Extending Land Administration Domain Models with a Goal Perspective

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Abstract: Land administration covers many complex processes for managing rights over land, estimating value, gathering revenues and regulating land use. Its organisation typically relies on land registration and cadastre. Over the years, elaborated domain models have emerged and have been standardised. While those models address many dimensions of this domain, they fail to capture the rationale behind the design of the model or leave it quite implicit. In this paper, we propose to augment such domain models with a goal dimension in order to provide better guidance in the design of new systems and better understanding of existing systems, especially in the perspective of driving the wide variety of E.U. systems to evolve towards more interoperability. Our work relies on the KAOS goal-oriented framework for system design and highlights the use of sound structuring and reasoning techniques.

1 INTRODUCTION

The term land administration (LA) was defined by the United Nations Economic Commission for Europe as: *"the process of determining, recording and disseminating information about ownership, value and use of land and its associated resources. These processes include the determination (sometimes called 'adjudication') of land rights and other attributes, their survey and description in a detailed documentation, and the provision of relevant information for supporting land markets"* (UNECE, 1996).

The key LA concepts were identified by (Henssen, 1995) and are shown in Figure 1. The owner ("Who") and parcel ("Where"/"How much") concepts are connected by a Right relationship which is often generalised into "triple-R" for Right/Restriction/Responsibilities (for the "How").

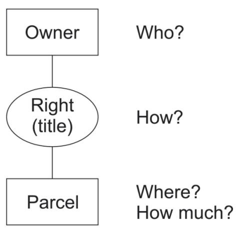

Figure 1: Key domain concepts (Zevenbergen, 2004).

Those concepts form the core of reference domain models such as Core Cadastral Domain Model (CCDM), the Land Administration Domain Model (LADM, ISO 19152) and the Social Tenure Domain Model (STDM). Those models are discussed and compared in section 2. The processes managing those concepts are usually split across the following two systems which can be managed by a single or different organisations (Henssen, 1995):

Land registration deals with the official recording of rights on land concerning changes in the legal situation of defined parcel. It can be organised either through deed or title registration, with a progressive transition to the second option observed in many E.U. countries (Yavuz, 2005). This covers the "Who" and "How" questions.

Cadastre maintains a comprehensive public inventory of data concerning properties of a country or district. It is based on a survey of their boundaries and value. It gives an answer to the questions "Where" (spatial dimension) and "How much" (both for ownership transfer and taxation purposes).

The mentioned domain models essentially provide a reference vocabulary (or ontology) for describing the complex data (rights, geometry of parcels,...) involved LA. Such models support the development and interoperability between LA systems in an efficient way. However, they are less good at driving the design of new systems or at understanding the rationale behind the design of existing systems. The reason is that the "Why" dimension of the different model fea-

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tures are currently not explicitly captured but it would be worth being supported because:

- E.U. member countries have all deployed their own LA systems. Although they follow similar principles they are not harmonized at all which is the long term goal to achieve for the E.U. An overview of all European systems has already been carried out as well as some targeted comparative work (Yavuz, 2005)(EU PCC, 2009).
- main LA actors (FIG/World bank) are increasingly stressing that LA systems should be "fit-for-purpose" rather than blindly complying with complex technological solutions and rigid regulations, i.e. LA should be designed to meet people's needs and relationship to land in a sustainable way (Enemark et al., 2014). This is especially for developing countries (Williamson, 2000).

This paper aims at proposing an extension to existing domain models that explicitly address the missing goal dimension. In order to achieve this, we apply methods and notations from the goal-oriented requirements engineering field (van Lamsweerde, 2001). This work also applies specific spatio-temporal annotations for guiding in structuring and reasoning on goal models (Touzani and Ponsard, 2016).

This paper is organised as follows. Section 2 presents and compares three main domain models for LA. Section 3 details the goal-oriented framework applied to extend the existing models with explicit goal and responsibility modelling. The extension itself is detailed in section 4 while section 5 discusses some related work. Finally section 6 draws conclusions and gives some perspectives to further extend this work.

2 REVIEW OF DOMAIN MODELS

2.1 Core Cadastral Domain Model

The Core Cadastral Domain Model (CCDM) was proposed at the FIG 2002 Congress. It broadly covers land registration and cadastre. It provides an extensible ontology supporting the sound design of a cadastral system using a model-driven architecture that relies on that shared model. CCDM Version 1.0 was presented in 2006 and also included 3D aspects (Oosterom et al., 2005). The core model is depicted in Figure 2 which is very close to the abstract model of Figure 1. CCDM concepts also carry explicit identifiers and date attributes enabling traceability and temporal reasoning.

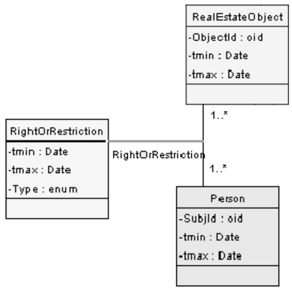

Figure 2: Overview of CCDM.

2.2 Land Administration Domain Model

The Land Administration Domain Model (LADM) is a conceptual model, and not a data product specification. It is meant to be a descriptive standard and not a prescriptive one. Domain specific standardisation is needed to capture the semantics of the LA domain on top of the agreed foundation of basic standards for geometry, temporal aspects, metadata and also observations and measurements from the field. The LADM goals are to establish a shared ontology, support development of related software, facilitate the exchange of data and provide support for quality management in LA (Lemmen et al., 2015). It has been standardised under ISO 19152 (ISO, 2012).

LADM is quite elaborated and has very detailed specialisation hierarchies for all the LA concepts. Figure 3 is a refinement of Figure 1. Owner and Parcel are the LA_Party and Spatial Unit respectively located in the top left and bottom right cornet while the rest of the concepts presented details different kinds of Rights/Restrictions/Responsibilities (RRR).

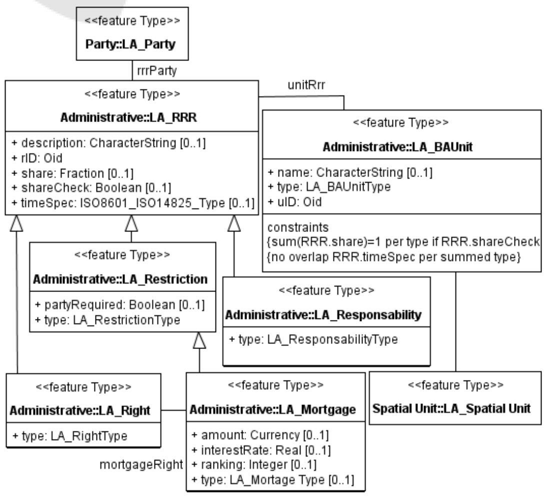

Figure 3: Overview of LADM.

2.3 Social Tenure Domain Model

The Social Tenure Domain Model (STDM) is a variant of the LADM that presents a generic and inclusive solution. It was released in 2014 together with Open Source tools with the aim to help in building flexible land administration systems. For this purpose, it proposes a modelling of relations that is independent from their level of formalization and/or legality. For example, it supports all forms of land rights including customary and informal rights as shown in Figure 4 borrowed from (Christl et al., 2015).

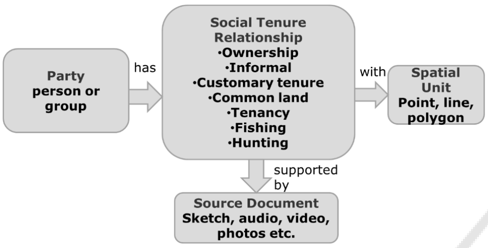

Figure 4: Overview of STDM.

2.4 Comparison

The above models are compared in Table 1. LADM and STDM column show extra (+) features w.r.t. the previous column. In short, LADM is the standard and covers CCDM while STDM is a less formal variant. For sake of simplicity, this paper will use CCDM.

Table 1: Comparison of main LA domain models.

Concept	CCDM	LADM	STDM
Owner	Natural person	+group +cooperative	+company +municipality +couple
Property	Parcel, building, ways	+land surveys	+text descr. +unstruct. lines +3D volume
Rights	Formal ownership	+Restriction +Responsib.	+special rights (e.g. hunting)

3 METHOD: GOAL-ORIENTED SPATIO-TEMPORAL ANALYSIS

Goals capture, at different levels of abstraction, the objectives the system under consideration should achieve. Goal-Oriented Requirements Engineering (GORE) is concerned with the use of goals for eliciting, elaborating, structuring, specifying, analysing, negotiating, documenting, and modifying requirements. To support our research, we focus on KAOS, a specific GORE method (van Lamsweerde, 2009). However, the same concepts and methods can be applied in other GORE variants like i* (Yu and Mylopoulos, 1997) and GRL (ITU, 2012).

The KAOS method is organised in four sub-models graphically depicted in Figure 5:

- The **goal model** structures functional and non-functional goals. It also helps to identify related conflicts and reason about their resolution. It is graphically represented as a goal tree which can also capture system design variants.
- The **object model** defines and interrelates all concepts involved in goal specifications. Its representation is aligned with the UML class diagram.
- The **agent model** identifies the agents of both the system and the environment as well as their interfaces and responsibilities. They can be shown as part of goal trees or in more specific diagrams.
- The **operations model** describes how agents functionally cooperate to ensure the fulfilment of their assigned requirements and hence the system goals. Functional flow diagrams are used here.

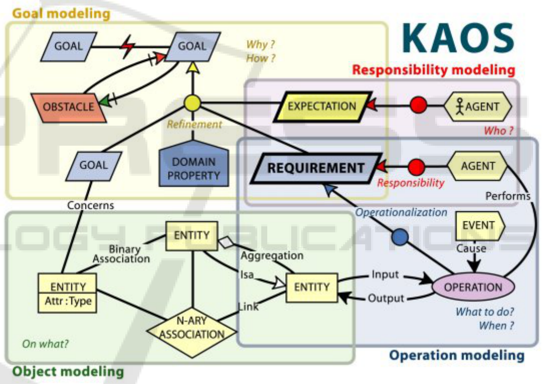

Figure 5: KAOS Meta-model.

Reasoning on both space and time is important as Geographic Information Systems (like LA) and Cyber-Physical Systems are increasingly developing. For this purpose, specific notations depicted in Figure 6 have been integrated into the goal and object models together with a set of patterns and heuristics guiding in the discovery and structuring of goals, e.g. spatial and temporal refinement patterns, quantitative reasoning, transposition across domains, etc.

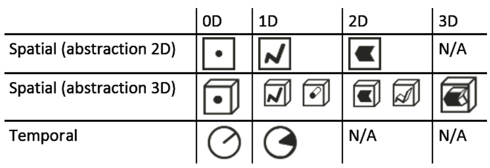

Figure 6: Space-time pictograms.

4 GOAL-AWARE MODEL FOR LAND ADMINISTRATION

This section provides excerpts of the goal-oriented model with the aim to illustrate its global structure and systematic building techniques. The full model is available online at doi:10.13140/RG.2.2.21197.84969. It was build using the Objectiver toolset (Respect-IT, 2005).

4.1 Capturing the Relevant Vocabulary

In a goal-oriented context, the object model aims at gathering and structuring the vocabulary required for expressing goals. It can be built iteratively together with the goal model. We could validate that the CCDM model fits this purpose. In our modelling, depicted in Figure 7, identifiers and time intervals during which an entity exists have also been explicitly modelled with more meaningful names (e.g. *dateOfDeath* for a person, *dateOfExpiration* for *RRR*). Concept specialisations were detailed here but are similar to those available in existing domain models. We also used spatio-temporal decorators to tag the dimensions that are present in each concept.

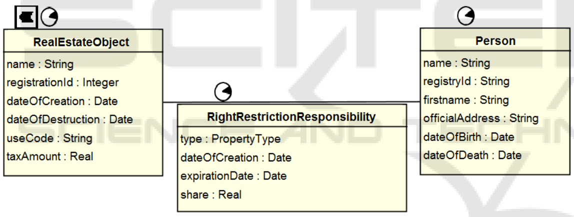

Figure 7: Object Model.

4.2 Capturing Strategic Goals

The top goals of our system modelling are of strategic nature and are depicted in Figure 8. Those goals are also aligned with strategic goals and responsibility assignments published in key literature references such as (Enemark, 2001) and (Zevenbergen, 2004). The diagram should be read vertically with more abstract goals at the top and more operational goals at the bottom and following yellow refinement nodes connecting goals with their sub-goals. So going up/down respectively means asking "Why?"/"How?".

The goal introduced at the top is about sustainability which has three dimensions: financial, social and environmental which can be identified in later sub-goals. However, the first refinement is based on the classical functional versus non-functional distinction. The former is called "effectiveness" and covers main functions related to the planning and enforcement of land use. The later is called "efficiency" and is expressed in terms of legal protection and value management, covering both citizen aspects (e.g. for property transfer) and the public authorities (e.g. for collecting taxes).

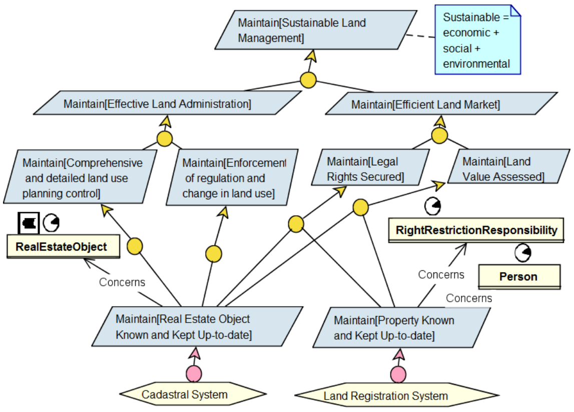

Figure 8: Strategic Goals.

Further refinements are not fully detailed. However a major observation is that they all rely on two key subsystems: land registration and cadastre. The rationale between this decomposition is based on information control. Looking at the object-model:

- *land registration* is controlling the *Right/Restriction/Responsibility* relationship, and consequently many related contractual and legal aspects.
- *cadastre* is controlling the *RealEstateObject*, especially its classification, associated topographic characteristics and the associated value.
- an external system, the *Population Register*, manages the *Person* information.

4.3 Robust Design Rationales

High-level goals assigned to sub-systems can be further refined to make explicit all the relevant requirements. Different techniques can be used to provide some assurance of completeness and robustness:

- refinement patterns drive goal decomposition towards completeness with rationales. Some common patterns are temporal milestones and case-based decomposition.
- obstacle analysis enables the identification of undesired behaviours and mitigate them by making existing goals more realistic or by the introduction of goals correcting or anticipating obstacles.

Figure 9 shows the refinement of the main cadastral goal *Maintain[Real Estate Object Known and Kept Up-to-date]*. The left part of the refinement is a milestone pattern composed of three key steps controlled by different agents. However this design does not allow to detect changes that occur outside of a transaction, e.g. when some work increases the cadastral rent. To address this, the right goal introducing a periodic systematic assessment is introduced. However, this goal might suffer from other obstacles, as detailed in the next section.

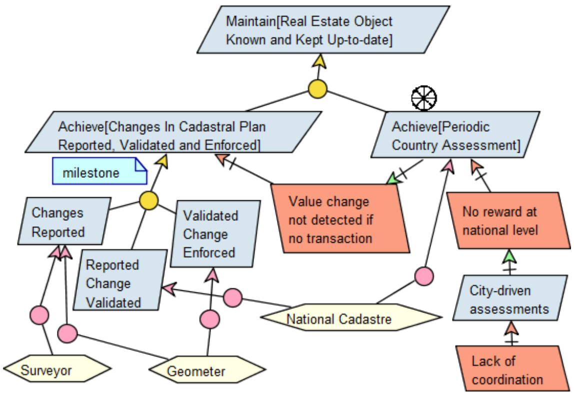

Figure 9: Modelling cadastre updates.

4.4 Capturing Design Variability

Although systems are developed to fulfil common strategic goals, the fact they where historically designed in different countries implies that there is a large variability in the way those goals are implemented in national systems. We review here the main variability points (Bogaerts and Zevenbergen, 2001):

Deed Registration Versus Title Registration. Deed registration is based on the transaction document (with rules like: an older document prevails) and thus provide no guarantee of the title. Title registration means the right is really associated to the parcel and can be guaranteed. Both systems are modelled in Figure 10. Two distinct refinements are used at the top of the diagram. Each alternative is further refined and analysed.

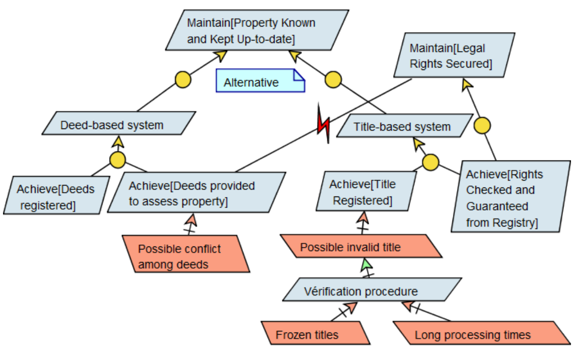

Figure 10: Modelling the titles vs deeds alternatives.

In the deed-based systems the main obstacle (in red) is that deeds can be questioned and introduce a conflict with the strategic goal of legal protection. In a title-based system, the registration process must be careful and might induce long processing times or even frozen titles. The tendency is to move to title guarantee but could still rely on an underlying “deeds system”, thus combining both alternatives. So the distinction is evolving towards positive versus negative systems, given they provide or not a guarantee.

Land Registration and Cadastre Components Separated or Integrated: within the same organisation. Given their close interrelation, those components should ideally be integrated. However for historical reasons, they might have been developed independently with some data replication. Different technical designs can cope with this, like synchronisation procedures or a linking database. Long term evolution towards a integrated system is also possible. Those aspects are less relevant to capture in a goal model.

Centralized Versus Decentralized Deployment. Decentralisation can be decided for organisational or political reasons (e.g. in a federal country) but will keep a national authority ensuring consistency, e.g. the global cadastre can be kept at the federal level while tax can be perceived at regional or city level. However, this can induce possible cooperation problems in the organisation, e.g. in Belgium, the cadastral rent is not being systematically updated because the federal level has no revenue out of it and this impacts the funding of cities.

Fiscal (Tax-based) Versus Legal Background. The former is easier to fund and update (only for market value and on a yearly basis) while the later is more complex and expensive because it needs to be accurate and kept up-to-date on a daily basis.

General Boundaries Versus Fixed Boundaries. The former relies on visible features of the ground while the later uses exact and marked coordinates. This is already captured by the parcel ontology.

5 DISCUSSION AND RELATED WORK

A systems approach to land registration and cadastre was developed by (Zevenbergen, 2004). This work focuses on the technical, legal and organisational aspects, and their interrelation of such systems of land registration. The work stresses the need to have a fully integrated system view covering both land registration and cadastre. It covers not only the static dimensions (as described in section 2) but also dynamic dimensions, with a focus on the important adjudication, transfer and subdivision processes. However, it only relies on informal process modelling and is also missing the capture of all the rationales driving the system design.

A UML model for cadastral system was proposed by (Tuladhar, 2003). It shows how different UML diagrams can capture both structural and behavioural dimensions of the system. However UML models have a total lack of goal perspective: the closest diagram is the use case diagram which can only capture functional requirements and performing actors.

A KAOS model was build for modelling the Belgian cadastre in 2002 (Dechesne et al., 2002). The goal was to support the development of an unified cadastral database. The object part of the model was not aligned with the still emerging standards but is based on the same key notion of right between a person and a real property. Those concepts are also detailed using a rich inheritance hierarchy. The proposed goal model first details the "as-is" system focusing on the main missions like: maintaining the cadastral map up-to-date, performing value estimation, managing sales, etc. It reveals some duplicated data which were addressed by an improved "to-be" goal model used to drive the system evolution.

6 CONCLUSIONS

In this paper, we have shown how goal models can provide useful enhancements to LA domain models in order to provide a better understanding and reasoning capabilities on the design of such complex systems. We illustrated some key mechanisms to structure goals and variants and also to reason on them.

Our modelling is still being enhanced to reach better completeness (e.g. for planning tasks), more design variants (e.g. adjudication strategies) and also to introduce the missing operation level that can provide a stronger link with technical requirements and give better control on how to evolve the deployed systems. Our ultimate goal is to be incorporate our results in future evolutions of LA domain models because this will definitely help in the process of setting up or evolving a LA system. We are currently applying our framework to the co-analysis of LA systems in the perspective of European convergence with an initial focus on the neighbouring countries of Belgium.

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REFERENCES

Bogaerts, T. and Zevenbergen, J. (2001). Cadastral systems alternatives. *Computers, Environment and Urban Systems*, 25(45):325 – 337.

Christl, A. et al. (2015). Standard Open Source Software for the Social Tenure Domain. Annual World Bank Conference on Land and Poverty.

Dechesne, B., Delannay, G., and Massonet, P. (2002). Agora Project: Requirements Analyse for the Creation of an Unified Cadastral Database.

Enemark, S. (2001). Land administration infrastructures for sustainable development. *Property Management*, 19.

Enemark, S. et al. (2014). *Fit-For-Purpose Land Administration: Joint FIG*. FIG.

EU PCC (2009). Cadastral Information System, a resource for the E.U. policies. Overview of the Cadastral Systems of the E.U. Member States - Part I-II-III.

Henssen, J. (1995). Basic Principles of the main cadastral Systems in the World. In *Proc. Seminar Modern Cadastres and Cadastral Innov., FIG Commission 7*.

ISO (2012). 19152 - Geographic information - Land Administration Domain Model. http://www.iso.org.

ITU (2012). Recommendation Z.151 (10/12), User Requirements Notation (URN) Language Def.

Lemmen, C., van Oosterom, P., and Bennett, R. (2015). The Land Administration Domain Model. *Land Use Policy*, 49:535 – 545.

Oosterom, P. V., Stoter, J., and Lemmen, C. (2005). Modelling of 3d cadastral systems.

Respect-IT (2005). The Objectiver Requirements Engineering Tool. http://www.respect-it.com.

Touzani, M. and Ponsard, C. (2016). Towards modelling and analysis of spatial and temporal requirements. In *24th IEEE Int. Requirements Eng. Conf.*

Tuladhar, A. M. (2003). Why Is Unified Modeling Language (UML) for Cadastral Systems? M.Sc. University of Twente.

UNECE (1996). Land Administration Guidelines With Special Reference to Countries in Transition. United Nations Economic Commission for Europe.

van Lamsweerde, A. (2001). Goal-oriented requirements engineering: a guided tour. In *5th IEEE Int. Symposium on Requirements Engineering*.

van Lamsweerde, A. (2009). *Requirements Engineering - From System Goals to UML Models to Software Specifications*. Wiley.

Williamson, I. P. (2000). Best practices for land administration systems in developing countries. World Bank Other Operational Studies 16732, The World Bank.

Yavuz, A. (2005). A comparative analysis of cadastral systems in the eu countries according to basic selected criteria. FIG Working Week.

Yu, E. S. K. and Mylopoulos, J. (1997). Enterprise modelling for business redesign: The i* framework. *SIGGROUP Bull.*, 18(1):59–63.

Zevenbergen, J. (2004). A Systems Approach to Land Registration and Cadastre . Nordic Journal of Surveying and Real Estate Research.