A Subject Domain Model of Kenya's Cadastral System

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Key words: Data Model, LIMS, Cadaster, Land Information System, LADM

SUMMARY

During the recent past, Kenya has initiated several Land Information Management Systems (LIMS) initiatives, most notably the National Land Information Management System. These initiatives have only been partially successful, which is attributable to, among other factors, the absence of an accepted cadastral data model. As a result, the country risks non-standard data and processes, poor quality land information and increased cost of land information management. With this in mind, this study addresses two objectives: first, to document a subject domain model (i.e. a model highlighting the things that a typical LIMS deals with, such as land parcels, tenure, and their interrelationships) of Kenya's cadastral system anchored on contemporary legal framework. Secondly, to derive a mapping between the data model and the Land Administration Domain Model. The methodology involves desk review of prevailing literature on land information management including the legal framework, and analysis of primary data collected through a questionnaire. The developed model will contribute to better development of LIMS, which will address Kenya's lack of reliable land information, despite several past initiatives without tangible success.

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1. INTRODUCTION

Land Information Management System (LIMS) facilitates access to information on land, including rights, responsibilities and restrictions (Williamson et al., 2010). Successful LIMS provides access to secure, accessible, consistent, reliable, accurate, complete and timely land information.

Kenya’s cadastral system is characterised by several problems, including an incomplete spatial coverage, and the varying degree of accuracy of its form (Siriba et al., 2011). Furthermore, the system has a complex legal regime dating back to the colonial era, which has resulted in multiple approaches overseeing registration (torrens and deeds), boundary (fixed and general), coordinate (UTM and cassini soldner), tenure (customary, private and public), amongst others. Crucially, the country lacks a formalised cadastral data model from which the development of LIMS at various levels can be based (Siriba and Mwenda, 2013).

Although the amended legislation, such as the Land Act (2012a) offers a ray of hope in addressing some of these challenges, the corollaries will be felt for a long time. At the same time, data modelling is an emerging trend in contemporary cadastres (Wayumba, 2013), meaning that land information ought to be considered an enterprise resource. This lofty tagging implies that the information should be ubiquitous and independent of systems, and forms an integral component of national systems, such as the Land Information Management System (LIMS) and the National Spatial Data Infrastructure (NSDI).

Given this background, the development of LIMS in Kenya is a tall order, yet there is an increasing need for computerised land information. Existing systems are largely manual, disconnected, unintegrated, and of little value, and computerized systems do not conform to agreed data models.

Like any other Computer-Based Information System, the development of LIMS follows standard processes, including analysis (identifying and specifying system requirements), design (determining the best way to construct the system) and implementation (constructing and testing of the system).

This paper focuses on the development of a subject domain (SD) model of Kenya’s cadastral data model, and aligns it with the country’s legal framework. Specifically, the paper dwells on two objectives: first, it presents a Unified Modelling Language (UML) SD model of Kenya’s cadastral system, based on fixed and geo-referenced boundaries. Second, given the global recognition of the Land Administration Domain Model (LADM), the paper derives a mapping between the developed SD model and the LADM.

The basis of the study is that cadastral data models should not only precede the development of LIMS, but also lead to LIMS that are loosely coupled with the data models, and can support systems at various administrative units, including the national and county levels.

The SD model will facilitate a better understanding of Kenya’s cadastral system, and to lead to improvements to the country’s land information management. Kenya’s ailing national SDI, the KNSDI (Mwange et al., 2018) will benefit from the study, since the successful development of Spatial Data Infrastructure (SDI) is often associated with a robust culture of computerization in the lands sector (GeoConnections, 2013).

The rest of this paper is structured as follows. Section **Fejl! Henvisningskilde ikke fundet.** presents the analytical framework of the study, section **Fejl! Henvisningskilde ikke fundet.** covers the methodology; and the results and discussion are presented in section **Fejl! Henvisningskilde ikke fundet.**. Section **Fejl! Henvisningskilde ikke fundet.** draws conclusions from the study, and offers recommendations for further studies.

2. ANALYTICAL FRAMEWORK

Data modelling is a well-recognized trend in modernization of cadastral systems and land administration. Siriba *et al.* (2011) concluded that Kenya's cadastre is generally not based on any formalized data model, despite the latter being globally recognised in supporting contemporary cadastres. The third statement of Cadastre 2014 proposed that data modelling would be at the centre stage of future cadastral systems, replacing their outdated standalone and manual counterparts.

A good understanding of the cadastral data model is important because cadastres are now playing a critical role in national development, and in supporting the development of national systems, such as LIMS and SDI (Kuria et al., 2016). Significant benefits can be attained by integrating cadastres in SDI, including access to up-to-date land information on tenure, use and value (Mwangi and Nyika, 2018).

2.1 Recent Studies

Kenya is not new to the process of computerization in the lands sector. Over the recent past, the government ministry responsible for lands, currently known as the Ministry of Lands and Physical Planning (MoLPP), has initiated various programmes, including digitization of land records. The main drawback is that these efforts often fail to link cadastral maps and plans to their corresponding records in the register, which questions their completeness.

Wayumba (2013) modelled some of Kenya's cadastral processes but was not able to query the resulting database. Although the author attributed this incapacity to database normalization, it is likely that the absence of an accepted cadastral data model contributed to the problem. In spite of its drawbacks, the study presents a vivid documentation of Kenya's cadastral processes using activity diagrams, which can form a significant contribution to the development of LIMS in the country.

Siriba and Mwenda (2013) documented Kenya's cadastral processes and mapped them to the LADM standard. However, the study did not focus on the cadastral data model. The current study borrows from their work especially on the process of establishing the mapping the SD model to the LADM standard.

Kuria *et al.* (2016) developed a pilot LIMS for Nyeri County. The study focused on the county's cadastral data model; its mapping to the LADM, and implementation of the change of user process. There was a commendable review and validation exercise by the stakeholders, although some syntactic and semantic characteristics of their data model could be improved.

More recently, the Cabinet Secretary responsible for lands appointed a taskforce on electronic land transactions, registration and conveyancing. The taskforce undertook a general review of the Kenyan land laws that inform land registration, and produced a road map for Kenya's digitization efforts. The report will play a pivotal role in the development of LIMS in the country.

A notable gap in the existing body of knowledge is the tendency to focus on cadastral processes rather than the data models, which the current research addresses.

2.2 System Development

System development encompasses three interlinked stages, namely analysis, design and implementation. The substance of analysis is typically three-fold: information modelling; identifying the scope of the system; and determining system behaviour (Brough, 1994). The scope of information modelling is usually enterprise-wide, while system scope and behaviour are system-specific. Design and implementation primarily focus on mapping the conceptual model of analysis onto design and runtime models, respectively.

The result of analysis is a conceptual model, which is often used in the design process to produce the design model. Implementation, on the other hand, maps the design model onto runtime architectures, such as relational databases and object-oriented programs, commonly referred to as the runtime model.

The system analyst typically clarifies subject domain concepts, including entities and their interrelationships, attributes, operations, and identifiers. In LIMS, subject domain concepts are the "things" that participate in the provision of land information. Some of the entities are tangible, such as person and land parcel; but others are more abstract, such as tenure and servitude.

System analysis is a conceptual phase in which technology is suppressed, aiding peer review and validation of the model by people who are not conversant with technology. Generally, the cost of fixing syntactic and semantic errors at the conceptual phase is much lower compared to the design and implementation phases, and the goal of system analysis is to minimize the errors.

As illustrated in Figure 1, an enterprise, such as MoLPP, utilizes many autonomous systems, including search, valuation, Enterprise Resource Planning (ERP), and other cadastral systems. From the enterprise point of view, these systems are akin islands floating in a sea of information: each system has a defined scope and behaviour; but all systems share the same integrated information. The goal of analysis is therefore to discover or update the information used by the enterprise, and to specify the scope and behaviour of each system.

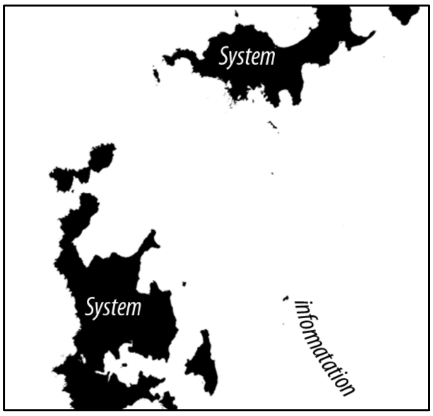

Figure 1: The information, system and enterprise metaphor (Source: own study)

2.3 Basic UML Concepts

The Unified Modelling Language (UML) is an object-oriented system development method, which can be used to identify system requirements. UML emerged in the mid-90s, largely through the work of Grady Booch, James Rumbaugh, Ivar Jacobson. The method provides various tools for modelling systems: class diagrams, use-case diagram, state charts and object sequence diagrams. This paper is primarily concerned with the class diagrams.

In UML, a class is an abstraction of a role, or a “thing” which can be distinctly identified, such as land parcel, person and land tenure. Figure 2 is extracted from the SD model, and represents classes as rectangles. The properties of classes are known as attributes: for instance, the class person has attributes such as name, ID, address and telephone. Some attributes are obtained from defined sets of values referred to as Abstract Data Types (ADT). An example is the ADT Property Type, consisting of the enumeration {community, private and public}. Instances of classes are real objects: the parcel with identifier LR 171/6 is an occurrence of the class parcel.

Generally, information in a system resides in the properties and relationships between the classes. The connection between instances of classes constitutes a relationship. Classes may play roles in relationships – for example, a person playing the role proprietor in a parcel ownership relationship. As shown in Figure 2, UML distinguishes several types of relationships: inheritance; aggregation; composition; dependency and association. Similar to classes, relationships can have instances (Chen, 1976): each instance of a relationship records an interaction between instances of classes participating in the relationship.

Inheritance connects generalized (super) classes to more specialized (sub) classes (Rumbaugh et al., 1999). For example, encumbrance and servitude are specialized classes of the more generalized class interest. An instance of the specialized class is also the generalized class: for example, an occurrence of servitude is an interest. This proposition is useful because it cements the (is a) inheritance relationship.

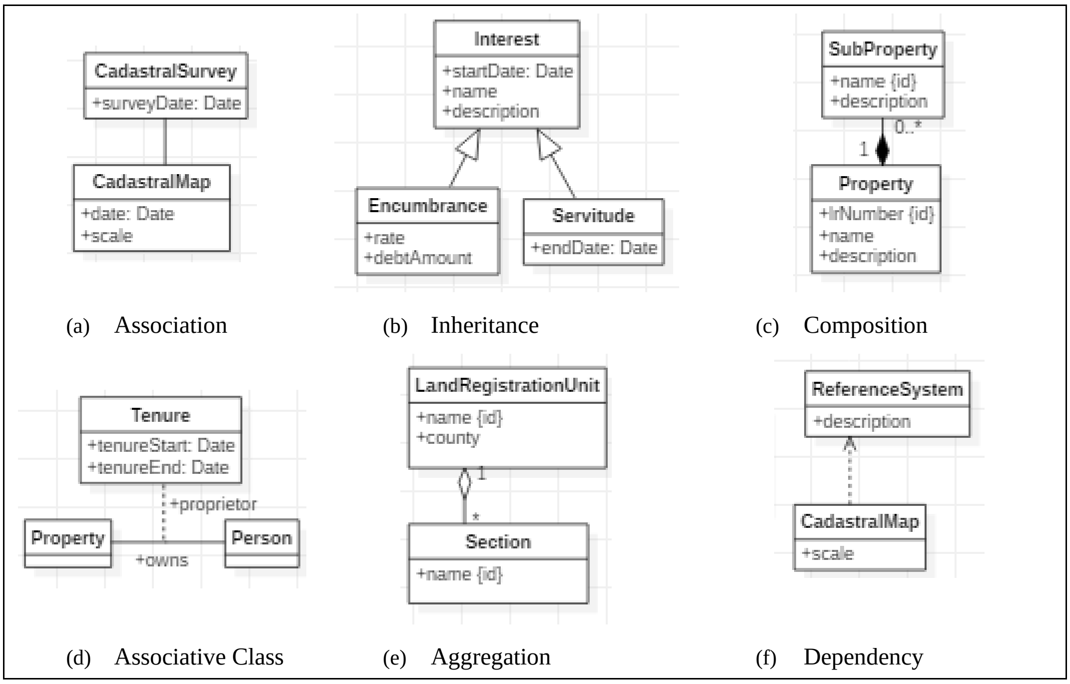

Figure 2: Basic UML relationships

Association is a structural relationship between classes, indicating that instances of one class are connected to those of another (Rumbaugh et al., 1999): for example, each Cadastral Map is prepared from a Cadastral Survey. Some associations can have attributes and therefore act as classes: they become associative classes. For example, the relationship in a person owning a parcel could have attributes such as the start date of the ownership.

Aggregation and composition are whole/part relationships (Rumbaugh et al., 1999): objects of the "whole" contains objects of the "part". The difference between the two relationships is that in the case of the latter, the lifetime of instances of "parts" is controlled by the lifetime of the "whole". Thus, if a parcel were to be destroyed, perhaps through the processes of reparcellation, so would any of its sub-parcels.

Dependency is a using relationship (Rumbaugh et al., 1999), denoting the fact that a class may use another to carry out some operation. For example, parcel coordinates may be transformed using a given reference system, which may contain datum and projection properties, such as Kenya's 1960 Arc Datum in UTM Clarke 1880.

3. METHODOLOGY

As illustrated in Figure 3, the methodology involves desk review, followed by the analysis of primary data collected through a questionnaire.

3.1 Desk Review

The desk review was mainly used to extract existing policy from the current legal framework: the Constitution of Kenya (2010), the Land Registration Act (2012b), the Survey Act (2012c), the Land Act (2012a), the National Land Commission Act, the Stamp Duty Act, the Sectional Properties Act, and the Physical Planning Act. Additionally, relevant reports on national computerization efforts and similar research studies were reviewed. The output of this phase was the draft SD model, which was subsequently subjected to validation through analysis of data collected from a questionnaire as shown in Figure 3.

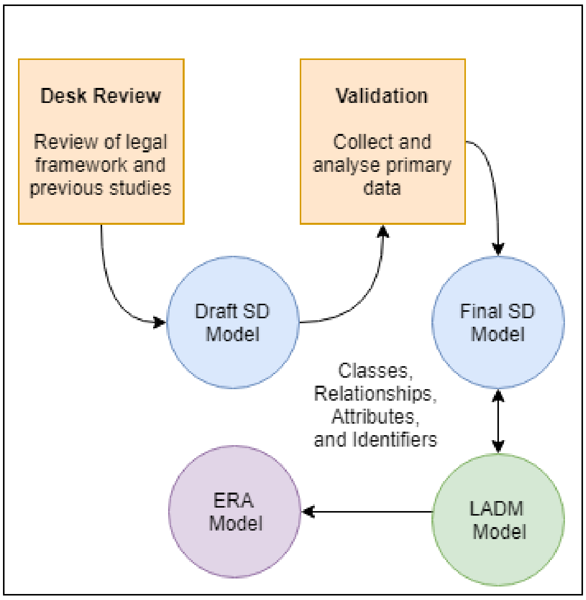

Figure 3: Summary of the Methodology

3.2 The Questionnaire

The questionnaire probed interviewees to validate the existence of entities, relationships, and attributes. For example, the question on tenure was: *1. Tenure (e.g. freehold, leasehold ...) arises when a party (e.g. Person, Company ...) has an ownership interest in Property (e.g. Land Parcel)? Yes or No.* Depending on the response, the interviewee was subjected to further questioning: *2. If No, describe how Tenure arises?* and *3. List any properties (attributes) of a Tenure (e.g. the start date of the Tenure)?* In other cases, the questionnaire included questions with phrases (such as *is a* for inheritance relationship*)* to validate the relationship.

As can be seen in the preceding paragraph, the questionnaire expressed syntactic and semantic aspects of the draft SD model in plain English. This approach was favoured because most of the target respondents are professionals in the lands sector with little competence UML modelling.

Apart from validating the SD model, the questionnaire was used to gather additional information to extend the model, by identifying new classes, relationships, properties and attributes.

The final step consisting of mapping of the SD model to the LADM is trivial, because similar studies have already been carried out by other researchers notably Siriba and Mwenda (2013) and Kuria *et al.* (2016).

4. RESULTS AND DISCUSSION

This section elaborates on the SD model, which is presented in Figure 4. Figures 5 and 6 support Figure 4 by removing the depth of connections, thus improving readability of the model. Whereas Figure 5 is concerned with property classes, Figure 6 focuses on tenure classes.

4.1 Questionnaire Results

The questionnaire targeted profesionals in Kenya’s lands sector, including Land Surveyors, Geospatial Information Management Surveyors, Engineering Surveyors, Valuers, Building Surveyors and Land Administration Managers. The questionnaire was circulated to the profesionals through the Institution of Surveyors of Kenya, whereby ten responses were received. The responses greatly helped the reseacher in finalizing the SD model.

4.2 The Subject Domain Model

According to the Land Registration Act (2012b), a land registration unit is divided into one or more registration sections, and each section may be further divided into blocks. Each section or block contains parcels (Government of Kenya, 2010). Each land registration unit maintains a land registry, which in turn maintains a land register and a community register.

A person is an entity playing roles such as proprietor, co-tenant, valuer, surveyor, lessor, and chargor in the cadastral system. Examples of person include natural person (individual person), juridical person (such as company, County Government, community, co-operative society (Siriba et al., 2011)), or group (consisting of any number of natural persons, juridical persons or even other groups). Instances of person can be identified by the attribute personId, which may refer to the national identity card, passport, or company registration number. The inheritance relationship allows all categories of persons to participate in property interests.

Although the land parcel is the main spatial unit in Kenya’s cadastral system, the model uses the more generic concept of *property,* to allow the modelling of spatial units that are not necessarily parcel. As shown in Figure 5, the model portrays immovable real property in n-dimensions: 2-dimensional, such as a land parcel or sectional property; and 3-dimensional, such as a structure, building and townhouse. These dimensions are related by inheritance relationships, which will allow for flexibility in the modelling of future 3D and 4D cadastres. A property, which can be classified as private, community or public (Government of Kenya, 2012a, 2010), is identified by the attribute *propertyId,* and may include *lrNumber*, *buildingId* among other property identifiers.

The legal framework permits conversion between different types of properties, largely through provisions of section 9 of the Land Act (2012a). For instance, community land may be converted into public land through compulsory acquisition, transfer or surrender. To facilitate this, the SD model introduces an associative class between instances of property, named *PropertyConversion*, which allows the serialization of mode and date of conversion. Property conversions may trigger changes in tenure or user, and a recording of the changes can facilitate the tracking of proprietors prior to and after the conversion, as required by section 8 of the Land Act (2012a).

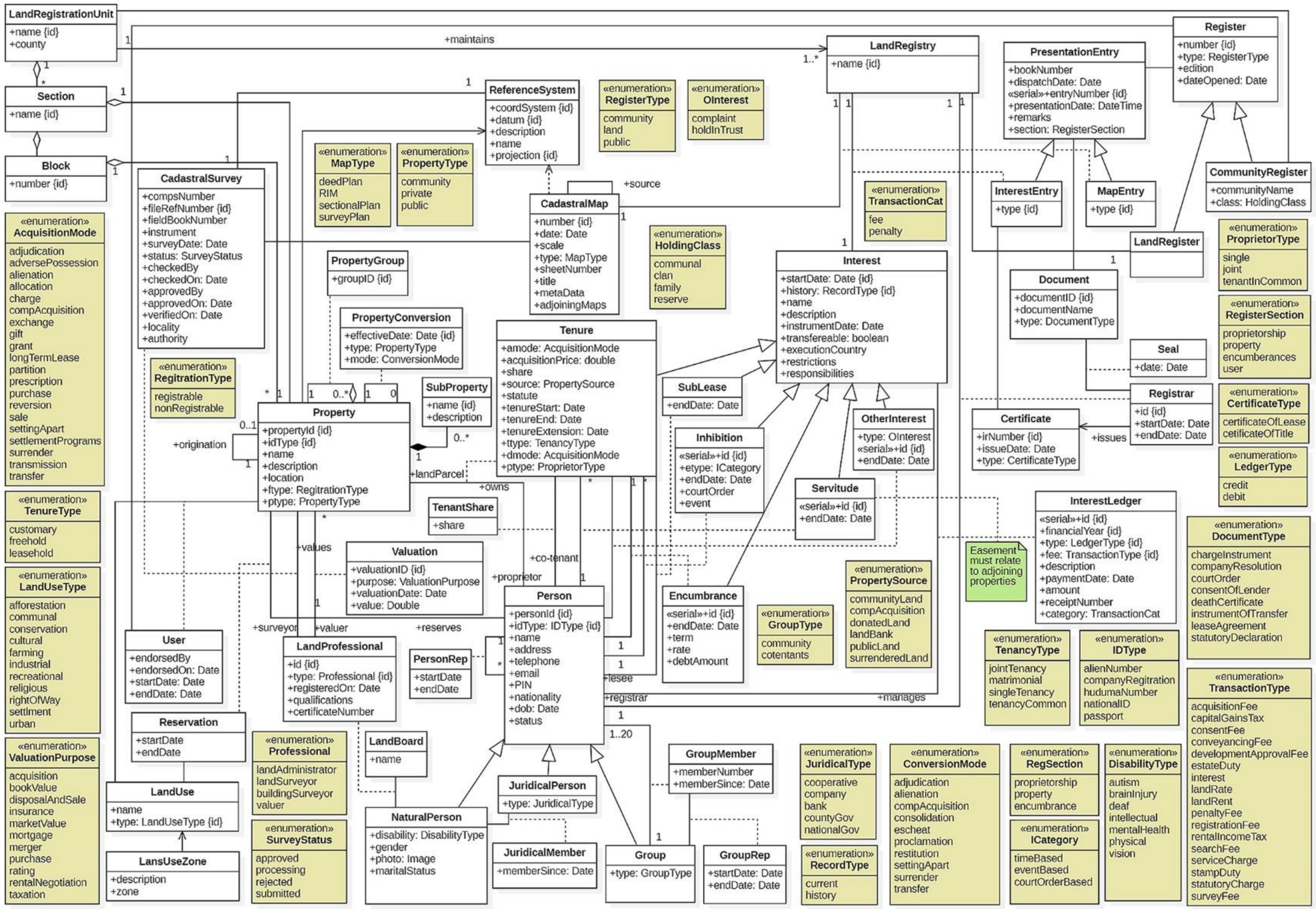

Figure 4: The Subject Domain Model

A property can be comprised of sub-properties, which are related by a recursive composition relationship (a composition between instances of the same class). Sub-properties may not necessarily participate in ownership interests, but can facilitate the demarcation of extents such as wayleaves, reservations and portions of land set aside for communal use as required by the Community Land Act (2016). A property can be associated with a cadastral plan, meaning that some sub-properties can have cadastral plans of their own. Sometimes, a person may set aside a sub-property for a particular use, which is generally known as a *reservation*.

A fundamental relationship in cadastral systems concerns person with an ownership interest in property, which is represented by the association between person and property. This relationship could have attributes, notably the start and end date of the interest, and is therefore modelled as an associative class named tenure (see Figure 4). Figure 6 presents an elaboration of the subclasses *tenure*.

Associative classes such as tenure, which are both relationships and classes, can participate in the building of the SD model. This reifies the fact that some relationships, once established, can participate in other relationships (Chen, 1976). For example, a person playing a role such as chargor may burden a tenure, giving rise to encumbrances (charge or mortgage). Proprietors of abutting parcels may exercise power over a tenure, resulting in servitudes (easement or restrictive covenant). Other relationships that may affect tenure include inhibition and sub-lease.

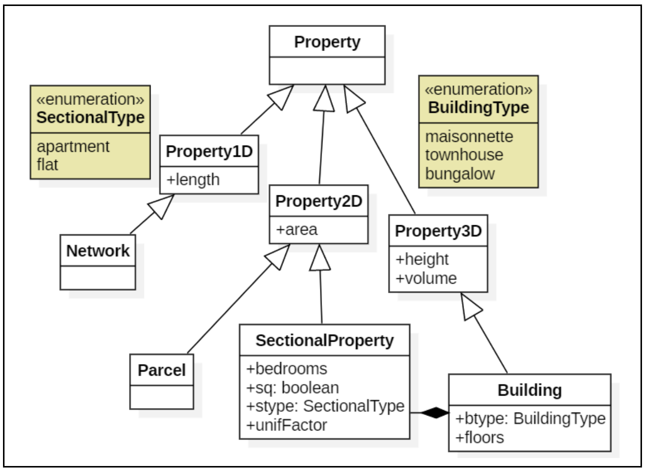

Figure 5: SD Model: Property Classes

As highlighted in the preceding paragraph, tenure, encumbrance, servitude, sublease and inhibition are all interests in property. To this end, an abstract class named interest generalises the fact these interests possess common properties, such as the start date, name and description. The more specialized interests such as *tenure* are modelled with an inheritance relationship to the abstract class *interest*.

Generally, interests in property often involves dual persons playing diverse roles, and notable examples include *lessor* and *lessee*, *chargor* and *chargee*, and *transferor* and *transferee*. The duality comes about because of person (one party) associating with a tenure; and the latter is an association involving person (another party) and property.

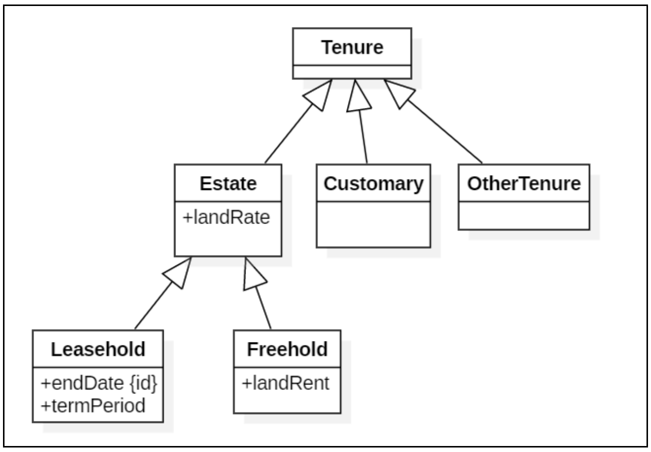

Figure 6: SD Model: Tenure classes

An identifier can be thought of as an attribute or set of attributes which can be used to identify unique instances of entities (Rolland, 1998). Instances of tenure may be identified by the attribute set {lrNumber, proprietor, history and startDate}, encumbrances such as charge by {lrNumber, chargor, chargee, interestType, history, startdate, id}. In the case of encumbrance or inhibition, the attribute *id* is serialized by the other identifier attributes, implying that multiple encumbrances or inhibitions can be lodged concurrently on a tenure. Section 76 of the Land Registration Act (2012b) provides that inhibitions may be active until the occurrence of an event or a court order, and the attribute event is introduced to serve this purpose.

Some sections of Kenya's cadastral system are based on georeferenced or fixed boundaries (Government of Kenya, 2012b, 2012c). In this case, invisible boundaries connecting survey marks generally demarcate the bounds of parcels. Legally, properties are delineated by boundaries, which are demarcated on the ground by survey marks or topographic features. The advantage of adopting survey marks as boundary demarcations is vital, since the delineated boundaries can help in enforcing topology. An example of a survey mark is the legendary beacon, which is a permanent survey mark identified by a list of coordinates (for example x, y and an orthometric height H) in a given reference system (datum, projection, and coordinate).

Some cadastral workflows such as easements, parcel combinations and reparcellations require operations on instances of contiguous parcels (Government of Kenya, 2012b), while others such as subdivisions may result in the creation of adjacent parcels. Contiguous parcels includes those that are separated by roads, railways, watercourses, reserves and unallocated public land (Government of Kenya, 2012a). To model this relationship, the class property has a recursive association (an association between instances of the same class) named adjoining. This relationship is associated with topology, which means that it can be derived from topological relationships in the geometry of features in the model.

The actual registration process involves persons or their representatives presenting various instruments and documents, named PresentationEntry, in the land registry. Each land registry is identified by its name, which can facilitate the merging of information in all land registries in the country to form the national LIMS. Instances of presentations are distinguished by a serialized id, depending on the date and time that an instrument is presented. Presentations are kept in a register, which is either a land or a community register. The latter is maintained for every land registration unit, while the former is maintained in the land registry.

Because of the inheritance relationships between the generalised class interest and its specialised classes such as sublease, the former carries information on tenure, which is the relationship between persons and properties. Part of this information constitutes what is presented for registration in the land register.

Several types of payments can be made towards dealings in property interests. The class InterestLedger captures these payments, and comes about as a result of the association between person and interest. The type of payments are captured by the ADT TransactionType, and includes land rates, rents, and search fee, among others.

Section 9 of the Land Registration Act (2012b) requires that the register shall contain names and addresses of previous proprietors. Apart from the mechanisms documented by Siriba and Mwenda (2013), which include versioning and time stamping of records, there are several other semantically richer ways to support this requirement.

The first method uses a tenure's identifier, which in the case of a leasehold is the attribute set {startDate, endDate, lrNumber, personId}, or the set {startDate, lrNumber, personId} for a freehold. Given that time is a continuum, distinct epochs referencing the duration of a tenure i.e. {startDate, endDate} can help to identify previous owners.

The second approach is because some property dispositions, notably partitions, subdivisions and repacellations, typically result in the creation of new parcels. Registration of these dispositions involves closing the registers of the original parcels and opening new ones (Government of Kenya, 2012b). To preserve the history, instances of the class parcel have a recursive association named origination.

4.3 Mapping to LADM

The Land Administration Domain Model (LADM) identified as ISO 19152 provides an abstract, conceptual schema with five packages: parties, spatial units, rights, restrictions and responsibilities (RRR), spatial sources, and spatial representations (Lemmen et al., 2010). The mapping between the SD model and LADM is now presented in and Figure 7.

Table 1 and Figure 7.

Table 1: LADM Mapping

SD Model	LADM Model	Package
Person	Party	Party
Group	GroupParty	Party
GroupMember	PartyMember	Party
Interest	RRR	Administrative
PropertyGroup	BAUnit	Administrative
Property	SpatialUnit	Spatial Unit
SubProperty	SubSpatialUnit	Spatial Unit
SectionalProperty	LegalSpaceBuildingUnit	Spatial Unit
Utility	LegalSpaceNetwork	Spatial Unit
CadastralMap	SpatialSource	Surveying
CadastralSurvey		Surveying
Document		Surveying

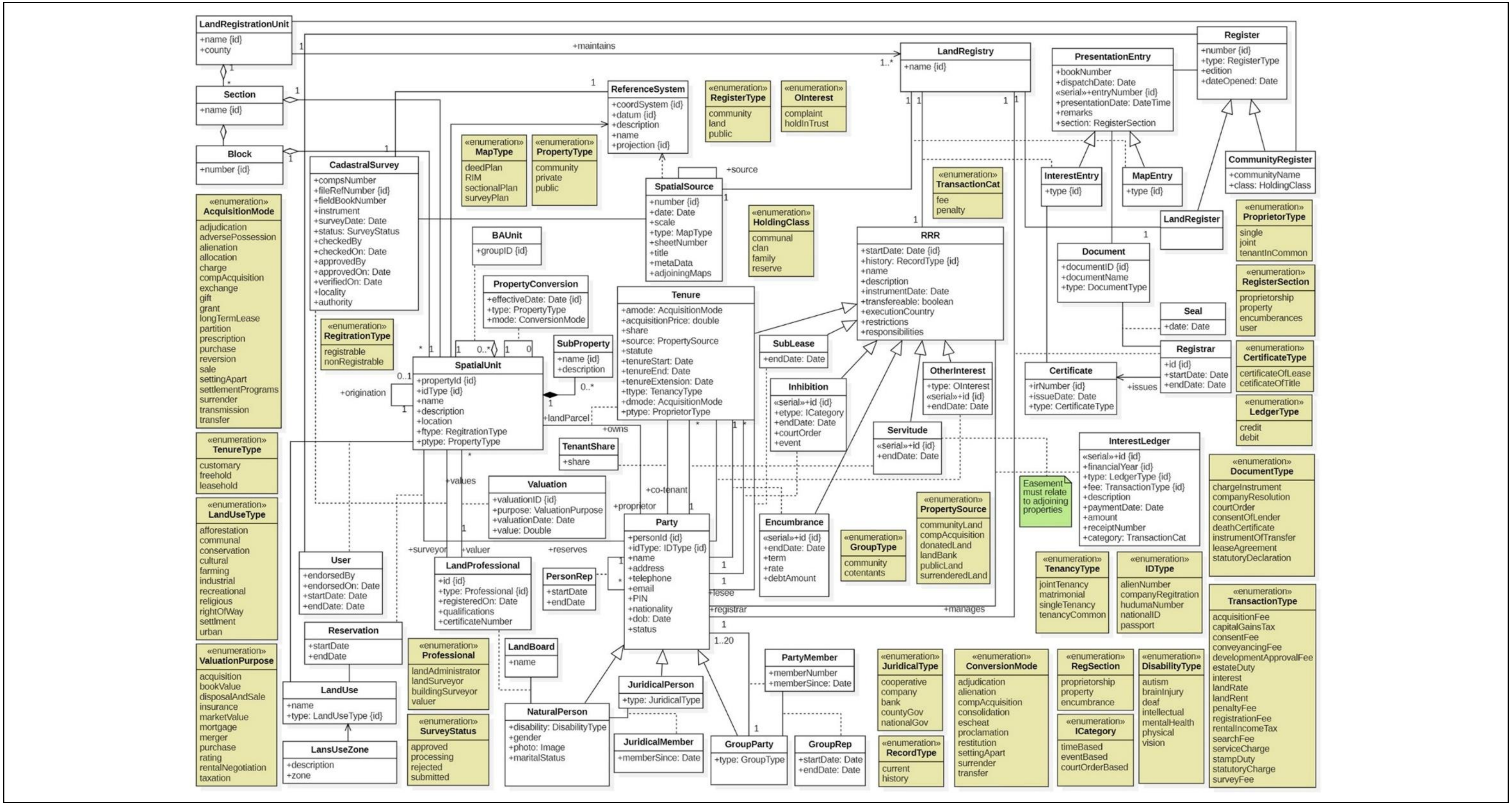

Figure 7: SD Model mapped to LADM

5. CONCLUSION

In this paper, the subject domain model of Kenya's cadastral system had been developed. A desk review combined with analysis of primary data collected from a questionnaire was used. The SD model is a critical step towards achieving standard cadastral data and processes within Kenya's LIMS, and to lead to better land information management practices. With an accepted data model, emerging technologies such as block chain will be easily facilitated.

6. AREAS FOR FURTHER RESEARCH

Further studies are needed to test the model within Kenya's cadastral practice, through actual systems developed and implemented at various levels. An obvious area of further research is to develop an Entity Relationship Diagram based on the subject domain model, and to carry out further analysis depicting system behaviour of typical Kenya's cadastral processes, such as land subdivision and change of user.

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BIOGRAPHICAL NOTES

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