system can be reduced significantly.

Cadastral work is characterized by long transactions. Legal land objects usually come into existence as soon as an application for an alteration or a decision is taken, e.g. a construction permit is given out. An additional component in the model is the possibility to handle information concerning objects, which are in a status of project to meet the requirements of Cadastre 2014. The basic model construction is therefore extended by tables containing information about the data maintenance (figure 24).

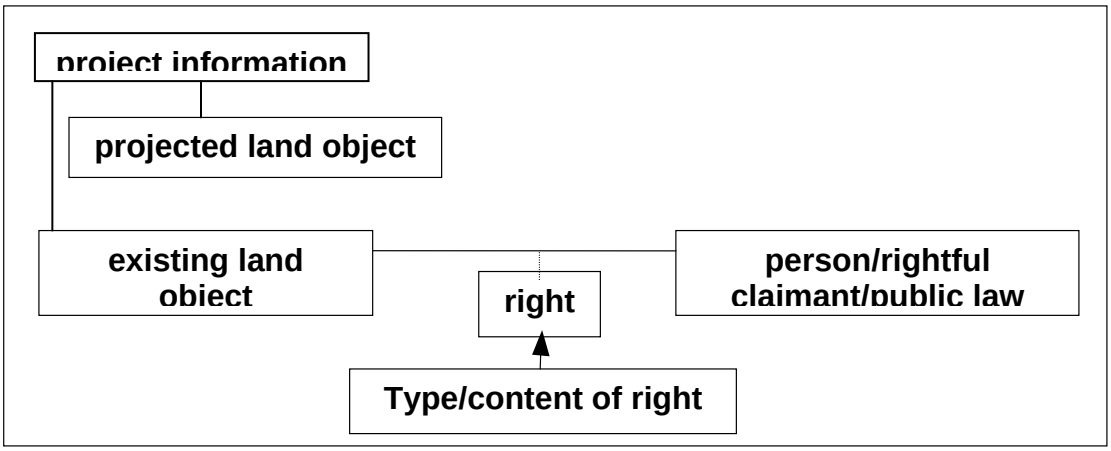


Figure 24 Model containing projected information

With these basic elements the basic models can be created. The real models depend from the laws in the different jurisdictions of the world. From the laws the legal land objects shall be derived and the types of rights are also defined by the respective legal base. The basic models are to be refined on the base of the existing legal situation.

6 Basic models

The basic models shall show the principles for modelling different situations. The final modelling and the types of rights must be elaborated for each jurisdiction individually according to the existing legal prescriptions.

Within the different topics more than one description may occur, e.g. for land use planning and environment protection.

6.1 Model for traditional land objects

The right to have private property is usually defined in the constitution of a certain country. A land code or a law on private property defines the types of property rights and the way to document them. The basic model can be seen from figure 25.

The types of right may be ownership, co-ownership, possession, etc.

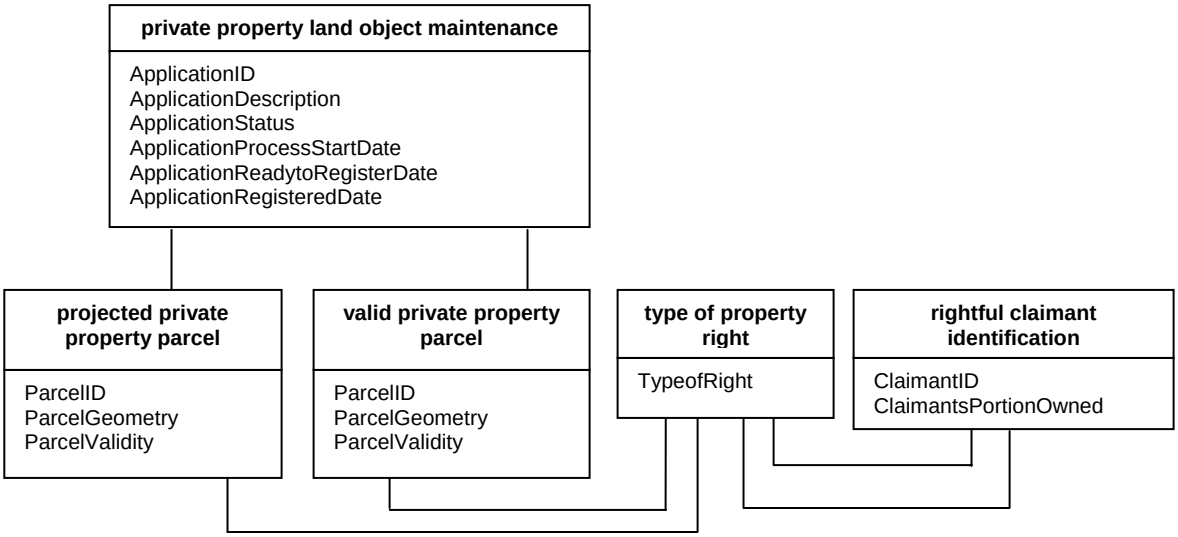


Figure 25 Model for property parcels

If encumbrances have a geographical extension, they are modeled according to the basic rules of Cadastre 2014 (figure 26). Encumbrances which are not localized (do not have a distinct legal description/boundaries), are considered as an attribute to the private property parcel.

Types of encumbrances may be access rights or restrictions, use and usufruct rights, and similar.

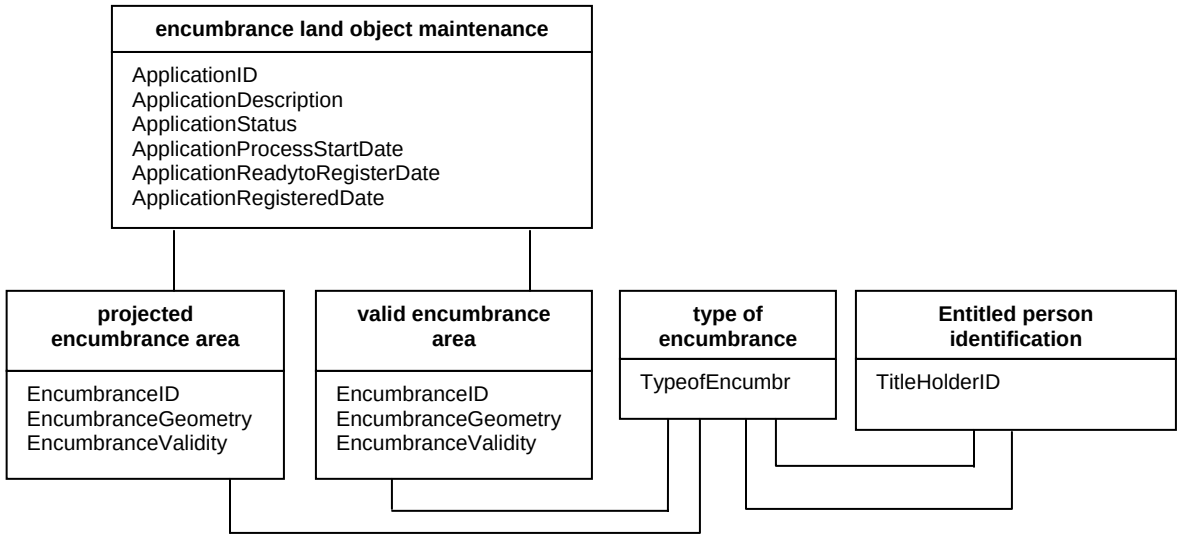


Figure 26 Model for encumbrances

6.2 Model for traditional building

Buildings are legal land objects being subject to building and construction laws. The construction laws define types of use of buildings. Types of rights may be construction, reconstruction, demolition, etc.

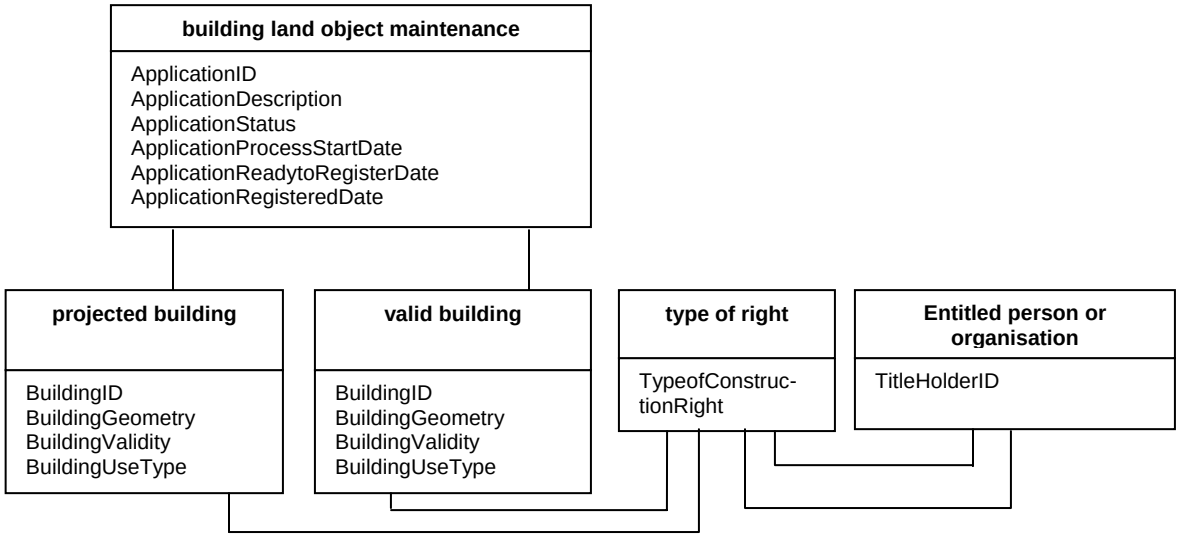


Figure 27 Model for buildings

6.3 Models for land objects from public legislation

Land-use planning laws define zones, where the type of construction is regulated or where activities are restricted or forbidden. Model see figure 26.

The respective laws can define different types of use right, as one- or multiple-storey constructions, industrial or dwelling use, zones clear from construction, etc.

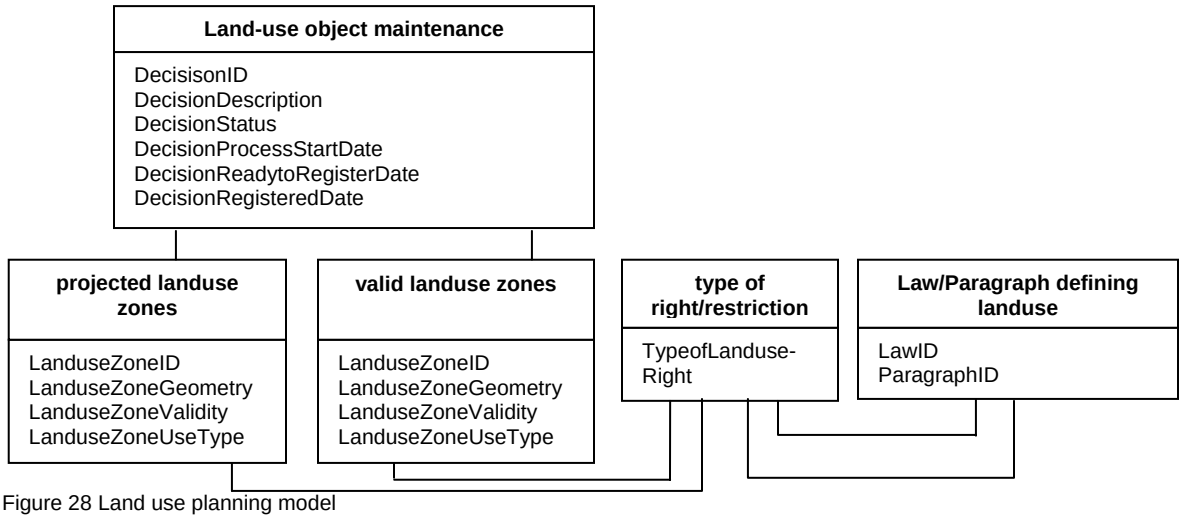


Figure 28 Land use planning model

Laws on environmental protection define areas or locations, where human activities are allowed, restricted or forbidden (figure 29).

The respective laws can define different types of activities to be executed or refrained from, as restrictions of the utilization of fertilizers, restrictions of noise emission, regulation of hazardous material emission, etc.

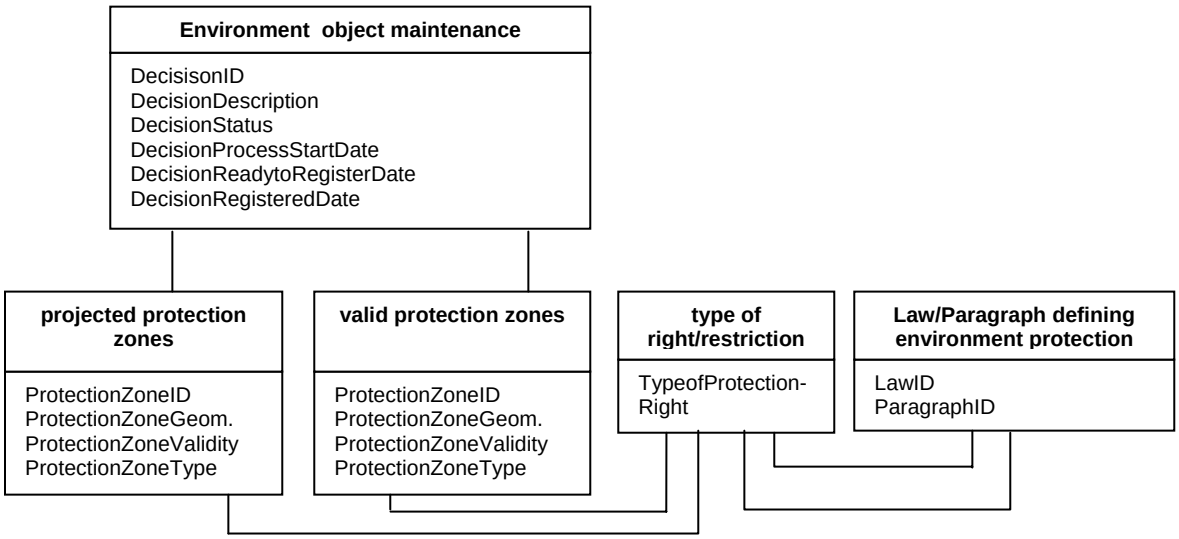


Figure 29 Environmental protection model.

6.4 Models for informal and customary land objects

Informal land rights are any rights to a land object, which is not coming from a formal legislation framework. They may be written or not.

The contents are common utilization for construction, agricultural production, usufruct, resource exploitation, utilization as burial ground, etc.

Titles for informal rights are to be created during the investigations, the boundaries are to be fixed in cooperation with the group of people claiming the informal rights.

Indigenous land objects exist in general in the heritage of tribes and clans. The members of these societies know the extent and content of their rights. If this knowledge is not documented already in written form, a title may be created during the necessary investigations.

Indigenous rights may be rights for hunting, fishing, using resources, holding celebrations, etc. This rights often overlap with a formal property right system.

As soon as informal rights are integrated into cadastre 2014 they are changed to formal rights based on agreements within a certain society.

The basic model for these cases is as shown in figure 30.

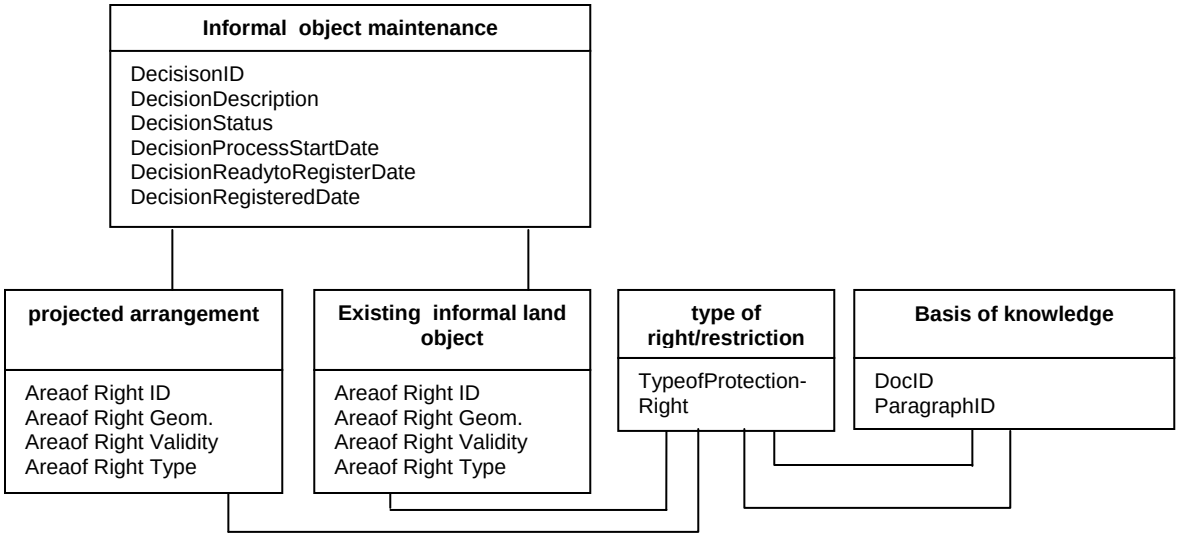


Figure 30 Model for informal and indigenous land objects

7 Formal data modeling

The examples show, that Cadastre 2014 works with similar data models for all the different cases of legislations. The differences are occurring not in the structure, but in the contents of different rights and restrictions.

The basic model necessary to implement Cadastre 2014 applications was described in UML and is shown in annex 1 of this report.

The UML description was translated by the UML-Interlis-Compiler available as freeware at www.interlis.ch. The resulting INTERLIS2 description, which was edited to add restrictions and conditions, which can not be expressed in UML.

The result can be seen in annex 2.

Annex 3 shows the XML format generated automatically from INTERLIS2.

In the annexes 4 to 6 models for buildings, apartments and traditional land rights are represented.

8 Conclusion

The basic data model required by Cadastre 2014 is simple and has the same structure for all types of land objects occurring in formal and informal legal environments.

The Cadastre 2014 concept allows a maintenance and development friendly, efficient and economic solution for a rather complex problem, which will become even more

complex in the future. Taking into consideration the basic rules applied in legislation and making use of the polygon overlaying techniques to omit unnecessary links, which are not easy to handle, adverse to data maintenance and overloading applications, this concept reduces complexity and makes the comprehensive legal documentation system of the future possible.

Cadastre 2014 can easily be implemented, when the principles are respected and when feasible, correct and reliable algorithms for the comparison of the positions of land objects are at disposition. These can apply on one- two or three dimensional land objects. ESRI software has those features.

The important work in Cadastre 2014 is to identify the legal land objects which are defined by formal laws and also by informal rules and to find the correct interpretation of the contents of rights. This is what citizens and societies need for a peaceful cohabitation and a sustainable development.

9 References

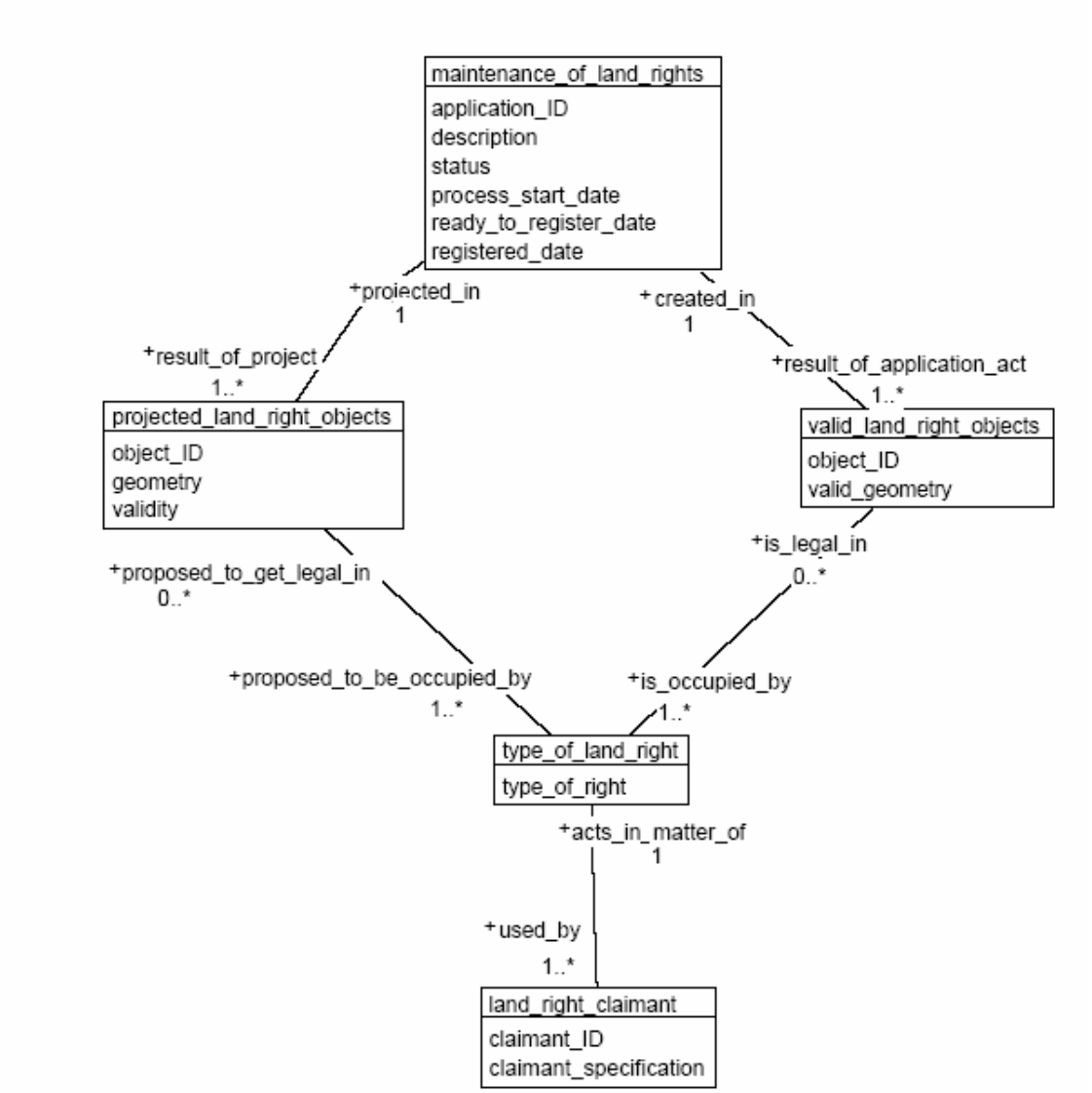
Kaufmann J., Steudler D. with Working Group 7.1 FIG Commission 7 [1998] Cadastre 2014 – A Vision for A Future Cadastral System.

De Soto, H. (2000). *The Mystery of Capital: Why Capitalism Triumphs in the West and Fails Everywhere Els*e. ISBN 0465016146, September, 276 p.

Christiaan Lemmen[1], Paul van der Molen[1], Peter van Oosterom[2], Hendrik Ploeger[2], Wilko Quak[2], Jantien Stoter[2], and Jaap Zevenbergen[2] [2003], *A MODULAR STANDARD FOR THE CADASTRAL DOMAIN,* [1]Dutch Cadastre, Apeldoorn

Annex 1: Model for land property represented in UML

This UML schema is produced from the INTERLIS-description by the UMLeditor software available from http://www.interlis.ch/interlis2/download_e.php



Annex 2: Model for land property described in INTERLIS2

!!The following example from Kosovo shows a model with different types of rights to land existing in parallel, but are not overlapping. Land can belong to property owners, claimants with a possession right, to the state as claimant or to enterprises, which had the power to distribute land to their employees.

```
INTERLIS 2.2;
MODEL ESRI_Example_land_right_model (de)=
  TOPIC land_rights=
    CLASS maintenance_of_land_rights (ABSTRACT) =
      application_ID : TEXT*10;
      description : TEXT*100;
      status : (announced,proved,valid);
      process_start_date (ABSTRACT) : NUMERIC;
      ready_to_register_date (ABSTRACT) : NUMERIC;
      registered_date (ABSTRACT) : NUMERIC;
    END maintenance_of_land_rights;

    CLASS valid_land_right_objects (ABSTRACT) =
      object_ID : TEXT*10;
      valid_geometry (ABSTRACT) : AREA WITH (ARCS,STRAIGHTS) VERTEX
      INTERLIS.LineCoord WITHOUT OVERLAPS>20;
    END valid_land_right_objects;

    CLASS projected_land_right_objects (ABSTRACT) =
      object_ID : TEXT*10;
      geometry (ABSTRACT) : SURFACE WITH (ARCS,STRAIGHTS) VERTEX
      INTERLIS.LineCoord;
      validity : (proposed, announced, submitted(checking, approved,
fixed));
    END projected_land_right_objects;

    CLASS land_right_claimant =
      claimant_ID : 1..100000;
      claimant_specification : TEXT*60;
```

```
    END land_right_claimant;

    CLASS type_of_land_right =
    type_of_right        :        (individual_private_property_right,
shared_private_property_right,              private_possession_right,
shared_private_possession_right,               state_property_right,
social_ownership_right);
    END type_of_land_right;

    ASSOCIATION maintenance_of_land_rights_to_valid_objects =
      created_in -- {1} maintenance_of_land_rights;
      result_of_application_act -- {1..*} valid_land_right_objects;
    END maintenance_of_land_rights_to_valid_objects;

    ASSOCIATION maintenance_of_land_rights_to_projected_objects =
      result_of_project -- {1..*} projected_land_right_objects;
      projected_in -- {1} maintenance_of_land_rights;
    END maintenance_of_land_rights_to_projected_objects;

    ASSOCIATION land_right_to_claimant =
      acts_in_matter_of -- {1} type_of_land_right;
      used_by -- {1..*} land_right_claimant;
    END land_right_to_claimant;

    ASSOCIATION valid_object_to_land_rights =
      is_legal_in -- {0..*} valid_land_right_objects;
      is_occupied_by -- {1..*} type_of_land_right;
    END valid_object_to_land_rights;

    ASSOCIATION projected_object_to_land_right =
proposed_to_get_legal_in -- {0..*} projected_land_right_objects;
      proposed_to_be_occupied_by -- {1..*} type_of_land_right;
    END projected_object_to_land_right;
  END land_rights;
END ESRI_Example_land_right_model.
```

Annex 3: Model for land property described in XML

The XML-transfer-file was produced automatically from the INTERLIS-description by the INTERLIS2-Compiler available from

http://www.interlis.ch/interlis2/download_e.php.

```
<xsd:schema xmlns:xsd="http://www.w3.org/2001/XMLSchema"
xmlns="http://www.interlis.ch/INTERLIS2.2"
targetNamespace="http://www.interlis.ch/INTERLIS2.2"
elementFormDefault="qualified" attributeFormDefault="unqualified">
  <xsd:element name="TRANSFER" type="Transfer"/>
  <xsd:simpleType name="IliID">
    <xsd:restriction base="xsd:string">
      <xsd:pattern value="x[0-9a-zA-Z]*"/>
    </xsd:restriction>
  </xsd:simpleType>
  <xsd:complexType name="Transfer">
    <xsd:sequence>
      <xsd:element name="HEADERSECTION" type="HeaderSection"/>
      <xsd:element name="DATASECTION" type="DataSection"/>
    </xsd:sequence>
  </xsd:complexType>
  <!-- ALIAS TABLE
    <ENTRIES FOR="ESRI_Example_land_right_model">
      <TAGENTRY FROM="ESRI_Example_land_right_model.land_rights"
TO="ESRI_Example_land_right_model.land_rights"/>
      <TAGENTRY
FROM="ESRI_Example_land_right_model.land_rights.type_of_land_right"
TO="ESRI_Example_land_right_model.land_rights.type_of_land_right"/>
      <TAGENTRY
FROM="ESRI_Example_land_right_model.land_rights.land_right_claimant"
TO="ESRI_Example_land_right_model.land_rights.land_right_claimant"/>
      <TAGENTRY
FROM="ESRI_Example_land_right_model.land_rights.valid_object_to_land_rights"
TO="ESRI_Example_land_right_model.land_rights.valid_object_to_land_rights"/>
```

```
      <TAGENTRY
FROM="ESRI_Example_land_right_model.land_rights.land_right_to_claimant"
TO="ESRI_Example_land_right_model.land_rights.land_right_to_claimant"/>
      <TAGENTRY
FROM="ESRI_Example_land_right_model.land_rights.projected_object_to_land_right
"
TO="ESRI_Example_land_right_model.land_rights.projected_object_to_land_right"/>
      <TAGENTRY
FROM="ESRI_Example_land_right_model.land_rights.maintenance_of_land_rights_t
o_projected_objects"
TO="ESRI_Example_land_right_model.land_rights.maintenance_of_land_rights_to_p
rojected_objects"/>
      <TAGENTRY
FROM="ESRI_Example_land_right_model.land_rights.maintenance_of_land_rights_t
o_valid_objects"
TO="ESRI_Example_land_right_model.land_rights.maintenance_of_land_rights_to_v
alid_objects"/>
    </ENTRIES>
     ALIAS TABLE -->
  <xsd:complexType name="HeaderSection">
    <xsd:sequence>
      <xsd:element name="ALIAS" type="Alias"/>
      <xsd:element name="COMMENT" type="xsd:anyType" minOccurs="0"/>
    </xsd:sequence>
    <xsd:attribute name="VERSION" type="xsd:decimal" use="required" fixed="2.2"/>
    <xsd:attribute name="SENDER" type="xsd:string" use="required"/>
  </xsd:complexType>
  <xsd:complexType name="Alias">
    <xsd:sequence>
      <xsd:element name="ENTRIES" type="Entries" minOccurs="0"
maxOccurs="unbounded"/>
    </xsd:sequence>
  </xsd:complexType>
  <xsd:complexType name="Entries">
    <xsd:sequence>
      <xsd:choice maxOccurs="unbounded">
```

```
      <xsd:element name="TAGENTRY" type="Tagentry"/>
      <xsd:element name="VALENTRY" type="Valentry"/>
      <xsd:element name="DELENTRY" type="Delentry"/>
    </xsd:choice>
  </xsd:sequence>
  <xsd:attribute name="FOR" type="xsd:string" use="required"/>
</xsd:complexType>
<xsd:complexType name="Tagentry">
  <xsd:attribute name="FROM" type="xsd:string" use="required"/>
  <xsd:attribute name="TO" type="xsd:string" use="required"/>
</xsd:complexType>
<xsd:complexType name="Valentry">
  <xsd:attribute name="ATTR" type="xsd:string" use="required"/>
  <xsd:attribute name="FROM" type="xsd:string" use="required"/>
  <xsd:attribute name="TO" type="xsd:string" use="required"/>
</xsd:complexType>
<xsd:complexType name="Delentry">
  <xsd:attribute name="TAG" type="xsd:string" use="required"/>
</xsd:complexType>
<xsd:complexType name="BasketValue">
  <xsd:attribute name="TOPIC" type="xsd:string" use="required"/>
  <xsd:attribute name="KIND" type="xsd:string" use="required"/>
  <xsd:attribute name="BID" type="IliID" use="required"/>
</xsd:complexType>
<xsd:complexType name="CoordValue">
  <xsd:sequence>
    <xsd:element name="C1" type="xsd:double"/>
    <xsd:element name="C2" type="xsd:double" minOccurs="0"/>
    <xsd:element name="C3" type="xsd:double" minOccurs="0"/>
  </xsd:sequence>
</xsd:complexType>
```

```
    <xsd:complexType name="ArcPoint">
      <xsd:sequence>
        <xsd:element name="C1" type="xsd:double"/>
        <xsd:element name="C2" type="xsd:double"/>
        <xsd:element name="C3" type="xsd:double" minOccurs="0"/>
        <xsd:element name="A1" type="xsd:double"/>
        <xsd:element name="A2" type="xsd:double"/>
        <xsd:element name="R" type="xsd:double" minOccurs="0"/>
      </xsd:sequence>
    </xsd:complexType>
    <xsd:complexType name="RoleType">
      <xsd:simpleContent>
        <xsd:extension base="xsd:string">
          <xsd:attribute name="REF" type="IliID"/>
          <xsd:attribute name="EXTREF" type="IliID"/>
          <xsd:attribute name="BID" type="IliID"/>
          <xsd:attribute name="NEXT_TID" type="IliID"/>
        </xsd:extension>
      </xsd:simpleContent>
    </xsd:complexType>
    <xsd:complexType name="DataSection">
      <xsd:sequence>
        <xsd:choice minOccurs="0" maxOccurs="unbounded">
          <xsd:element name="ESRI_Example_land_right_model.land_rights"
type="ESRI_Example_land_right_model.land_rights"/>
        </xsd:choice>
      </xsd:sequence>
    </xsd:complexType>
    <xsd:simpleType name="INTERLIS.HALIGNMENT">
      <xsd:restriction base="xsd:string">
        <xsd:enumeration value="Left"/>
        <xsd:enumeration value="Center"/>
```

```
    <xsd:enumeration value="Right"/>
  </xsd:restriction>
</xsd:simpleType>
<xsd:simpleType name="INTERLIS.VALIGNMENT">
  <xsd:restriction base="xsd:string">
    <xsd:enumeration value="Top"/>
    <xsd:enumeration value="Cap"/>
    <xsd:enumeration value="Half"/>
    <xsd:enumeration value="Base"/>
    <xsd:enumeration value="Bottom"/>
  </xsd:restriction>
</xsd:simpleType>
<xsd:simpleType name="INTERLIS.URI">
  <xsd:restriction base="xsd:string">
    <xsd:maxLength value="1023"/>
  </xsd:restriction>
</xsd:simpleType>
<xsd:simpleType name="INTERLIS.NAME">
  <xsd:restriction base="xsd:string">
    <xsd:maxLength value="255"/>
  </xsd:restriction>
</xsd:simpleType>
<xsd:simpleType name="INTERLIS.INTERLIS_1_DATE">
  <xsd:restriction base="xsd:string">
    <xsd:maxLength value="8"/>
  </xsd:restriction>
</xsd:simpleType>
<xsd:complexType  name="INTERLIS.METAOBJECT">
  <xsd:sequence>
    <xsd:element name="Name" type="INTERLIS.NAME"/>
  </xsd:sequence>
```

```
  </xsd:complexType>
  <xsd:complexType  name="INTERLIS.METAOBJECT_TRANSLATION">
   <xsd:sequence>
    <xsd:element name="Name" type="INTERLIS.NAME"/>
    <xsd:element name="NameInBaseLanguage" type="INTERLIS.NAME"/>
   </xsd:sequence>
  </xsd:complexType>
  <xsd:complexType  name="INTERLIS.AXIS">
   <xsd:sequence>
   </xsd:sequence>
  </xsd:complexType>
  <xsd:complexType  name="INTERLIS.REFSYSTEM">
   <xsd:sequence>
    <xsd:element name="Name" type="INTERLIS.NAME"/>
   </xsd:sequence>
  </xsd:complexType>
  <xsd:complexType  name="INTERLIS.COORDSYSTEM">
   <xsd:sequence>
    <xsd:element name="Name" type="INTERLIS.NAME"/>
    <xsd:element name="Axis">
     <xsd:complexType>
      <xsd:sequence>
       <xsd:element name="INTERLIS.AXIS" type="INTERLIS.AXIS"
maxOccurs="3"/>
      </xsd:sequence>
     </xsd:complexType>
    </xsd:element>
   </xsd:sequence>
  </xsd:complexType>
  <xsd:complexType  name="INTERLIS.SCALSYSTEM">
   <xsd:sequence>
    <xsd:element name="Name" type="INTERLIS.NAME"/>
```

```
    </xsd:sequence>
  </xsd:complexType>
  <xsd:complexType  name="INTERLIS.SIGN">
    <xsd:sequence>
      <xsd:element name="Name" type="INTERLIS.NAME"/>
    </xsd:sequence>
  </xsd:complexType>
  <xsd:complexType
name="ESRI_Example_land_right_model.land_rights.type_of_land_right">
    <xsd:sequence>
      <xsd:element name="type_of_right" minOccurs="0">
        <xsd:simpleType>
          <xsd:restriction base="xsd:string">
            <xsd:enumeration value="individual_private_property_right"/>
            <xsd:enumeration value="shared_private_property_right"/>
            <xsd:enumeration value="private_possession_right"/>
            <xsd:enumeration value="shared_private_possession_right"/>
            <xsd:enumeration value="state_property_right"/>
            <xsd:enumeration value="social_ownership_right"/>
          </xsd:restriction>
        </xsd:simpleType>
      </xsd:element>
    </xsd:sequence>
  </xsd:complexType>
  <xsd:complexType
name="ESRI_Example_land_right_model.land_rights.valid_land_right_objects">
    <xsd:sequence>
      <xsd:element name="object_ID" minOccurs="0">
        <xsd:simpleType>
          <xsd:restriction base="xsd:string">
            <xsd:maxLength value="10"/>
          </xsd:restriction>
```

```
  </xsd:simpleType>
</xsd:element>
<xsd:element name="valid_geometry" minOccurs="0">
  <xsd:complexType>
    <xsd:sequence>
      <xsd:element name="SURFACE">
        <xsd:complexType>
          <xsd:sequence>
            <xsd:element name="BOUNDARY" maxOccurs="unbounded">
              <xsd:complexType>
                <xsd:sequence>
                  <xsd:element name="POLYLINE" maxOccurs="unbounded">
                    <xsd:complexType>
                      <xsd:choice minOccurs="2" maxOccurs="unbounded">
                        <xsd:element name="COORD" type="CoordValue"/>
                        <xsd:element name="ARC" type="ArcPoint"/>
                      </xsd:choice>
                    </xsd:complexType>
                  </xsd:element>
                </xsd:sequence>
              </xsd:complexType>
            </xsd:element>
          </xsd:sequence>
        </xsd:complexType>
      </xsd:element>
    </xsd:sequence>
  </xsd:complexType>
</xsd:element>
<xsd:element name="created_in">
  <xsd:complexType>
    <xsd:attribute name="REF" type="IliID"/>
```

```
          <xsd:attribute name="EXTREF" type="IliID"/>
          <xsd:attribute name="BID" type="IliID"/>
          <xsd:attribute name="NEXT_TID" type="IliID"/>
        </xsd:complexType>
      </xsd:element>
    </xsd:sequence>
  </xsd:complexType>
  <xsd:complexType
name="ESRI_Example_land_right_model.land_rights.land_right_claimant">
    <xsd:sequence>
      <xsd:element name="claimant_ID" minOccurs="0">
        <xsd:simpleType>
          <xsd:restriction base="xsd:double">
            <xsd:minInclusive value="1.0"/>
            <xsd:maxInclusive value="100000.0"/>
          </xsd:restriction>
        </xsd:simpleType>
      </xsd:element>
      <xsd:element name="claimant_specification" minOccurs="0">
        <xsd:simpleType>
          <xsd:restriction base="xsd:string">
            <xsd:maxLength value="60"/>
          </xsd:restriction>
        </xsd:simpleType>
      </xsd:element>
      <xsd:element name="acts_in_matter_of">
        <xsd:complexType>
          <xsd:attribute name="REF" type="IliID"/>
          <xsd:attribute name="EXTREF" type="IliID"/>
          <xsd:attribute name="BID" type="IliID"/>
          <xsd:attribute name="NEXT_TID" type="IliID"/>
        </xsd:complexType>
```

```
      </xsd:element>
    </xsd:sequence>
  </xsd:complexType>
  <xsd:complexType
name="ESRI_Example_land_right_model.land_rights.projected_land_right_objects">
    <xsd:sequence>
      <xsd:element name="object_ID" minOccurs="0">
        <xsd:simpleType>
          <xsd:restriction base="xsd:string">
            <xsd:maxLength value="10"/>
          </xsd:restriction>
        </xsd:simpleType>
      </xsd:element>
      <xsd:element name="geometry" minOccurs="0">
        <xsd:complexType>
          <xsd:sequence>
            <xsd:element name="SURFACE">
              <xsd:complexType>
                <xsd:sequence>
                  <xsd:element name="BOUNDARY" maxOccurs="unbounded">
                    <xsd:complexType>
                      <xsd:sequence>
                        <xsd:element name="POLYLINE" maxOccurs="unbounded">
                          <xsd:complexType>
                            <xsd:choice minOccurs="2" maxOccurs="unbounded">
                              <xsd:element name="COORD" type="CoordValue"/>
                              <xsd:element name="ARC" type="ArcPoint"/>
                            </xsd:choice>
                          </xsd:complexType>
                        </xsd:element>
                      </xsd:sequence>
                    </xsd:complexType>
```

```
            </xsd:element>
           </xsd:sequence>
          </xsd:complexType>
         </xsd:element>
        </xsd:sequence>
       </xsd:complexType>
      </xsd:element>
      <xsd:element name="validity" minOccurs="0">
       <xsd:simpleType>
        <xsd:restriction base="xsd:string">
         <xsd:enumeration value="proposed"/>
         <xsd:enumeration value="announced"/>
         <xsd:enumeration value="submitted.checking"/>
         <xsd:enumeration value="submitted.approved"/>
         <xsd:enumeration value="submitted.fixed"/>
        </xsd:restriction>
       </xsd:simpleType>
      </xsd:element>
      <xsd:element name="projected_in">
       <xsd:complexType>
        <xsd:attribute name="REF" type="IliID"/>
        <xsd:attribute name="EXTREF" type="IliID"/>
        <xsd:attribute name="BID" type="IliID"/>
        <xsd:attribute name="NEXT_TID" type="IliID"/>
       </xsd:complexType>
      </xsd:element>
     </xsd:sequence>
    </xsd:complexType>
    <xsd:complexType
name="ESRI_Example_land_right_model.land_rights.maintenance_of_land_rights">
     <xsd:sequence>
      <xsd:element name="application_ID" minOccurs="0">
```

```
  <xsd:simpleType>
    <xsd:restriction base="xsd:string">
      <xsd:maxLength value="10"/>
    </xsd:restriction>
  </xsd:simpleType>
</xsd:element>
<xsd:element name="description" minOccurs="0">
  <xsd:simpleType>
    <xsd:restriction base="xsd:string">
      <xsd:maxLength value="100"/>
    </xsd:restriction>
  </xsd:simpleType>
</xsd:element>
<xsd:element name="status" minOccurs="0">
  <xsd:simpleType>
    <xsd:restriction base="xsd:string">
      <xsd:enumeration value="announced"/>
      <xsd:enumeration value="proved"/>
      <xsd:enumeration value="valid"/>
    </xsd:restriction>
  </xsd:simpleType>
</xsd:element>
<xsd:element name="process_start_date" minOccurs="0">
  <xsd:simpleType>
    <xsd:restriction base="xsd:double">
    </xsd:restriction>
  </xsd:simpleType>
</xsd:element>
<xsd:element name="ready_to_register_date" minOccurs="0">
  <xsd:simpleType>
    <xsd:restriction base="xsd:double">
```

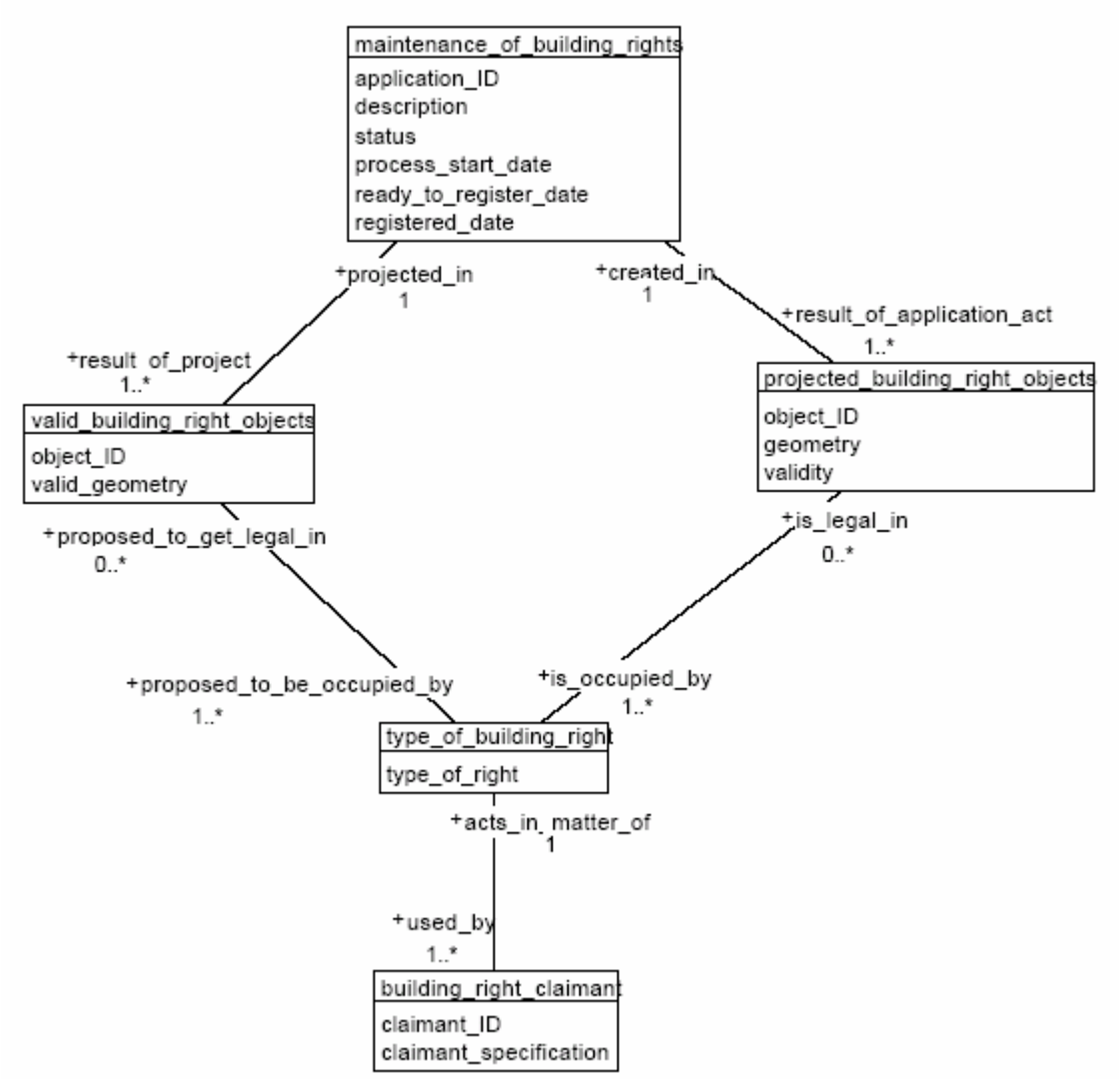
```
          </xsd:restriction>
        </xsd:simpleType>
      </xsd:element>
      <xsd:element name="registered_date" minOccurs="0">
        <xsd:simpleType>
          <xsd:restriction base="xsd:double">
          </xsd:restriction>
        </xsd:simpleType>
      </xsd:element>
    </xsd:sequence>
  </xsd:complexType>
  <xsd:complexType
name="ESRI_Example_land_right_model.land_rights.valid_object_to_land_rights">
    <xsd:sequence>
      <xsd:element name="is_legal_in" type="RoleType"/>
      <xsd:element name="is_occupied_by" type="RoleType"/>
    </xsd:sequence>
  </xsd:complexType>
  <xsd:complexType
name="ESRI_Example_land_right_model.land_rights.land_right_to_claimant">
    <xsd:sequence>
    </xsd:sequence>
  </xsd:complexType>
  <xsd:complexType
name="ESRI_Example_land_right_model.land_rights.projected_object_to_land_right"
>
    <xsd:sequence>
      <xsd:element name="proposed_to_get_legal_in" type="RoleType"/>
      <xsd:element name="proposed_to_be_occupied_by" type="RoleType"/>
    </xsd:sequence>
  </xsd:complexType>
```

```
   <xsd:complexType
name="ESRI_Example_land_right_model.land_rights.maintenance_of_land_rights_to
_projected_objects">
     <xsd:sequence>
     </xsd:sequence>
   </xsd:complexType>
   <xsd:complexType
name="ESRI_Example_land_right_model.land_rights.maintenance_of_land_rights_to
_valid_objects">
     <xsd:sequence>
     </xsd:sequence>
   </xsd:complexType>
   <xsd:complexType name="ESRI_Example_land_right_model.land_rights">
     <xsd:sequence>
      <xsd:choice minOccurs="0" maxOccurs="unbounded">
        <xsd:element
name="ESRI_Example_land_right_model.land_rights.type_of_land_right">
          <xsd:complexType>
            <xsd:complexContent>
              <xsd:extension
base="ESRI_Example_land_right_model.land_rights.type_of_land_right">
                <xsd:attribute name="TID" type="IliID" use="required"/>
                <xsd:attribute name="BID" type="IliID"/>
                <xsd:attribute name="OPERATION" type="xsd:string"/>
              </xsd:extension>
            </xsd:complexContent>
          </xsd:complexType>
        </xsd:element>
        <xsd:element
name="ESRI_Example_land_right_model.land_rights.land_right_claimant">
          <xsd:complexType>
            <xsd:complexContent>
              <xsd:extension
base="ESRI_Example_land_right_model.land_rights.land_right_claimant">
```

```
            <xsd:attribute name="TID" type="IliID" use="required"/>
            <xsd:attribute name="BID" type="IliID"/>
            <xsd:attribute name="OPERATION" type="xsd:string"/>
          </xsd:extension>
        </xsd:complexContent>
      </xsd:complexType>
    </xsd:element>
    <xsd:element
name="ESRI_Example_land_right_model.land_rights.valid_object_to_land_rights">
      <xsd:complexType>
        <xsd:complexContent>
          <xsd:extension
base="ESRI_Example_land_right_model.land_rights.valid_object_to_land_rights">
            <xsd:attribute name="TID" type="IliID" use="required"/>
            <xsd:attribute name="BID" type="IliID"/>
            <xsd:attribute name="OPERATION" type="xsd:string"/>
          </xsd:extension>
        </xsd:complexContent>
      </xsd:complexType>
    </xsd:element>
    <xsd:element
name="ESRI_Example_land_right_model.land_rights.projected_object_to_land_right"
>
      <xsd:complexType>
        <xsd:complexContent>
          <xsd:extension
base="ESRI_Example_land_right_model.land_rights.projected_object_to_land_right"
>
            <xsd:attribute name="TID" type="IliID" use="required"/>
            <xsd:attribute name="BID" type="IliID"/>
            <xsd:attribute name="OPERATION" type="xsd:string"/>
          </xsd:extension>
        </xsd:complexContent>
```

```
          </xsd:complexType>
        </xsd:element>
      </xsd:choice>
    </xsd:sequence>
    <xsd:attribute name="BID" type="IliID" use="required"/>
    <xsd:attribute name="TOPICS" type="xsd:string"/>
    <xsd:attribute name="KIND" type="xsd:string"/>
    <xsd:attribute name="STARTSTATE" type="xsd:string"/>
    <xsd:attribute name="ENDSTATE" type="xsd:string"/>
  </xsd:complexType>
</xsd:schema>
```

Annex 4: Model for buildings in UML and INTERLIS2



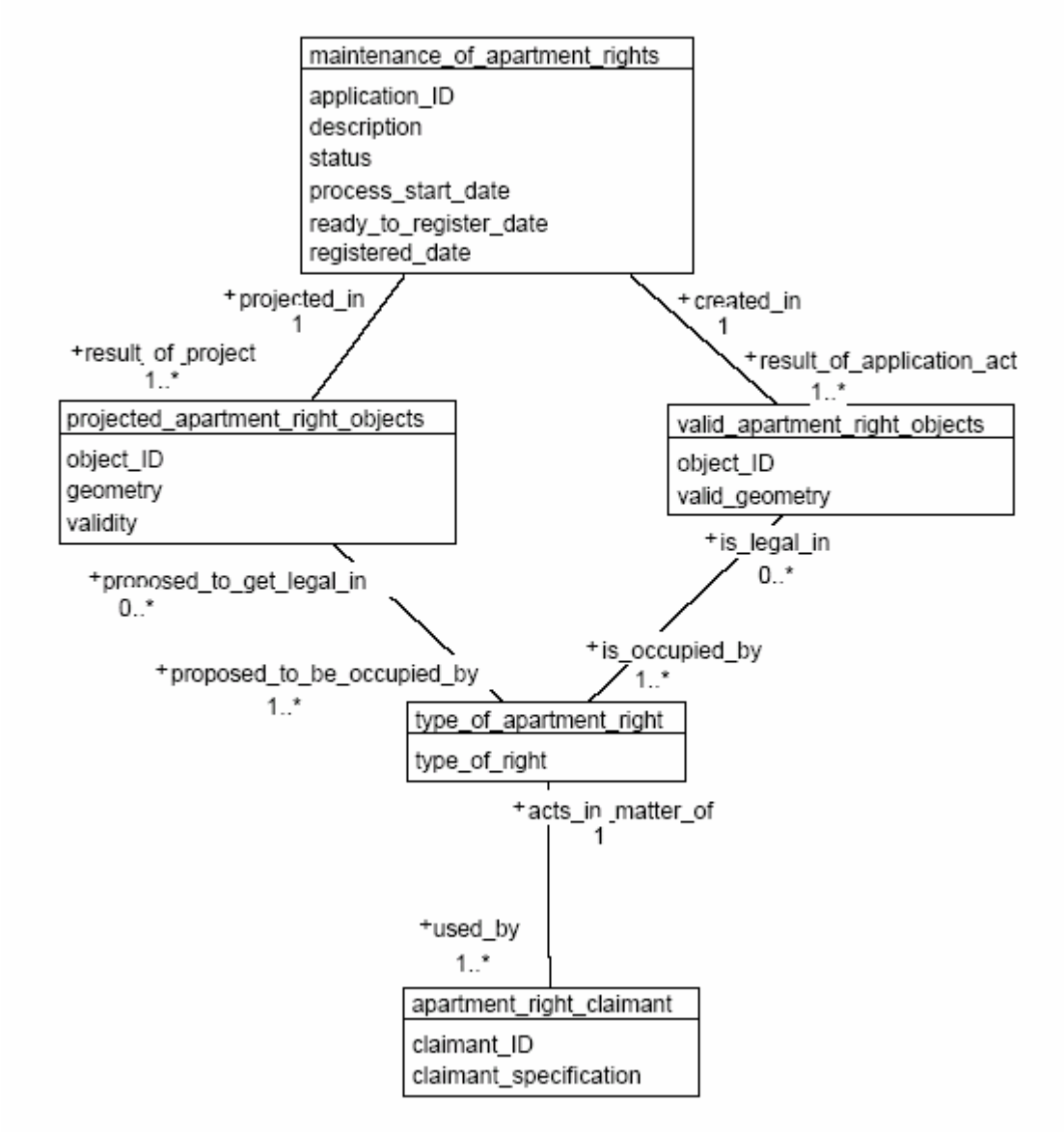
!!The following example shows a model where buildings are represented by a point only. The respective legislation does not consider the representation of the shape of buildings in the cadastre as necessary. However the cadastre shall show what buildings exist on what parcels and who has what rights on buildings. As a consequence of conflict, it is not known in every case who is the owner and what rights he had. A type of right 'unknown_right' is introduced.

```
INTERLIS 2.2;
```

```
MODEL ESRI_Example_building_right_model (de)=
  TOPIC building_rights=

    DOMAIN
      Point2D = COORD
0.000 .. 200.000 [INTERLIS.m], !! Min_East Max_East
0.000 .. 200.000 [INTERLIS.m], !! Min_North Max_North
ROTATION 2 -> 1;
Orientation = 0.0 .. 359.9;

    CLASS maintenance_of_building_rights (ABSTRACT) =
      application_ID : TEXT*10;
      description : TEXT*100;
      status : (announced,proved,valid);
      process_start_date (ABSTRACT) : NUMERIC;
      ready_to_register_date (ABSTRACT) : NUMERIC;
      registered_date (ABSTRACT) : NUMERIC;
    END maintenance_of_building_rights;

    CLASS valid_building_right_objects (ABSTRACT) =
      object_ID : TEXT*10;
      valid_geometry (ABSTRACT) : Point2D;
    END valid_building_right_objects;

    CLASS projected_building_right_objects (ABSTRACT) =
      object_ID : TEXT*10;
      geometry (ABSTRACT) : Point2D;
      validity : (proposed, announced, submitted(checking, approved,
fixed));
    END projected_building_right_objects;

    CLASS building_right_claimant =
      claimant_ID : 1..100000;
      claimant_specification : TEXT*60;
```

```
    END building_right_claimant;

    CLASS type_of_building_right =
    type_of_right              :              (private_property_right,
private_possession_right,                        state_property_right,
social_ownership_right, unknown_right);
    END type_of_building_right;

    ASSOCIATION maintenance_of_building_rights_to_valid_objects =
      created_in -- {1} maintenance_of_building_rights;
      result_of_application_act                --               {1..*}
valid_building_right_objects;
    END maintenance_of_building_rights_to_valid_objects;

    ASSOCIATION maintenance_of_building_rights_to_projected_objects =
      result_of_project -- {1..*} projected_building_right_objects;
      projected_in -- {1} maintenance_of_building_rights;
    END maintenance_of_building_rights_to_projected_objects;

    ASSOCIATION building_right_to_claimant =
      acts_in_matter_of -- {1} type_of_building_right;
      used_by -- {1..*} building_right_claimant;
    END building_right_to_claimant;

    ASSOCIATION valid_object_to_building_rights =
      is_legal_in -- {0..*} valid_building_right_objects;
      is_occupied_by -- {1..*} type_of_building_right;
    END valid_object_to_building_rights;

    ASSOCIATION projected_object_to_building_right =
proposed_to_get_legal_in -- {0..*} projected_building_right_objects;
      proposed_to_be_occupied_by -- {1..*} type_of_building_right;
    END projected_object_to_building_right;
  END building_rights;
END ESRI_Example_building_right_model.
```

Annex 5: Model for apartments in UML and INTERLIS2



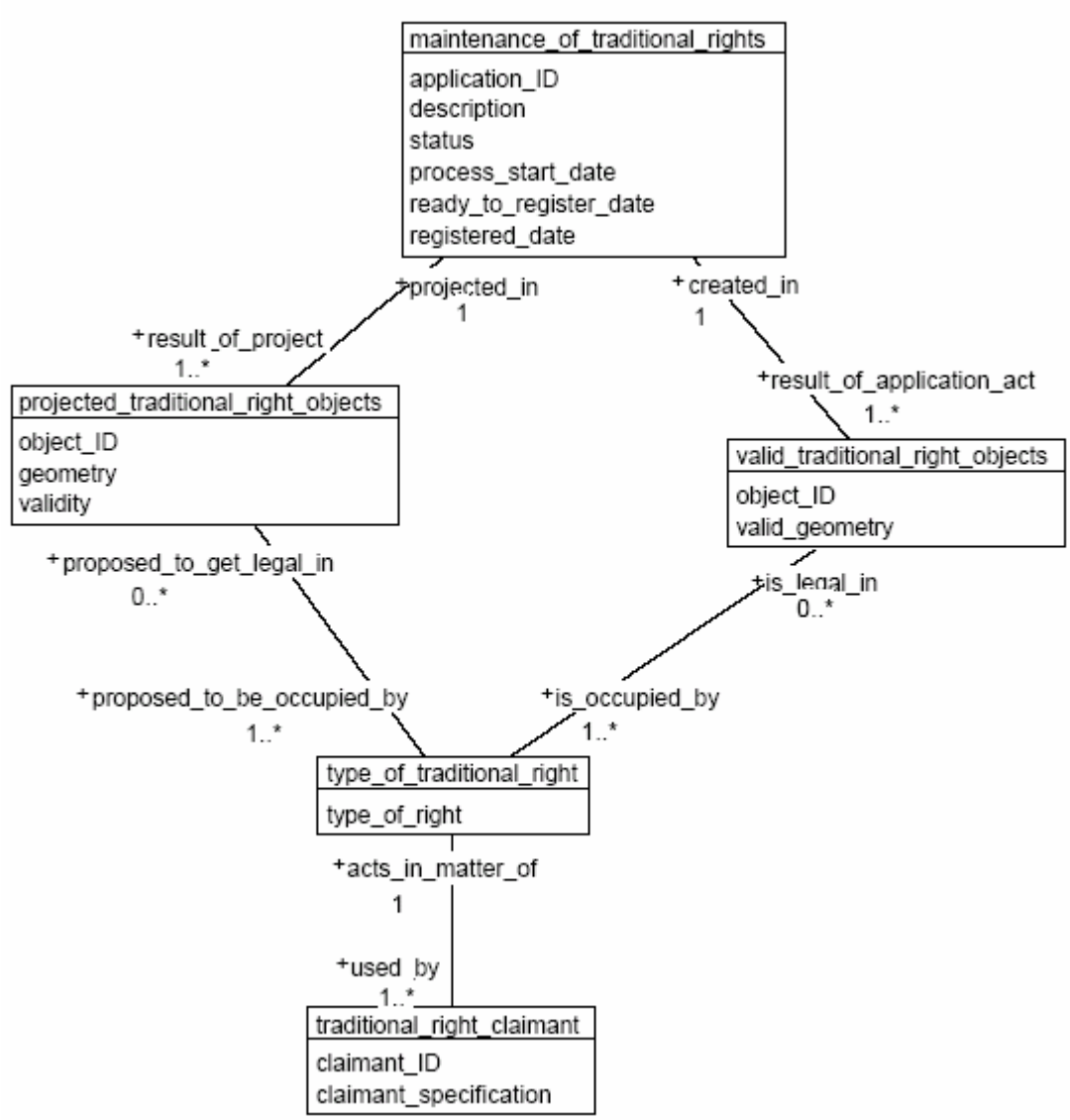

```
!! Example for modelling rights on apartments


!! The following example shows a model for apartments. The geometry
is the outlines in the horizontal projection.
```

```
INTERLIS 2.2;

MODEL ESRI_Example_apartment_right_model (de) =

  TOPIC apartment_rights =

    DOMAIN
      Point2D = COORD
0.000 .. 600000.000 [INTERLIS.m], !! Min_East Max_East
0.000 .. 200000.000 [INTERLIS.m], !! Min_North Max_North
ROTATION 2 -> 1;
Orientation = 0.0 .. 359.9;

    CLASS maintenance_of_apartment_rights (ABSTRACT) =
      application_ID : TEXT*10;
      description : TEXT*100;
      status : (announced,in_construction, built);
      process_start_date (ABSTRACT) : NUMERIC;
      ready_to_register_date (ABSTRACT) : NUMERIC;
      registered_date (ABSTRACT) : NUMERIC;
    END maintenance_of_apartment_rights;

    CLASS valid_apartment_right_objects (ABSTRACT) =
      object_ID : TEXT*10;
      valid_geometry  (ABSTRACT)  :  SURFACE  WITH  (ARCS,STRAIGHTS)
VERTEX     Point2D;
    END valid_apartment_right_objects;

    CLASS projected_apartment_right_objects (ABSTRACT) =
      object_ID : TEXT*10;
      geometry  (ABSTRACT)  :  SURFACE  WITH  (ARCS,STRAIGHTS)  VERTEX
Point2D;
      validity : (proposed, announced, in_construction, built);
    END projected_apartment_right_objects;
```

```
    CLASS apartment_right_claimant =
      claimant_ID : 1..100000;
      claimant_specification : TEXT*60;
    END apartment_right_claimant;

    CLASS type_of_apartment_right =
type_of_right          :          (individual_private_property_right,
shared_private_property_right,               private_leasehold_right,
state_property_right);
    END type_of_apartment_right;

    ASSOCIATION maintenance_of_apartment_rights_to_valid_objects =
      created_in -- {1} maintenance_of_apartment_rights;
      result_of_application_act               --               {1..*}
valid_apartment_right_objects;
    END maintenance_of_apartment_rights_to_valid_objects;

    ASSOCIATION   maintenance_of_apartment_rights_to_projected_objects
=
      result_of_project -- {1..*} projected_apartment_right_objects;
      projected_in -- {1} maintenance_of_apartment_rights;
    END maintenance_of_apartment_rights_to_projected_objects;

    ASSOCIATION apartment_right_to_claimant =
      acts_in_matter_of -- {1} type_of_apartment_right;
      used_by -- {1..*} apartment_right_claimant;
    END apartment_right_to_claimant;

    ASSOCIATION valid_object_to_apartment_rights =
      is_legal_in -- {0..*} valid_apartment_right_objects;
      is_occupied_by -- {1..*} type_of_apartment_right;
    END valid_object_to_apartment_rights;

    ASSOCIATION projected_object_to_apartment_right =
proposed_to_get_legal_in -- {0..*} projected_apartment_right_objects;
```

```
      proposed_to_be_occupied_by -- {1..*} type_of_apartment_right;
    END projected_object_to_apartment_right;

  END apartment_rights;

END ESRI_Example_apartment_right_model.
```

Annex 6: Model for traditional land rights in UML and INTERLIS2



!! Example for modelling traditional informal rights of indigenous societies

!! The following example shows a model of informal rights of traditional societies in countries which have been colonized. The traditional rights often overlap with those deriving from the statutory legislations introduced by the colonizers. The maintenance CLASSES have been retained, despite no dynamic development is to be expected. However also these rights might undergo changes, due to the development.

```
INTERLIS 2.2;

MODEL ESRI_Example_traditional_right_model (de) =

  TOPIC traditional_rights =

    CLASS maintenance_of_traditional_rights (ABSTRACT) =
      application_ID : TEXT*10;
      description : TEXT*100;
      status : (announced,proved,valid);
      process_start_date (ABSTRACT) : NUMERIC;
      ready_to_register_date (ABSTRACT) : NUMERIC;
      registered_date (ABSTRACT) : NUMERIC;
    END maintenance_of_traditional_rights;

    CLASS valid_traditional_right_objects (ABSTRACT) =
      object_ID : TEXT*10;
      valid_geometry (ABSTRACT) : AREA WITH (ARCS,STRAIGHTS) VERTEX
      INTERLIS.LineCoord WITHOUT OVERLAPS>20;
    END valid_traditional_right_objects;

    CLASS projected_traditional_right_objects (ABSTRACT) =
      object_ID : TEXT*10;
      geometry (ABSTRACT) : SURFACE WITH (ARCS,STRAIGHTS) VERTEX
      INTERLIS.LineCoord;
      validity : (proposed, announced, submitted(checking, approved,
fixed));
    END projected_traditional_right_objects;

    CLASS traditional_right_claimant =
      claimant_ID : 1..100000;
      claimant_specification : TEXT*60;
    END traditional_right_claimant;
```

```
    CLASS type_of_traditional_right =
type_of_right  :  (right_to_hunt,  right_to_fish,  right_to_usufruct,
right_to_celebrate);
    END type_of_traditional_right;


    ASSOCIATION maintenance_of_traditional_rights_to_valid_objects =
      created_in -- {1} maintenance_of_traditional_rights;
      result_of_application_act               --               {1..*}
valid_traditional_right_objects;
    END maintenance_of_traditional_rights_to_valid_objects;


    ASSOCIATION
maintenance_of_traditional_rights_to_projected_objects =
      result_of_project                   --                   {1..*}
projected_traditional_right_objects;
      projected_in -- {1} maintenance_of_traditional_rights;
    END maintenance_of_traditional_rights_to_projected_objects;


    ASSOCIATION traditional_right_to_claimant =
      acts_in_matter_of -- {1} type_of_traditional_right;
      used_by -- {1..*} traditional_right_claimant;
    END traditional_right_to_claimant;


    ASSOCIATION valid_object_to_traditional_rights =
      is_legal_in -- {0..*} valid_traditional_right_objects;
      is_occupied_by -- {1..*} type_of_traditional_right;
    END valid_object_to_traditional_rights;


    ASSOCIATION projected_object_to_traditional_right =
proposed_to_get_legal_in                  --                   {0..*}
projected_traditional_right_objects;
      proposed_to_be_occupied_by -- {1..*} type_of_traditional_right;
    END projected_object_to_traditional_right;


  END traditional_rights;
END ESRI_Example_traditional_right_model.
```