Evolutionary Land Tenure Information System Development: The Talking Titler Methodology

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Key words: land tenure information systems, evolutionary design and development, wicked problems, uncertain land tenure situations.

SUMMARY

Conventional land registration systems often do not produce the desired results in uncertain land tenure situations such as peri-urban areas in developing world cities, post-conflict situations, land restitution cases and aboriginal lands. The Talking Titler system is a software system where flexibility in creating relationships between people and between people and their interests in land has been the primary design feature. It used a range of data types as evidence such as videos, photographs, documents, maps, digital graphics and sound recordings. It is most suited as a tool for prototyping and for evolutionary land tenure information system design and implementation. In its current form it is also a good training and information design support tool, although it can be used as a local level land records system. The methodology was originally conceived in urban informal settlement upgrade projects and land reform and land restitution projects in South Africa in the 1990's. In rcent years, the concepts have been tested through interviews with aboriginal peoples groups in Canada and field trials in Nigeria.

This paper provides an overview of the conceptual design of the system, how the design was formulated, testing of the system, and current development. The current version uses a conventional relational database design. The research team has experimented with evolutionary database development using extensible markup language (XML) databases and self adapting software to reduce the human input into system changes.

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1. INTRODUCTION

We present a an evolutionary design approach and some of the software design and testing procedures in developing a flexible, evolving, land tenure information data mode in wicked land tenure problem situations (Barry and Fourie 2002a). We then describe an initial attempt at developing a self-adaptive land tenure information system based on XML data structures and the eXist database as a way to reduce some of the problems associated with evolutionary design approaches.

The focus is on land tenure management in uncertain situations. It draws on field work in informal settlement upgrades, peri-urban customary tenure regimes, post-conflict situations, land regularisation as part of programmes to mend dysfunctional land administration systems, and land reform and land restitution cases (Barry *et al* 2002, Barry 2009c). We have also examined the feasibility of the approach in using recordings of oral history and oral tradition in aboriginal land claims (Barry and Khan 2005).

Flexible database structures are likely to form a significant area of interest in land administration systems. Over the past decade, there has been much interest in standardized data models for land records, such as the Land Administration Domain Model (LADM), which is an ISO standard (ISO/FDIS 19152, Lemmen *et al* 2011). However, uncertain tenure situations are unlikely to be well served by a standard model, or top down design approach, as user needs are often difficult to define. If justice and fairness at the local level are driving principles in a land administration programme, which we submit should take priority over grand economic development plans, then we should be careful not to inadvertently extinguish the interests of vulnerable groups. We argue that a land record system in uncertain situations should be sufficiently flexible to handle frequent change in system requirements, unconventional data forms and structures, and unforeseen user requirements.

In essence, we are arguing for design in wicked problem situations. In designing for wicked problems, from an information system designer's perspective, the problem is not easily defined and stakeholders seldom agree on the exact problem to be "solved". In short, wicked problems require complex judgements about the level of abstraction at which to define the problem. They lack clear rules as to when a project should end, the development process is heuristic as there are no better or worse solutions, and there are no objective measures of success. Information system development requires iteration, as there are no given alternative solutions; these must be discovered through trial and error. Importantly, wicked problem scenarios often have strong moral, political and professional dimensions (Rittel and Webber 1973, 1984, Buckingham Shum 1997, Barry and Fourie 2002a, Patel 2009). In short, attempting to state the problem is a major problem in itself, and many situations in which tenure transformation takes place can be classified as wicked problems.

Land registration is the conventional means of statutorily securing rights in land. In terms of the land title theory, recently popularised by de Soto (2000), but postulated by a number of others dating back to the mid 1800's, land titles provide tenure security, which in turn allows property owners to secure loans using their land as collateral, which in turn stimulates economic activity and thus alleviates poverty (Shipton 2009). Advocated as an economic development and poverty alleviation strategy, in practice this theory can be shown to work for the affluent, the middle class and some of the less affluent sectors of society.

Although it has been presented as a grand theory for economic upliftment and poverty alleviation, empirical evidence suggests the land title theory is not valid in many situations. A number of observers are strongly critical of it, as practical titling projects have been implemented based on this theory without due regard for the conditions that have to be in place for it to hold. Instead of promoting tenure security, the risks of applying the titling theory uncritically include (1) it may be contrary to complex, changing, continually contested, land tenure practices on the ground, and instead of supporting a stable, secure tenure environment, titling may foment conflict, (2) it can disempower certain sectors of a community and extinguish existing land interests, and facilitate land grabbing, and (3) secondary market transactions may not be registered which in turn means it fails as a prescription for economic activity and the formal land market is frozen as few formal financial institutions will accept cloudy titles as collateral; (informal money lenders might well encourage off register transactions) (e.g. Payne 2002, 2008, Payne *et al* 2009, Gilbert 2002, Deininger 2003, Deininger and Feder 2009, Augustinus and Deininger 2005, Shipton 2009, Roux and Barry 2011, Cousins *et al* 2005, Sjaastad and Cousins 2008, Platteau 1996).

We briefly examine different initiatives to develop land tenure information systems (LTIS) that serve as alternatives to registered titles, information system design strategies, aspects of evolutionary information system design, why this is necessary, and some design aspects of the Talking Titler software. We then move onto methods of creating land records in uncertain situations, and how these records may evolve as a situation changes. Following this we overview a part of our current work, namely schema evolution and self adapting software, as a way of addressing the open ended evolutionary system design concept. Finally, we overview a case study on the design and testing of schema evolution and self adapting software methods in land tenure information systems using an XML based database.

2. LAND TENURE INFORMATION SYSTEM (LTIS) INTITIATIVES

There are a number of recent initiatives to develop information systems that will cater for situations where titling is inappropriate or unaffordable. These include the UN-Habitat supported Social Tenure Domain Model (STDM) (Lemmen et *al.* 2007) and a commercial package, Open Titler, which is based on the STDM design (Edmead 2010). In addition, UN-FAO are developing the Solutions for Open Source Software (SOLA) system, that uses the Land Administration domain Model (LADM) as a point of departure. It aims to make land registration and a computerised cadastre affordable for developing countries (Pullar 2012). In the early stages, there were links between the SOLA initiative and the OSCAR/OCDM system (Hay and Hall 2009). The UN-FAO SOLA system initiative, however, is not targeted at situations where registration is unlikely to suit the particular circumstances at a given time. The mission is to make registration more accessible (Pullar 2012).

The Talking Titler system is a design methodology, which the authors are working on, which aims at addressing wicked problem situations where titling is inappropriate at a given time. The methodology is based on field work and design work in South Africa dating back to the 1990's (Barry 1995, Mason *et al* 1998, Barodien and Barry 2004, Barry *et al* 2002, Roux and Barry 2001, Barry *et al* 2009, Barry 2009c), Barry 2009a) and Ghana (Danso and Barry 2012), and an exploratory investigation with First Nations communities in Canada (Barry and Khan 2005).

We first analyse the STDM, and compare it with the Talking Titler design. We do not review the SOLA initiative as it is not targeted at wicked problem situations, albeit it adopts an agile software development approach which implies evolutionary development (Pullar 2012).

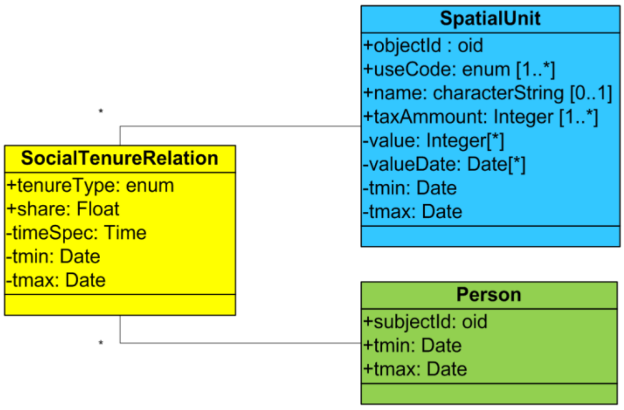

Figure 1: Core of the Social Tenure Domain Model (STDM) after Lemmen *et al.*(2007).

STDM is an adaptation of the Land Administration Domain Model (LADM). The LADM is an ISO standard linked to initiatives by the Open GIS Consortium (OGC) and Infrastructure for Spatial Information in the European Community (INSPIRE). The LADM core is based on three classes Person, RegisterObject (e.g. a title or deed), and RRR (Rights, Restrictions, and Responsibilities), which can be expanded into a number of specialised sub-classes (Hespanha *et al* 2008, Lemmen and van Oosterom 2006). The STDM is proposed as a specialisation of the LADM as an ISO standard (Lemmen 2010).

As per figure 1, the STDM has relabelled the Rights, Restrictions and Responsibilities relationship Social Tenure. The RegisterObject class has been renamed SpatialUnit, and the Person class is unchanged. Lemmen *et al* (2007) argue that it is possible to merge formal and informal tenure systems in STDM. This is achieved by introducing lookup tables and keywords to represent different kinds of SocialTenureRelations (formal and customary relations, instead of rights, restrictions and responsibilities) such as ownership, apartment rights, possessory rights, Waqf (Islamic law), occupation interest, and other similar rights and interests.

The simple form of the STDM design is a major strongpoint, as this should make it easy to use. However, as noted above, simple form may not capture the complexity of a number of situations, especially if these are wicked problem scenarios. It is an adaptation of the LADM core, which was developed for a very different set of circumstances (i.e. Europe) and grounded in a top down rather than systemic way of thinking about problem situations. The three primary classes in figure 1 may well prove to be suited to many situations, especially the Person and Spatial Unit classes which are well established in land tenure information systems, but we argue that they should be subjected to a rigorous critical examination before they are employed. Our main criticism is that setting the STDM as an ISO standard is premature. It is a prescription yet to be supported by compelling evidence derived from long and sustained usage. An international standard should be based on empirical support in a number of different types of situations over long periods of time. As the discussion above indicates, there is empirical evidence to show when titling is appropriate in a given situation and when not. In contrast, we have yet to acquire sufficient, appropriate, long-standing and diverse empirical evidence for any alternative LTIS to be promoted as an international standard. The risk of setting it as an ISO standard may result in it being specified in project documents without the critical scrutiny to check if it suits the local circumstances. Suitability to circumstances is nothing new as a critical success factor (CSF) in land tenure information systems; it was listed as a CSF for a registration system by Fortescue-Brickdale (1913) one hundred years ago.

The Talking Titler philosophy is has parallels with grounded theory research methdologyn in the social sciences. The design should be grounded in the data, and in an uncertain situation the design should emerge from the data rather thana top-down prescription. Our limited experience at the local level indicates that several system starts ups and failures may occur in uncertain situations (including an implementation of the Talking Titler system). Low usage of installed information systems in general remains a troubling issue (Venkatesh and Davis 2000), and this is a likely scenario in uncertain land tenure situations.

Talking Titler is a hybrid of evolutionary approach as, like the STDM, it has predetermined core classes. It has four primary classes Media, Person, Land Object and Reference Item (see figure 4). The Person and Land Object classes are equivalent to the Person and SpatialUnit classes in the STDM. The Reference Item class, missing in the STDM, reflects what happens in practice most of the time. In our studies, local record systems tend to be based on some form of reference document, such as a title, a file number, a rent card or occupation permit.

Media may comprise both unstructured data items, such as video clips, photographs, sound recordings, written notes and reports, and formal or iconic data items such as title deeds, contracts, permits, wills, marriage contracts and cadastral survey plans. However, the Person, Land Object and Reference Item classes may be discarded in the event they do not fit the situation. Outlined more fully below, in concept the design starts with the data, the Media class. The starting point may include one or more of the Person, Land Object and Reference

Item classes. It may revert back to the starting point, i.e. the data in the Media class, if the first design does not work. Experience has shown that in certain situations, a “well designed” GIS may be ignored by people on the ground, even if they participate in its development. Instead, completely unstructured data, such as the noting of events and relationships in a notebook (or sound recordings or a video) may be appropriate at a particular time (Barry and Fourie 2002a).

Our recent focus has been on developing the Talking Titler system as a tool for design strategy, scenario testing and data management rather than developing a working software solution. The emphasis is design for complexity and change that may inform operational strategies and LTIS development. The design priority is promoting equity and fairness at the local level, incorporate the claims of vulnerable groups in what are often highly complex, rapidly changing, local political situations.

3. INFORMATION SYSTEM DESIGN STRATEGIES

We can consider two forms of information system design and development, top down and evolutionary. A top down approach is ideal in stable situations where the problem contexts are simple and well understood. Top down, detailed design is especially appropriate in the design and implementation of information systems which support land registration. Land registration’s primary purpose is to provide procedural effect to real property law (Ziff 2006). There may be severe legal and social repercussions if an information system that supports legal procedure is ineffective, particularly if it does not deliver what the law. At the national or jurisdiction level, a host of other land administration functions draw on land registry data, hence the need for broad top-down inter-institutional LIS planning and design.

In evolutionary design, the planning philosophy is not to plan; information systems evolve and a clear end goal is not known (Patel 2009, Miller 1985). Innovative solutions may arise from this method, but the risks are that incompatible systems and nodes of information systems power may emerge in different locations and institutions. Ideally, however, some form of coordination institution should oversee the process to avoid vastly different, incompatible designs emerging which cannot be integrated or at least harmonised with a jurisdiction based LTIS at a later stage. Thus standards such as the LADM serve as a useful reference point, even if the design emerges and evolves from the data. However, this is outside the scope of this discourse. We now move on to a discussion of the conceptual data model for evolutionary LTIS development based on the Talking Titler model.

4. CONCEPTUAL EVOLUTIONARY MODEL

The evolutionary model involves continual prototyping and development. Prototypes can take on a number of forms. Of relevance are throwaway prototypes and evolutionary forms. The throwaway type is used to explore and experiment with certain parts of the final system design and it is then discarded. The evolutionary form has many of the features that the software is likely to have in its final form and an initial form of the software is gradually developed (Davis 1992, Budgen 2003). Both of these forms may be relevant to LTIS evolution.

An evolutionary development approach starts with an initial operational system which gradually evolves over time. The initial operational system builds the requirements that are well-understood, and it progresses as modifications occur to requirements and/or other requirements become clearer. This approach works well when users do not know what they want initially (*i.e.* uncertain user needs), but they can formulate an idea about them when they see them implemented in a working system (Boehm 1988). In evolutionary development, the system changes on an on-going basis. There is no notion of a final product, but rather the notion of current state of the system (Patel 2009, Budgen 2003, Beynon-Davies *et al* 1999).

Our thinking is to create an evolutionary form which may evolve as useable software, but it may be discarded at some stage and replaced by a design that has been informed by the evolutionary model. A desirable feature of the design is that in the long term it should be possible to assimilate the different localised systems that evolve through this prototyping approach into a jurisdiction based LTIS, or that the data can exported into a format that will allow this, at least in part.

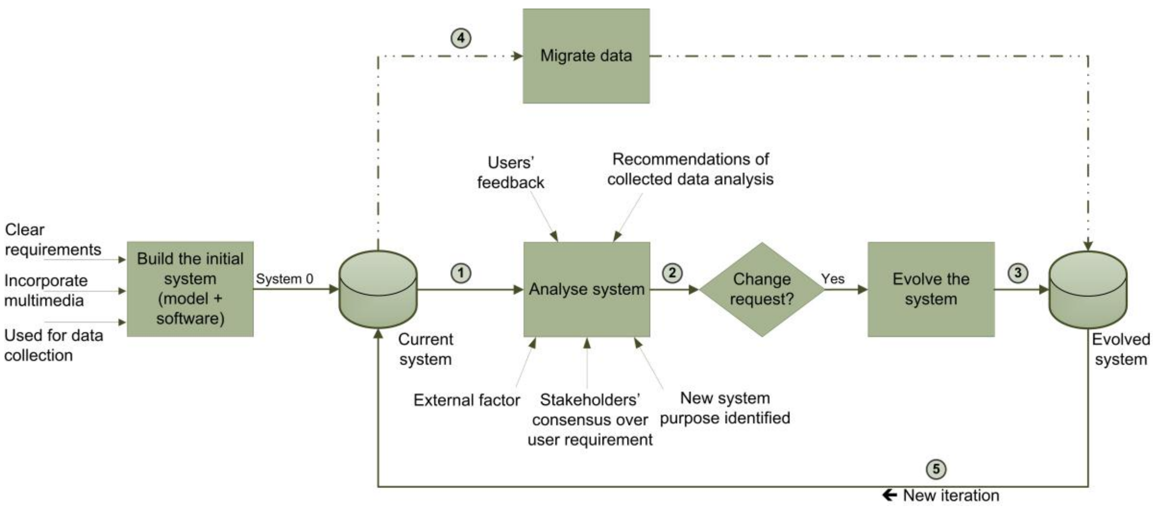

Figure 2 Evolutionary Approach to LTIS Development

The process commences with a simple, yet flexible, initial system portrayed in figure 2. The initial system is designed to address an immediate problem situation, such as the post-conflict rebuilding process following civil war, where the social and political environment is likely to be unstable, uncertain and rapidly changing (Augustinus and Barry 2006). The initial system implements basic requirements only, while allowing a great deal of flexibility in how this is achieved. The primary purpose is to collect data quickly, allowing different data types to be collected within a loose structure (Muhsen 2008). The more uncertainty in the situation the information system is meant to serve, the more flexible it should be.

Our initial system comprises two main components, an initial three class data model and the initial software prototype. The data model has three general abstract classes, namely Person, Land Object and Media as per figure 3. Each of these can be related to the other classes and to itself.

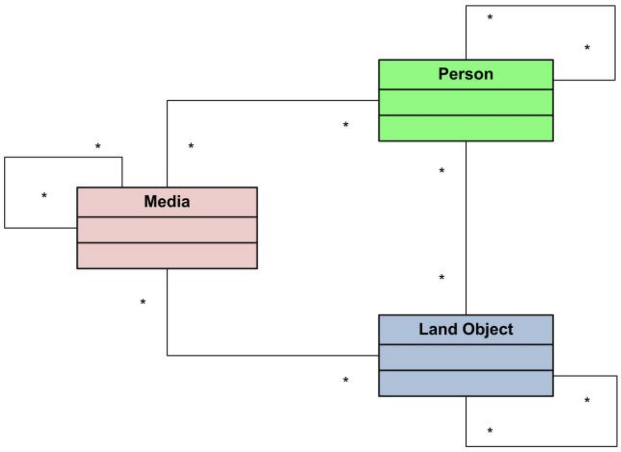

Figure 3 High-level conceptual view of the three-class model.

The Person class includes anyone (e.g. individual person, legal person, money lender) who might hold an interest in land and/or be involved in administering it (*e.g.* a land surveyor, system operator). Social structures and lineage groups are represented via recursive relationships (a relationship between a person and another person) which enable modelling parent–child relationships, inheritance, and other interpersonal relationships.

The Land Object class may represent things such as parcels, volumes of space, dwellings, trees, hunters' trap lines, religious artefacts, water bodies, and/or any spatial object of economic or cultural value (Muhsen and Barry 2008). Recursive relationships on Land Objects allow situations within and between objects to be modelled. For example, a dwelling is located on a parcel and a tree may be located on the same parcel. Relating these land objects to people, for example, the land may be held by one person, the dwelling by another, and the tree by yet another.

The Media class contains a mix of records that might represent different items of evidence relating to the existence of persons or land objects and the relationships between them such as interests and obligations between people and between people and the land. Media items might include, for example, titles, deeds, and survey plans describing parcel lots, marriage certificates, and rent cards, and multi-media recordings of dances, stories, ceremonies, video recordings of customary rules relating to chieftaincy succession and land allocation rules, recordings of symbolic land transactions, meetings, dispute resolution proceedings, and personal testimonies. The recursive relationship relates a media item to another media item. For example, in a conventional cadastral survey records system when a new survey diagram supersedes a cancelled survey diagram, it is necessary to keep both media items in the system and relate them to retain the chain of title. Or, audio recordings may be used in conjunction with photographs (a slide show) to capture an event, and all of these media items should be related to one another or to the event.

As mentioned earlier, the primary purpose which the initial prototype serves is data collection. The significance of this data collection step emanates from the principle that the more land tenure information is collected, regardless of its format and type, the more likely security of tenure can be delivered\achieved in the future. The data may be structured, semi-structured and unstructured. Ideally, the initial prototype should be used to collect information about people, land, social relations, and other land tenure information on the ground without necessarily intervening. In concept this is similar to what Kingwill (2008) labels a library of evidence. It may assume significant value where it can be consulted to support future applications and projects. For example, the information may support restitution claims; assist in dispute resolution, unravelling wrongful land allocation, land formalization and regularization.

5. SYSTEM EVOLUTION

The system may evolve in a number of different ways, and we have experimented with schema evolution to manage this (Molero *et al* 2010). Schema evolution implies adding more general classes to the three main classes in Figure 2, and by decomposing the generalized classes into more specialized ones, and perhaps adding additional attributes to these classes.

Using our example of a post conflict situation, it is important in a vastly changing environment to change the schema to address more specialised needs. For example, we may introduce a fourth general class, Reference Instrument as shown in figure 3. We may start off using a variety of reference instruments, such as certificate of occupation, taxation certificate, title deed and so forth, in this class and differentiate between them by identifier type.

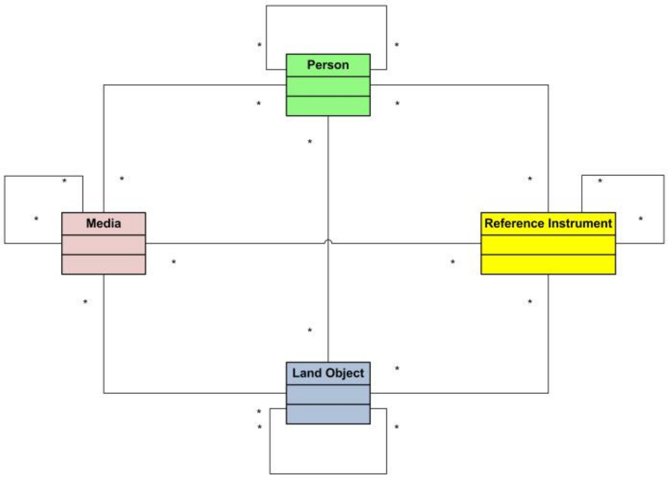

Figure 4 Four Class Conceptual Model

We might then choose to separate these into sub-classes of the reference instrument class at a later stage once we are reasonably certain that the design meets the situation's requirements. As figure 5 shows, we would specialise two classes in the reference class, namely a deed and a valuation record, and keep all other types of references instruments in the parent reference class until we're reasonably certain that we will keep these classes and then separate them into specialised classes as the system evolves.

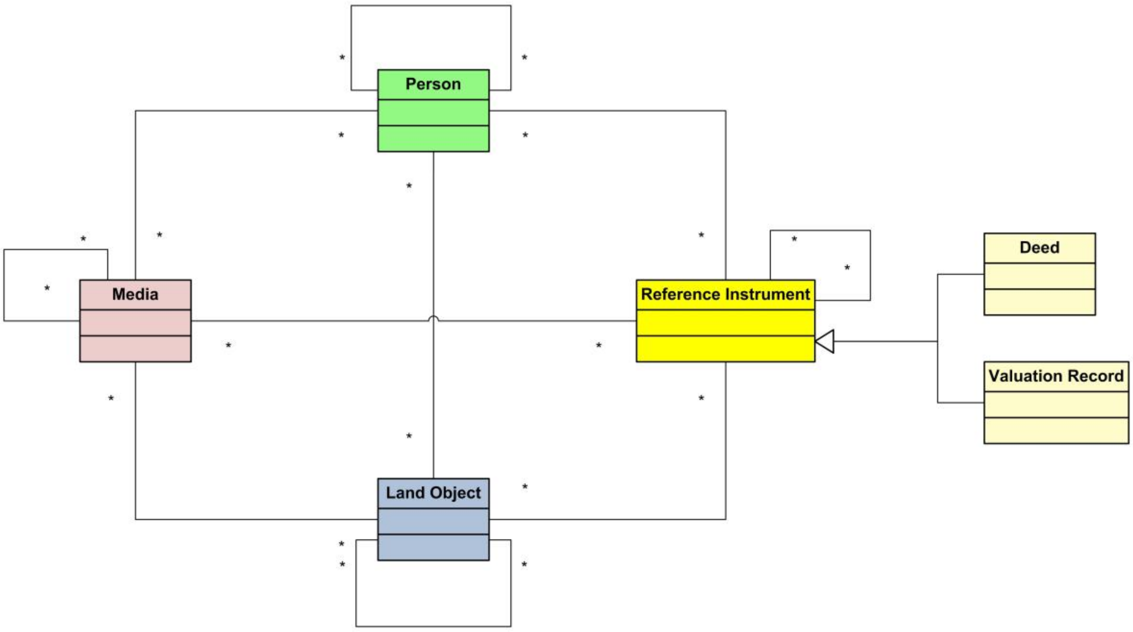

Figure 5 Specializations of Reference Instrument class.

In an ideal design, we should be able to generalise the system to revert back to an earlier state. In a conflict for example, a situation may stabilise and then the conflict may resume again. Prior to this resumption of conflict, the system may have evolved from System0 through several stages to say System7 (Figure 2). Ideally, we should be able to revert back to any particular one of these stages.

6. DATA MIGRATION

Data migration is the last step of a cycle in the methodology outlined in figure 2. It aims to move the data from the old design to the evolved one. In principle, the migration process involves three main tasks, namely: data extraction from the old model; transformation of data to suit the format and requirements needed for the new model, and data loading in which data is imported to the new model. Lastly, data verification should be performed at the end of the migration to check for errors (Kimball and Caserta 2004).

In the context of this study, data migration is case-specific. It can be done manually or by using automated procedures. It also varies in its simplicity and cost, based on the amount of refinement and differences between the old and the new models.

We now describe the concept of self adapting software and the use of XML to facilitate the evolutionary process and to ensure that at any particular stage, the data may be extracted and used by a new system.

7. COST OF FREQUENT CHANGE

Changes in a system can be frequent, unforeseen, and caused by a diversity of factors (Buckley *et al.* 2005). Continual prototyping and development associated with the evolutionary process implies repeated refactoring of the system. Continual re-engineering requires skilled IT personnel to be available throughout the system life cycle to perform the task, with associated high maintenance costs. This places a question mark over the feasibility of an evolutionary model, given that budgets and IT skills capacity are often limited in uncertain land tenure situations (Barry and Fourie 2002b). Additionally, data migration processes might be time consuming depending on the volume of data stored in the system, during which time the system cannot be used until a full iteration in the evolution of the system is complete.

In order to reduce the negative impacts of the evolutionary development approach, self-adaptive systems may alleviate some of these problems. A self-adaptive system contains built-in support for change, striving to reduce human intervention when a system performs software updates on itself (Salehie and Tahvildari 2009). To achieve the ideal where no human intervention is needed is perhaps utopian, but a self-adaptive approach may enable a significant reduction in human intervention and also reduce the skill levels required to refactor the system.

8. SELF-ADAPTIVE APPROACH

A self-adaptive system is a system which has the capacity to modify itself at runtime in response to changes introduced by an internal decision making process or by external factors such as user input (Andersson *et al*. 2009). To achieve self-adaptation, a system should be able to handle whole feedback loop iterations of the evolutionary development process on its own (see Figure 2). Drawing on Cheng *et al*. (2009), there are four major factors to be addressed in developing a self-adaptive system:

- Modelling Dimensions. This concerns the definition of models that represent: (1) objectives, (2) changes occurring at runtime, (3) how the system should react to those changes, and (4) dealing with the effects of changes.

- Requirements. This concerns the specification of: (1) what the system should do, (2) what adaptations are possible, (3) constraints on these adaptations, and (4) how to deal with the uncertainty of not knowing what future requirements could be.

- Engineering. This concerns the implementation and control of the feedback loop that underlies the dynamic behaviour of the system which enables internal decision making and self-adaptation.

- Assurances. This concerns the assessment, verification and validation of the changes taking place on the system at runtime.

Addressing the above challenge is not trivial and there is no general or simple methodology for developing a self-adaptive system. To improve feasibility prospects, a self-adaptive LTIS development approach should address these factors in a manner that the complexity and overhead associated with self-adaption do not outweigh the benefits of flexibility. Special emphasis should be made on quality management as changes occur, especially data and relationship integrity, because LTIS are especially sensitive to users' trust. Incorrect information in land tenure recording processes can have major social and legal consequences.

We perceive a self-adaptive LTIS as a flexible LTIS that allows for evolution of a basic land administration model into a specialized LTIS suitable for a specific land administration situation. It should be capable of dealing with frequent requirements changes. In other words, we envisage a LTIS that is designed to change according to unforeseen requirements and that is also capable of handling the consequences of such changes by itself, and in so doing shielding the user from the complexity from the user. For example, such LTIS can be used to guide an informal settlement reallocation process from beginning to end, adapting as the reallocation process progresses. This example is illustrated in more detail in the next section as a self-adapting LTIS case study.

The LTIS encapsulates components such as the user interface, land records database, and the middleware that allows the interaction between these two. All of these components may be subject to change whenever a change is introduced in the IS and so may be affected by the self-adaption process. Currently we are experimenting with self-adaptation at the database level, which we describe in the next section.

9. CASE STUDY: EVOLUTION OF XML-BASED LAND RECORDS DATABASE

XML (W3C 2008) is a widely used markup language and data format, especially for data exchange between applications even when these applications do not store data under the same structure. Among its benefits are flexibility and ease of use due to the ability of users to specify their own data structure and extend the structure it to meet their specific needs (Harold and Means 2002). More recently, along with the eXist database, it has been adopted as the data format for government agencies in the USA, where all existing data are being migrated to this format to facilitate analysis of data generated by a number of different agencies (Lamont 2009).

This case study consists of design and assessment of a land records database with built-in database schema evolution mechanisms based entirely on XML. Database schema evolution is the process through which changes to the database schema are introduced into a populated database without loss of existing data and maintaining database consistency (Roddick 1995). The study is driven by the fact that uncertain land administration situations are unique and diverse and so require a specific LTIS to assist such unique situation. In this sense a land records database based on a general land administration model can be specialized into a specific land administration model to meet the requirements for a unique land administration situation, undergoing frequent changes to the model over time (Molero *et al.* 2010).

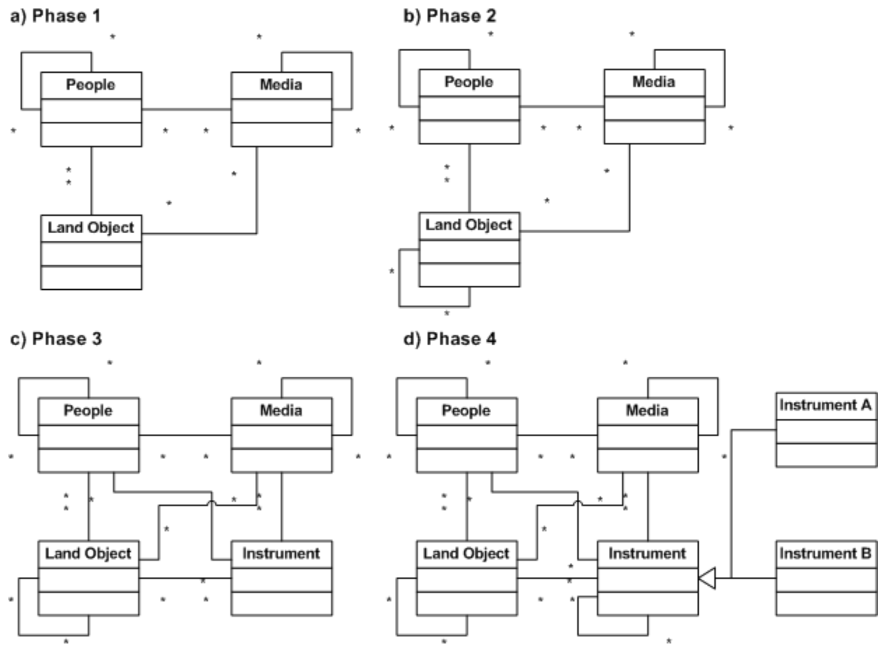

Figure 6 Evolution of the land administration model used in the case study.

We experimented with a self adaptive design based on an information system designed to move people from shacks in an informal settlement to formal houses in a newly developed greenfields site using experiences in the Marconi Beam settlement (Barry 2006). There are four phases or evolutionary steps in the experimental model (Figure 6).

- In Phase 1 (figure 6a) social and demographic information is captured as multimedia and text documents (MEDIA class) and related to the people living in the informal settlement (PEOPLE class) and the shack they occupy (LAND OBJECT class)
- In Phase 2 (figure 6b) the local authority decided to relocate the people in each shack to a formal house in a different location. This change is represented as a new relation between two land objects, the shack and the house.
- In Phase 3 (figure 6c), official recognition of rights over the new land is addressed by issuing a temporary document to the families, producing the model presented in Figure 5.c after introducing a new INSTRUMENT class and its relations to the existing classes.

- In Phase 4, formalization of rights over the new land is completed by issuing a title which is distinguished from the temporary instrument through specialization of the instrument class into two different classes.

Notice that changes applied to the initial land administration model (Phases 2 to 4) imply changes to the structure of the database which already contains the data collected in the first phase. The introduction of these changes is possible because of the database schema evolution process built in the database. The advantage of using XML as the underlying database model is that it facilitates the introduction of changes to the structure of the database, which facilitates structural changes to the existing data at a later stage. It is also text based and so the data can be saved in simple form, which has major benefits in the event of disaster recovery, and it is easy to incorporate into conventional database.

Using the terms of self-adaptive software introduced in the previous section, the case study can be roughly summarized as follows (Molero *et al.* 2010):

- Modelling Dimensions:
  - The main objective is to allow for specialization of the land administration model over time.
  - The database should be flexible enough to allow for database schema changes while preserving existing data and consistency.
  - The Talking Titler model (see Figure 2) was used as starting point in the evolution process.
  - The Talking Titler model was applied to a fictitious urban informal settlement upgrade model, albeit based on a real case –see Barry (2006), through several iterations.

- Requirements:
  - The initial land administration model should allow changes.
  - Possible changes to the initial model include: adding new classes, adding new attributes to existing classes, defining relations between classes, modifying existing classes, and specializing classes through inheritance, among others.
  - Changes in the initial model should be translated into database changes.
  - Existing instances of the data should be updated if their structure has been subject of change.
  - Automation of the adaptation process *model change - database schema update - instances affected migration* should be done without or minimal intervention of the database administrator (DBA) when possible.

- Engineering:
  - The initial model is represented in XML.
  - Initial model is translated into XML Schema (W3C 2004).
  - Data instances are stored following the current XML Schema.
  - Changes in requirements are introduced in the form of changes in the model.

    - The adaptation process is triggered by user input (a series of changes to the initial model out of the possible model changes allowed as mention in the requirements above).
    - The series of changes provided are in turn converted into XML Schema changes.
    - No XML instances update is performed unless they are solicited by the user in which case the instances are transformed to conform to the new schema before the instances reach the user.
    - The feedback loop is controlled in such a way that intervention from the database administrator is expected only if strictly necessary.
    - All changes occurring at runtime are documented within the database for validation purposes.

- Assurances:
    - Validation of the schema evolution mechanisms taking place is currently performed verifying the correctness of the data instances after the adaptation occurs; i.e. old instances still exists, old instances meet the new database schema, old instances are still correct, and new instances are stored using the new database schema.
    - The changes are evaluated at a later stage using the tracking information registered when the change took place.

The outcome of this case study showed that the complexity introduced by the database schema evolution process can be effectively encapsulated within the database satisfactorily, shielding the user from the underlying complexity. We could not get the process to work entirely with the eXist database, but we believe that this may be achieved with further work. This way user interaction with the system is reduced to data collection and entry of model changes. The self-adapting features of the system take care of performing the database schema changes corresponding to the changes in the model requested by the user, as well as the migration of the data instances affected by the propagation of changes. Also, intervention of the database administrator was only required in complex data migration situations. Additionally, updates to the user interface used for data collection was adapted internally by the system to allow for collection of data according to the current database schema.

10. CONCLUDING REMARKS

In conclusion, flexible and evolutionary LTIS systems are likely to be crucial where conventional land registration systems, with their rigid rules and procedures, are not suited to the local circumstances. We have described a conceptual approach to the evolutionary LTIS development problem and one area of design, development and testing that our research group has done in this area. These are concepts that may evolve into practical solutions in the future and significantly more work needs to be done in this area.

In the mean time, at the practical level, flexible evolutionary methods should be developed and applied in computer assisted applications on the ground that accommodate both analogue and digital data. In our observation, the reality is that many digital land information systems are designed and implemented using a project based approach, with little attention to the systems required for the system to be a going concern. Thus system planning should accommodate the scenario where a computerised system may collapse completely - for a variety of reasons (e.g. key staff members leave, computer hardware breaks down or is destroyed, failure of management to maintain administrative procedures). An XML based approach to data storage and sharing, along with well designed methods of storing data outside of the IT system but in parallel with it, e.g. using hard copy plans and documents to perform administration and filing systems that accommodate DVD’s and similar devices to store multimedia data, may mitigate some of these risks and facilitate the revival of the system.

The trade off is that this form of LTIS is it lacks appeal to the user community. As outlined elsewhere (Barry 2009b), the simpler the LTIS, the more likely it will be easy to use and the more likely the system will actually be used. Conversely the simpler the system, the less likely it will provide an adequate model of complex tenure situations or address wicked problem situations, and, in a worst case scenario, it may exacerbate an already troubled situation. The more flexible the system, the more relationships and the greater the level of complexity can be modelled, and the more likely it will be mirror the situation on the ground. But, the more flexible and complex the LTIS the less likely it will be easy to use, and the less likely it will actually be used. It is a conundrum that has kept information system designers occupied for a long time, and it should keep LTIS designers similarly occupied.

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