



# A modular standard for the cadastral domain: Application to the Portuguese Cadastre

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## Abstract

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. 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 occurs 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 occurs in several countries, then this should be added to the core model. (*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.

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Where it exists a correspondence with the standard model, the original English name is referred within brackets.)

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## 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 on the article “A modular standard for the Cadastral Domain” (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 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 (Erikson & Penker, 1998), 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 & Erik, 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.

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. It has been known by “Cadastró Geométrico da Propriedade Rústica”, that is, a Geometric Cadastre of Rural Property.

Such 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 where 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 (Melo, 1989). Eventually, this Cadastre began to face multiple problems due to lack of timely update procedures (Veigas, 2002).

The nineties brought new digital technologies to the Cadastre, involving the definition of a Cadastral Plan Data Model, implemented on five 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,<sup>1</sup> called “Cadastró 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 Title based system (Mendes, 2003a, 2003b), 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.

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<sup>1</sup> The Fiscal Role is only foreseen in the future “Real Property Cadastre National System”.

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, upgradable and scalable solution, based on state-of-the-art modeling techniques. In subsequent developments, presented static and dynamic models are to be prototyped using state of the art information and communication technology.

### 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, Section 3.1 discusses the three core classes of the model (RealEstateObject, RightOrRestriction, and Person). In Section 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 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 in Fig. 1 diagram reflect the distribution of the cadastral responsibilities between different Portuguese institutions.

Thus, real estate objects are included in the super class *ObjectoCadastralPredial* (*Real-EstateObject* 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 in 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.

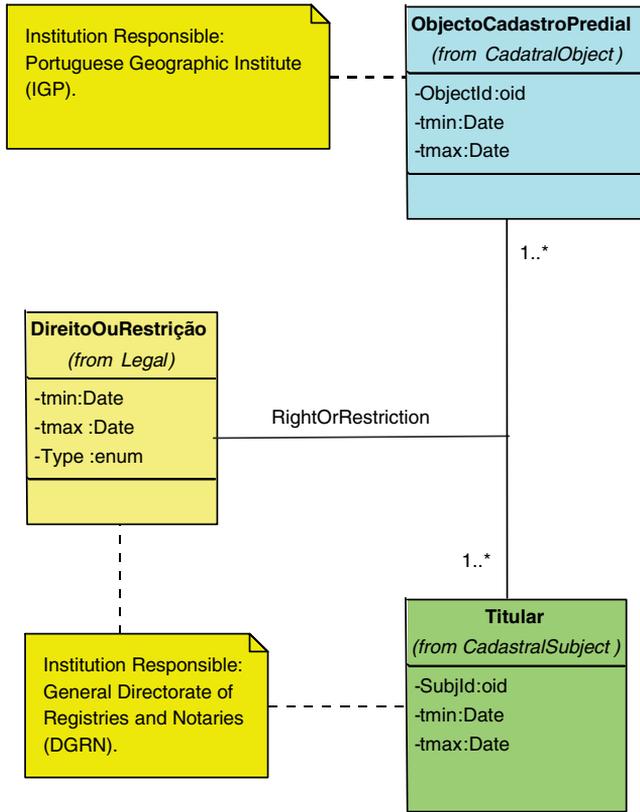


Fig. 1. Cadastral model core.

### 3.2. Geometric cadastre class diagrams

#### 3.2.1. The parcel component

Following class diagrams show the specialization (and associated) classes of the *ObjectoCadastralPredial* (*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 *ObjectoCadastralPredial* 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 *Parcel*s, or other areas of Public Domain (and with no identifiable *Titular*). Can also represent community pastures or other forms of communal land known as “Baldios”.

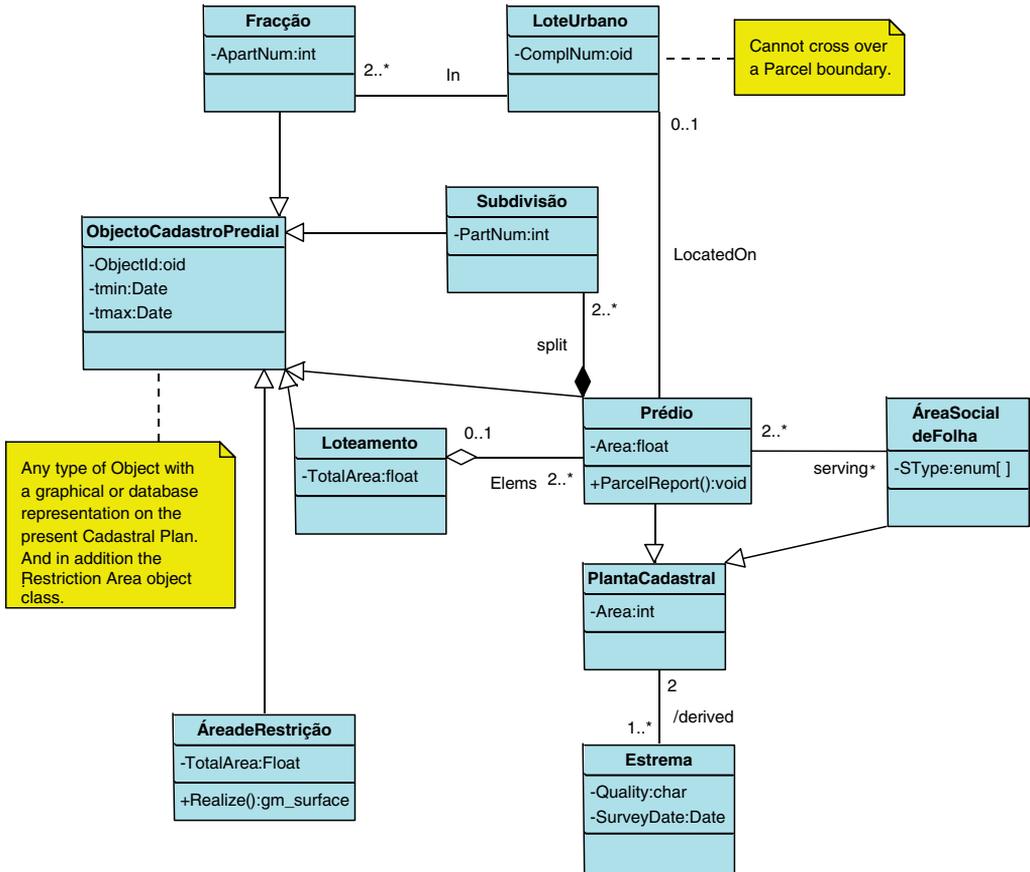


Fig. 2. Geometric cadastre—parcel component.

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 in 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*). An *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 ApartmentComplex 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.

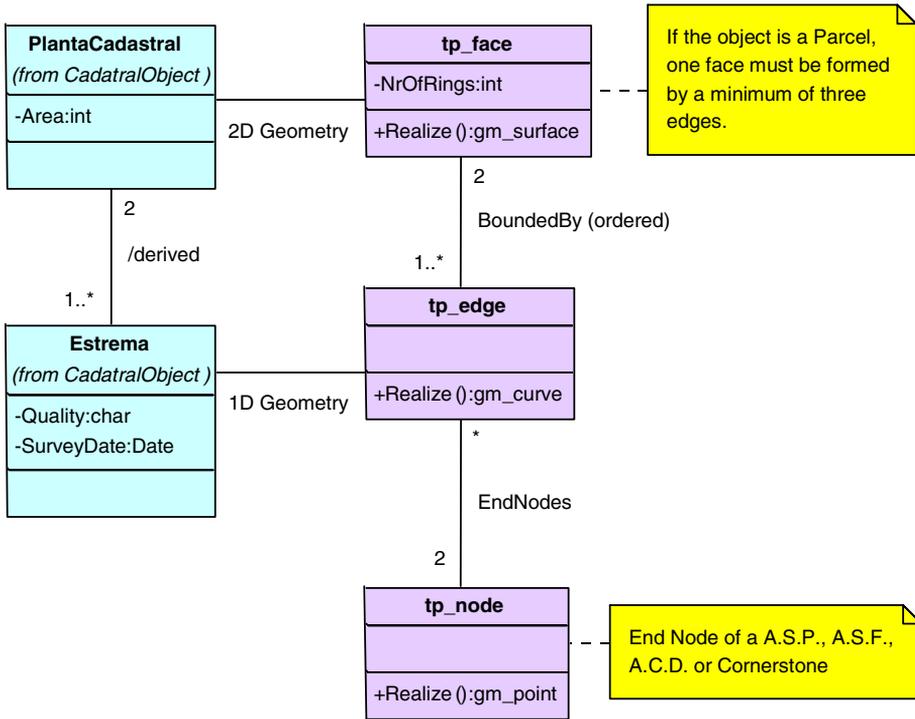


Fig. 3. Geometric cadastre—geometry and topology.

The following classes, shown also in 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 Section 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,<sup>2</sup> 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.

<sup>2</sup> 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.

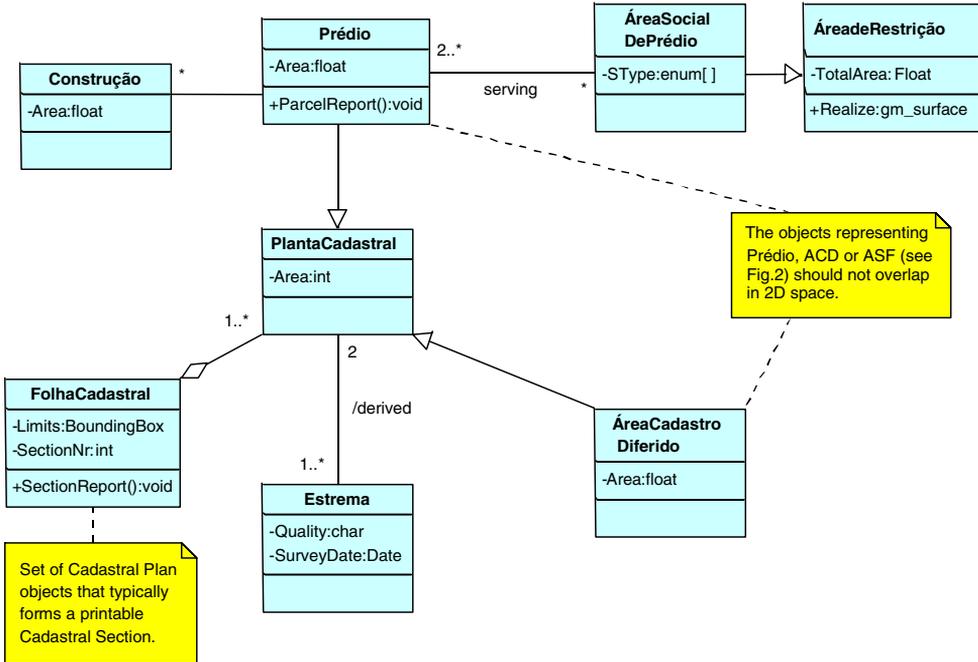


Fig. 4. Geometric cadastre—other objects.

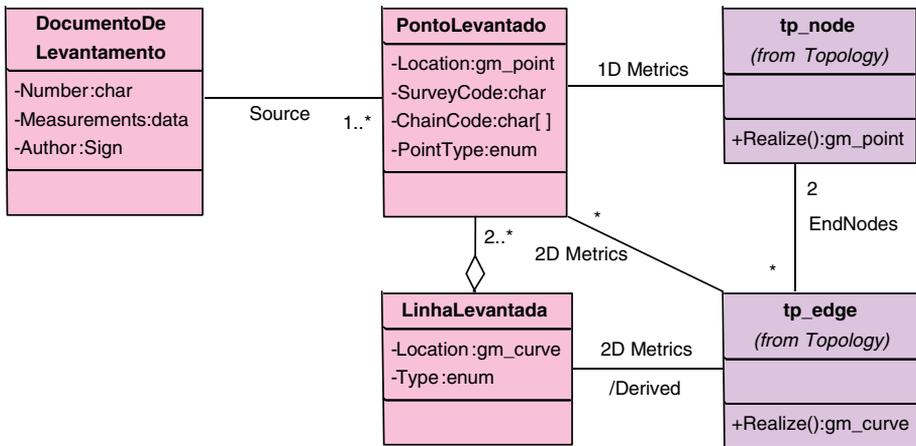


Fig. 5. Cadastral survey classes.

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* (English: Parcel's Social Area), described in Section 3.2.3, which exists in the current system and is acquired by IGP.

### 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 their 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), *ÁreaCadastralDiferido* (ACD), or *Prédio* (in the form of a parcel corner/cornerstone, or a passage mark), as described in Section 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*).

Current Portuguese Data Model forces Parcel objects to have a minimum of three *tp\_edge* to form a *tp\_face*, reflecting the concept that a cadastral edge must be a straight line between two cornerstones or end nodes or passage marks. No intermediate vertices are allowed in 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 Section 3.2.4 for an explanation on how to bring survey field data to the Cadastral Model.

### 3.2.3. Additional cadastral plan objects

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 in Fig. 2. To overcome this, a number of new classes are created, as shown in 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 *ÁreaCadastralDiferido* (English: 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*, *ÁreaCadastralDiferido* and *Prédio* form the 2D Partition of space, filling the whole area of any given Cadastral Section. The new class *Construção* (English: 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.
- *ÁreaCadastralDiferido* (ACD): sets of parcels where 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.

#### 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.

### 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 (Fig. 6), 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 *ObjectoCadastralPredial* 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* (*LegalDocument*) containing three types of documents, typically supplied by an Owner who wants to register a Title, or any interested party in

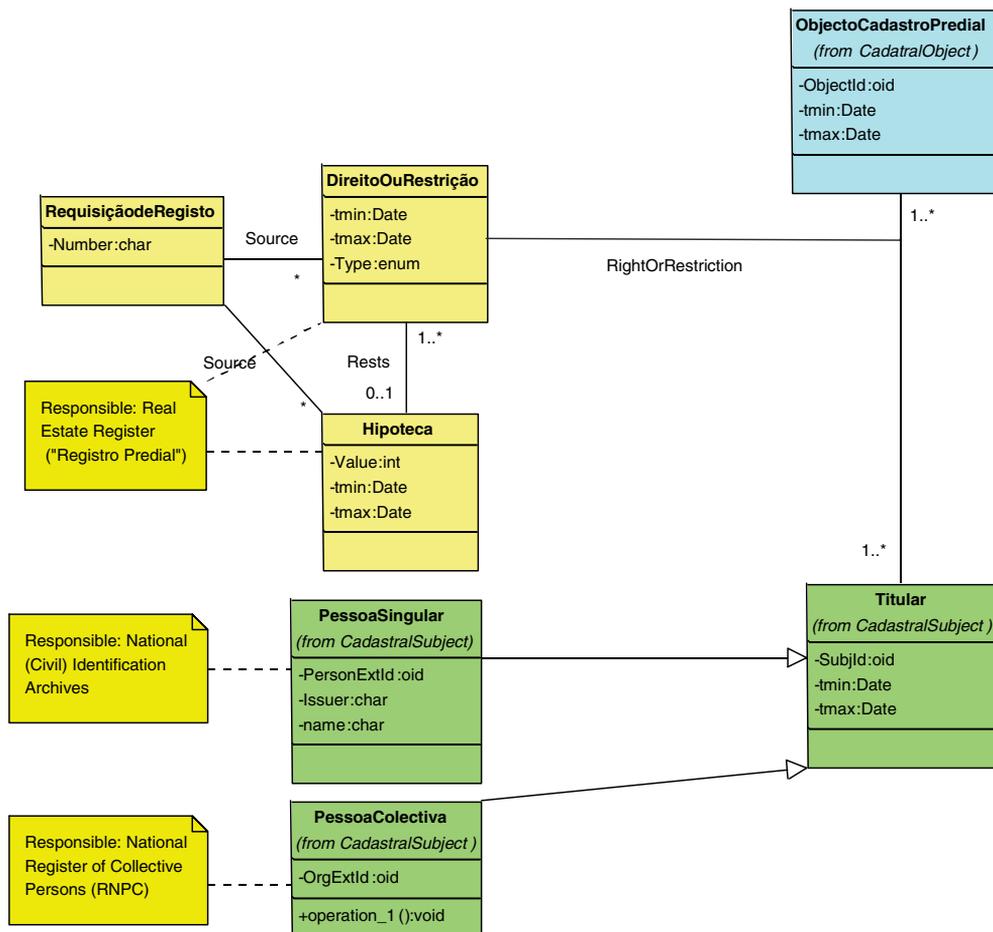


Fig. 6. Legal and administrative registers.

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).

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 *Direito Ou Restrição* 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 exist 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 *Objecto-Cadastral*. 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*<sup>3</sup>: 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;
- *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 *ObjectoCadastral* 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

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<sup>3</sup> It is a type of leasing which can involve movable or immovable goods. For example, 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.

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 Section 4.1). The second procedure is ‘Transformation of a rural into a urban parcel’ (see Section 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 and 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, let us 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 us 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 *ObjectoCadastralPredial* 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 sent to the Real Estate Register.

The process termination will occur when Titulars 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 Activity Diagram in Fig. 7 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”.

A comparison of the presented activity diagram with the subdivision or “Parcelling Out” transactions as documented for Denmark and England and 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 and Wales is roughly equivalent to current situation in Portugal.

The Surveyor's role, absent in England and 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.

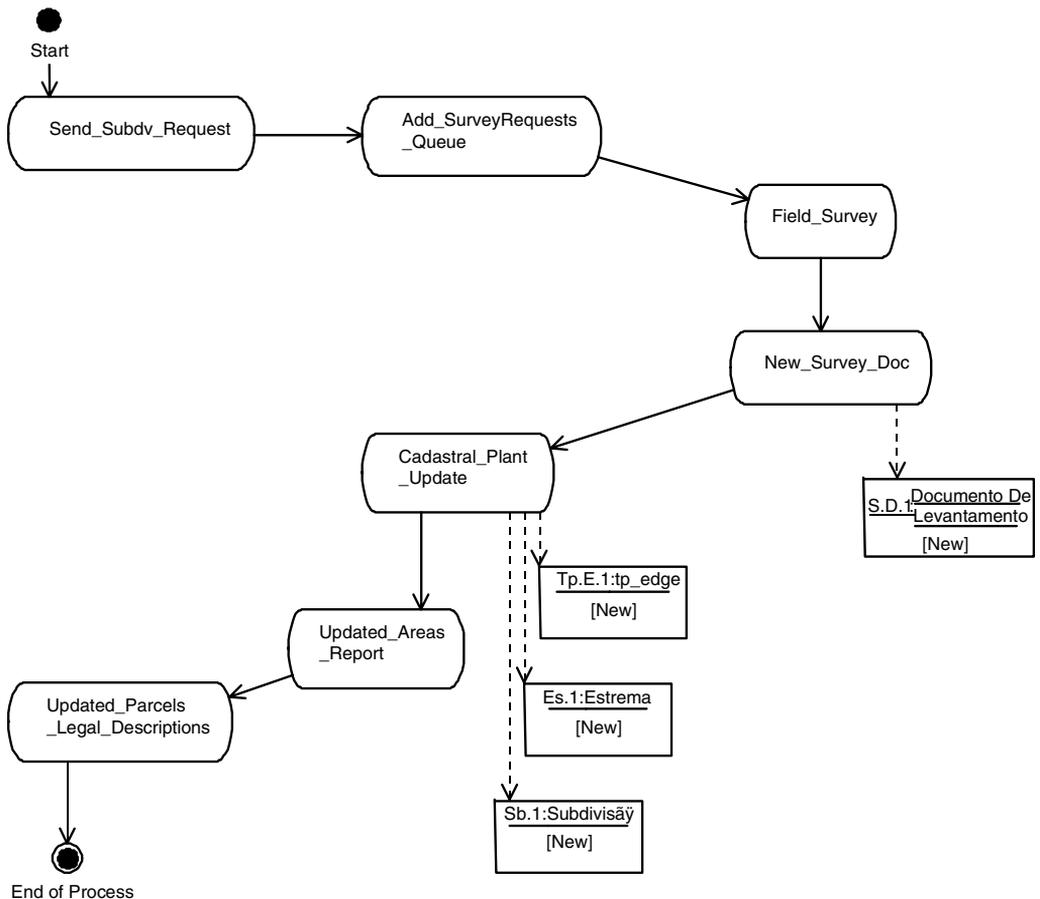


Fig. 7. Cadastral geometric update (UML activity diagram); see Fig. 10 for overall UML Activity Diagrams with the involved actors indicated.

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,<sup>4</sup> 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 first owner) receives also an Apartment (*Fracção* Object) as part of the original deal.

Let us 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).

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<sup>4</sup> 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

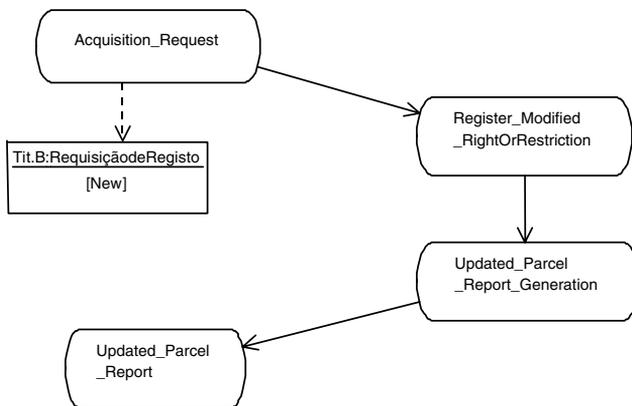


Fig. 8. Parcel change of ownership (complex activity).

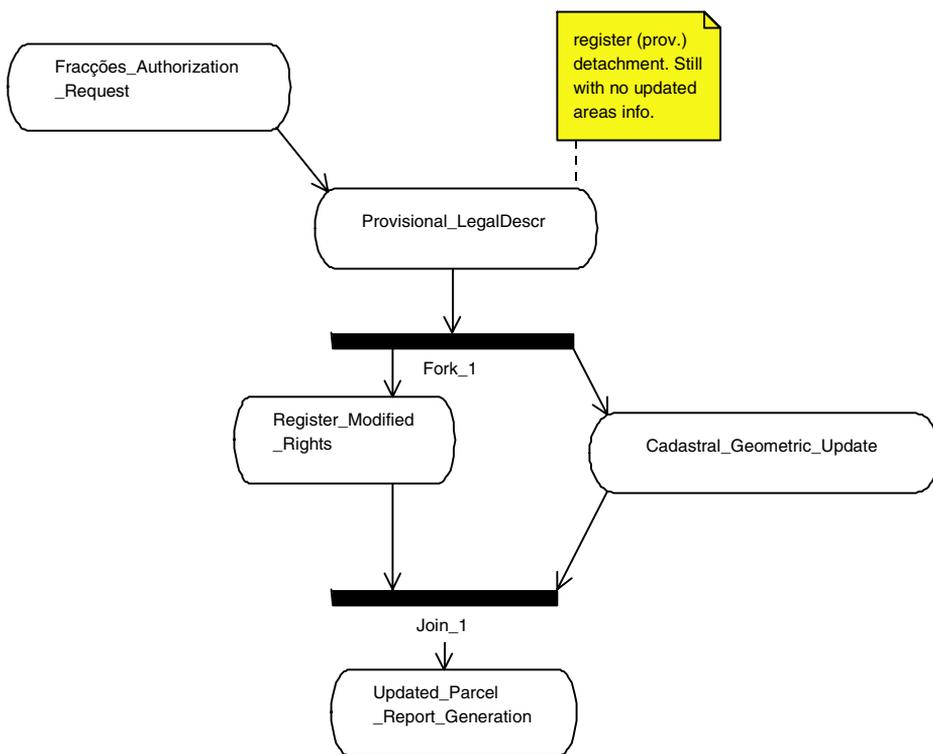


Fig. 9. “Fracções” Constitution w/boundary change (complex activity); see Fig. 11 for Activity Diagrams.

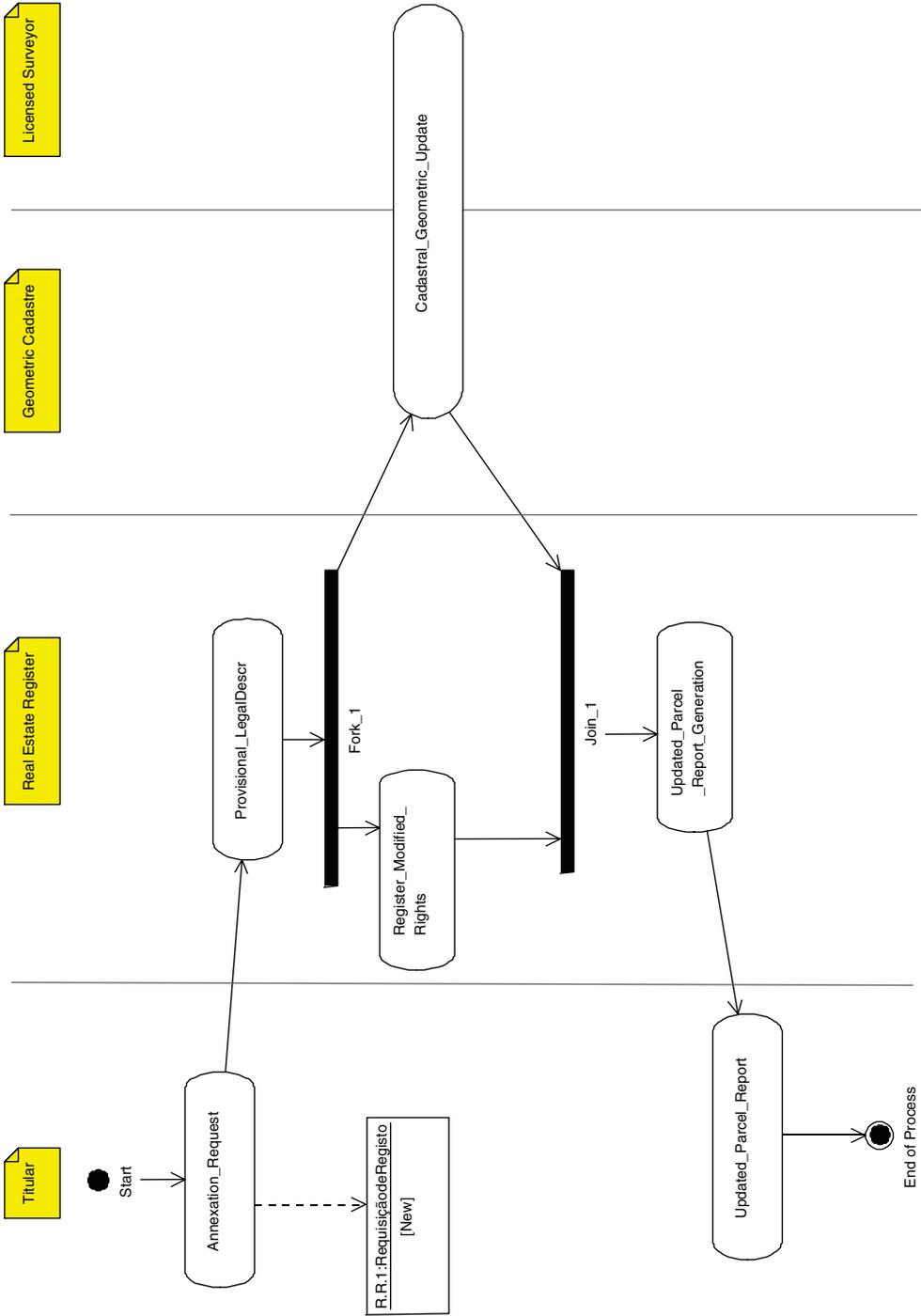


Fig. 10. Annexation UML Activity Diagram.

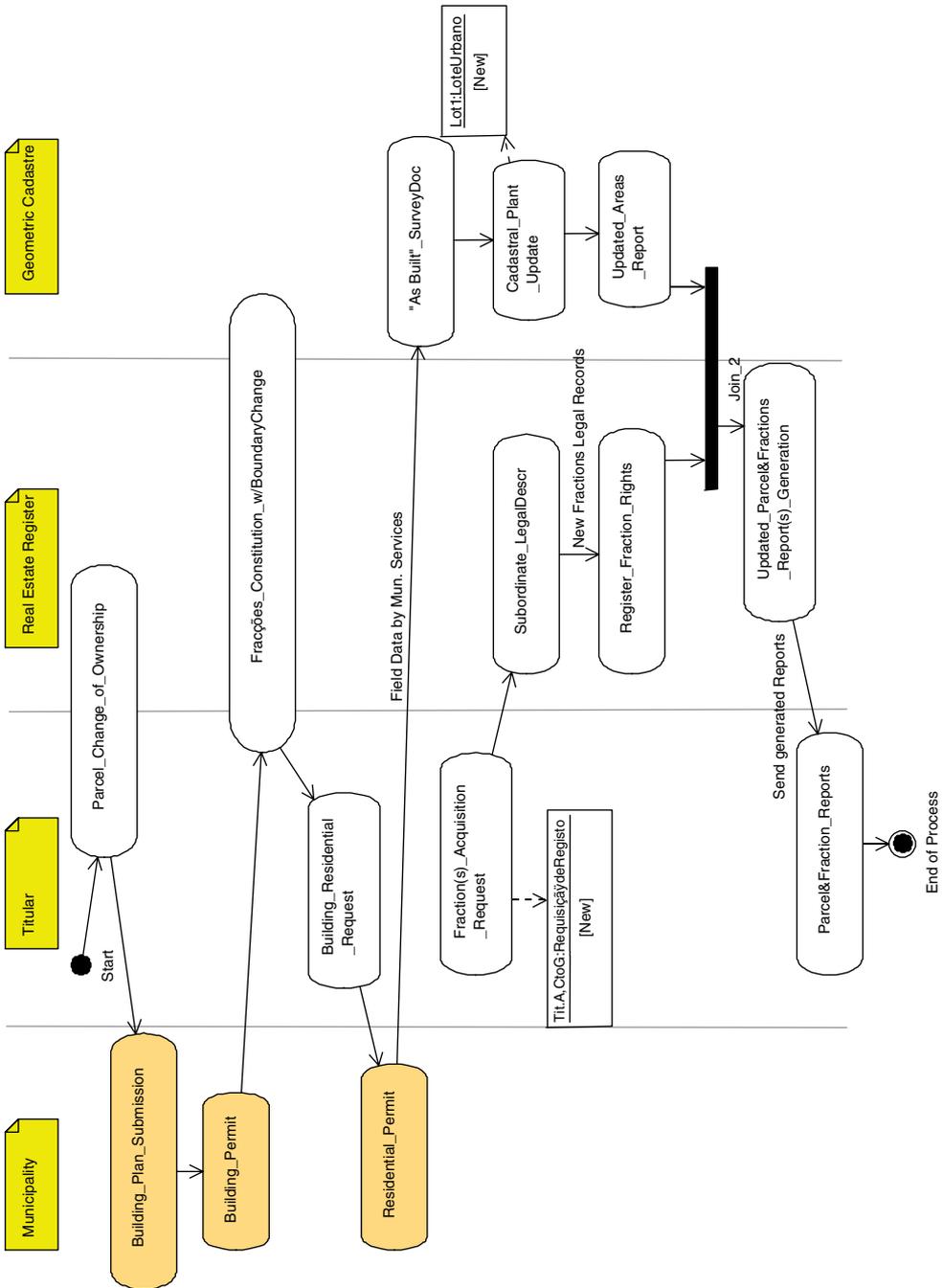


Fig. 11. Urban Lot creation w/Detachment.

- 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 Figs. 8 and 9.

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 five countries (Portugal, Denmark, England and 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 (Figs. 10 and 11).

## 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 and 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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## References

- Coelho, R. M. (1989). O Cadastro e o Registo Predial. In *Proceedings from SICRUM, international symposium on multifunctional rural and urban cadastre*, 20–25 November 1989, Lisbon.
- Erikson, H.-E., & Penker, M. (1998). *UML toolkit*. Wiley Computer Publishing, John Wiley & Sons.
- IPCC (Portuguese Institute for Cartography and Cadastre) (1995). ‘Cadastre of Real Property’, Ministry for Planning and Land Administration (IPCC is now called Portuguese Geographical Institute).
- IPCC (1996). Programa de Concurso e Caderno de Encargos para a Execução do Levantamento Cadastral nos Concelhos de Ovar, Murtosa e Estarreja. Document belonging to International Public Tender no. 7/96 from IPCC.
- Lemmen, C., van der Molen, P., van Oosterom, P., Ploeger, H., Quak, W., Stoter, J., et al. (2003). A modular standard for the cadastral domain. In *Proceedings on the 3rd international symposium on digital Earth*, 21–25 September 2003 (pp. 399–419), Brno, Czech Republic.
- Melo, C. (1989). Conservação do Cadastro—Problemas e Perspectivas. In *Proceedings from SICRUM, international symposium on multifunctional rural and urban cadastre*, 20–25 November 1989, Lisbon.
- Mendes, I. P. (2003). *Código de Registo Predial. Anotado e comentado com formulário* (13th ed.). Livraria Almedina, Coimbra, Portugal.
- Mendes, I. P. (2003). *Estudos sobre Registo Predial*. Livraria Almedina, Coimbra, Portugal.

- Pinto, R. H. G. B. (1986). O Cadastro da Propriedade Rústica e o seu papel no Desenvolvimento do Território, Documentation and Information Centre of Portuguese Geographical Institute. <http://www.igeo.pt/IGEO/portugues/servicos/Biblioteca.htm>.
- RNPC (National Registry of Collective Persons), Ministry of Justice, Portugal, <http://www.rnpc.mj.pt/>. Note: the RealEstate Register section of this site just provides access and download of some standard register request forms, identified as “Requisição de Registo” in the Class Diagrams.
- Silva, M. A., & Erik, S. (2002). A review of methodologies used in research on cadastral development. *Computers, Environment and Urban Systems*, 26, 403–423.
- Sumrada, R. (2004). Modeling real property transactions. COST G9—Workgroup 2 meeting at Székesfehérvár, 2–3 September 2004, Hungary.
- Vaskovich, M. (2004). Comparative analysis of property transaction models for Denmark, England and Wales. Report on STSM at University Ljubljana, 22–28 August 2004 for COST G9, Royal Institute of Technology, September 2004, Stockholm.
- Veigas, D. (2002). El Catastro en Portugal. In *1. Congreso sobre Catastro en la Unión Europea*, 15–17 May 2002, Granada.
- Zevenbergen, J. (2003). Studying transfer of part-parcels and easements in Finland. Report on the short-term scientific mission in the COST framework at Helsinki University of Technology, Finland.