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Development of a GIS-based Land Registry for Tanzania

by

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"*A land administration is more than a GIS because it represents social relationships which are meaningful in a society, and not attributes in a geographical object only.*"

(van der Molen & Lemmen 2004, p.7)

"*There still may be deeds or some kind of records in someone's hands, but the real ownership status of these assets has slipped out of the official registry, leaving records and maps outdated. The result is that most people's resources are commercially and financially invisible. (…) Dead capital, virtual mountains of it, lines the streets of every developing and former communist country.*"

De Soto (2000, p.32)

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Abstract

At present, the legal land administration in Tanzania provides tenure security to a minority of people only with only 11% of land being legally registered. Consequently, Tanzanian people developed a grassroots land administration based on customary practices, extralegal institutions and documents. The Government of Tanzania is aware of the importance of the extralegal economy and initiated the Property and Business Formalization Programme, which aims at integrating extralegal and informal land rights into the legal system.

This dissertation develops a framework for a Universal Land Registry (ULR) based on Geographic Information System (GIS) technology to support the formalization of extralegal, customary and informal land rights in Tanzania. First, the demand for such a system as well as the Tanzanian environment is assessed. The ULR implementation strategy is developed based on the institutional setup, institutional needs and on experiences made so far in land right formalisation. Data capture strategies and registration methods are presented for adequately georeferencing different land rights. System requirements and the functional capacity of the ULR are discussed. The dynamic and functional view of the application is discussed based on activity, deployment and class diagrams developed in the Unified Modelling Language (UML). The ULR data model is based on the 'Social Tenure Domain Model', a new standard in the cadastral domain.

The identification of persons is identified as major pre-condition for the ULR implementation and requires special attention in the process management. Extralegal documents are a valuable source for land right formalization. They also offer opportunities to secure land rights using simple spatial identifier such as points. The proposed registration practice requires frequent data exchange between local registries and a national database, which can be a handicap to the system due to the weak communication network and unreliable electrification. However, this is still of major value to ensure transparent and non-corrupt use of the system.

The study concludes that in a next step pilot studies are required to test the feasibility of the suggested URL. The pilot studies should further contribute to developing national standards for customary practices, spelling of geographic locations, topographic mapping as well as measures to ensure usability of the system by illiterate people.

Keywords: Universal Land Registry, land right formalization, cadastral modelling

Disclaimer

The results presented in this dissertation are based on my own research. All assistance from other individuals and organisations has been acknowledged and full reference is made to all published and unpublished sources used.

This thesis has not been submitted previously for a degree at any institution.

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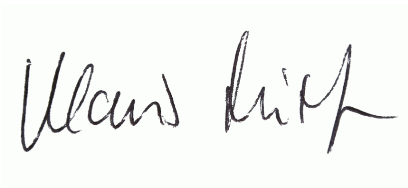

Signed: Klaus Mithöfer

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List of Acronyms and Abbreviations

AAA	Authentication, Authorisation, Accounting
AFREF	African Geodetic Reference Frame
CCDM	Core Cadastral Domain Model
CCRO	Certificates of Customary Right of Occupancy Tenure
CVL	Certificate of Village Land
COGO	Co-ordinate Geometry
DGPS	Differential Global Positioning System
ESRI	Environmental Systems Research Institute
FIG	International Federation of Surveyors
ICT	Information and Communication Technology
ILD	Institute of Liberty and Democracy
FIG	International federation of Surveyors
GDP	Gross domestic product
GIS	Geographic Information System
GPS	Global Positioning System
ISO	International Organisation for Standardization
LADM	Land Administration Domain Model
LDAP	Lightweight Directory Access Protocol
LIS	Land Information System
MKURABITA	Swahili acronym for 'Property and Business Formalization Programme'
OGC	Geospatial Consortium, Inc.®
OMG	Object Management Group
PDA	Personal Digital Assistant
RRR	Right, Restriction, Responsibility
SDI	Spatial Data Infrastructure
STDM	Social Tenure Domain Model
SWOT	Strength, Weakness, Opportunities and Threats
UML	Unified Modelling Language
ULR	Universal Land Registry
UN-HABITAT	United Nations Human Settlements Programme
WAAS	Wide Area Augmentation System
WGS84	World Geodetic System 1984
WFS	Web Feature Service
WMS	Web Map Service

1 Introduction

1.1 The challenge of land administration in Tanzania

"*A Cadastre is normally a parcel based, and up-to-date land information system containing a record of interests in land (e.g. rights, restrictions and responsibilities)*" FIG 1995, p.1). Cadastres were established preliminary for tenure security and land taxation. Today, cadastral data build the foundation of modern Land Information Systems (LIS) for efficient land management (Ezigbalike et al. 1995, FIG 1995, Österberg 2001). A functioning cadastre is the basis of active land markets permitting land to be bought, sold, mortgaged or leased. It is increasingly accepted that a modern LIS is a key infrastructure for economic development and environmental management especially in developing countries (Williamson 1997, ECA 1998, UN-FIG 1999, Enemark 2001, Fourie 2002, UN-HABITAT 2004).

The land administration in Tanzania has been blamed for being very bureaucratic, time consuming, not productive and usually far too expensive for most Tanzanians (Kombe & Kreibich 2001, de Soto 2006, CLEP 2006, p.6, Silayo 2005). Only 11% of the land in Tanzania is registered with the legal administration (de Soto 2006). One reason for the failed land administration is the fact, that customary land rights were never fully implemented until the advent of the new land laws in 2001 (Larsson 2006). Consequently they were never incorporated into the legal cadastre.

In response the Tanzanian people developed their own grassroots administration based on customary practices. Studies (ILD 2005b) revealed the existence of an informal administration system based on extralegal[1] institutions, adjudication processes and written documents describing existing land rights. But extralegal documents are only of limited value to obtain mortgages and credits. Land tax collection is in disorder depriving the Government of the resources to build an effective system of land registration to assure land tenure security for all. Tenure security is fundamental for human shelter, food production and all economic activities. Secure rights to land

[1] Unlike a squatter in urban informal settlements the landholder in rural areas usually does not hold land informally, but according to an alternative formality, a community-based formality. This formality is reflected in the term extralegal introduced by ILD researchers during the MKURABITA Programme (ILD 2005: Volume II). The extralegal economy is a self-organised system of documented institutions, which allows people to govern their action (de Soto 2006).

encourage people to invest in their land and property and can enable people to access public services and sources of credit (UN-HABITAT 2008).

The economic impact due to the lack of legal land registration is tremendous. The value of not legally registered Tanzanian assets is estimated at 29.3 billion US$; capital that is largely underutilized (de Soto 2006). The Government of Tanzania is aware of the extralegal economy and its impact. It implemented the Property and Business Formalization Programme whose Kiswahili acronym is MKURABITA[2] to formalize extralegal businesses and property ownership for economic growth and poverty alleviation. In 2001, the Government implemented a new market oriented land policy for mainland Tanzania through the Land Act 1999 and the Village Land Act 1999. The land acts recognize existing customary land rights as equal to existing statutory rights and intend to streamline the existing land management system (Derby 2002).

1.2 Research problem

The 'Strategic Plan for the Implementation of the Land Laws' (MLHSD 2005) outlines the possible re-organisation and decentralization of land registration in Tanzania and highlights the demand for an efficient land registration system based on modern Geographic Information System (GIS) technology. The ongoing MKURABITA programme endeavours to design a formalization process based on the existing grassroots practices and written documents. Pilot studies conducted in Tanzania analysed the implementation of land laws and the formalization of informal and extralegal land rights. First experiences were gathered in the use of unconventional approaches in surveying and the development of GIS databases to establish local cadastral systems. But a concept outlining a possible technical setup for a nationwide system based on data exchange and dissemination, which integrates such information into the legal cadastre, does not exist yet.

The Tanzanian land administration requires the development of a demand-driven and cost-effective GIS based system[3] to support the formalization of land rights embedded in a system architecture, which promotes the generation of standardized datasets to support the development of a national LIS in Tanzania.

[2] *Mpango wa Kurasimisha Rasilimali na Biashara za Wanyonge Tanzania*

[3] The term system incorporates the software with its functionality as well as the system architecture and organisation.

General recommendations and experiences in alternative surveying methods and procedures in land administration are documented for Tanzania and other developing countries. Extralegal documents provide valuable bases for the land right formalization. New standards for modelling the cadastral domain using the Unified Modelling Language (UML) for universal tenure relationships are presently under development (Lemmen et al. 2007).

This thesis aims at combining the experiences made in Tanzania and other developing countries with the general guidelines and new approaches to modelling the cadastral domain for developing countries in order to meet the demand for a universal land registry as defined by the Tanzanian context.

The land registration system which needs to be developed must (i) support the MKURABITA formalisation process and (ii) enable local communities to establish local land registries in a decentralized framework. The system targets (iii) the registration of existing legal and extralegal documents as well as other informal or customary land relationships. Further, the tool should be (iv) a supportive instrument for land adjudication and conflict management. Finally (v), system design and architecture must support the efficient distribution of land right information throughout the administration on all levels and enable public access to data.

Thus, a broad approach needs to take into account the particularities of the land property situation in Tanzania. It further needs to make use of the potentials of new technologies to support the formalization of land rights, to build locally administered cadastres and to serve the government's demand for information on land. Modern information and communication technology (ICT) and interoperable GIS technology (OpenGIS®) play an important role in the design of a demand driven application (Huber et al. 2008). The development of the land registration system outlined in this thesis is based on approaches in business engineering which aim to integrate GIS into envisaged business processes.

1.3 Research objectives and methodology

The intention of this study is to:

- Outline the framework for a Universal Land Registry (ULR) based on GIS and ICT to support the MKURABITA programme to formalize land rights.
- Describe methods and possibilities to integrate legal and extralegal documented

land rights as well as orally transmitted claims into a GIS based system.

- Catalogue the functionality of the ULR.
- Outline procedures for establishing and operating the system.
- Design business processes and a data model in UML to integrate and maintain cadastral data based on the Social Tenure Domain Model (STDM).

This dissertation focuses on the framework, the business processes and the data model of the ULR. The outcomes of this thesis aim at building the foundation for the technical specification of the ULR, which is the topic of the thesis by Schär (2008). The study approach follows the FIG guideline Cadastre 2014 (Kaufmann & Steudler 1998) and the Social Tenure Domain Model (Lemmen et al. 2007) as de-facto standards in cadastral domain modelling.

The following methods are used:

- Business (re)-engineering and strategic planning: assessment of the current situation, environmental analysis, goals.
- Functional analysis: catalogue the core functions of the system for data integration, georeferencing processes, data analyses, etc.
- Model building: develop a process model using UML to maintain and continue analogue and digital data integration.
- Model building: develop a basic data model using UML for the ULR.

1.4 Thesis structure

Chapter 2 assesses the environment in Tanzania enabling strategic planning for the general framework of the ULR. A brief background is given concerning the general situation in Tanzania (population, infrastructure). New strategies and policy programmes to formalize land tenure and to enhance the capacity of the land administration are presented to explain the present status and to develop strategies for the implementation of the ULR. The extralegal land registration and its documents are described in chapter 2.3.

Chapter 3 takes a deeper look at recent developments in cadastre design and highlights recommendations on how cadastres can or should be implemented in developing countries with focus on sub-Saharan Africa. General guidelines and experiences from

Tanzania and other developing countries illustrate unconventional approaches and new possibilities how low-cost and effective cadastres can be developed. Chapter 3.3 introduces recent developments in modelling the cadastral domain with focus on Cadastre 2014 and the Social Tenure Domain Model (STDM) which is the basis for the ULR data model.

Chapter 4 describes the general framework of the ULR and outlines possible institutional and practical implementations into the Tanzanian formalisation programme. The formalisation process is discussed to outline the functional and architectural requirements of the ULR application. Chapter 4.5 describes the envisaged integration strategies for spatial data, technologies and methodologies, which are relevant for the ULR implementation. Finally, the ULR principles, general requirements and the ULR functions are summarized.

Chapter 5 concludes the system development based on UML. Activity diagrams describe in detail the relevant registration processes. The data model based on the STDM approach is presented as well as a deployment model to outline the system architecture.

The primary relationship between the chapters is described in figure 1.

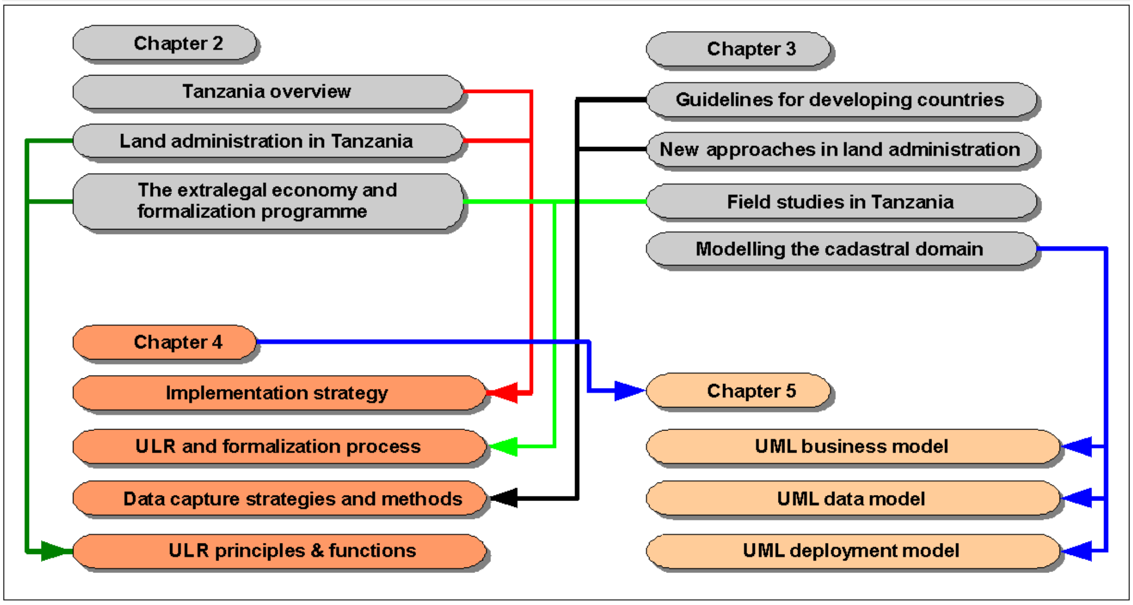

Figure 1: Thesis structure

2 Land administration and extralegal economy in Tanzania

2.1 Tanzania: land and population

The United Republic of Tanzania is situated in East Africa at the Indian Ocean and consists of the formerly independent states Tanganyika (known as mainland Tanzania) and the islands of Zanzibar[4]. With a total area of about 945,000 km^2 Tanzania is double the size of Germany, Switzerland and Austria.

The mainland is divided into 21 regions (Figure 2) and 106 administrative districts. In total there are 117 urban and district local authorities and around 12,500[5] villages (Kironde 2006).

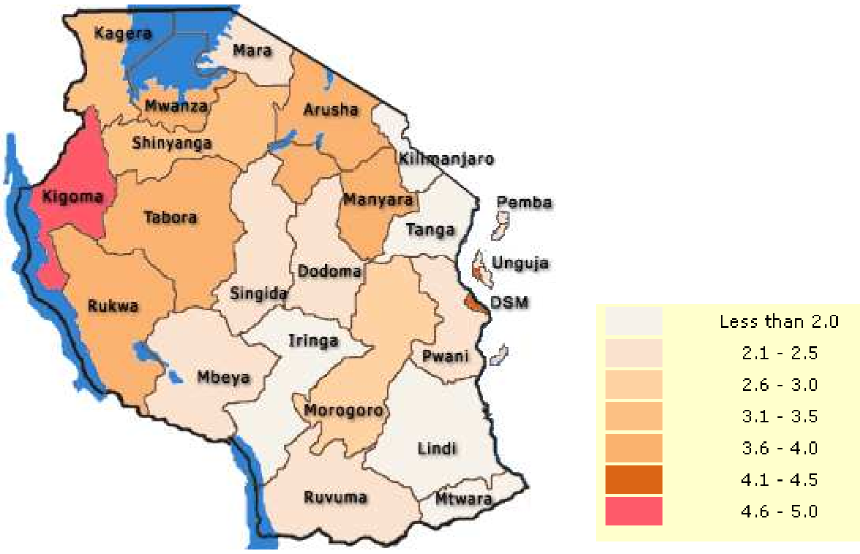

Figure 2: Population growth rate by region 1988 - 2002 (GoT 2003)

Tanzania consists of a large central plateau with grasslands and national parks and a very mountainous north-eastern part of the country with Mt Kilimanjaro, the highest peak in Africa. Only 5 to 10% of the land is under cultivation, predominantly by smallholder farms. 65-70% of the land is covered with forests, woodlands, pastures or uncultivated arable land. The remaining land is composed of National Parks and reserves (Odgaard, 2006).

The population of Tanzania consists of about 120 different ethnic groups with the

[4] Zanzibar consist of the islands Pemba and Unguja (often referred as Zanzibar)

[5] The number of villages varies a lot in publications. The ILD Report (ILD 2005c) states 10,319 villages

majority of Bantu origin. The Bantu people are predominantly agricultural farmers. The people of Nilotic origin like the Maasai are predominately pastoralist by tradition (Odgaard 2006).

The Tanzanian population has doubled nearly every 20 years from approximately 12m in 1967 to more than 39.5m today at a present growth rate of 2.6% (Kironde 2006, World Bank 2007a, see also Figure 2). 25% of the Tanzanians live in urban areas (World Bank 2007a). Tanzania is one of the countries with the fastest growth in urban agglomerations in sub-Saharan Africa (Kombe & Kreibich 2001). Dar es Salaam for example receives up to 300,000 people a year, most of them tend to settle in unplanned areas (Kironde 2006).

Tanzania is one of the poorest countries in the world. The per capita Gross Domestic Product (GDP) is at 324 US$ only (World Bank 2007a). Agriculture is still the backbone of the economy[6] and main source of livelihood for most Tanzanians (Kironde 2006). The Government of Tanzania has implemented several policy programmes for poverty reduction and empowerment of the poor to reach the Millennium Development Goals.

The infrastructure in Tanzania is in a poor condition. District roads are usually unpaved and overwhelmingly bad maintained (Kironde 2006). The energy production relies to more than 80% on hydropower (CIA 2008) which makes it susceptible to prolonged droughts as happened in 2006. The electrification rate is at 11% only (UNDP 2008) and is predominant biased against rural areas. Power cuts can be regarded as part of everyday life in many parts of the country.

However, the communication network for mobile phones has improved. 25% of the population has coverage (World Bank 2007b). The number of subscribers is growing at a high rate and outstrips the number of internet users by far[7]. Analysts regard the mobile phone technology as a key technology for development in Africa since it is already in use for many applications like money transfer or market price information system (The Economist 2007).

[6] 45.3% of GDP in 2006 (World Bank 2007a)

[7] The number of subscribers grew from 3 to 52 per 1000 people between 2000 an 2005, the number of internet users from 1 to 9 per 1000 people (World Bank 2007b).

2.2 Land administration and cadastre in Tanzania

2.2.1 Land right management in Tanzania

A dual land administration based on the ownership concept introduced by the colonial rulers and a resilient system based on indigenous customary land tenure is characteristic for many countries in sub-Saharan Africa (Ezigbalike et al. 1995, van der Molen 2006). Tanzania makes no difference in that regard. Customary land rights still play an important role in land management but they have not been fully incorporated into the written legislation (Larsson 2006).

Customary law is different from our western experience and traditional parcel-based ownership concept. According to Kironde (2006, p.18) customary law can be described as a "*non-formal complex of codes of behaviour and social control that have guided rural life in tribes and societies from generation to generation*" which may vary among societies and even between villages of the same tribe. Land security is created through the idea that labour creates value. Continuous cultivation of land leads therefore to tenure security (Kironde 2006). The most characteristic feature of customary land tenure is the predominance of group rights. Land rights are held corporately by a group (e.g. tribe, clan, family) as a consequence of group control and discipline. Family land can be regarded as the most important type of group right (Ezigbalike et al. 1995). The administration of land is in customary practice assigned to the village community and the elders. Customary laws are traditionally kept in oral tradition, whereas written documentation is not fully accepted yet (Kironde 2006).

Local land administration practices depend on the cultural background of the people and the natural conditions of the area. Migration of people and mixing of cultures leads consequently to a diffuse conglomerate of land right arrangements. The parallel existence of indigenous customary rights, customary rights of immigrants, rights allocated through village authorities, borrowed or rented land right, land rights gained through commercial transaction and registered granted rights is characteristic for Tanzania. But in practice it is often difficult to distinguish between the rights, changes are applied and new mixed forms arise (Odgaard 2006). Overlapping claims on land (legal and customary) are frequent and induce land disputes in Tanzania (Ojalammi 2006, p.3).

The Land Act 1999 and the Village Land Act 1999 in May 2001 integrate customary law into the legal system. They build the new foundation for land administration for mainland Tanzania[8]. According to the Acts land is divided into the categories village land, reserved land (e.g. national parks) and general land, which includes all urban areas (Kironde 2006, Odgaard 2006). Villages are the player of the new decentralized land administration since village land comprises nearly 70% of all lands in Tanzania (ILD 2005c). Village land falls now under the jurisdiction of the Village Council which administers land in accordance with customary law (Odgaard 2006). Customary Right of Occupancy is supposed to be applied within village land by the Village Council and Granted Right of Occupancy to be used outside village land. Both rights have an equivalent status (Kironde 2006).

The Village Land Act provides also for the sharing of land by pastoral and arable farmers on the basis of adjudication and mutual agreements (Mutakyamilwa 2002 cited in van der Molen 2006). Nevertheless, the political discussion on customary land rights is still ongoing in Tanzania despite the new land laws and policy strategies. Kironde (2006) states that more needs to be done to improve the security of tenure for all land users. Property rights should encompass the formalization of land rights of pastoralists, fishermen, hunters and gatherers and other secondary rights holders (Adams & Palmer 2007).

2.2.2 Land administration and land conflicts

Cadastral surveying and land administration is centralized under the Ministry of Lands with only few regional offices. Services are not only expensive, they are nearly inaccessible for poor people from remote rural areas due to the poor road infrastructure and high transport costs The land registry is not computerized and has outdated procedures for locating information and registering rights (ILD 2005c). Land and title records are kept in hard-bound registers, index cards and paper files maintained by six independent regional divisions (Derby 2002), which complicates national land administration and planning.

Another weakness which constrains the development of any new land administration is the inadequate geodetic reference framework. The existing network is inconsistent and in need of improvement using the Global Positioning System (GPS). The network has not yet been transformed into the World Geodetic System 1984 (WGS84, Africover n.d.) but Tanzania has started to implement the African Geodetic Reference Frame

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[8] Zanzibar has an autonomous government with independent ministries, legislature, cabinet and President.

(AFREF). A continuous operating GPS station was installed in Dar es Salaam in 2006, two additional ones are planned in Mbeya and Dodoma (RCMRD 2007). The development of a spatial data infrastructure (SDI) in Tanzania is still in an early stage with funding not in place (Kalande & Ondulo 2006).

All of this results in only 11% of the property being registered with the existing legal system (de Soto 2006). The cadastre is sporadic, only 8,021 plots were surveyed between 1991 and 2001 (Silayo 2002b). Erratic land grabbing, uncontrolled urbanisation and establishment of spontaneous settlement are some of the consequences of the failed land administration. The lack of formal registration leads to insecure tenure relationships and discourages people to invest in their land.

Land disputes are common in Tanzania. The constantly growing number of cases led to the establishment of land tribunals, increasing costs and delaying land development. Origins of land conflicts are often the increasing competition over access to land and the increased scarcity of resources like pasture, water, wood or fertile soils (Lugoe 2007). Growing conflicts can be observed especially between agricultural farmers and pastoralists as well as around expanding urban areas adjacent to village land (Hayuma & Conning 2006, Odgaard 2006, Lugoe 2007) and between pastoralist people (Ojalammi 2006).

The Government of Tanzania has implemented new policies and laws to improve the situation. The Land Disputes Courts Act of 2002 reflects the common practices of conflict handling on village level. Land disputes are solved with the local administration trough the Village Land Councils and Ward Tribunals. Their main objective is to mediate between the conflicting parties to achieve mutual agreement (Odgaard 2006).

2.2.3 New strategies in land administration in Tanzania

Silayo (2006) discusses new methods for cadastral survey in terms of survey accuracy and low-cost technologies like the use of remote sensing images. He states that high surveying and registration cost hinders particularly the registration of low value land, small scale farms and informal settlements in Tanzania. Derby (2002) emphasises the need to re-organize and streamline the registration process and data flow. He also suggests the implementation of a database based record keeping system to develop an efficient LIS. The author further outlines procedures to clean and digitize existing records and a streamlined process to integrate new land records into his case study database covering six divisions. Kironde (2006) states in addition to such aspects, that public access to information is a very important factor for improving the present system.

The Ministry of Land's 'Strategic Plan for the Implementation of the Land Laws' (MLHSD 2005) identifies concepts for achieving an efficient and economical land administration. Key objectives for further action and development are summarized in the following points:

- Install appropriate land administration infrastructure and services (e.g. registration, titling).
- Decentralize the land administration to district level. Planning, surveying and land registration will be duty of District Land Officers.
- Establish a land administration infrastructure based on ICT and GIS technology on all administrative levels as part of a national SDI to enhance data management and information flow.
- Involve the private sector in the execution of services.
- Build capacity and educate the public on land laws and administration.
- Introduce a system for the identification of persons.

The strategic plan aims at tackling the rampant tenure insecurity in all settlements whereby the categories cities and small towns are prioritized. Curbing of land conflicts is the crucial issue for village land (MLHSD 2005). At the present state of the land reform process in Tanzania, the Ministry of Lands and other stakeholders have conducted trainings and established local land registers at village and district level, but only few are yet in place (Adams & Palmer 2007).

2.3 The Property and Business Formalization Programme MKURABITA

The rise of land conflicts during the 1980s led to increased awareness of the value of land and led to the development of informal land markets (Kironde 2006, Larsson 2006). The deficits of the legal administration were increasingly compensated through the introduction of informal institutions and procedures. For example, local people in Dodoma and Morogoro developed grassroots institutions for tenure security, land transaction and land dispute arbitration (Kombe & Kreibich 2001).

As response to the informal and extralegal practices the Government of Tanzania launched in 2004 the Property and Business Formalization Programme. The aim of the programme is to design and implement a reform to transfer locally registered business and property documents into legal, standardised equivalents. In a first phase, an in-depth analysis commissioned by the Government of Tanzania regarding the extralegal economy was conducted by the Peruvian Institute of Liberty and Democracy (ILD) led by the economist Hernando de Soto. The results are published on a Government website[9]. The programme is now in the second phase, the reform design (Adams & Palmer 2007)

The diagnosis report (ILD 2005a-c) describes in detail the failure of the present formal land administration and the environment of extralegal land management. One of the astonishing findings is, that all across the country Tanzanians have developed structures and procedures including written documents to manage interests on land. This indicates a clear shift from the tradition of a social cadastre based on group memory towards a documented cadastre. The ILD report (2005b) lists the following patterns of newly developed customary practices (archetypes) of property management.

Table 1: Archetypes of property (ILD 2005b)

Archetype	Description
Adjudication	Local authorities adjudicate land disputes. Documents of the adjudication process create property.
Documentation	Document indicating mutual agreements like transfer of property.
Registration	Storing of property related documents at a central place to get access.
Fungibility	Property title as guarantee to get credits.
Collateral	Land as collateral for loan.
Testament	Express individual will.

Documents related to these archetypes contain depending on the purpose for example photographs of persons, descriptions and sketch maps of plot boundaries (Figure 3). The documents are signed by the stakeholders involved, witnesses and persons responsible like village or urban sub-ward Chairman (Mwenyekiti).

Tanzanians have created these institutional archetypes corresponding to their cultural setting. However, these archetypes lack systematic standards, information management and a basic infrastructure. Institutional changes within government and an improvement of customary practices towards standardized documentation provide the opportunity for the development of a unified land administration in-between the existing systems (de Soto 2006, p.55).

[9] http://www.tanzania.go.tz/mkurabita_report_indexf.html [cited 23.4.2008]

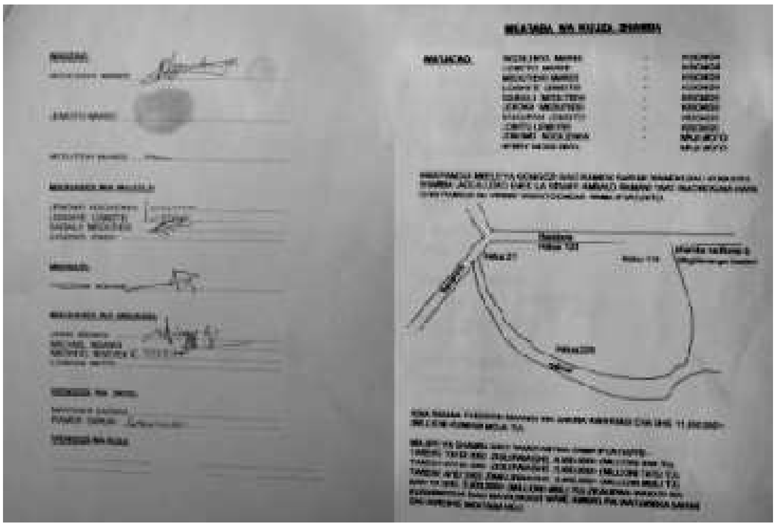

Figure 3: Figure: Archetype of Documentation of property (ILD 2005a)

The ILD report lists recommendations for the improvement of the legal system and the customary practices to merge legal and extralegal land administration in a new legal system (ILD 2005c, p.380):

- Introduce simplified, standardized and low cost formalization procedures provided by private professionals.
- Establish simplified, standardized and low cost registration procedures based on a geographic database.
- Design rules for standardisation of extralegal documents and introduce standard archives for record keeping in villages according to customary practices (Mwenyekitis store) to pave way for future nationwide registry.
- Facilitate access to archives to provide copies of certificates.
- Professionalize and systemize adjudication processes and support the authorities with identification material like lists of owners and maps of properties.
- Establish simplified mechanisms to solve land disputes and foreclose mortgages and pledges.

The existing archetypes of property build a solid foundation to formalize customary land rights according to the new land laws. However, Adams and Palmer (2007) state that the programme needs to be harmonised with other governmental programmes e.g. the Ministry of Land's 'Strategic Plan for the Implementation of the Land Laws' (MLHSD 2005).

3 Developments and trends in cadastre

3.1 Guidelines for developing countries

The International Federation of Surveyors (FIG) and United Nation (UN) agencies have published several declarations and guidelines on criteria for successful implementation and re-engineering of land administration practices including appropriate tools for developing countries (FIG 1995, FIG 1996, ECA 1998, UN-HABITAT 2003)[10]. These guidelines based on expert group meetings during which new strategies, tools and technologies for efficient and affordable cadastral systems in sub-Saharan Africa were discussed (FIG 2001, FIG 2004, UNDP 2005). An ULR application and architecture is seen as a first step to build a nationwide cadastre based on legal, extralegal and informal land rights. Thus this section briefly reviews existing concepts and recommendation for best practices in land administration.

Table 2: Criteria for actual or potential success of a cadastre (FIG 1995, p.8)

1 Security	The system should be secure such that a land market can operate effectively and efficiently. The geographic extent of the jurisdiction of the system and the characteristics of the rights registered should be clear to all actors.
2 Clarity and Simplicity	The system should be clear and easy to understand for use by administrators and the general public.
3 Timeliness	The system should provide up-to-date information in a timely fashion.
4 Fairness	The system should be fair in development and operation and be perceived as being so.
5 Accessibility	Within the constraints of cultural sensitivities, legal and privacy issues, the system should be capable of providing efficient and effective access to all users. This includes providing equitable access to the system through, for example, decentralized offices, simple procedures, and reasonable fees.
6 Cost	The system should be low-cost, or operated in such a way that costs can be recovered fairly and without unduly burdening users.
7 Sustainability	Mechanisms must exist to ensure that the system is maintained (management, procedures, technologies) over time and that the formal system is understood by and affordable to the general population

Table 2 shows criteria for measuring the actual or potential success of a cadastre (FIG 1995). Many authors have contributed to these best practices regarding good land administration practice in developing countries.

The cadastral system design should not be too complex and only as accurate as needed

[10] Further publications are available at http://www.fig.net [cited 14.4.2008]

to make it manageable at implementation stage (van der Molen & Lemmen 2004). In general, cadastral systems designed for poorer countries must be simple, flexible, openly accessible and at low cost (Williamson 1997, ECA 1998, Fourie 2001). A decentralized approach following the principle of subsidiarity, where local registries are maintained based on local knowledge about property rights and responsibilities is favoured to ease access, support acceptance, build local capacities and reduce costs (Enemark 2001, ECA 1998, Fourie 2001, UN-HABITAT 2003, Augustinus et al. 2006). The protection of woman rights becomes very important in the context of customary practices and legal rights (Fourie 2002, UN-HABITAT 2003). Conflict solution management e.g. trough the registration of conflicts is seen as an important capability of land cadastre in Africa. (Österberg 2001, van der Molen 2006).

Different types of spatial representation like the use of points (dots on plots), block registration or even simple sketch maps are proposed besides the traditional parcel to georeference the various existing rights on land in an adequate way (Williamson 1997, ECA 1998, Fourie 2001, van der Molen 2006, van der Molen & Lemmen 2004). The cadastre should be able to maintain spatial data of various degrees of accuracy for boundary delineation because of the high costs for high accuracy survey (Enemark 2001, ECA 1998). The correct spelling of person names or geographical names is a frequent problem in developing countries like Tanzania, where multiple languages are spoken. The correctness of names is a serious accuracy factor for a flawless cadastre (Augustinus et al. 2006).

3.2 New approaches in land administration

3.2.1 Tools for surveying and data logging

The advent of simple GPS receiver, high resolution satellite images and web-based map services like GoogleEarth has paved way for new innovative approaches in surveying and mapping of the spatial component of land administration systems.

The use of photogrammetric or remote sensing techniques to survey land is very cost effective and more suitable for mass production compared to field survey techniques (Tuladhar 2005, Kansu & Gazioglu 2006). Pilot studies from Zambia (Nordin 2004), Mosambique (Anderson 2000, Trinade 2004) and Tanzania (MLHSD 2006) show the potential of high resolution remote sensing images for registration or upgrading projects in informal settlements. The advantage of these images compared to orthophotos is that they cover a larger area and that they are continuously taken which allows a frequent update and maintenance of the database (Tuladhar 2005).

New innovative instruments like palmtops or field computer equipped with GPS receiver, GIS software and remote sensing images allow the combination of field and office based survey techniques. Barry & Rüther (2005) demonstrate the use of palmtop computers interfaced with a GPS receiver to collect socio-economic and spatial data for informal settlements. The use of handheld GPS receiver and amateur cameras to locate and document shacks in a settlement has proved to be sufficient for an inventory. The researcher used the Cybertracker[11] data collection method based on simple icons to represent questions and answers which aims to support staff with moderate level of literacy. Further, the researcher used digital photographs to register persons and experienced video imagery to record information relating to land rights and integrated them into the information system.

The 'Talking Titler', a product derived from the system describe above, is developed to incorporate multi-media data such as video clips and sound files in a database containing records regarding evidence of rights. The system is aimed to support societies where oral traditions play a major role in the land tenure (Barry & Rüther 2005)[12]. Figure 13 shows the user interface with brief information on the locality and a playable video clip.

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[11] http://www.cybertracker.co.za/ [cited 14.4.2008]

[12]http://www.geomatics.ucalgary.ca/~barry/Research/ResearchHome%20Page/TalkingTitlerPage/IndexTalkingTitler.htm [cited 14.4.2008]

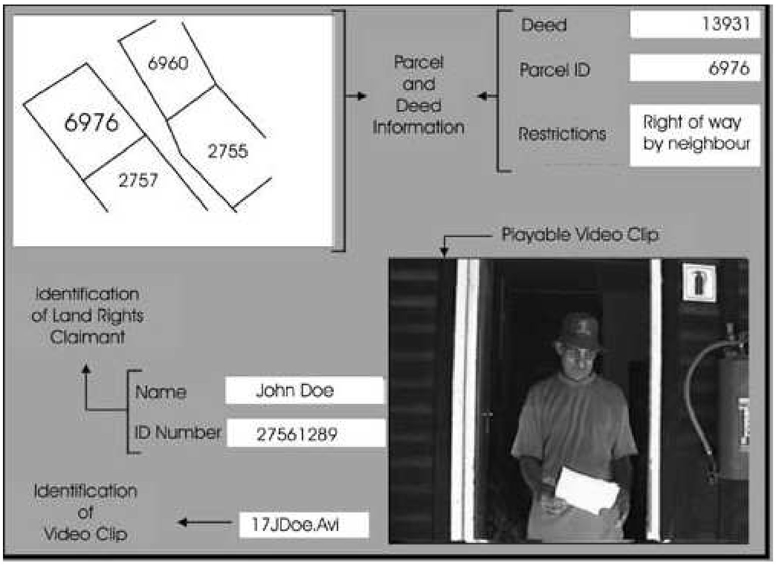

Figure 4: Talking Titler: On-screen title certificate (Barry & Rüther 2005)

The use of a GPS receiver is another option for conducting low cost ground surveys. Different devices are available with an accuracy ranging from 0.01 to 25 m (Schurr 2004). Differential GPS (DGPS) receivers provide co-ordinates with a sufficient accuracy for cadastral purposes and even data received using a simple handheld GPS can be accurate enough for specific purposes. Barnes & Eckl (n.d.) recommend analysing the required accuracy against its cost by the end-user to avoid unnecessarily expensive and accurate surveys. The level of accuracy depends highly on parcel size, land value, land potential and relationship between neighbours.

Nafantcham-na & Borges (1998) used the combination of low-accuracy GPS (2 to 5 m) and geo-referenced satellite images in Guinea for village boundary delimitation. Rawlins (2004) used relative inaccurate data produced with a handheld GPS to generate polygons from points in an environment without any properly defined spatial framework in South Africa. Jackson (2002, p.12) recommends in this regard "*not to worry about boundaries at first*" and proposes the registration of single point information prior to parcel delineation. The boundary information can be supplemented as text information attached to the point.

Gustafson (2005) promotes the DataGrid GPS receivers/datalogger product[13]. Connected with a Personal Digital Assistant (PDA) or field computer the instrument represents a universal data logger specialized for the environment in developing countries. The collector captures GPS data with decimetre accuracy and automatic

[13] http://www.datagrid-international.com [cited 14.4.2008]

integrity checking to eliminate the effects of multipath and human error. The system is able to merge GPS co-ordinates with various data like images, voice recordings and even biometric data like fingerprints and iris scans, which is important in many countries where persons often do not have identification papers.

3.2.2 Integrating customary and informal land rights

Several new approaches in developing land administration policies and techniques were discussed during UN-FIG meetings in Nairobi, Kenya (FIG 2001, FIG 2004). The following case studies are good examples to demonstrate possibilities to include informal and customary land rights into the legal land administration.

Juma & Christensen (2001) and Christensen (2004) describe the Namibian Flexible Land Tenure System which aims at formalizing land ownership in informal settlements. A second interchangeable property registration was introduced parallel to the existing registration system to create an inexpensive and simple form of land registration. 'Landhold' and 'starter' title were issued to informal settlers to provide them with a certain degree of tenure security. To simplify the registration process a block is registered as a single entity in the freehold ownership register to the national deed database while the individual land right is kept in a local registry on district level.

Tembo & Simela (2004) propose an improved Land Management System for tribal lands under customary right in Botswana. At present, land can be registered to the information system either using a non-georeferenced sketch map or a survey diagram, where only the latter way enables one to obtain a title deed. Therefore it was decided to improve the concept for boundary delineation based on GIS and digital topographic maps (1:5,000). An outlined new decentralized LIS model consists of a central national database linked with distributed databases and data collection units (data capture, manipulation) on local level. The access to data is limited depending on the administrative level. Data generated in the filed is uploaded to the database without manual interference to avoid human errors. The authors recommend a rapid data capture strategy using a tool with GIS functionality to speed up the registration process.

3.2.3 Case studies in Tanzania

In Tanzania, several pilot studies were conducted to develop procedures and test new technologies for land registration and management on the background of the new land laws (Majani et al. 2005, Hayuma & Conning 2006, Kironde 2006, MLHSD 2006). The pilot studies aimed at generating field experience in the formalization of informal or customary land rights in different environments. These studies outline the environment of the present study and model.

The Dar es Salaam 20,000 pilot project

The goal of the project was to establish an urban land registry containing individual land parcel data for informal settlements. Residential Licenses were issued as legal documents to formalize land ownership[14]. More than 220,000 properties were identified and 38,000 licenses issued by August 2006 (Kironde 2006, MLHSD 2006). The topographic mapping was conducted through acquisition of high resolution satellite images using GIS. The spatial data were linked with survey data in a Microsoft Access database to enable data query and mapping as basic functions of the land registry system. Local street registries were established where people applied for residential licenses. The report (MLHSD 2006) concludes the following project challenges:

- Inappropriate remote sensing images (cloud cover) and outdated orthophotos hindered the digitization of objects.
- Political unwillingness of local persons in charge complicated the project (e.g. access denied to some streets).
- Relative high costs for licensing reduced the motivation of tenants.
- Data transfer between offices was delayed through lack of network connection.

The project report does not mention activities or concepts regarding data dissemination and maintenance.

Village Titling Process: the Mbozi District

The aim of the study, which started in 1999, was to initiate the registration process of land rights to issue Certificates of Customary Right of Occupancy Tenure (CCRO) under the Village Land Act. The project put emphasis on technical assistance and capacity building, process re-engineering and improving infrastructure for surveying, mapping and registration.

A participatory approach incorporating all stakeholders constituted a cornerstone of the

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[14] http://www.ardhi.go.tz/projects/20000 [cited 14.4.2008]

project. The application of computer technology was considered to be very important. The pilot study implemented the following steps to issue CCROs to the villagers:

- Conducted awareness workshops and sensitization meetings to demarcate village boundaries to register the village and obtain the Certificate of Village Land (CVL).
- Surveyed village boundaries and individual plots in the village. Aerial photographs were used as alternative survey method.
- Developed a GIS based village database (Kironde (2006).

All 175 villages in Mbozi district were surveyed, 158 of them received a CVL and 1,117 CCROs were issued. The experience of Mbozi district has since been extended to 10 other districts (Hayuma & Conning 2006).

MKURABITA pilot in Handeni

The Handeni District pilot study was carried out in 2006 in the framework of the MKURABITA formalisation programme. Its aim was to test innovations in land use planning and registration for the implementation of the Village Land Act. The following activities were regarded as cornerstones of the study:

- Adjudicated village boundaries (sign agreement of boundary description, get boundary co-ordinates, sketch village map).
- Prepared a digital Village Land Use Plan using participatory mapping, transect walks and group discussions).
- Established village land registry (building).
- Processed applications and issued CCROs (file processing, survey of land, data management (MKURABITA 2006, TAPHGO 2006).

A GIS unit was formed to support the process of surveying, mapping and managing cadastral data using GIS Arc Info and Arc View. Handheld GPS receivers and remote sensing images were used to demarcate village and plot boundaries in a participatory process. GIS receivers were also used to map natural resources like forests, water sources or protected areas and helped to overcome the lack of commonly available maps. Throughout the process, community participation was a central issue to turn local knowledge into public knowledge using GIS technology (LHRC 2006).

The following statements summarize the lessons learned and general recommendations:

- Awareness creation is crucial for the success of the formalization.
- Land grabbing is due to the misinterpretation of the term "customary right of occupation" and can be avoided by defining the term in the local context.
- Village demarcations are often unclear and existing boundaries are not accepted by the villagers. Sometimes boundaries overlap and this need to be clarified.
- Participatory mapping (from village sketch map to GIS database) is practical and important for the overall acceptance of the project.
- GIS is a important tool to overcome lack of a commonly available base mapa for the assessment and management of natural resources such as forests, water resources, protected and reserved areas, agricultural land, grazing land and village settings plus their customary locations.
- GIS turns local knowledge into public knowledge and out of local control. Therefore people require access and insight to data.

3.3 Modelling the cadastral domain

3.3.1 Cadastre 2014 – the multipurpose cadastre

Cadastral modelling points towards describing the social relationship between people and land characterized through land tenure. The main functions of every cadastral system are according to van der Molen (2006):

- Keep the content of the relationship up-to date.
- Provide information on registration.

Initially, cadastral systems were mainly established to serve legal and/or fiscal purposes and used the parcel as representation of individualized ownership on land. It became clear that this approach "*does not provide enough information to assemble a complete picture of the legal situation of land*" (Kaufmann 2002, p.3). A new cadastral vision called 'Cadastre 2014' was introduced to outline new principles to implement a multipurpose cadastre. "*Cadastre 2014 is an institution that inventories and registers all types of rights and restrictions that have an impact within a defined contour of the surface of the earth*" (Kaufmann & Steudler 1998, p.36).

A fundamental principle of Cadastre 2014 is to extend the narrow approach of parcel-based registration towards an inventory of data concerning all legal land objects. "*A land object is a piece of land in which homogeneous conditions exist within its outlines*" (Kaufmann & Steudler 1998, p.13). The relationship between rightful claimants and land objects corresponds with the land related title approach (Figure 5), where the right referring to the parcel (title) is registered together with the personal data of the claimant in relation to the land object (Kaufmann & Steudler 1998, p.28).

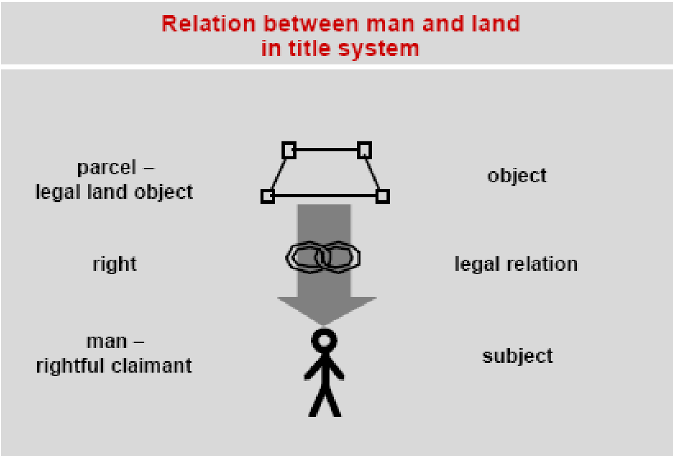

Figure 5: The title system (Kaufmann & Steudler 1998, p.28)

An individual data layer is defined for all legal land objects which are subject to the same law or unique adjudication and for every adjudicative process as described by a certain law. "*Cadastre 2014 is therefore based on a data model, organized according to the legislation for the different legal land objects in a particular country or district*" (Kaufmann & Steudler 1998, p.29). The goal of this approach is to holistically reflect the legal situation on land including public rights and restrictions (Figure 6). The different land right relationships are covered by different layers encompassing the legal topic, the claimant and the land object described through its boundary. This layer view allows the mapping and analysis of overlapping land rights to study the 'legal situation on land'. The approach is therefore very appropriate to support the modelling of the manifold tenure relationships existing in Tanzania.

The Cadastre 2014 guideline is the basis for the cadastral domain model discussed in the next chapter. Sievers (2000) and Kaufmann et al. (2002) discuss the implementation of Cadastre 2014 in Switzerland based on the INTERLIS data model.

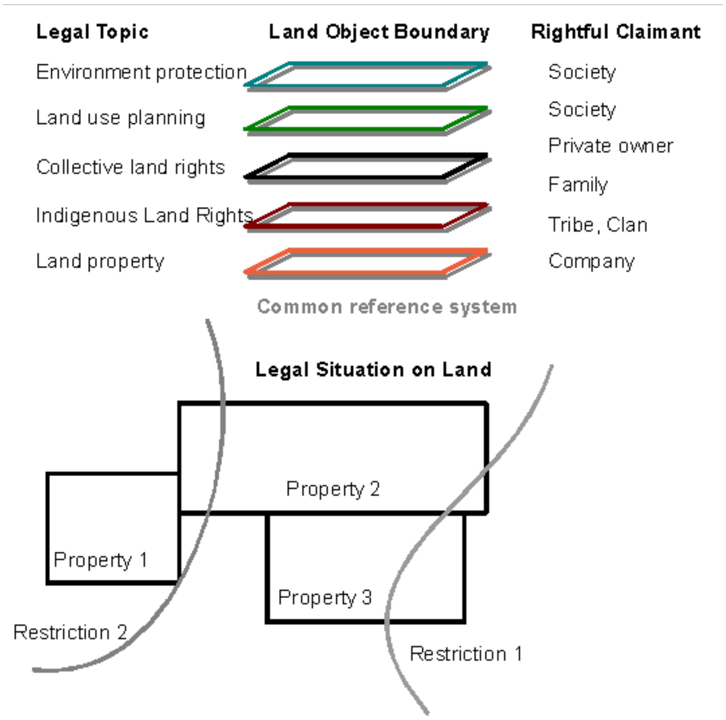

Figure 6: The Cadastre 2014 principle of independence and legal situation on land (Kaufmann & Steudler 1998, modified)

3.3.2 The Core Cadastral Domain Model

Standards in ICT and GIS technology support efficient data exchange between various stakeholders. Standards in geoinformatics defined by the Open Geospatial Consortium (OGC) intend to design interoperable infrastructures to support distributed GIS and help to overcome time consuming and expensive tasks like file transformation. Domain standards associated with specific tasks are required as a next step to simplify data exchange between user communities.

The Core Cadastral Domain Model (CCDM), developed in UML, aims at becoming a standard in the cadastral domain. The model was submitted to ISO in January 2008 as new working item called the 'Land Administration Domain Model'[15]. (LADM, Greenway 2008)

The CCDM covers land registration and cadastre in the broad sense of a multipurpose cadastre and intends according to van Oosterom et al. (2006) and Lemmen et al. (2006) to accomplish the following goals:

15 http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=51729 [cited 22.5.2008]

- Support cadastral system development based on a model driven architecture to avoid reinventing and re-implementing the same functionality.
- Enable standardized communication services based on the shared ontology implied by the model.

The CCDM is based on the conceptual framework of Cadastre 2014 and the adaptation of international ISO (International Organization for Standardization) and OGC standards.

Figure 7 shows the basic UML class diagram of the CCDM. The relationship between 'RegisterObject' (every legal land object) and 'Person' is described by rights, restrictions or responsibilities ('RRR'). The CCDM follows an object orientated approach and consists of a concept of different 'packages' as coherent part of the model like person aspects (green) or land administrative objects (yellow).

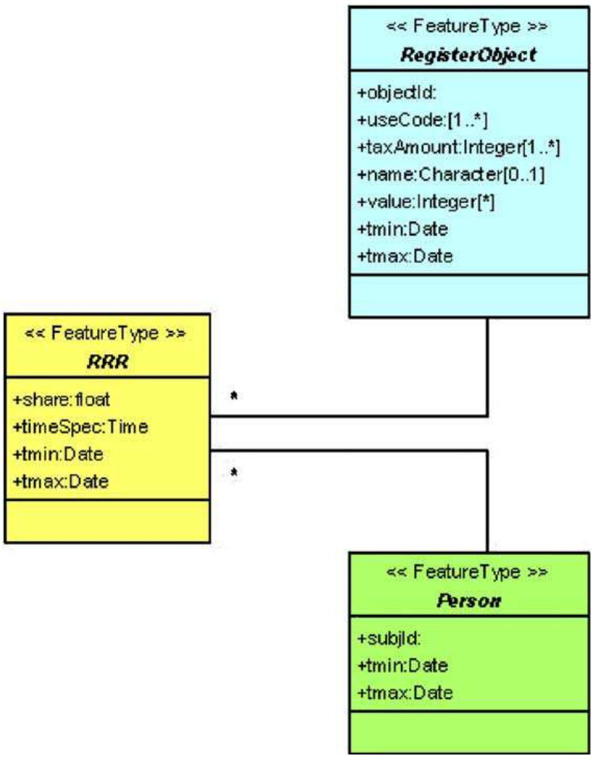

Figure 7: Core of the CCDM (van Oosterom et al. 2006)

The abstract 'RegisterObject' class (shown in blue) is an abstract class which consists of either moveable or immovable objects. The immovable objects are further differentiated in land (2D) or space (3D) objects. The land objects include spatial representations like parcel ('RegisterParcel'), spaghetti polygon ('SpaghettiParcel') or point 'PointParcel'. These classes can all have actual instances and these instances describe a piece of land. All these objects have associations with one or more 'Person' via the 'RRR' class (van

Oosterom et al. 2005).

The abstract class ‘Person’ is specified either through a ‘NaturalPerson’ or a ‘NonNaturalPerson’ like a company or organisation. Both classes can be aggregated to groups. The administrative ‘RRR’ class represents the association between ‘Person’ and ‘RegisterObject’ and is based on a ‘LegalDocument’ as source. Lookup tables support information about the kind of existing relations.

History and dynamic aspects of land administration can be modelled event based or state based:

- Event based modelling models transactions as separate entities within the system. This allows reconstructing every state in the past when the start state is known.
- State-based modelling aims at capturing only the state (result) of a transaction. Every object gets at least two timestamps which indicate the interval during which this object is valid.

The CCDM follows a hybrid approach. Survey or legal documents have explicit event based representation. In case of an update of attributes, a copy of the document will be generated with a new timestamp. This allows querying the spatial representation of cadastral objects back in time.

The definition of geometry and topology is based on common OGC standards like the OpenGIS® SQL simple features specification for SQL (OGC 2006). The spatial data model is described in the ISO9100 standard series which ensures that the data model fits into a distributed GIS network and enables the cost effective data exchange and maintenance.

3.3.3 The Social Tenure Domain Model

Chapter 3.1 summarized the various requirements on cadastre in developing countries with focus on sub-Saharan Africa with its dual land administration systems. On this background Augustinus et al. (2006) suggested the development of the Social Tenure Domain Model (STDM), a specification of the CCDM outlined in the previous chapter, which should incorporate formal, informal and customary tenure. Lemmen et al. (2007) presented a first draft of the model in 2007.

The STDM is equivalent to the CCDM by three abstract classes ‘SpatialUnit’, ‘SocialTenureRelation’ (‘RRR’ in CCDM) and ‘Person’. The ‘SpatialUnit’ incorporates a broad range of types such as one point (text), a set of lines (unclosed polygon), polygon (in different accuracy) and topologically structured parcel or 3D objects. The model distinguishes between a 'PlanarPartition' (PPR), where only well defined parcels in a topological structure exist, and the 'NonPlanarPartitionRegion' (NPPR), where 'PointBasedSpatialUnit', 'IncompleteSpatialUnit' or 'SketchPhotoSpatialUnit' exist. The 'OverlappingSpatialUnit' was introduced to the model to capture conflict areas (Lemmen et al. 2007).

Temporal aspects are included using 'tmin '/'tmax 'and 'TimeSpec 'attributes (Figure 8). The 'tmin '/'tmax 'attributes indicate to which system time period a version relates. The 'timeSpec' attribute attached to the 'SocialTenureRelation' is capable of handling temporal representation, e.g. reoccurring patterns such as dry seasons to support nomadic behaviour (Lemmen et al. 2007). The 'Person' class of the CCDM already covers the registration of natural persons, organisations and groups which can represent communities or tribes.

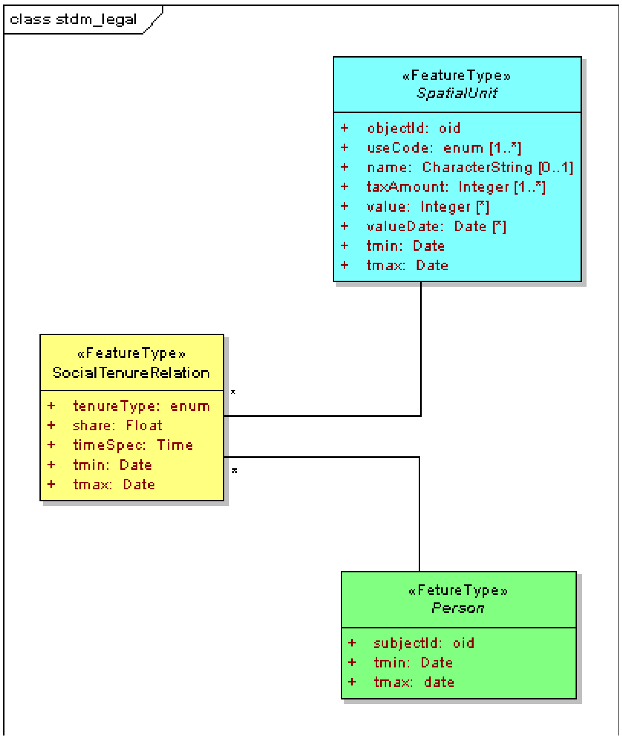

Figure 8: Core elements of the STDM (Lemmen et al. 2007)

Lemmen et al. (2007) propose that the existing UML class diagram needs to be completed by UML sequence or activity diagrams and use cases to cover dynamic aspects. A first pilot study to implement the STDM was planned for the town of Kisumu, western Kenya (Westman 2008, personal communication) but not yet conducted due to political difficulties in 2008.

4 The ULR implementation strategy

4.1 The Universal Land Registry (ULR) approach

The functional range and the system architecture of the ULR is based on the assessed demand and captured in the following points:

- Formalize informal and customary tenure in rural and urban areas trough low cost and standardized procedures to issue CCROs or any other legal document (e.g. residential license).
- Implement standardized and low-cost registration procedures and a uniform archive for record keeping based on GIS technology.
- Facilitate access to archives and provide copies of certificates.
- Support arbitration and adjudication processes with adequate information regarding person and land objects like lists and maps.
- Support the land administration with cadastral data for land management (e.g. to analyse overlapping land rights).

The application and system design is based on existing business processes and aims to implement GIS technology into the envisaged goals of the ULR. Huber (2006) states that the following requirements are important for a GIS based enterprise application:

- Support of business process management in a distributed organisation based on division of labour.
- Business specific data query and visualisation.
- Consistent processing of transactions to ensure that the data content mirrors the state of the business process.
- The design approach should implement only as much GIS as required to meet the envisaged business goals.

A user management system with AAA functionality (authentification, authorisation and accounting) controls all access to all ULR applications and maintains the replication of data between the system nodes. It provides a redundant source for the traceability of all transactions (Huber et al. 2008).

The ULR as an application is considered to be a GIS based application to register land rights. The ULR will be implemented in a distributed network using ICT and GIS standards for data replication and data dissemination. The system will be used on different administrative levels to promote data quality, timeliness and trustworthiness of content.

4.2 The ULR environment – opportunities and challenges

Because of the complex situation in Tanzania as highlighted in chapter 2, this section assesses the opportunities and challenges of the URL environment by SWOT analysis. SWOT Analysis is a strategic planning tool to evaluate the strengths, weaknesses, opportunities and threats involved in a project or in a business venture. Internal and external factors are classified as favourable or unfavourable to achieve the envisaged objective. Thus, strategies can be developed to use strength and opportunities in order to overcome or minimise the weaknesses and threads facing the project (Wikipedia 2008).

The following figure highlights the internal and external factors affecting the implementation of the ULR in Tanzania.

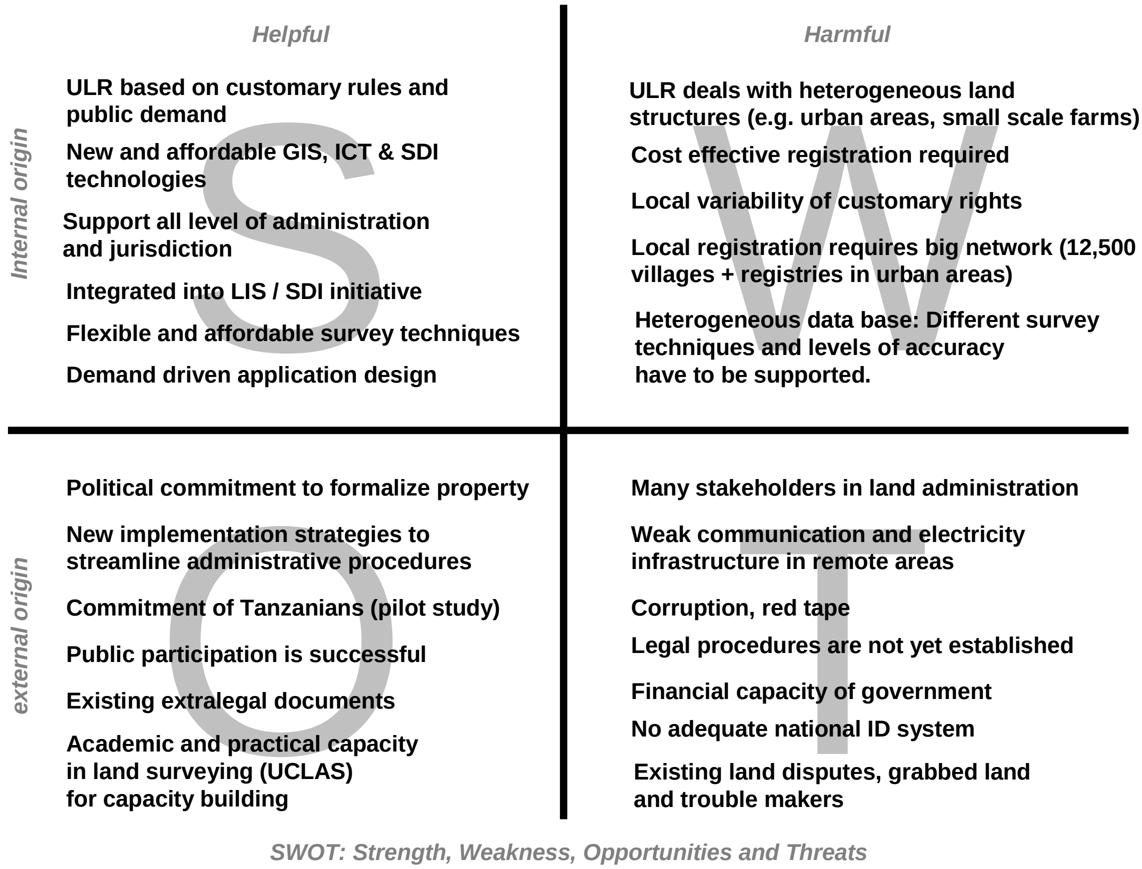

Figure 9: SWOT analysis of ULR environment

Strength: The ULR aims at supporting local registration as well as data dissemination on all levels of administration and jurisdiction. New information and communication technologies, standards in GIS (OpenGIS®), powerful open source software and tools to integrate GIS functionality (e.g. PostGIS, Geoserver, OpenLibraries[16] etc.) allow the development of a tailored application in a distributed network at low-cost. This strategy enables the developers to focus on the user demands as well as the technical capability of the personnel (trained local surveyors). The ULR supports different survey techniques and flexible spatial representations to support a low-cost registry for pro-poor land management. A system architecture based on standards for interoperability supports further existing initiatives to develop a national SDI in Tanzania.

Weakness: The system needs data to be updated and replicated regularly to guarantee up-to-date reliable information to all stakeholders. Security measures like verification of transactions must be implemented to prevent a corrupt use of the system. All this requires a functioning communication infrastructure for data transfer and access. This can be a major handicap in rural areas where the electrification rate and communication network coverage is low. The high number of local registries (villages) could negatively affect the data maintenance and quality control.

The ULR has to deal with different environments, with people of different cultural backgrounds and customs regarding administration of land rights. This heterogeneity requires careful considerations how data can best be structured in a database. The ULR has to integrate a broad range of spatial and non-spatial data in different accuracies and qualities which could negatively affect the usability of data for analysis.

Opportunities: The existing extralegal practices and documents are an excellent base to formalize land property. The political commitment and the good results of previous participatory land management projects in rural and urban areas build a solid foundation to speed up the process and establish nationwide standards and tools. The academic and practical experience in GIS and SDI technology is available for enhancement and transfer to local level capacity building. Educational capacity in GIS and surveying exists (Kironde 2004) and constitutes a foundation for capacity building for local registries. The successfully conducted pilot studies are evidence of the commitment of people and their ability to use GIS and spatial data in a participatory process to generate land use and land right information.

Threads: The present land administration with its financial constraints and involvement

[16] http://postgis.refractions.net/; http://www.openlayers.org/; http://www.geoserver.org/ [cited 1.5.2008]

of many stakeholders could threaten the implementation of any land administration tool. The system will be most likely implemented in an environment of an uncertain and dynamic political and administrative setup. Corruption and bureaucracy ('red tape') are not only frequent in land administration but also in other sectors which might affect a resource efficient, customer friendly and timely implementation of the ULR. The lack of person identification papers in Tanzania due to an insufficient national system requires alternative solutions for the ULR.

4.3 Institutional implementation

The Strategic Plan for the Implementation of the Land Laws outlines a first draft of the decentralized land administration with its institutions and relationships (MLHSD 2005, p.36). Figure 10 illustrates a possible integration of the ULR into this structure and shows the core support functions to administrative bodies.

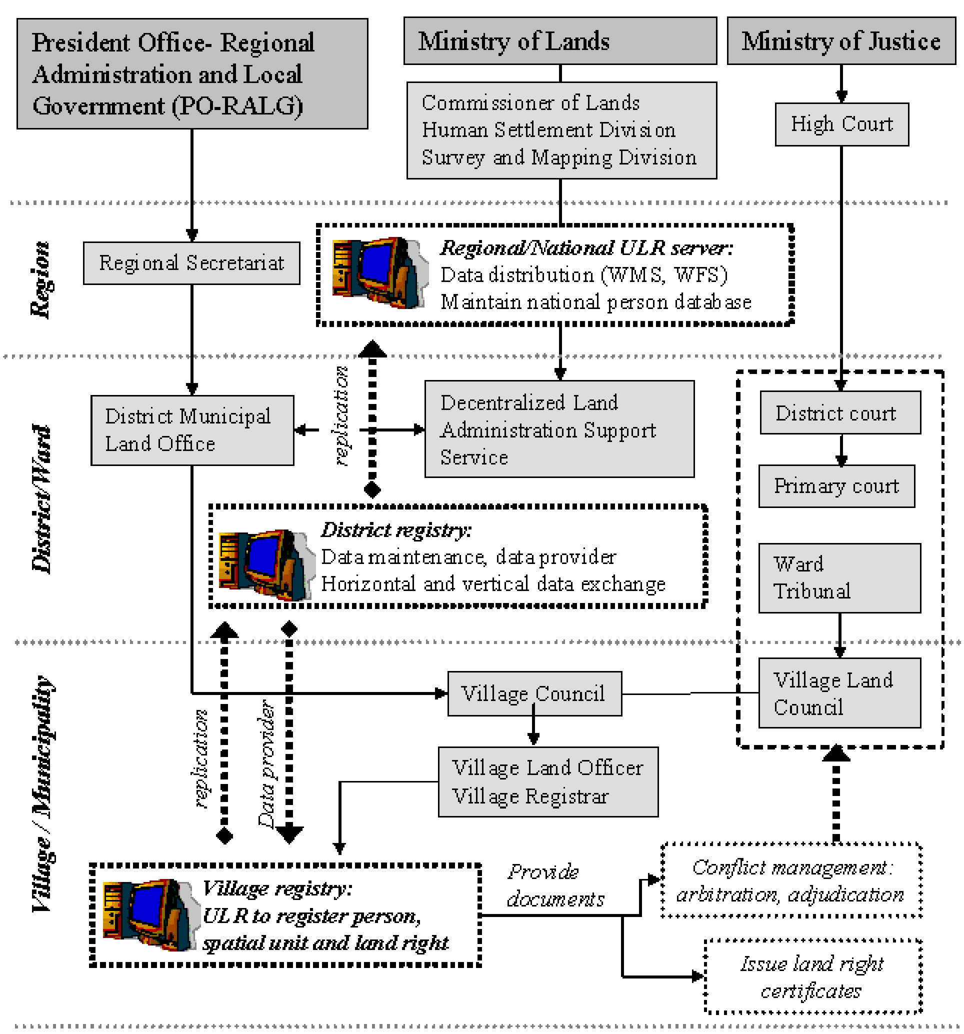

Figure 10: Institutional implementation of the ULR (MLHSD 2005, p.36), simplified and supplemented.

Data capture, maintenance and dissemination are the responsibility of District / Municipal Land Offices according to the decentralized and subsidiary approach (MLHSD 2005, p.48). All registration activities are monitored and guided by the District Land Officer.

Villages are granted more autonomy in managing their land according to the Village Land Act. By law they are obliged to set up their own registries for record keeping. The Village Council acts as entrusted land manager to manage and administer land issues. In practice, it is the Village Land Officer and Village Registrar who perform the duties and handle the village land register. The village council establishes a Village Land Council as informal land tribunal. District authorities monitor and assist with expert know-how and advice function. For general land, which includes all urban areas, land administration is managed directly by the District Council on behalf of the Commissioner for Lands (Larsson 2006, p.47).

The following section proposes the implementation strategy of the ULR, the process management for land right formalization and the use of the ULR in a distributed network.

Villages and municipalities in their administrative boundaries are the core entities of land registration. If one takes into account that Tanzania consists today of approximately 12,500 villages (Kironde 2006) it becomes clear that it is very unlikely to equip all village land registries with all technical equipment and capacity required for land registration. Therefore it is suggested that all data are captured in local village databases, but they are maintained at district level through the District Land Office. Equipment for data capture and output will be available at the villages only at specific times or on demand.

The land right formalization process is conducted in a first stage in campaigns comprising adjacent villages in a district. All data are registered in a local spatial database using a field computer with adequate screen size (laptop). Palmtop computer are considered as too small for the participatory mapping approach. The computer is equipped with ULR database and server and all necessary devices for data capture (e.g. GPS receiver, scanner, digital camera). The process of registration is usually conducted by the Village Land Officer and locally trained staff in a participatory process. The process is monitored and assisted by the District Land Office with spatial data, technical support and training.

The local database supports the establishment of the village cadastre required by law. The field computer will be available at agreed times in the village to update data, conduct transactions or to print land certificates. The village registry stores the paper based cadastre produced by the ULR (printouts of documents and maps) to provide information for periods when the technical equipment is not available at the village.

The ULR database is replicated to the District / Municipal Land Office database for quality control and data dissemination (Figure 10). The registration of land rights which overlap village and / or municipality boundaries is the responsibility of the District Land Office.

Data are replicated from district level in horizontal and vertical direction. The present plan for the setup of the new land administration is not clear about the responsibilities of the regional administrative level and its function. ULR server and databases can be established here for data access and management. However, the final goal is to create a national ULR database founded on district information.

The ULR supports conflict arbitration and adjudication measures on village and district level trough production of digital and/or paper documents e.g. land certificates (CCRO). The Handeni pilot study revealed that many land conflicts arise during the formalization process due to the misconception of the word "customary" (TAPHGO 2007). Direct support to any kind of conflict management is therefore considered to be a mandatory function of the ULR. Printouts of registered or analysed land disputes will be given to the Village Land Council or responsible bodies at district level for conflict arbitration or adjudication.

4.4 ULR implementation in the formalization process

4.4.1 Formalization process structure

The case studies conducted in Tanzania (Chapter 3.2.3) give an overview of possible strategies and technologies to formalize and register informal and customary land tenure in rural areas. The proposal for the Handeni district pilot project of land registration according to the Village Land Act outlines the administrative procedure and the steps involved to prepare land certificates in village land (MKURABITA 2006) (Figure 11). The procedures for village land use planning applied during the Handeni pilot project are regarded as a general model for land right formalization in rural areas (LHRC 2006).

The formalization processes is a participatory process where first the village boundaries are adjudicated and documented to register the village. Second, a Village Land Use Plan is compiled in a participatory process (transect walk, participatory mapping, group discussions etc.). The registration of land rights is conducted based on the landuse map. A person applies for a CCRO using the application form (form 18). Further, the applicant gets consent of his neighbours regarding the boundaries (form 44). Then the land is surveyed using a handheld GPS to establish all corners points (geographic co-ordinates) surrounding the farm. The points are used to complement the land certificate containing personal data including a photo with an appropriate map and co-ordinates. The Village Land Officer files a letter of offer to the District Land Officer who issues the certificate and sends it back to the village for verification. After all parties including the owner have signed, the certificated will be given to the owner. One copy remains in each the village and the district registry.

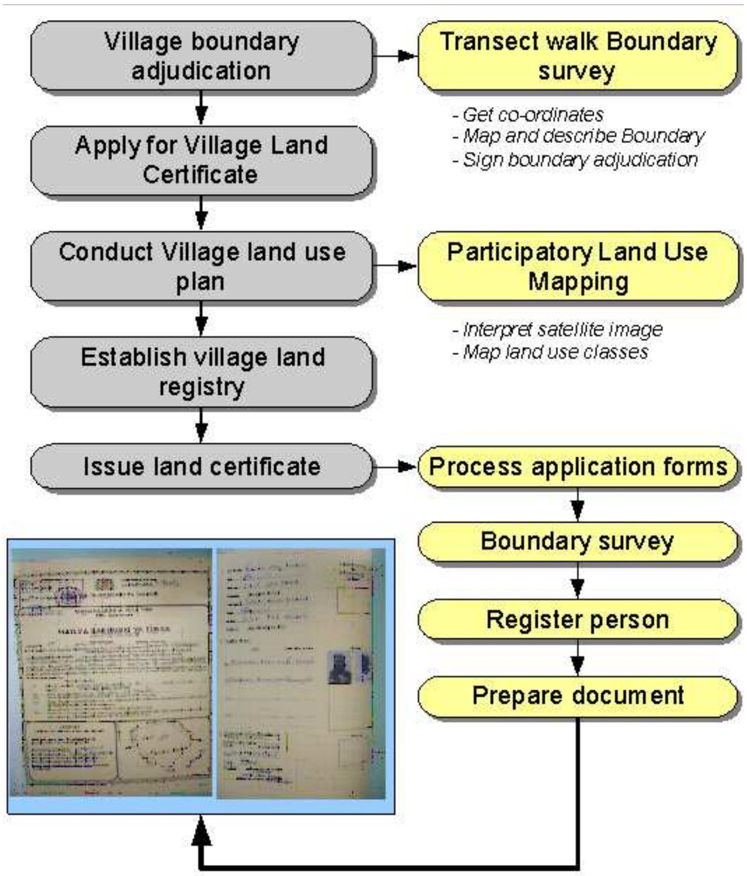

Figure 11: Formalization process for village land (according to MKURABITA 2006)

Urban areas by laws do not require the establishment of a land use plan but the procedure is similar to the one for village land. Based on the experience of the 20,000 pilot project in Dar es Salaam City the following principle can be derived as guideline for urban area slum upgrading and formalization (Kironde 2006, MLHSD 2006).

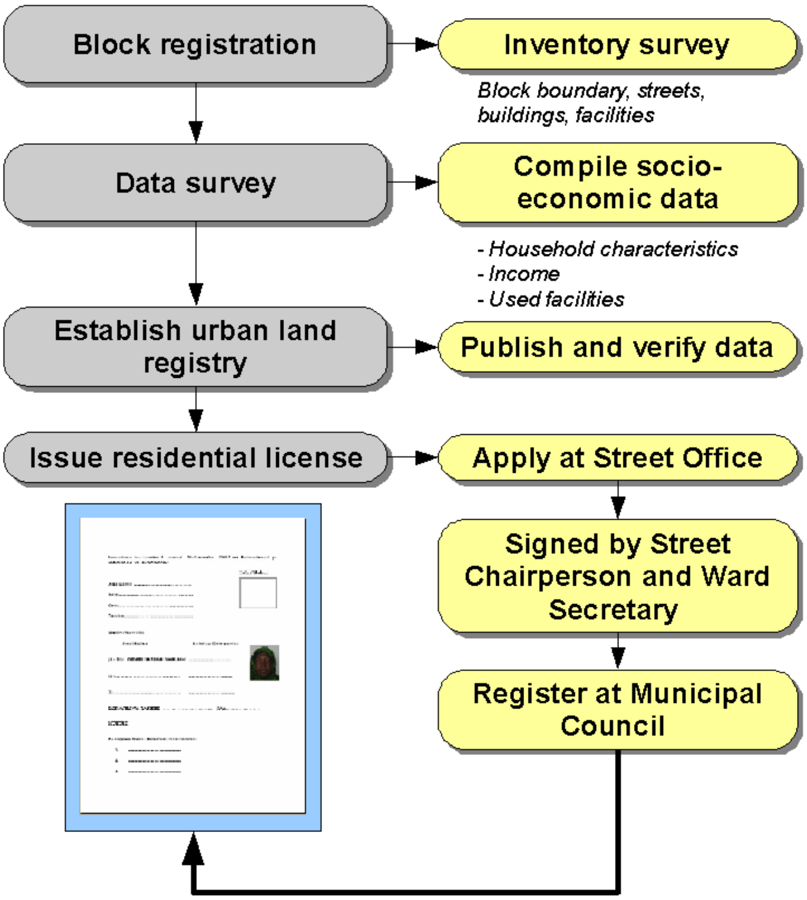

Figure 12: Formalization process in urban areas (according to MLHSD 2006)

The first step in urban upgrading is to identify and delineate block and street boundaries (Figure 12). Satellite image are used for the identification of properties on the ground like existing buildings, road network, open spaces, drainage structures, electricity lines, and public buildings. Boundaries of land parcels are interpreted and delineated to generate polygons as spatial entities.

The non-spatial data regarding each polygon are collected through questionnaire surveys and linked with the spatial information in a GIS database. Compared to usual data required for land registration the data contain a lot of socio-economic information like household characteristics, expenditure and income data, housing conditions and level of services (e.g. electricity) for land use planning.

After generating the database the register is published for verification through a person responsible (e.g. Street Chairman) as well as the public. After verification final printouts are prepared including maps and submitted to Street Offices for residential license issuing.

The procedures outlined above indicate that formalization of land rights contains generally the following procedures:

- Delineate the administrative boundary for land registration (village or block).
- Participatory mapping of environment to produce baseline data.
- Process application forms between applicants, local and district administration.
- Compile land right information (survey, adjudication process) and identify persons.

The ULR application and architecture is implemented with its functionality into the complete process of land registration. The topographic mapping is essential for participatory mapping of land resources and the registration of land properties because of the lack of appropriate data on land. Chapter 4.4.2.1 introduces to a concept on how topographic data is compiled and maintained using a GIS and/or the ULR application. Chapter 4.4.2.2 describes the integration of the ULR into the formalization process taking the example of the MKURABITA formalization process.

4.4.2 The integrated ULR concept

4.4.2.1 Land use mapping and registration

The Handeni project is a good example for demonstrating the importance of topographic mapping during the formalization process. The study was conducted according to existing guidelines for village mapping (NLUPC 1998).

Remote Sensing images and GPS receivers are used to delineate the boundaries and to compile the landuse plan. The outcome is a GIS landuse data base and map containing areas for farming, grazing, forest, residential and protected areas. The village landuse plan is the starting point for property registration and field surveys. Figure 13 shows the village landuse plan conducted for Bongi village in Handeni district. The boundary contains the surveying points. Landuse classes are assigned as well as important access ways (footpath), landmarks (signpost) and important facilities (watering point). The map indicates that the requirements on topographic mapping are adequate for the purposes and comprises fundamental topographic elements.

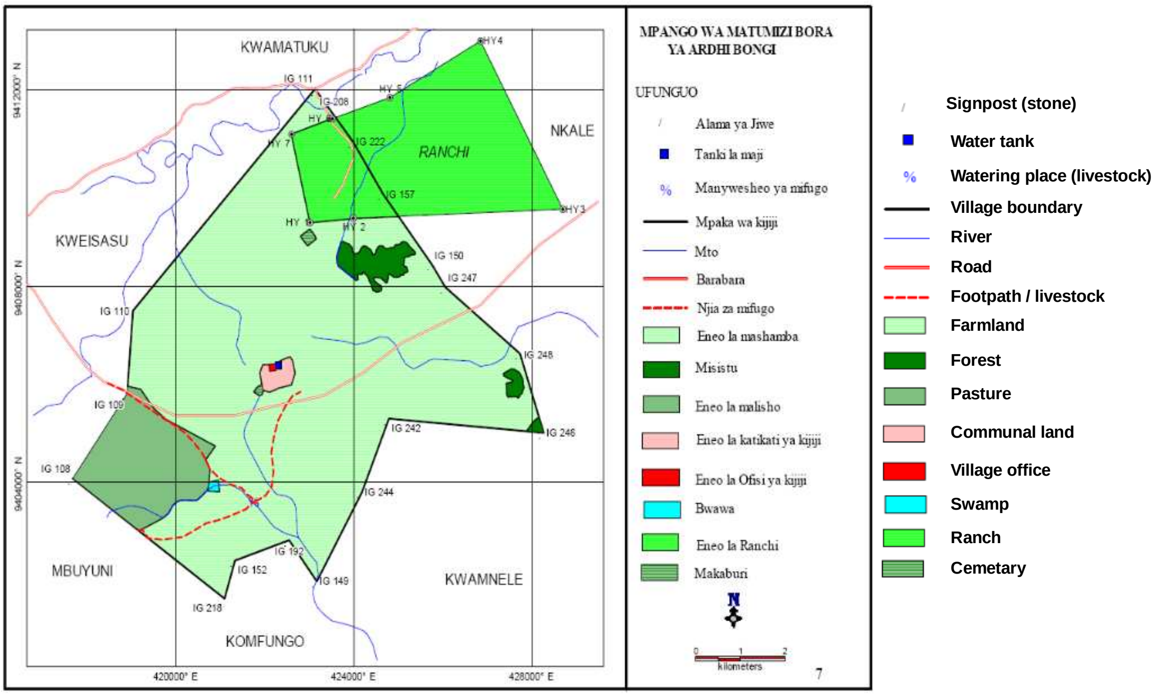

Figure 13: Village Land Use Plan conducted for Bongi Village (TAPHGO 2006, English terms added)

Some of the elements shown in Figure 13 can be relevant as objects containing land rights. The footpath for example is a spatial object in the topographic database which might have relevance as an object containing a land right like ‘access right to pasture’ in the ULR database. Watering places can be owned by the village community but use rights can exist for example for pastoralist people. The use right might further only be valid for specific periods of the year such as the dry season. Many customary land rights are related to linear or point based spatial entities.

The village landuse plan can be seen as a topographic inventory predominately focussing on land use classes and infrastructures such as roads. Other topographic element like landmarks or natural boundaries like hedges are important for general orientation during the participatory mapping and for the registration of land rights. Topographic elements can also be related to land rights and are therefore of great importance for the formalization process.

Figure 14 shows parcels surveyed based on the Village Land Use Plan for Bongi village as an example.

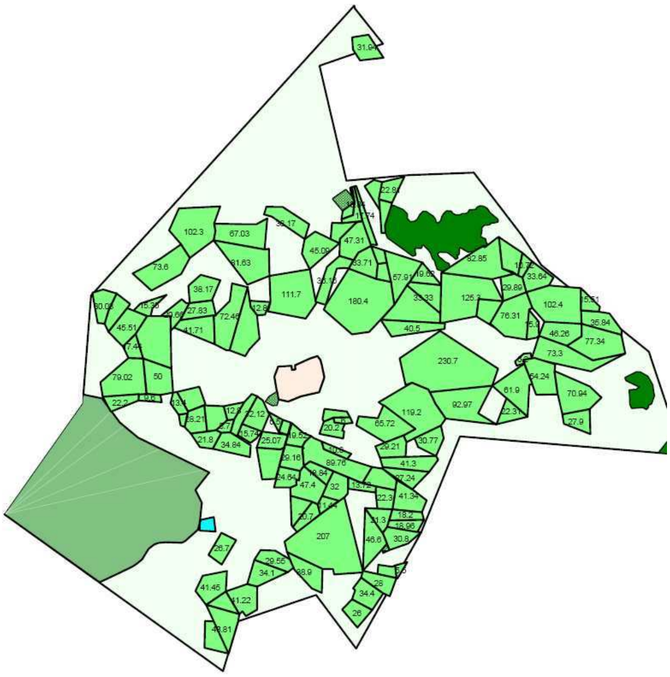

Figure 14: Surveyed parcel in Bongi village (TAPHGO 2006)

In order to integrate the ULR into the village registration and to use and maintain topographic data efficiently, the following procedures are proposed:

- The village land use mapping must be based on national topographic standards regarding element types and signatures. A simple catalogue containing standards for topographic mapping and signatures is mandatory.
- The land use plan can be compiled using any GIS application but the topographic database requires a standard interface to make data accessible for other applications like the ULR e.g. through a Web Feature Service (WFS).
- The ULR is not designed for topographic mapping but the application should enable the surveyor to use topographic elements from the topographic database for registration of land rights (e.g. footpath as access rights to pasture).
- The surveyor should be able to choose from pre-defined topographic elements in the topographic database which are necessary for land right registration.

The UPR application allows the user to switch between topographic mapping and land right registration as well as to copy spatial entities between the databases. These measures help avoid duplication in data capture and improve data consistency. Further, the land use plan can be maintained simply using the ULR. If standards for data capture and access are applied, the outlined system is even capable to support the update of topographic databases in Tanzania.

The procedure outlined above applies also to urban areas where the topographic elements are inventoried before socio-economic data, land right information and spatial data are gathered and linked.

4.4.2.2 The ULR principle to register land

Extralegal land registration corresponds well to known practices in land administration. However, customs vary between tribes and sometimes even between villages. Therefore the main challenge is to bring customary practices up to meeting national standards for documentation to enable a standardized data capture process in digital databases (ILD 2005c, p. 380). Such standards do not exist at present and need to be developed during the implementation of the ULR.

To transform the existing documents or oral information into a digital database, the ULR architecture needs to separate information on land objects, persons and the assigned land relationship to efficiently maintain data in a relational database. The formalization process either based on documents or on orally transmitted rights requires three steps to secure tenure relationships:

- Identification and registration of the person.
- Identification and registration of the spatial extent of the existing land right.
- Identification and registration of existing land relationship to link person and spatial unit.

Figure 15 shows the implementation of the ULR into the process of land registration in village land based on the MKURABITA case studies (MKURABITA 2006, TAPHGO 2006). This principle is also applicable for registration in urban areas.

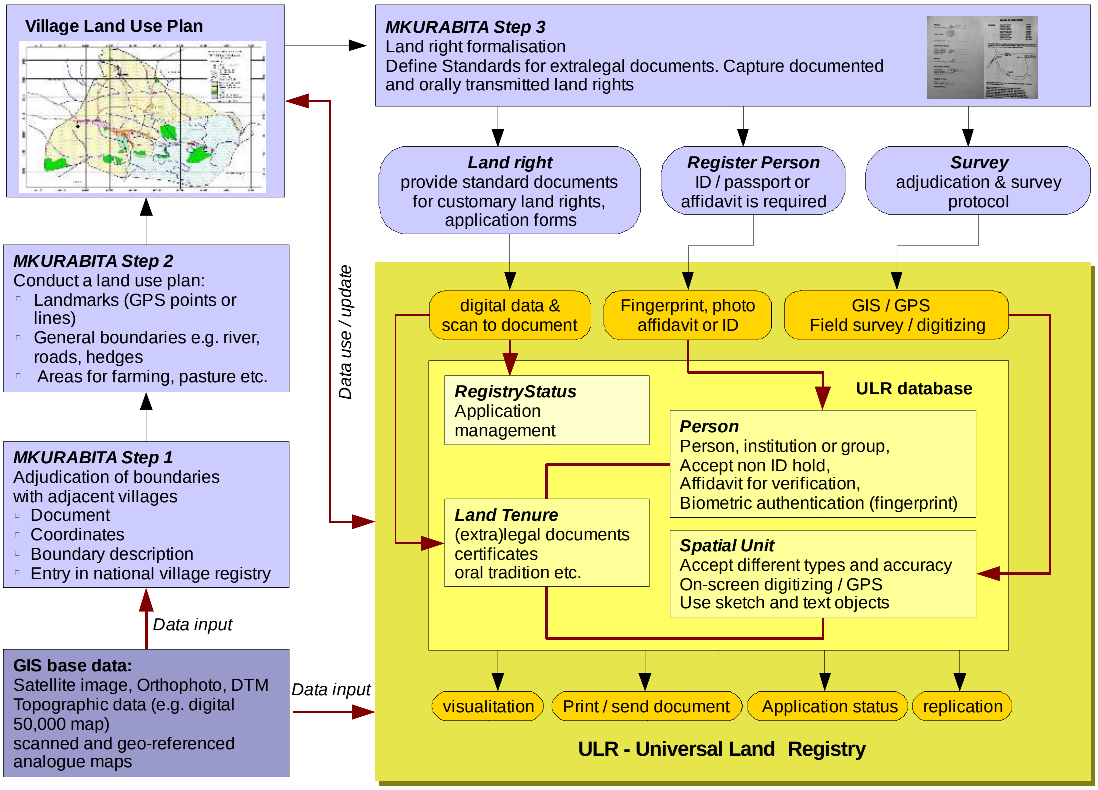

Figure 15: Implementation of ULR into the formalization process

The blue boxes describe the village land formalization steps. Spatial baseline data are essential to (i) develop the Village Land Use Plan and (ii) to georeference land rights. The yellow frame contains the ULR application, database and activities (round boxes) for the formalization of land rights and data output.

Person identification

Many Tanzanians do not possess an ID or passport, thus personal identification is a major concern in land registration (ILD 2005c, p.342, Hakikazi Catalyst 2007, p.11). The field studies conducted in Tanzanian and the existing extralegal documents show that person identification is the central issue to achieve proved documentation. The ULR uses a combination of passport photograph and biometric identifier (fingerprint) for person identification. The fingerprint as biometric identifier was very successfully introduced with the 'Bhoomi' land cadastre project in the Indian state of Karnataka. There, the fingerprint is used instead of a password system to give access for local people to land record via land record kiosks installed in private shops (Rajasekhar 2006, State of Karnataka 2008). The fingerprint as identifier is used in the ULR application to authorise applicants and administration personnel to the system as well as for process of transaction verification (e.g. issue CCRO, compare chapter 4.4.1). Affidavits from village or street chairpersons are accepted and integrated to confirm personal identity of applicants who do not possess personal identification papers. They can also be converted into official certificates of residence in a standard format (HAKIKAZI Catalyst 2007, p.20).

The following two ULR principles of registration are introduced:

- *ID holder*: ID number +scan of ID + personal photograph + fingerprint
- *Non-ID holder*: Affidavit + personal photograph + fingerprint

Persons usually apply as village member in their home village for land rights. If a non-member applies the application has to be accepted by the Village Council (LHRC 2006). However, it is generally possible for Tanzanians to own property everywhere in the country. Therefore the overall goal should be to establish a nationwide ULR user database. Registration as applicant should be possible at any administrative level. To avoid double registration it is suggested that all person files will be maintained on national level.

Land right identification

The formalization of existing land right documents such as extralegal documents and orally transmitted land rights requires transferring the content of the documents into a standardized format (paper form) to integrate the existing archetypes of property documents into a standardized database as attributes (Figure 15, ‘LandTenure‘ class). Thus, all customary documents need to be scanned and stored in the database to re-produce the original source document including signatures. Because of the frequent occurrence of land disputes during registration campaigns the ULR supports the documentation of land disputes as land right document.

Further research during field studies is required to identify to what extent tenure relationships should be maintained using the ULR. Not all aspects of customary land tenures can be easily computerised and incorporated into an LIS. Some social and cultural features may be based on spiritual or sentimental perceptions and be very subjective and not easily viewed objectively (Rakai & Williamson 2001).

Land object identification

Extralegal documents contain often a sketch map as well as a detailed textual description of the boundary to visualize and explain the plot in its environment. The

Village Land Act, however, requires a field survey and a survey protocol to register customary land rights.

A field survey is considered as not necessary if the extralegal document contains sufficient evidence to delineate the boundary using for example a remote sensing image. The content of the extralegal document is saved to database attributes and stored as a scanned document to the ‘SpatialUnit’ class. If a field surveys is conducted, the survey protocol is saved to database attributes and stored as a scanned document. (Figure 15).

Support of illiterate land right owner

Illiterate land right owner need special support to ensure that their interests on land are registered correctly. The land right formalization process involves according to pilot studies conducted in Tanzania in a first phase awareness campaigns and education programmes to prepare the local people. Special attention must be given at this stage to illiterate land right owner. Törhönen (2001) gives an example from a study conducted in Cambodia. Both, textual and graphical records were used there to assign land rights. An assistant was engaged to explain the records and helping to draft claims.

The design of the ULR application and its user interface must support illiterate land right owner. Graphical elements must be developed during the education phase to enable illiterates to express their land rights. These elements have to be integrated into the ULR application to enable illiterate land right owner to understand and verify the registered content of their land right. Experiences in this field exist for example due to the ‘Cybertracker’ technology (see chapter 3.2.1).

An independent consultant must assist illiterates during the registration process. The use of video clips to capture land rights as suggested by Barry & Rüther (2005) seems not an appropriate solution for the ULR concept. Video clips are large in size which would affect negatively the ULR concept of efficient data dissemination in a nationwide network. Further, the verification of registered land rights through the owner is mandatory and requires the readability of the assigned right to everybody.

The development of graphical elements is seen as a national initiative to develop standards for illiterate land right owner. This aspect must be included into the national programmes to formalize land tenure.

ULR field station

The ULR application requires basic visualisation and mapping functions to query and analyse the registry entries. The participatory process of land administration and adjudication requires field computers with appropriate displays to allow field discussions and visualisation of ULR content. Equipped with a printer, the system can printout legal certificates and documents in the villages to support the paper based local registry. This supports the provision of evidence to the local authorities for land dispute adjudication. Attached devices like digital camera, GPS receiver and biometric scanner (if not integrated into the laptop) allow the efficient registration of all objects as well as the immediate production of documents (Figure 16).

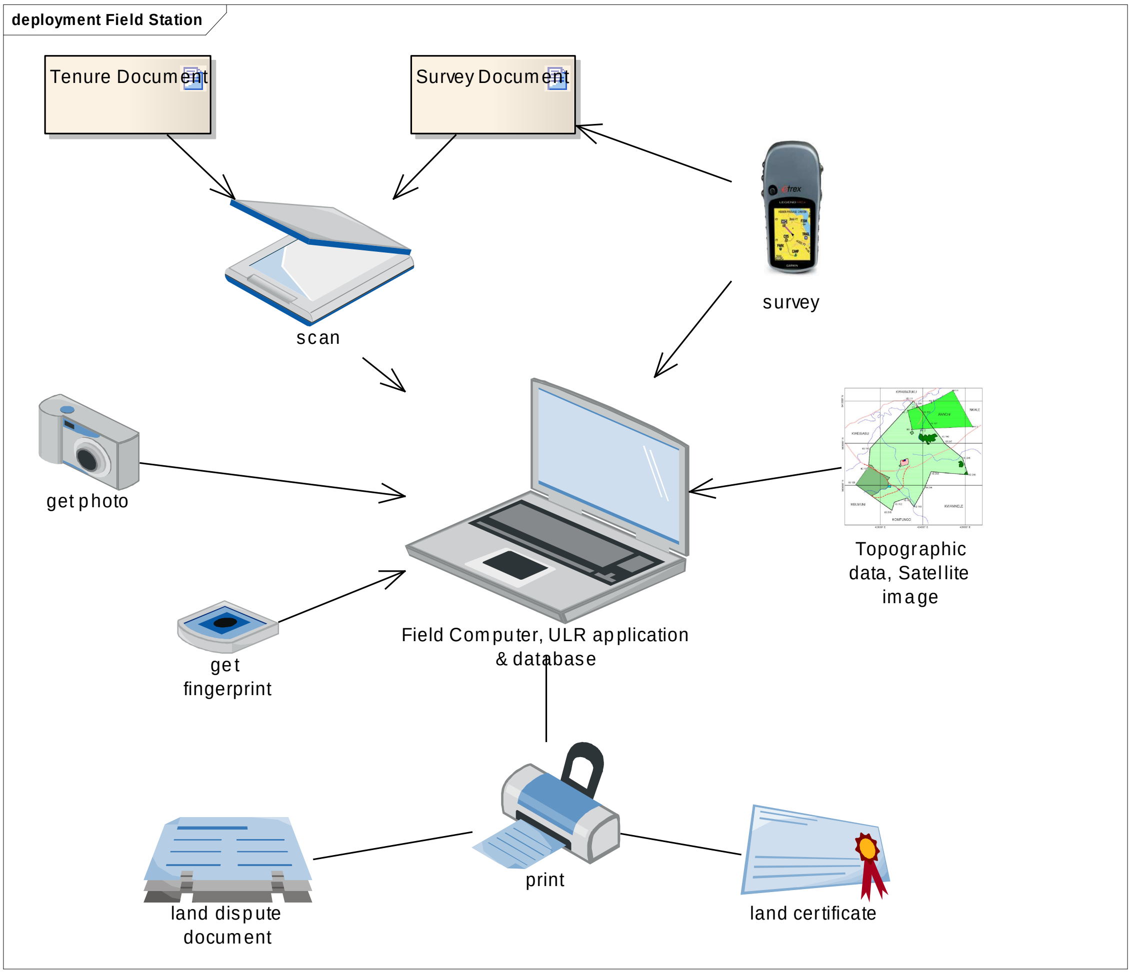

Figure 16: The ULR Field station for data capture and information output

4.5 Data capture strategies and methods

4.5.1 Strategic considerations

The experience of field studies and the general recommendations for land administration in developing countries (see Chapter 3) demonstrate clearly that alternative and unconventional approaches are required for the setup of a simple and low-cost cadastre. The recommendations are of foremost importance on the background of the ULR since this system focuses on the formalization of informal or extralegal land rights. The ULR architecture mostly caters for applicants who own low value land and/ or live as urban squatters in informal settlements.

Williamson (1997) states that the success of a cadastral system rather depends on adequate protection of land rights than on the cadastre's legal or technical sophistication. Land cadastre and methodologies for data capture and maintenance should be implemented corresponding to the different social contracts on administration of land in the particular country (van der Molen & Lemmen 2004). Appropriate survey activities and the choice of spatial representation should depend on norms and values on which for example a customary system relies on (Figure 17).

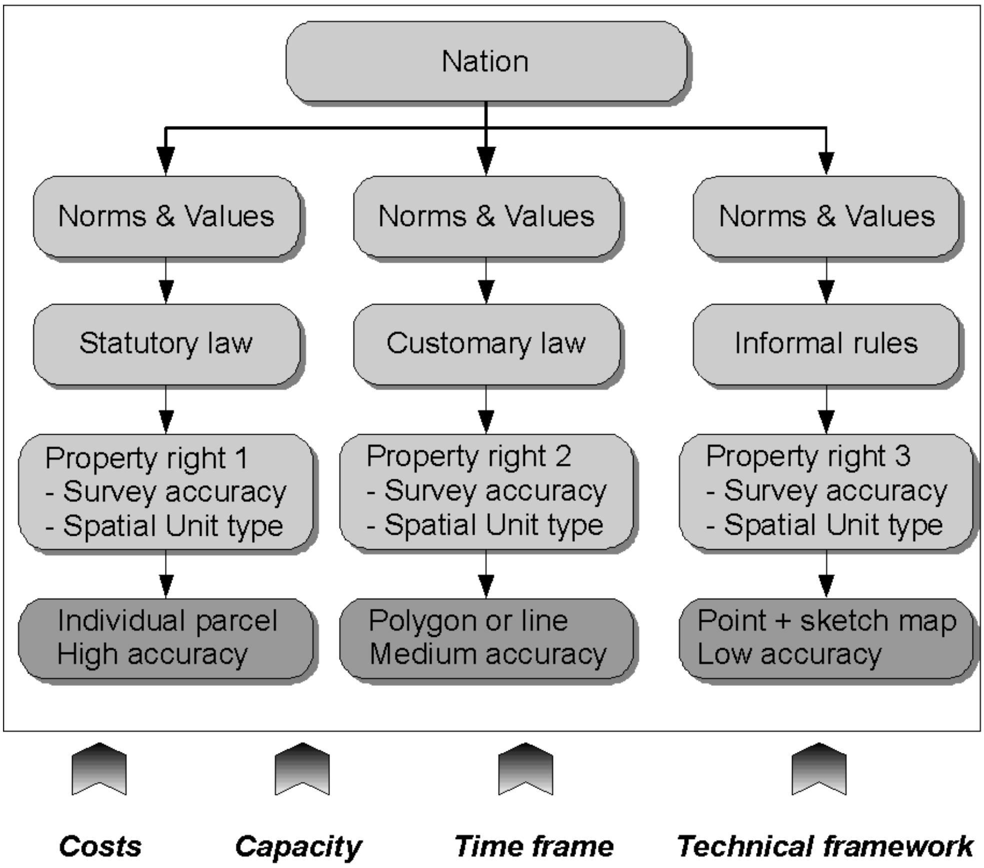

Figure 17: Principles for land representation (van der Molen & Lemmen (2004, modified)

Different communities in a nation accept different methodologies to secure their land rights. High accuracy ground surveys might be a demand from commercial farmers to secure their property whereas simple sketch maps are sufficient for urban squatters living in informal settlements. The implementation of a cadastre and its tools needs therefore to support a broad range of surveying techniques and spatial identifiers with different levels of accuracy.

Thus, any such system needs to reflect the demand of the Tanzanian people. The MKURABITA studies (ILD 2005a-c) on extralegal land registration and the field studies show that people have indeed high interest to secure their land rights. Extralegal documents show, that a combination of sketch maps and boundary description is widely used to adjudicate or document land rights. The registration of customary land rights often involves an adjudicative part, where neighbours agree in the field on boundaries and sign documents to proof the content. The tenure security of simple spatial representations can therefore usefully be enhanced using the traditional methods of the customary practices, which are often already content of extralegal documents. However, land conflicts are quite common and the presence of conflict changes existing norms and values and can lead to a higher demand on land security or different measures.

High land security is also an important issue for people who own expensive properties or high value farmland. This community might favour a high resolution survey and concrete blocks to demarcate their property opposed to low accuracy polygons. The international horticulture industry is at present looking for possibilities to invest in commercial farm land in Tanzania and they demand of course high tenure security. High value property and land might still require the support of sophisticated survey methods to meet the demand of local and foreign investors.

The system described in van der Molen & Lemmen (2004) needs to be seen in the context of available infrastructure, costs and capacities (Figure 17).

- The geodetic reference network is undeveloped and the surveying capacity lacks technical infrastructure and funding (MLHSD 2005, Silayo 2006). Capacity in GIS and surveying is developing (Kironde 2004) but it needs to be transferred and strengthened at local level. Efforts to develop a spatial data infrastructure are still at a very early stage (Kalande & Ondulo 2006).

- The costs of surveying concern not only the ability of a person to pay for a service but also his willingness (Silayo 2006). 36% of the Tanzanians live below the national poverty (World Bank 2007a) and rising food prices in 2008 will make it even more difficult for many people.

- The formalization process should deliver during the first phase information in short time to give an overview of existing land rights and land conflicts.

The ULR application requires therefore different surveying and mapping technologies to meet a broad range of demands:

- Support different methods in surveying and mapping of land rights to guarantee tenure security at acceptable costs for each community from the owner of expensive property in Dar es Salaam to the small scale farmer in rural areas.
- Where tenure security cannot be supplied using high accuracy survey data other measures are required to increase the security level (e.g. sketch maps, descriptions).
- Apply flexible, cost-effective and easy to use methods and applications to register land rights which can be applied by trained local staff.
- Focus on unconventional approaches because the majority of people require affordable registration practices to secure their land rights.

The use of various spatial representations based on different survey methods and spatial accuracy leads consequently to a spatial data model containing a high level of uncertainty. In Geoinformatics, uncertainty describes the concept, that a spatial data model is an abstraction of the real world and distorted by its conception, measurements and representations. Uncertainty is inherent in all spatial data models to a certain level (Longley et al 2005, p129).

Cadastral data compiled using the ULR are meant for spatial analysis for example to research land disputes or overlapping land rights. This capability can be limited by the high level of uncertainty described above. Maintenance of metadata regarding accuracy and survey methods are therefore of major importance for the successful use of the data. The user of the ULR or any GIS-client who accesses the ULR database must be aware of the uncertainty to design appropriate measures for data analysis and mapping.

The data capture process therefore requires detailed documentation through system metadata containing the data source, the surveying method applied and the co-ordinate accuracy according to international standards. The adequate use of system metadata is the foremost step to implement measure to ensure the correct use of data and the development of data analysis approaches. User metadata can be added for user information, but they are not important for data processing.

4.5.2 Applied surveying techniques

The ULR aims to serve a broad range of customers ranging from urban squatters settled in informal settlements to people and companies obtaining land rights for high value properties or commercial farmland. The ULR is designed predominately as a pro-poor tool. Considerations have to be made concerning what kind of data will be put into the database and how.

High accuracy ground surveys

Total Stations are the current state-of-the-art instrument to conduct field surveys. Survey data are stored in a database using the co-ordinate geometry (COGO) methodology, which uses the bearings and distances along boundaries and angles and distances along curves (Longley et al. 2005). GIS systems in comparison store data as 2D or 3D co-ordinates (x, y, z) to represent vector data like points, lines and polygons. Since high accuracy survey data play an important role in land administration in many western countries, modern GIS tools and databases were developed to implement survey data into the GIS environment. One example is the ESRI (Environmental Systems Research Institute) SurveyAnalyst, an extension for ArcGIS. The extension provides tools to surveyors and GIS professionals to create and maintain survey and cadastral data. The traditional GIS data model was extended to derive measured GIS features like polygons from survey measurements (ESRI 2007).

ULR Recommendation: The maintenance of high accuracy survey data is of minor importance for the ULR because of the estimated demand and the technical capacity on local level. The ULR supports the integration of ground survey data only through import of data in a GIS compatible format (polygon parcel) and as a list of co-ordinates. Survey data and information regarding the geodetic network (survey points) can be integrated into the ULR framework using standardized Web Feature Services (WFS) or Web Map Services (WMS).

GPS based field surveys

GPS based field surveys comprise a broad variety of instruments and levels of co-ordinate accuracy (see chapter 3.2 for .discussion of different experiences). Schnurr (2004) distinguishes in his publication four different GPS methods with different levels of accuracy.

Table 3: Levels of GPS accuracy (Schnurr 2004)

GPS level	Description and measurement method	Accuracy (m)
Level 1	Standalone pseudorange GPS Positioning	10 – 25
Level 2	Differential code GPS, or "DGPS"	2 – 5
Level 3	Carrier smoothed differential code GPS	0.4 – 0.8
Level 4	Double differenced carrier phase GPS	0.01 – 0.04

Simple hand-held GPS with the lowest accuracy (Level 1) are a simple and important instrument to be used by trained local staff. They allow data capturing using waypoints or tracks capture single points or lines. A GPS receiver can be used simultaneously with the field computer or as a stand alone application. Co-ordinates and lines can easily be captured directly through the ULR application or transferred into the ULR database through an interface.

The accuracy of pseudorange GPS data can be improved using ground station based differential GPS services or satellite based augmentation services like WAAS (Wide Area Augmentation System). The positional accuracy of the Garmin eTtrex Vista C for example can be improved from < 15 m to an order of 2 - 3 m (Garmin 2004) using the WAAS service. Unfortunately, the WAAS service is at present only available in the U.S. (FAA 2008).

DGPS services are not available in Tanzania. To improve data accuracy using the GPS service it is required to establish temporary networks consisting of a base station receiver and a mobile rover receiver for data capture. Real-time kinematic GPS delivers high accuracy data (cm) on-the-fly (Leica Geosystems 2000). The system is very productive but also very costly and requires highly experienced personnel. Security and optimal position for the base station has to be considered. Problems might occur due to the interruption of the radio link between the user and the base station (Leica Geosystems 2000, Roberts 2005).

For optimal results, all GPS systems require a clear sky and horizon to acquire satellite information. The use of GPS receivers is therefore problematic under canopy or in urban environments.

ULR Recommendation: A Level 1 GPS receiver is sufficient where parcel boundaries are of less importance or difficult to define, e.g. fuzzy boundaries such as grazing rights. They are also appropriate for areas where land disputes are less frequent disputed and the 'social cadastre' is still in place. The security level of point or polygon co-ordinates captured with low accuracy can be increased through attached boundary description, sketch maps or photos of the plot.

Level 2 to 4 GPS data require the availability of a temporary ground station during formalization campaigns. Level 2 data would be of great benefit for the formalization process since the accuracy is sufficient for most properties in urban and rural areas but it is most likely too expensive for the majority of people.

High accuracy GPS surveys Level 3 and 4 are only relevant for high value lands and properties where tenure security is required through high accuracy surveys and customers are willing and able to pay for the service. The procedure of data integration is equivalent to high accuracy ground surveys.

Image based data capture

The use of remote sensing images, aerial photographs and orthophotos is the most frequent technique used in many developing countries for low-cost data capture. Especially the advent of high resolution satellite images has opened new options for cost-effective data land registration.

Satellite images with a high spatial resolution like IKONOS or QuickBird (Table 4) provide the opportunity to use up-to-date images since they are produced regularly (Tuladhar 2005). This allows building an archive of images to analyse trends such as settlements in urban areas.

Table 4: Details of commonly used high resolution satellite images

System	IKONOS	QuickBird	WorldView-1
Swath width	11.3 km at nadir	16.5 km at nadir	17.6 km at nadir
Spatial resolution	Nadir: 0.8 m panchromatic, 3.2-m multispectral off Nadir: 1 m panchromatic, 4 m multispectral	0,61 m panchromatic (at nadir) 2.44 m multispectral at nadir	0.5 m panchromatic at nadir
Positional accuracy	2 to 15 m depending on product	CE 90%: 23 m circular error, 17 m linear error (without ground control), RMSE 14 m	6,5 m circular error
Revisit	Approximately 3 days at 1-meter resolution, 40° latitude.	1 to 3.5 days depending on latitude at 70 cm resolution	1.7 days at 1 m GSD or less 5.4 days at 25° off-nadir or less (59 cm GSD)
Organisation / website	www.geoeye.com/	www.digitalglobe.com/	www.digitalglobe.com

Different image products (e.g. orthorectified or stereo) are usually available from the data provider to meet the specific application demand. The positional accuracy depends on the product and varies for example for IKONOS images between 2 and 15 meter (GeoEye 2006). Further interesting products not mentioned in the table above are the French SPOT 5: 2.5 m panchromatic images or products of the Indian CARTOSAT-1 (IRS-P5) with an enhanced spatial resolution of 2.5 m.

The use of satellite images is considerably cheaper than aerial photographs or ground surveying and requires less effort to produce data. Kansu & Gazioglu (2006) achieved an accuracy of 3 m using IKONOS images in Turkey, which they considered as “very low” for satellite imagery. The accuracy of the results can be affected trough distortions due to image rectification or through uncertain quality of georeference network.

Another possibility to use high resolution images for data capture or visualisation is the integration of web-based map services like Google Earth, Microsoft Virtual Earth or Yahoo! Maps. One major obstacle is that the application requires reliable internet access which is most likely not available for data capture in rural areas. The spatial resolution and date of image capture is also unclear to the user. It is further unpredictable when the data content changes. At present the coverage of high resolution images is still incomplete in Tanzania and covers mostly urban areas[17].

Figure 18 shows as an example of two Google Earth screenshots from Tanzania located in Dar es Salaam showing an industrial area and adjacent informal settlements and a view on rural areas near Usangi, 60 km southeast of Moshi.

Figure 18: Screenshot GoogleEarth: Dar es Salaam (left) and Usangi (right)

[17] Google Earth: visual data content check 9.5.2008

ULR Recommendation: High resolution satellite image are very useful for many applications in the focus of the ULR in rural and urban environment. Satellite images fill the important gap in the GPS accuracy class between 1 to 3 m since DGPS services are not available and the setup of local reference networks is possibly too expensive for many users.

Map services like Google Maps are at present only interesting for data visualisation in areas where up-to-date images are present and internet access is available. They are a future option for data publication and public data access. The integration of map services should be supported by the ULR.

Existing cadastral data

In Tanzania cadastral data are kept in a cadastral survey register containing the spatial descriptions of parcels and a title register which contains parcel ownership particulars. The Surveys and Mapping Division of the Ministry of Lands and Human Settlements Development is digitizing all cadastral survey plans (Silayo 2002a). Digitized information can be imported into the ULR database using a standardized GIS format. Conventional maps can be georeferenced and used in the ULR application to digitize data for data capture and update.

Table 5 summarizes the recommendations above and indicates the data integration process.

Table 5: Recommendation for survey techniques and data integration

Technique	Accuracy	Use and opportunities for ULR	Data integration
Ground survey, high accuracy or GPS (Level 3 + 4)	< 0.8 m	Appropriate for high value land / property, commercial farms, expensive and time consuming product	Data import as GIS file (e.g. shape format) and/or co-ordinates, WFS
Satellite images	<= 3 m[18]	Point, Line or Parcel-based registration of land rights, accuracy is sufficient for many environments, data can be used directly by the ULR in combination with GPS device.	Images can be loaded into the ULR application for on-screen digitizing.
GPS (Level 1)	5 – 25 m	The GPS device will be used to capture co-ordinates or tracks in the field stand alone or attached to the field computer.	Real time data capture or upload of co-ordinates and/or tracks.

[18] According to Kansu & Gazioglu (2006).

Existing conventional maps (scanned)	Unknown	Existing cadastral maps can be scanned and digitized.	Data import as GIS file (e.g. shape format) and/or co-ordinates
Existing digital survey data	Unknown	The data have to be transformed into a GIS format for import.	Data import as GIS file (e.g. shape format) and/or co-ordinates

The ULR field computer should be equipped with a handheld-GPS receiver which also can be used stand alone to capture co-ordinates and/or tracks. The GIS tool of the application uses a high resolution satellite image besides the topographic information (Village Land Use Plan, urban block data) as baseline information for orientation and digitization. All other data have to be imported using standard interfaces (e.g. WFS, shape file).

4.5.3 Spatial representation of land rights

The FIG guideline cadastre 2014 (Kaufmann & Steudler 1998) recommends the incorporation of land objects to extend the limited view of parcel based systems towards multipurpose LIS. The parcel based view on land properties serves the registration of adjacent land objects in the sense of ownership in customary practice. But it has to be considered that other socio-territorial units are often difficult to delineate and have never been mapped. The only existing information regarding the extent of a land right might be a vague description of the area or local names of escarpments or valleys. Further, many land rights are seasonal only and may vary depending on external factors like prolonged droughts. Last but not least, simple and flexible spatial representations are required to support cost-effective and efficient cadastre in developing countries. Augustinus et al. (2006) promote the following identifiers on the background of the STDM:

- Lines.
- Polygons, Polygons with fuzzy boundaries.
- Text, including lists of names and unique numbers.
- Parcels -poorly surveyed, georeferenced and non geo-referenced.
- Sketch maps and photographs.

The ULR concept requires that all land rights are georeferenced using any kind of spatial identifier. The ULR application must enable spatial analysis besides the query of attribute tables. This is of great importance for mapping and analysing disputed land or overlapping land rights. Users beyond the ULR application on district or higher administrative level require cadastral data for data analyses and land management purposes. Land right information, which is not spatially identifiable gets lost and is not suitable for efficient land management.

According to the strategic considerations in chapter 4.5.1, the ULR concept allows different approaches to model the tenure security. In principle, tenure security can be achieved through combining spatial accuracy (based on survey method), the kind of spatial identifier and additional attributes describing or visualizing the extent of the land object (Figure 19). The factors can be joined effectively to meet the specific demand of the targeted community or land right owner (e.g. costs, level of tenure security, cultural issues). A simple point identifier for example delivers itself a low level of tenure security which can be improved by attaching a sketch map or a textual description of the boundary. Conversely, if extralegal documents already contain detailed information about the spatial extent of the land object, a point might be very sufficient to register this land right in a short time at low cost.

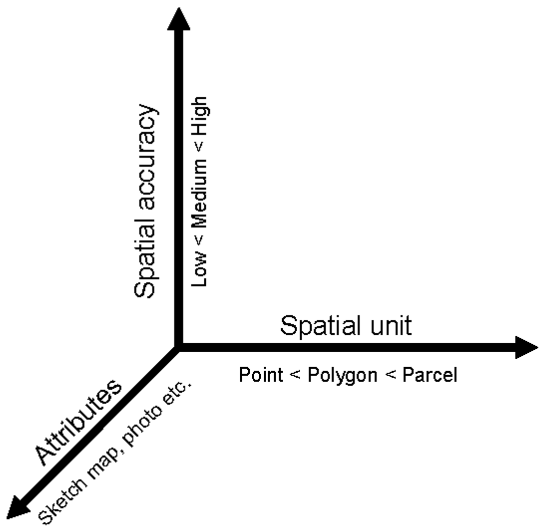

Figure 19: Factors maintaining the tenure security

The ULR strategy supports the application of different spatial identifier and the use of additional attributes to model the required tenure security (Figure 20).

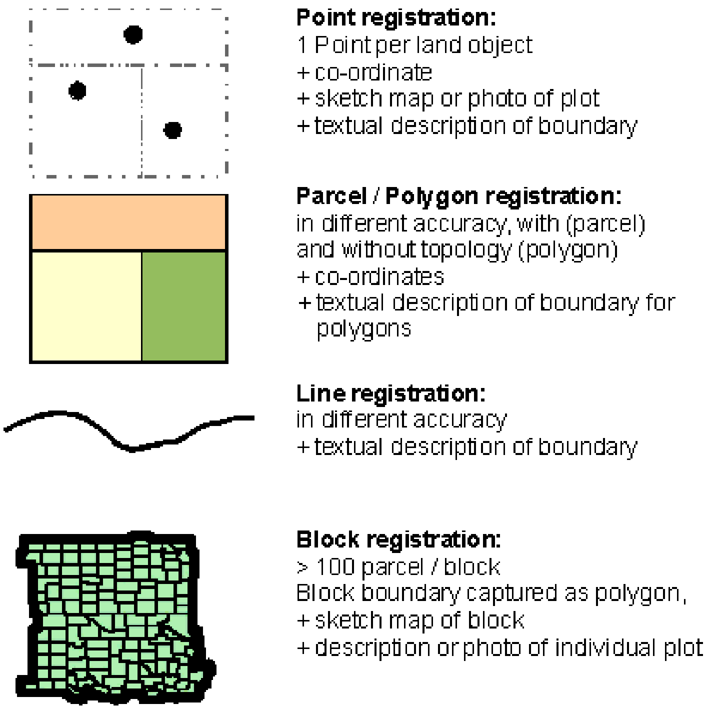

Figure 20: ULR types of spatial identifier

All land rights have to be surveyed according to the new land laws. The co-ordinates of corner-points are taken to delineate plots and parcel. But to streamline the process it is suggested to implement simpler forms of boundary delineation and integrate customary practices like textual descriptions to secure tenure.

The simplest form is the registration of point identifiers without corner-point co-ordinates. A point can represent a parcel or polygon as well as a land right with little extent like a use right for a well. The point identifier requires a sketch map or a photograph attached to explain the locality and the boundaries of the land right. A textual description is mandatory.

Polygons represent a parcel based view or indicate areas of overlapping land rights. The parcel view for representing ownership uses topological rules for maintenance. Overlapping of parcel is not allowed in this view. A list of co-ordinates is attached to the polygon according to the general surveying practice in Tanzania. Co-ownership of land is registered as a separate parcel.

The polygon represents the simple parcel based view based on data acquisition in lower spatial accuracy. The polygon view maintains no topology and overlapping is possible. A textual description is mandatory because many land rights cannot be delineated accurately along natural boundaries or topographic elements like roads. Fuzzy boundaries have to be indicated to the user to ensure the appropriate use of the data for mapping and spatial analysis. Disputed land is also captured as a separate polygon referring to a land conflict document and involved parties.

Lines are used to map linear land rights like access rights. A textual description is mandatory to explain details such as a corridor in use.

The last option recommended is the use of block registration as implemented in Namibia to formalize land ownership in informal settlements (Juma & Christensen 2001, Christensen 2004). This approach is suggested to be used for issuing residential licenses in urban areas or to register small scale farms in undisputed lands.

A block containing at least 100 tenants is surveyed and stored as a parcel or polygon in the spatial database. A sketch map containing the individual plots is attached to add further details about the individual land rights. The sketch map is not geo-referenced but can be designed as an interactive map to query the plots using the PC mouse.

This setup allows the specific view on spatial elements regarding their land right (type, class) and spatial representation. A spatial layer containing ownership rights can be subdivided into different types (e.g. customary right of occupancy, informal land right) represented through different spatial identifier like polygons (parcel) or simple points as shown in Figure 21. The overlay allows the spatial analysis of overlapping land rights and disputed land. Signatures for mapping have to be introduced to mark uncertain areas where a boundary cannot be delineated exactly (fuzzy boundaries). Linear elements map access rights like footpaths leading to pasture. These are important elements in village land where shared land use is quite common.

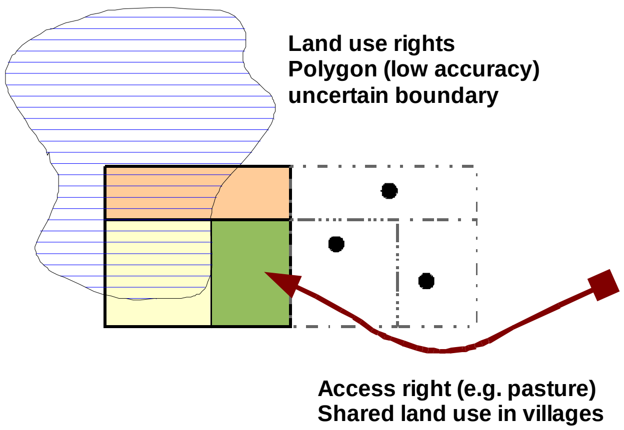

Figure 21: ULR spatial identifier layer view

4.6 ULR principles and functions

The previous chapter outlined the implementation strategy and highlighted several functional capacities of the ULR application. Software development requires a detailed cataloguing of core functions and the definition of system requirements to design business processes, data model and interface in the software design process.

ULR principles

- The ULR registers persons and land objects via their tenure relationship and according to standards in cadastral modelling (Cadastre 2014, STDM).
- The identification and registration of persons is of particular importance because many Tanzanians do not possess identification papers. The ULR applies the use of photographs, affidavits and fingerprints to build a national ULR user database.
- Different survey techniques and levels of spatial accuracy are supported like use of handheld GPS / DGPS for field surveys, on-screen digitizing based on remote sensing image / orthophoto, import of spatial data or co-ordinates.
- Tenure relationships are registered using different spatial identifiers (point, polygon, line) as well as field sketches and textual descriptions.
- The ULR architecture contains security measures to prevent corruption of the system and assures sustainable tenure security (e.g. user authentication and authorization).
- The system architecture is a distributed network based on well acknowledged GIS and ICT standards for data replication and dissemination.
- The ULR business concept focuses on the registration process with simple data visualization and output. The application requires specific GIS, database and user management functionality.
- The ULR application is a tailored GIS application developed with open-source software to minimize costs and maximise customer friendly design and functionality.

General requirements

- The ULR application must support Swahili and English as language for operating the system. Swahili is the official language in Tanzania, but English is the primary language of commerce and administration. Local languages are not supported. The ULR supports illiterate land right owner with appropriate graphical content.

- The ULR system must be able to work offline to enable the registration process in rural areas. Online access is only required to replicate and disseminate data between the nodes or to use internet based map resources.
- The spatial database requires the implementation of well known standards to support interoperable data exchange and access. Cost-effective open source products are recommended to reduce the cost of implementation and maintenance.
- The ULR application requires standards for topographic mapping and geographic names as well as interoperable access to concerned libraries and/or databases.
- The ULR application interface must be designed in a way that it can easily be used by trained local staff who has limited knowledge and experience in computer technology and mapping applications.

The following tables summarize the functional capabilities or the ULR.

Registration of persons

The registration of persons requires the identification of natural persons, groups and institutions (Table 6).

Table 6: Description: Registration of persons

Registration of persons	
Registration single person	The ULR requires registration of single persons, institutions or groups. Applicants without ID card require affidavit to proof identity. **A) data capture ID holder:** • Copy of id (image). • Get personal photograph. • Fingerprint for biometric authentication. • Get attributes: ID number, date of issue and location, name, sex, date and name of birth, address (name, location, nearest landmark), plot number, phone, e-mail. • define function: land right owner, affidavit, land right owner and deponent of affidavit

	B) data capture non-ID holder: • Copy of affidavit (image). • Fingerprint for biometric authentication. • Get attributes: name, sex, date and name of birth, address (name, location, nearest landmark), plot number, phone, e-mail. • Link personal file to deponent of affidavit.
Register groups	Groups are represented trough a specific number of members as representatives. A list of all members is not implemented since it is too difficult to maintain for large groups as clans. All representatives will be registered as single persons. • Group name • Description of group
Register institution	Legal and extralegal companies are accepted. The registration should be in accordance to the formalization of business. • Person data of company owner or representative. • Copy of registration document [legal, extralegal] (image) • Attributes in institution form: Name of institution, Registration ID (e.g. Tax id, church register number etc.) extralegal company registration: scan document, capture company data (ownership)
Import and verify identity file	The ULR application is capable of exchanging personal data with the national user database to verify identity of persons and to import person identity files.
Security measures	The registration of a person requires the verification of the national person ID management unit [check of fingerprint]. The personal file has to be sent to the national ID management unit to verify the correctness. If the applicant is not registered yet, an ID number will be attached and sent to the local registrar as confirmation. In case a person is already registered in another village the personal file has to be requested from the national ID management unit.
Print registration document	Every person has the right to get a printed copy of his registration to the system containing personal data, status, attached documents [Id, affidavit], picture.
Issue user-ID	The correct spelling of names is a concern in maintaining personal data in countries with many local languages and low literacy rate. A user ID card should be issued containing name, address and ID number to all applicants (person, group, etc. All personal data will be maintained in a national database to avoid double registration and fraud.
Search & visualisation	The ULR application allows the search for persons by name, ID number or fingerprint and visualisation of related documents and land objects.

Since the literacy rate of persons older than 15 years is only 69% (World Bank 2007b, UNDP 2008) measures have to be taken to support the correct identification of persons and the spelling of names. The user database will be maintained at national level. A national user ID is issued as personal identification number. A user ID card containing the applicant name, address, user ID and passport picture is handed to all users to ease system access and communication especially for illiterate people.

The ULR application supports the query of the registration status of an applicant and the printout of registration documents. The security measures ensure that the registration process is traceable and transparent.

Registration of land rights

The ULR is implemented hand in hand with an in-depth analysis of existing customary practices of land administration and documentation. These customary practices have to be systematized, professionalized and better harmonized with the existing legal system to be enforced at national scale. Nationwide standards have to be defined to classify the content of documents (ILD 2005c, p.381). The content of existing documents will be stored in the ULR database as document attributes and scanned to keep the original document (Table 7).

Table 7: Description: registration of land rights

Registration of land rights	
Land right document	The ULR supports the registration of all land right relationships based on documents (legal or extralegal) or in oral tradition in a standardized database format (standard forms and attributes). To register a land right, the applicant/group has to provide a written document approved by the legal body of land administration (e.g. Village Council). If no extralegal document exists (land right in oral tradition) a standard form will be provided by the Village Executive Officer. Data capture: • Tenure type (use right, access to water etc.) and tenure class (meta-class or tenure types e.g. ownership). National standards are required for tenure types and classes to enable systematic mapping and analysis of existing rights (adjacent rights of occupancy, overlapping use rights etc.) based on the ILD archetypes (ILD 2005b). • Date of registration. • Village name and ID [National standards are required]. • Local name (mountain range name etc.) [National standards are required]. • Description of right or relation to land (e.g. occupancy, lease, sub-lease, use-right, access rights collateral etc.). • Time span: in/out (e.g. lease hold). • Time span for seasonal rights (grazing rights, access to water). • Copy of document (image). • Get attributes in a standardized form: kind of right, duration, seasonal aspects. Further attributes are required to register documents for collateral or testaments. These details have to be defined according to national standards.
Application processing	The application for land rights requires paper processing between the applicant, the Village Executive Officer and the District Officer. The preparations of the forms and the processing must be supported by the ULR. The application status must be registered and accessible to the applicant e.g. through request using a short message service (SMS).
Print certificate	The ULR supports the printout of land certificates or land dispute documents. The documents are designed in a standard format containing the personal particulars, personal photographs, description of land right / land dispute and map.

Query status	The registrar must be able to query the status of the land right registration and verification process. Land right owner can request the status using a short message service (SMS).

The ULR further maintains the application process according to different existing practices. The form should be compiled digitally and printed for the person who applies for the land right. The application forms paper should be processed digitally between the persons responsible. The ULR application supports the query of the registration status. The security measures ensure that all transactions are traceable and transparent.

Spatial data capture and GIS functions

The GIS functionality comprises very basic viewing, mapping and query tools. The user must be able to create and edit point, line and polygon features. Topology rules are only required for the registration of parcel, which is optional for the registration of ownership rights.

Table 8: Description: data capture spatial unit

Spatial data capture and GIS functions	
ULR database	Recommendation: all data will be stored in a spatially enabled relational database following the OGC Simple Features Specification for SQL (OGC 2006). This standard is implemented in PostGIS[19], an open-source extension for the PostgreSQL[20], the object-relational database management system.
Data integration	Data are integrated using the digitization capabilities of the ULR application, through import of data or through integration using WFS / WMS services based on international standards for interoperability defined by OGC and ISO. A) Digitization of points, polygon (multi-polygon) and line (multi-line). B) Import through pre-defined Interfaces: • Existing cadastral data or data compiled using ground survey instruments: WFS or industry standards like dxf or ESRI shape files. • GPS co-ordinates compiled using handheld GPS. The file format depends on the system chosen.
Data editing	The ULR allows manipulation of spatial data: • Manage rights and restriction on spatial data (edit modus, view only etc.). • Create and edit geographic features (point, line, polygon) and join them with land right information • Copy geographic features from/to topographic database • Upgrade features (point to polygon, polygon to parcel etc.). • Maintain topology for parcel.

[19] http://postgis.refractions.net/ [cited 30.4.2008]

[20] http://www.postgresql.org/ [cited 30.4.2008]

	• Spatial keys for efficient data query. • Edit tools: Define snapping tolerance, snap to feature (vertex, line).
Data view & analysis	Key GIS functions: • Data viewer (satellite image, topographic data or combined) with basic zoom / pan functions, measure distances. • Cadastral mapping: layer overlay: customize feature layer (based on TenureType, TenureClass etc.). • Attribute query, identify objects using cursor. • Spatial analysis to detect disputed lands. • Print view with legend. • Add data from neighbouring villages (view only).

The import of data requires several interfaces to integrate data from different resources like GPS points or GIS data files. The specification depends on systems available and used by the land administration professionals in Tanzania (type of GPS receiver, GIS software available). De-facto industry standards like ESRI shape file or dxf are considered as mandatory interfaces to integrate existing digital data. The ULR should also be able to integrate data while online via WFS or WMS.

Only very basic GIS analysis capabilities are required to support the participatory registration process. Data viewing on maps with map navigation (zoom, pan) using different data resources is essential for visualisation. The user should be able to switch between the use of remote sensing images, scanned maps and topographic data (e.g. Village Land Use Plan) to register and visualize land rights.

Spatial query functions are required to support the analysis of land disputes. The cursor query is essential to request the information for a specific spatial unit. The interoperable database design enables data access using GIS clients and workstations with additional GIS functionality to analyse for example overlapping land rights. Furthermore, the ULR application requires of course all capabilities to maintain security measures and data replication. The ULR requirements and functions summarized above build the foundation for the in-depth application development and design using UML. Chapter 5 presents the dynamic and functional view of the application based on UML activity and deployment diagrams. The data model is discussed as UML class diagram. Schär (2008) describes the logical and physical system architecture as well as the user interface of the prototype based on the presented UML diagrams.

5 The ULR business and data model

5.1 Application development in UML

UML is a globally accepted de-facto standard defined by the Object Management Group (OMG) for object orientated specifying, documenting and visualizing software. The language is also used for the modelling of non-software systems and is extensively relied on in many sectors including finance, military and engineering (Sparx Systems 2008). The use of different diagram types allows examination of a software product from different perspectives like that of the user, the data modeller or the process management.

The UML provides a common vocabulary for business analysts, designers and programmers discussing software design (Borland 2006). UML 2 defines thirteen basic diagram types, divided into two general types as summarised in table 9:

Table 9: UML diagram types (Erler 2004)

Structural modelling diagrams	**Behavioural modelling diagrams**
Package	Activity
Class or Structural	State machine
Object	Communication
Composite structure	Sequence
Component	Timing
Deployment	Interaction overview
	Use-case

The ULR processes outlined in chapter 4 are modelled and analysed using the following diagram types for defining the ULR framework for land registration in Tanzania:

Activity diagram

"*In UML an activity diagram is used to display the sequence of activities. Activity diagrams show the workflow from a start to the finish point detailing the multitude of decision paths that exist in the progression of events contained in the activity. They may be used to detail situations where parallel processing may occur in the execution of some activities. Activity diagrams are useful for business modelling where they are used for detailing the processes involved in business activities*" (Sparx Systems 2008). Activity diagrams are used to model the ULR registration processes for persons and land rights.

Deployment diagrams

"*A deployment diagram models the run-time architecture of a system. It shows the configuration of the hardware elements (nodes) and shows how software elements and artefacts are mapped onto those nodes*" (Sparx Systems 2008). The deployment diagram is used to outline the ULR distributed network and major processes between the nodes in the ULR architecture.

Class diagrams

The class diagram gives an overview of a system by showing its classes and the relationships among them (Borland 2006). "*The class diagram shows the building blocks of any object-orientated system. Class diagrams depict a static view of the model, or part of the model, describing what attributes and behaviour it has rather than detailing the methods for achieving operations. Class diagrams are most useful in illustrating relationships between classes and interfaces. Generalizations, aggregations, and associations are all valuable in reflecting inheritance, composition or usage, and connections respectively*" (Sparx Systems 2008). The class diagram is used to illustrate and analyse the ULR data model.

All modelling was conducted using Enterprise Architect Version 7 (Sparx Systems®).

5.2 Business processes

5.2.1 Register person

The UML activity diagram register person (Figure 22) describes the process of registration and the interdependency and link between the local registry and the national database. All person data are registered at local administrative level (village, district) but maintained at national level.

The start condition describes an applicant who requests to be registered for a land right. The first and mandatory condition in this process is that the applicant is registered to the ULR 'Person' database. Two cases are considered in this diagram:

- The applicant is not registered at all.
- The applicant is registered to the national database, but his file is not yet available at the local registry.

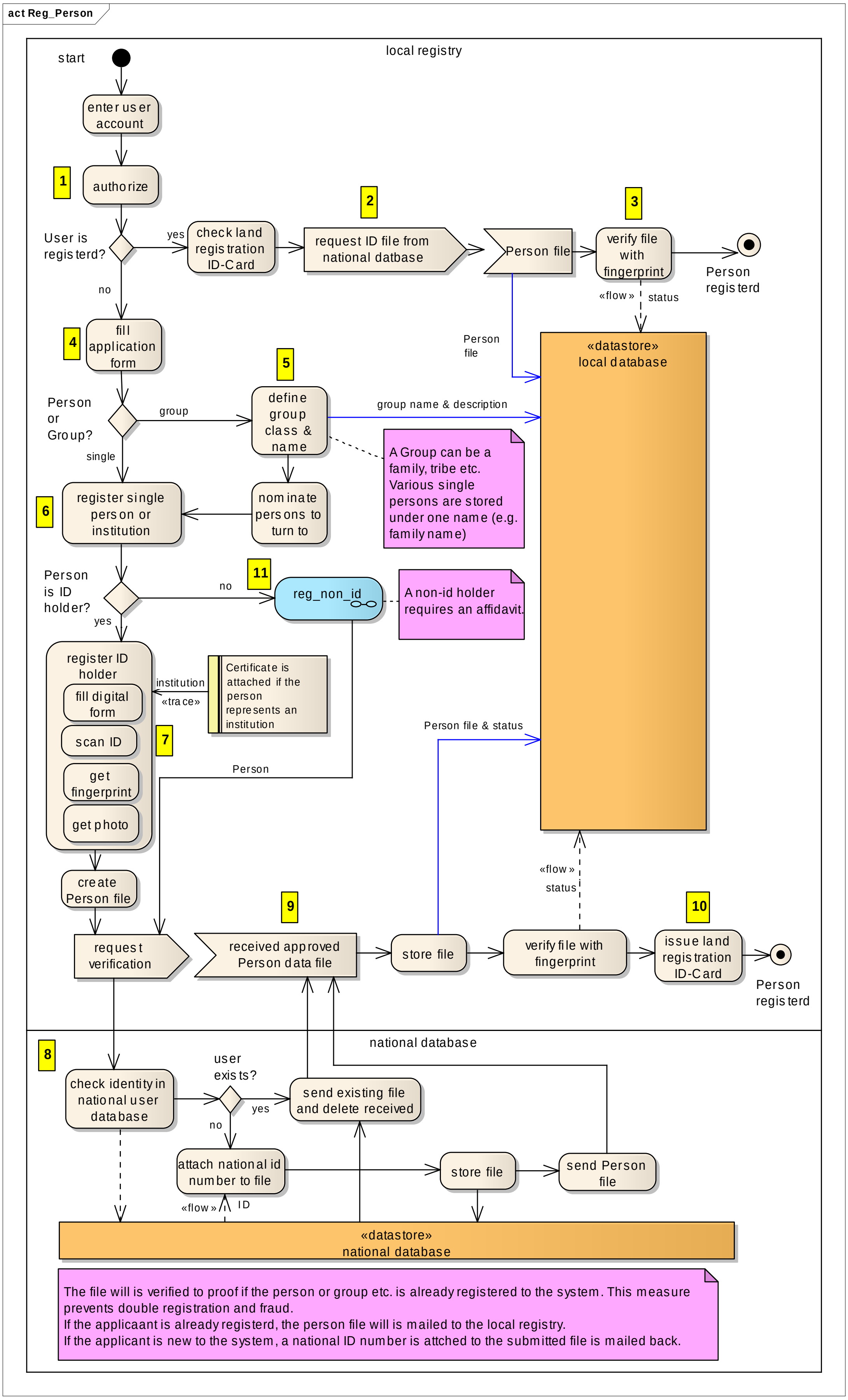

Figure 22: UML activity diagram: register person

The registrar logs in to the ULR system (authorize) using his fingerprint as identifier (1)[21]. If the applicant is already registered to the national database, the registrar requests the personal file using the national user ID number of the applicant (2) which is included to his user ID card. The request is verified at national level and if approved, the verification is sent to the local registry and stored in the local database. The applicant has to verify and thereby accept the file content with his fingerprint (3). The applicant is now registered as person to the local database. The status of his personal file changes to 'valid user'.

If the applicant is not yet registered in the URL national database, he has to fill the application form (4). The procedure then depends on the type of applicant, whether the applicant is a single person or a group of persons.

Groups require the definition of the group through type (e.g. family, clan), name and description (5). The group has to name representatives, who are registered as single persons to the 'Person' class und the umbrella of the group name. A list of group members as proposed for the STDM by Lemmen et al. (2007) is not included. Such a list seems to be not practical because groups can comprise many members and maintenance of such large list is most likely not manageable. Lists containing individual personal data are only controllable if the persons can be identified and that would require consequently that all group members have to be registered to the ULR database. The maintenance of these data would require too much effort. It is therefore proposed to register a group through a limited number of group representatives under the group name. However, more field studies are required to ensure that this methodology is appropriate in the local context.

The registration of the single person (6) is the core function of the registration process. Group or company names are attached as attributes to single persons to model these entities. In case of an institution, a copy of any legal, extralegal or informal business certificate is attached to the file.

The registration of a single person depends whether the person has official personal identification papers or not. If the person has an ID or passport, all personal details are captured and supplemented with the fingerprint file and a personal photo (7). The ID card is scanned and the ID number is registered. A person file is then created and mailed

[21] The number in brackets refers to the relevant step in the diagram, which is being discussed.

to the national database for verification (7). Until the file is verified the applicant is registered at the local database as 'non-valid user'. After verification at national level (8), the file is be verified by the local registrar and the applicant (9). The status of the registration file then changes to 'valid user '. Finally, the ULR user ID card is issued containing personal detail, national user ID number and personal photo (10).

If the person does not possess an ID or passport an affidavit is required to proof the identity of the applicant. The affidavit provider is registered to the ULR system as a single person (7) with the function 'AffidavitProvider'. The affidavit provider must have official personal identification papers. The registration procedure (11) for the affidavit document and the applicant is documented in figure 23.

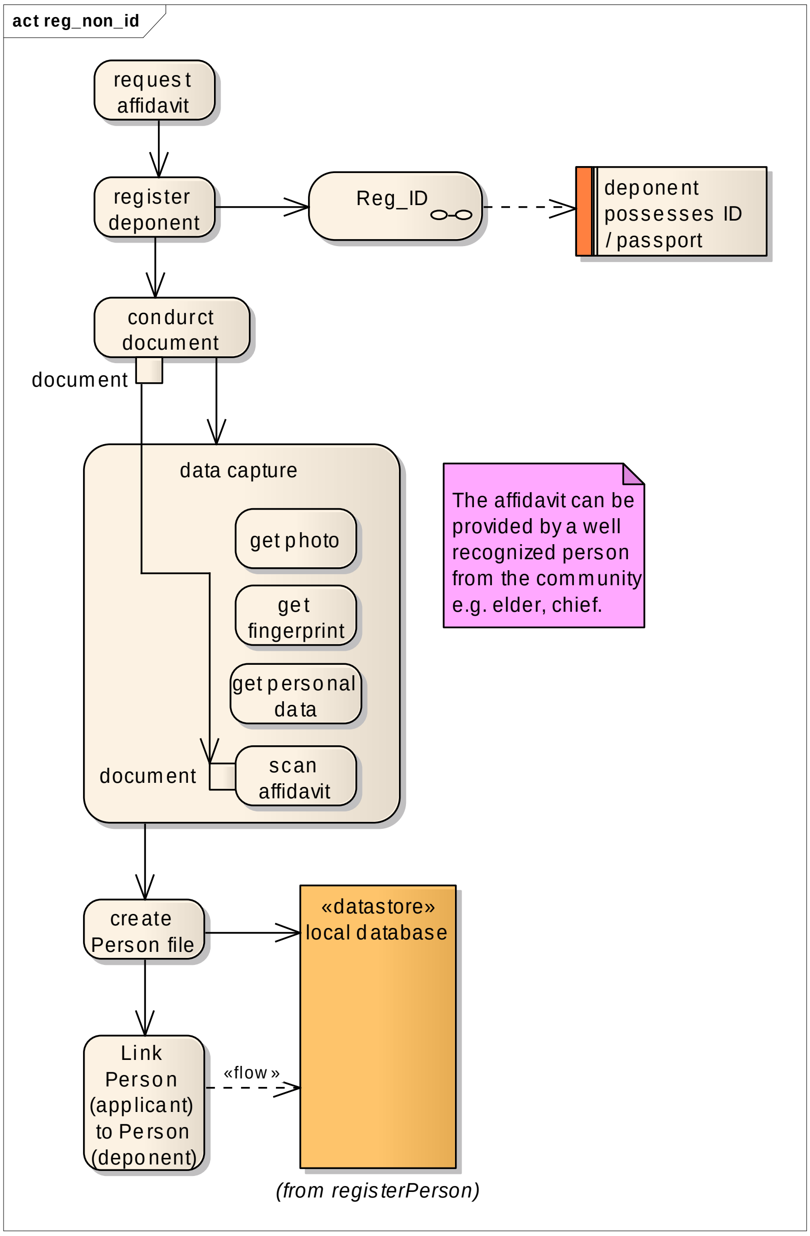

Figure 23: UML activity diagram: register non-ID holder

Persons will usually be registered using an offline field computer. The immediate verification of the person file through the national database at the national server is therefore not possible in most registration situations. To avoid unnecessary delay, especially during the initial phase of the formalization campaign, a solution should be considered so that the registration of land rights can be processed without final verification of person data file. Also, it is very unlikely that reliable and affordable internet connection will be available in remote areas within in a short time. Thus a strategy to cater for this particular situation has to be defined to enable the registration campaign and create a customary friendly and transparent registration environment.

5.2.2 Register land right

The process of land registration depends on the type of land right and the papers required for the application process. The following activity diagram (Figure 24) considers 3 cases: The registration of a customary Right Occupancy, a Granted Right of Occupancy and customary land rights based on extralegal documents. Depending on the local situation and customary practices, the local registry might require additional or different types of land right registration.

The allocation for the CCRO requires the processing of form 11 and 18 (1). All application forms are transferred as digital documents between the local registry and the District Land Office for verification.

Based on the current situation in Tanzania, it can be expected that the most commonly requested option for land right formalization will be the registration of existing extralegal documents (2). Orally transmitted land rights are transferred to a standard document form (provisional document) provided by the registrar (3). All provisional documents have to be approved by the Village Land Council. If the claims are granted, the document is registered digitally and scanned as copy to keep the signatures of adjudication. A land dispute document is compiled and linked to all parties involved if land is disputed (4).

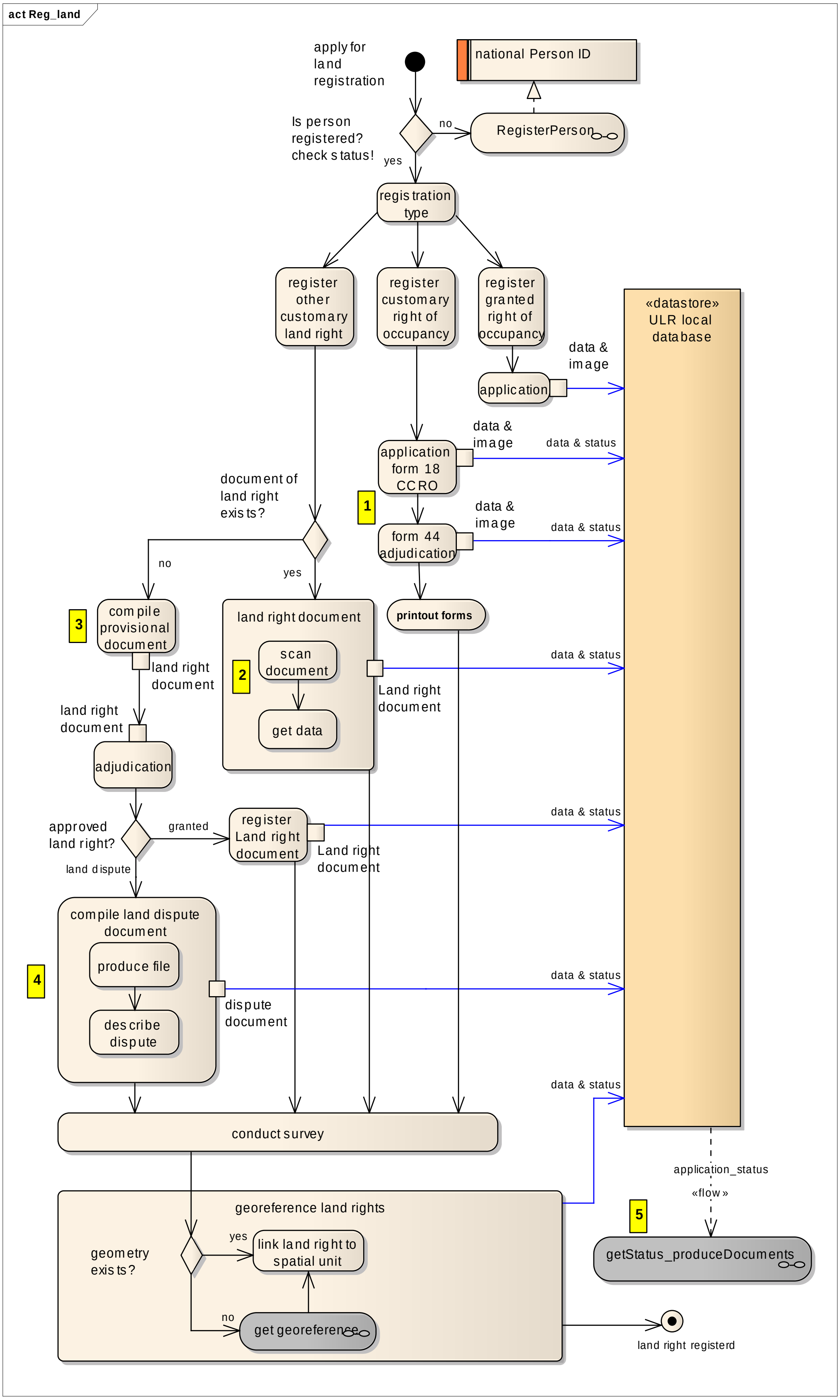

Figure 24: UML activity diagram: register land right

A field survey is conducted after application papers and land documents are processed. Land right is georeferenced ('getgeoreference') depending on the availability of data and documents. Figure 25 shows the decision tree to georeference land right documents.

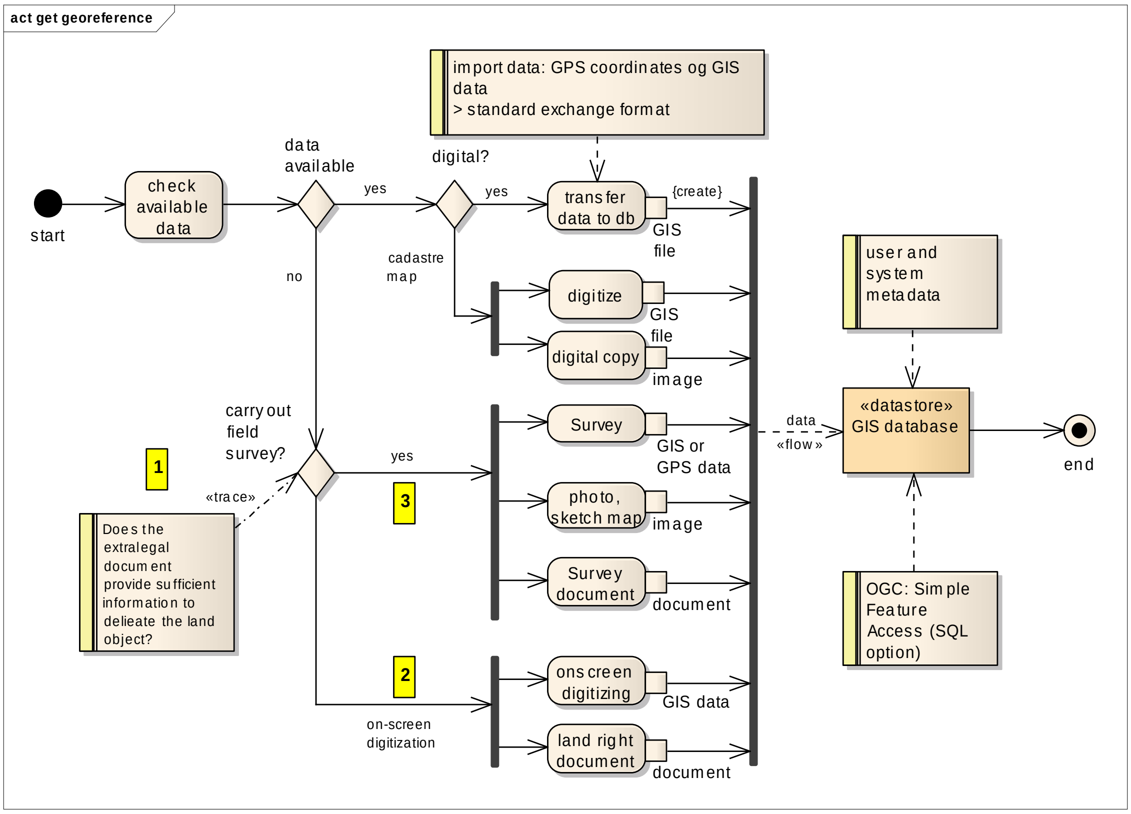

Figure 25: UML activity diagram: get georeference

Existing digital data are imported through a standard interface (e.g. dxf, shape). If data are digitized from a scanned and georeferenced map, the scan of the map detail is stored as image with the file to maintain the original source.

The decision of whether a field survey is required depends on the content of existing extralegal or informal land right documents (1). A field survey can be avoided if the document is accepted by the registrar as legal survey document (2). The land object is digitized based on the existing information.

A survey protocol is compiled and attached to the land object in case a field survey is conducted (3). The document contains a description of the boundary as well as the corner point co-ordinates. If necessary, a sketch map is drawn and scanned. The land object is registered using the GPS co-ordinates or simply through on-screen digitizing.

The status of the land right registration can be requested by the applicant or the registrar (Figure 24: 5). The request can be processed by the registrar using the ULR application or accessed by the applicant using a simple SMS (Figure 26).

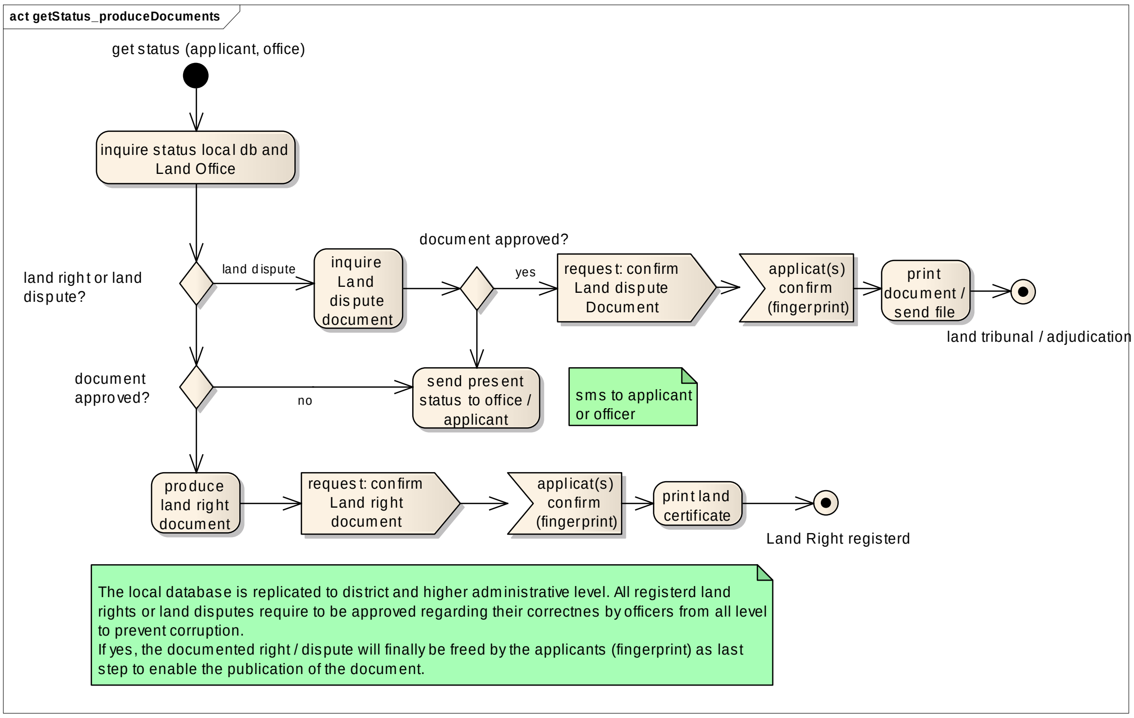

Figure 26: UML activity diagram: get status

5.3 ULR data model

The registration of a land right comprises the registration of the land right owner, the land right document and the land object. These objects build the main features of the ULR data model developed in UML. A generalized view of the model is presented in figure 26. The relationship between the land right owner (‘Person’) and the land object (‘SpatialUnit’) is realized through the tenure relationship (‘LandTenure’).

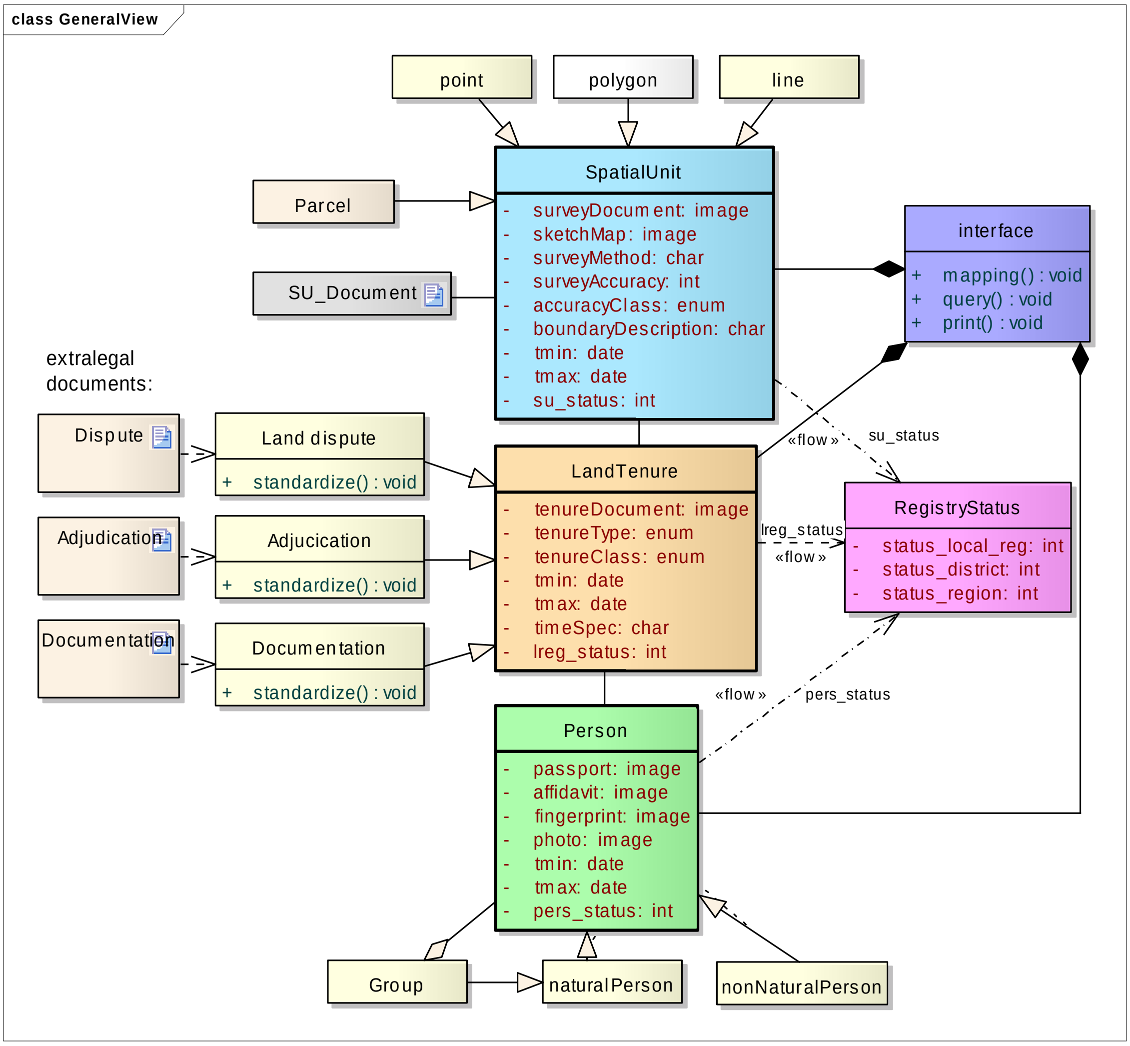

Figure 27: UML class diagram: data model – generalized view

A person can be an individual person, an institution or a group. The spatial unit is designed flexibly and can be realized as a simple point or a polygon. The survey document or any other extralegal document containing a spatial description of the land object is attached to the ‘SpatialUnit’ to save the original land object description. The ‘LandTenure’ class is based on any written land right document with focus on the registration of extralegal land right documents. The content of the documents is saved as attributes of the class (e.g. ‘tenureType’). The original extralegal document is scanned and saved as image (‘tenureDocument’).

Dynamic aspects describing the temporal validity of land rights are modelled according to the STDM approach. All documents (legal document, survey document) are considered as a representation of an event (transaction). The time related aspect to these elements is saved in the ‘tmin‘ and ‘tmax‘ attributes of all classes. This approach allows updating of documents or spatial entities and the query of cadastral objects over time.

The interface is an aggregation of ‘Person’, ‘LandTenure’ and ‘SpatialUnit’ to support the generation of required products and services such as printing of documents and queries with respect to land disputes.

The process of land registration creates a permanent information flow on the status of the registration of the ‘Person’, the ‘LandTenure’ relationship and the ‘SpatialUnit’. This information are saved in each class (e.g. ‘su_status‘) and transmitted as information flow to the ‘RegistryStatus‘. The information are combined here with all status information concerning the verification of transactions made by different persons responsible (e.g. ‘status_district‘,‘status_region‘). The ‘RegistryStatus‘ class enables efficient status management of the land right registration process and supports the query of the status at any phase of registration.

‘*Person’*

Figure 28 presents a detailed view of the ‘Person’ class. A ‘Person’ can be any legal person (‘naturalPerson’) or and institution (‘nonNaturalPerson‘). A group can consist of both types of ‘Person‘, but is limited to the number of persons (maximum 10). Lookup tables are used to assign the kind of institution (‘institutionType’). Administration staff (e.g. surveyor) and persons who provide an affidavit are further specifications.

The ‘function’ enumeration assigns the role of the person who is registered. A registered person can be a land right owner or a provider of an affidavit**. A** land right can not be assigned to the ‘AffidavitProvider’. If this person applies for a land right, his status has to be changed to ‘LandRightOwnerAffidavitProvider’. This lookup table can be extended if required.

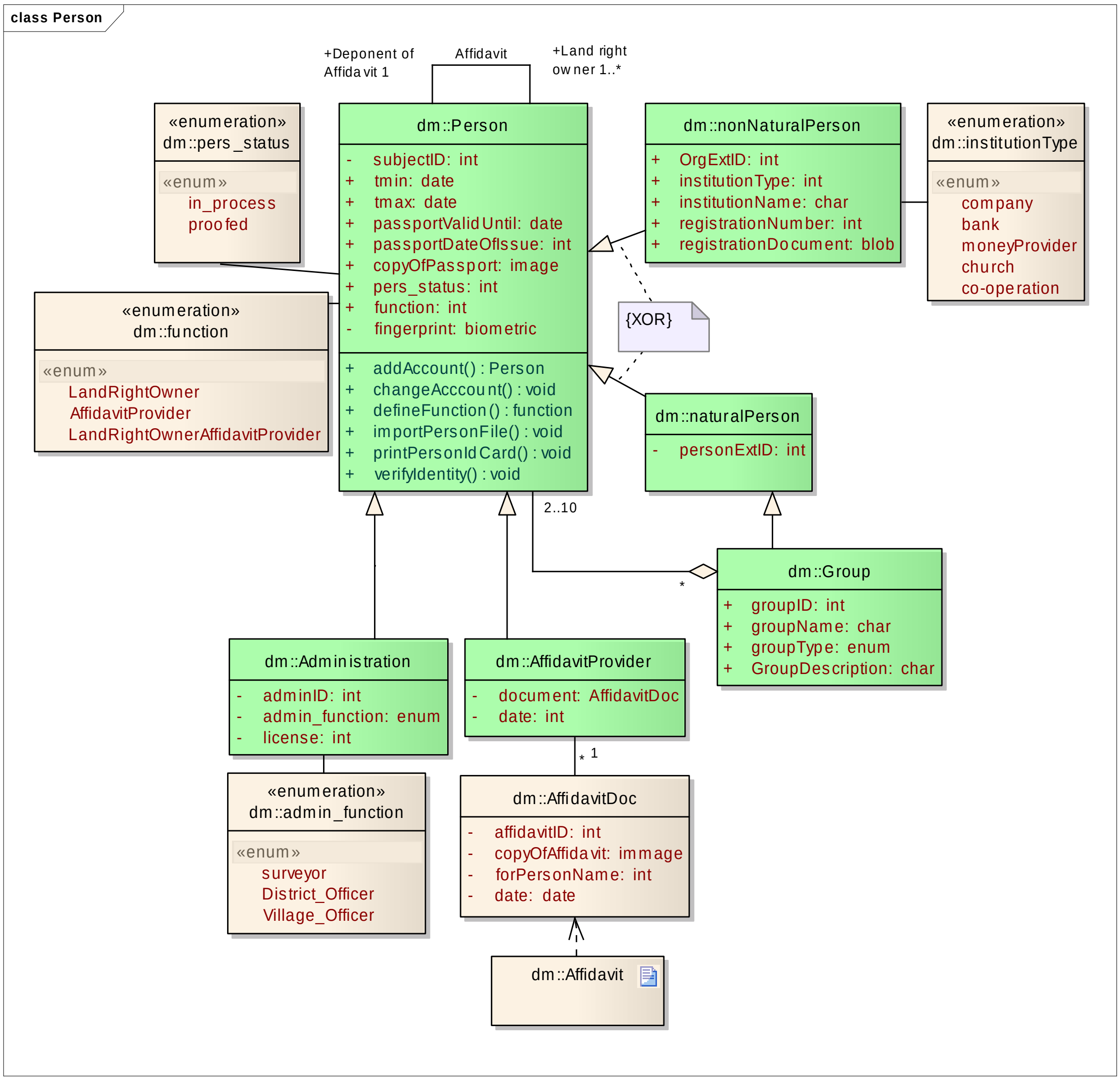

Figure 28: UML class diagram: Person

The ‘Person’ class contains various attributes including the fingerprint for authorisation. The operations assigned to this class comprise amongst others the import of an account (‘importPersonFile) and the verification of content (‘verification’). These functions are important for data exchange between the local registry and the national database.

‘SpatialUnit’

The ‘SpatialUnit’ (Figure 29) can be represented through different spatial identifiers depending on need. The ‘Parcel’ is the only unit maintaining topology in order to model ownership of adjacent land rights. The ‘Polygon’ or ‘MultiPolygon‘ class can overlap in their spatial extent, which indicates either overlapping land rights or land disputes. A separate class assigned to overlapping land rights as suggested in the STDM approach is not integrated.

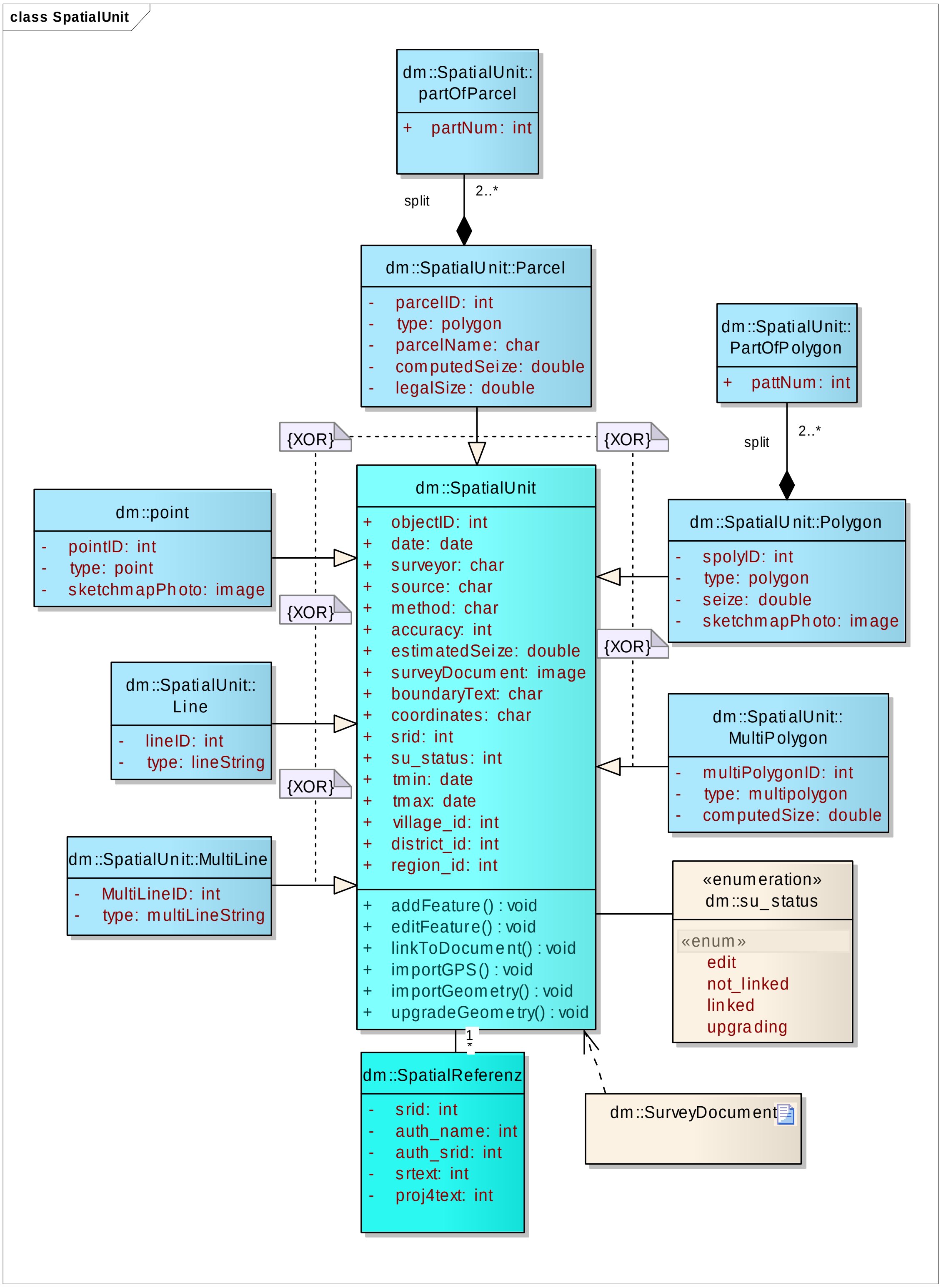

Figure 29: UML class diagram: SpatialUnit

The survey document, sketch map and/or photo are attached to the ‘SpatialUnit‘ where required (e.g. point). A description of the boundary can separately be stored in the ‘boundaryText’ attribute. A lookup table is integrated to register the status of the ‘SpatialUnit’. ‘Parcel’ and ‘Polygon’ can be subdivided through a transaction which leads the ‘partOfParcel’ and ‘partOfPolygon’ class. The operations assigned to the

‘SpatialUnit’ summarize the required registration functionality.

The ULR model does not include survey points and other classes of the non-planar region described in the STDM like the ‘SketchPhoto’ or the ‘Incomplete SpatialUnit’. Images or sketch maps are attached to the existing point, line or polygon classes where required.

‘LandTenure’

All original documents (‘TenureDocument’) are scanned and saved in the database as ‘tenureDocument’ (Figure 30). Lookup tables allow the specification of land rights as ‘tenureType’ or ‘tenureClass’ (meta-type). The ‘timeSpec’ attribute captures data on temporal aspects of land rights. This supports for example modelling of pastoralists’ rights such as grazing rights to a specific site during the dry season.

The system metadata are important for identification of different tenure relationships and support of the spatial analysis of land disputes and overlapping land rights. These system metadata have to be defined during field studies in the proposed standardisation process of customary land right documents according to the MKURABITA program. The development of additional system metadata may be required.

The system metadata captures details of the kind of land right and its representation as spatial entity. The combination of land right classes or meta-classes and different types of identifiers classified by type, survey method and accuracy allow a layer based view on existing land rights according to the FIG cadastre 2014 guideline. The database content can be easily combined in a LIS with other existing data layers. This enables for example the analysis of existing grazing rights in restricted areas like national parks. The documentation of land disputes is of foremost importance considering their frequency in Tanzania.

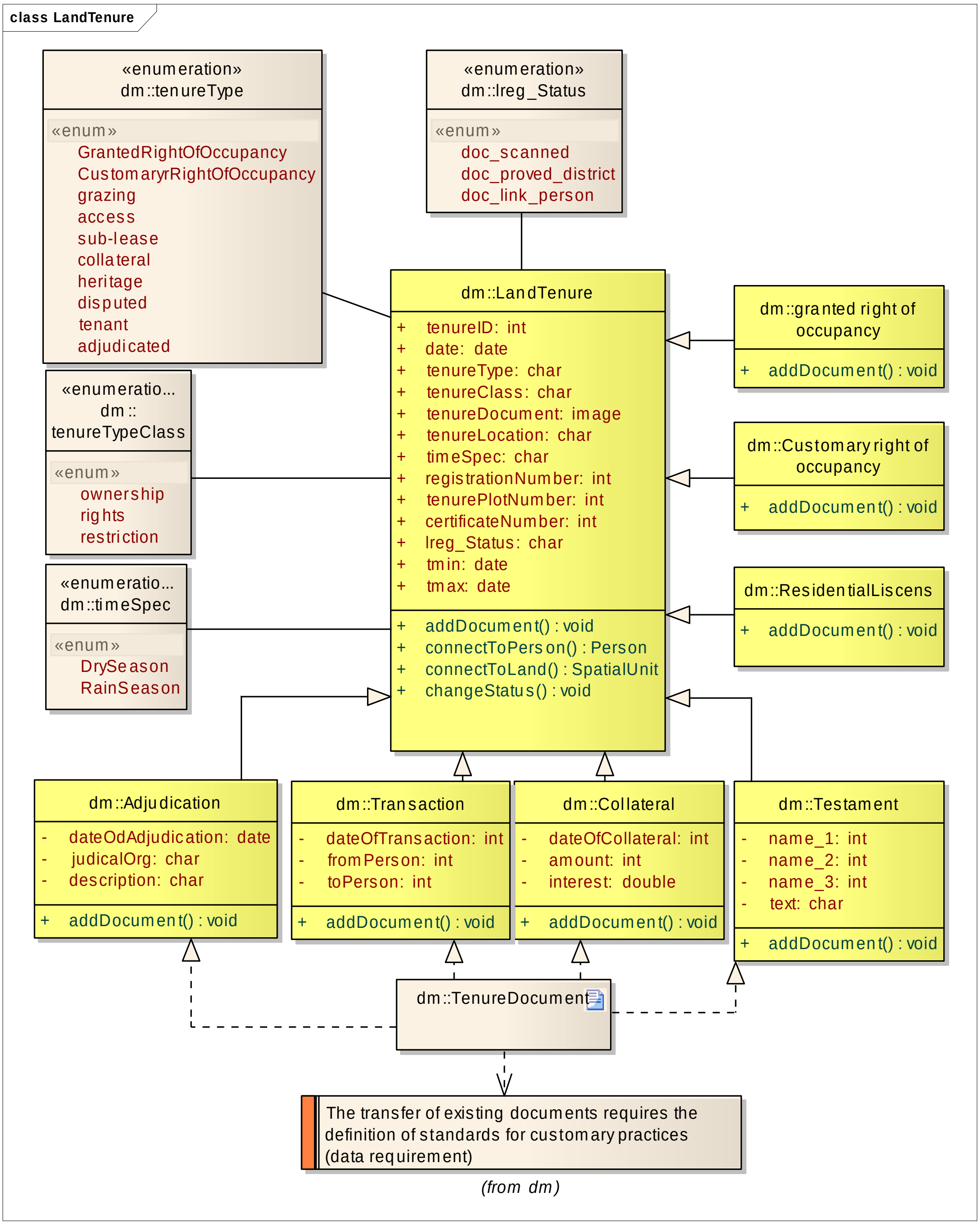

Figure 30: UML class diagram: LandTenure

5.4 ULR architecture – the distributed network

The following UML deployment model (Figure 31) describes the logical ULR architecture. The approach presented here is a modification of the architecture discussed in Huber et al. (2008).

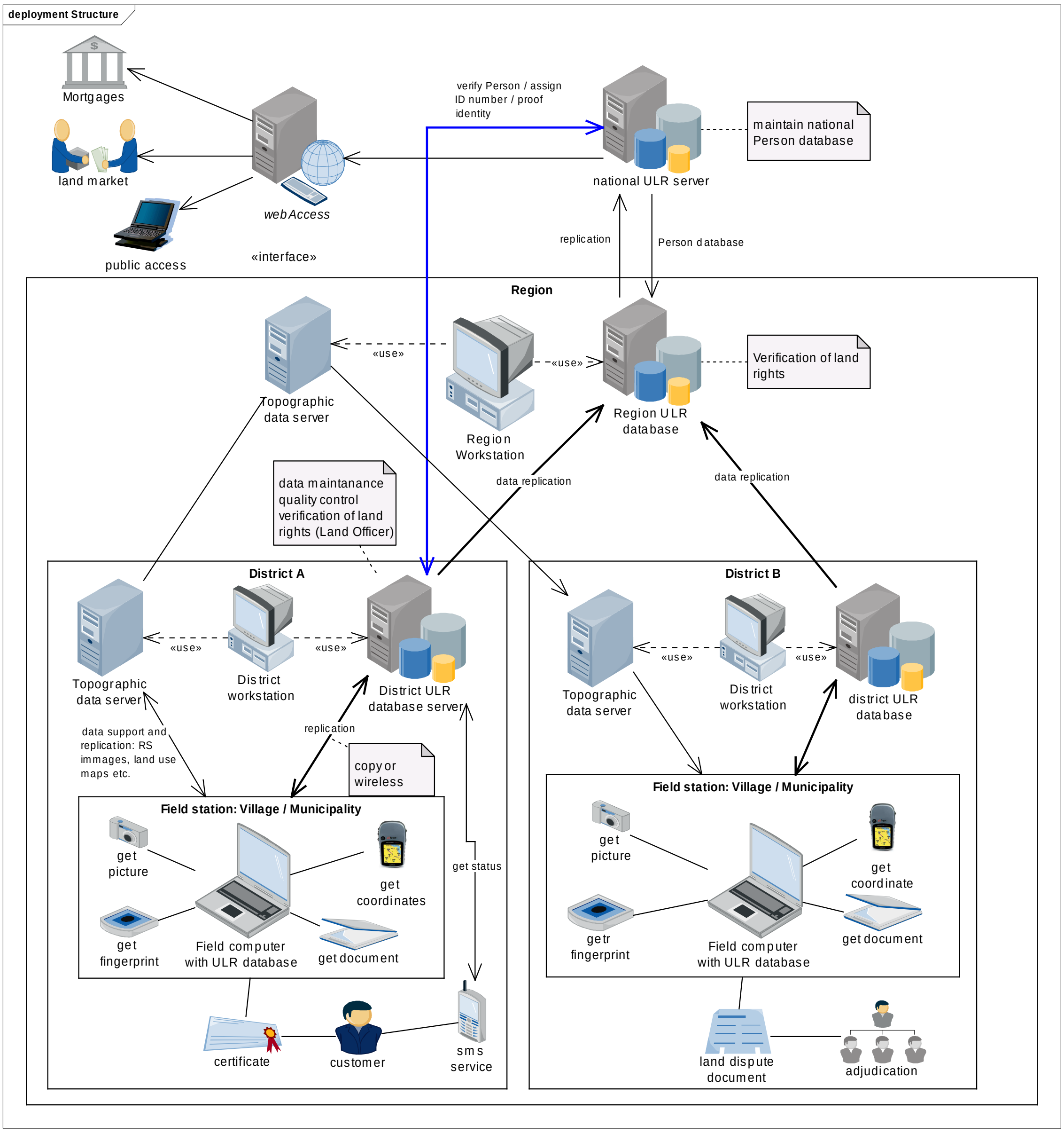

Figure 31: The ULR architecture

According to the 'Strategic Plan for the Implementation of the Land Laws' District Land Offices are the key agencies in the new land administration setup. Every District / Municipal Land Office is responsible for maintenance of data for several villages or upgrading projects (blocks). The data capture process is conducted using flexible field computers, which must be able to work offline during the registration phase. Usually, the computer stores the local database with read-write access to the local data and read only access to data of adjacent villages or districts and overlapping land rights. The topographic data and satellite images are also provided by the District Land Office. If topographic data are updated during the land registration process the data will also be transferred to the district database.

All ULR servers are based on the same database design and management system to enable data replication between the nodes from local level up to the national ULR server. Data are replicated first from the data capture unit to the district server. The District Land Officer is responsible for quality management and control of data. He also verifies land transactions and processes the application papers. After verification all data are replicated back to the local registry and to other villages / municipalities who require these data. The data will be further replicated horizontally to other districts and vertically to the regional and national ULR server.

The management of data replication is based on Lightweight Directory Access Protocol (LDAP) which allows data and user management in a distributed network (Schär 2008).

Security and traceability of transactions are maintained with AAA services that control access to all ULR applications (Huber et al. 2008). The registration of land rights always includes the verification through different persons responsible at different administrative levels to prevent misuse and corruption of the system. Fingerprints are used for authentication and identification of ULR users and personnel. Authorization works by assembling a set of attributes, which describes activities the user is authorized to perform. Accounting ensures that all transactions are traceable to minimize misuse and provide evidence in case of corruption. The use of fingerprints also offers the future option to use simple eGovernment kiosks for land administration purposes as demonstrated in the 'Bhoomi' land cadastre project in the Indian state of Karnataka (Rajasekhar 2006, State of Karnataka 2008).

All administrative levels use the ULR application as well as other GIS-clients for data management and basic data analysis. Data access is enabled through standard WFS / WMS services based on well known OGC specifications. This allows a detailed data analysis using different GIS clients and efficient data sharing between different stakeholders in land administration. This architecture additionally enables the distribution of land right information through web portals supporting public access. Institutions linked to the land marked such as microfinance organisations can be provided with information to support functioning and transparent land markets.

The deployment model also emphasises the importance of data exchange between the different administrative levels for data dissemination and the verification process. These processes are most likely negatively affected by the weak communication and/or electrification infrastructure in the rural areas. This especially affects the data exchange between local registry and District Land Office. Data replication might not be possible at any time, which may lead to delays especially in the initial phase of the formalization process during which land rights are registered en masse in campaigns.

The implementation therefore requires careful planning with well defined schedules and deadlines for replication to ensure a transparent and reliable process. The replication of data between local database and the district database should be processed at least weekly. Unconventional methods like the use of messengers carrying data storage devices might be an option to deal with weaknesses in infrastructure. The emerging mobile phone sector might be the solution to better connect rural land registries in the near future.

6 Conclusion

The use of GIS technologies provides new opportunities for land management systems especially in developing countries. Traditional cadastres base on surveyed point data of high accuracy maintained in survey databases. GIS based systems focus more on the spatial representation of existing objects through vector data with focus on spatial analysis. This functionality is very valuable to countries like Tanzania, where different land rights overlap and land disputes are frequent. Modern GIS and ICT technology therefore build the foundation for the development of the Universal Land Registry in Tanzania.

This study defines a framework for the ULR to support the formalization of land rights in Tanzania. In a first step user needs are assessed and the Tanzanian setting is evaluated to design an appropriate implementation strategy as well as to specify the functionality of the system. General recommendations for the implementation of a cadastre and experiences especially from other African countries are reviewed with special reference to unconventional approaches in surveying and cadastral design. Methods and possibilities for integrating legally and extralegally documented land rights into a GIS based system are analysed.

The development of the ULR is based on the 'Strategic Plan for the Implementation of the Land Laws', which outlines a new setup for land administration in Tanzania. The exact specification of responsibilities and management capabilities is not yet finally agreed upon in Tanzania and still under development. The proposed ULR design is therefore flexibly designed allowing its extension and adjustment. All suggested business processes are based on previous field studies conducted in Tanzania by other researchers and represent a preliminary stage. However, they highlight for example the importance of land right application management as a core function of the ULR. The pilot studies also provide insight in experience gathered in the use of GIS for cadastral database design and management in rural and urban areas.

The ULR approach requires the correct identification of persons, land right documents and land objects. The lack of national identification papers is one of the major handicaps identified in the SWOT analysis of this dissertation. The support of person identification procedures is therefore of foremost importance for the implementation of the ULR. The ULR concept proposes that all person data are maintained at national level to avoid the multiple registrations of land right owners. Frequent data exchange between local registries and the national ULR server is obligatory for the system. This could delay registration processes since the communication network coverage is incomplete especially in rural areas; however, it is deemed vital to minimize corrupt use of the system.

The existing extralegal land right documents constitute the foundation for registration of customary land rights. They usually contain all necessary information including maps and descriptions. Extralegal documents also indicate the level of security people require. Point information and polygons with a moderate accuracy seem to be an appropriate method to register land rights in rural areas and also for land of low value. However, the use of different spatial identifiers with different accuracy leads to a data model with high spatial uncertainty. This complicates the maintenance of data as well as the mapping and analysis of land rights. Further, it has to be considered, that boundaries of customary land rights such as pastoralists' grazing rights cannot be delineated very accurately along natural boundaries. Such fuzzy boundaries not only complicate the mapping of land rights; they nearly disable data analysis and overlay to assign rights and restrictions.

The functional capacity of the ULR is reduced to the required core functions for land registration and participatory mapping. It is suggested that the ULR should possess a limited capability to use and update a topographic database to support the registration of village land. This implementation strategy makes sense because the formalization process requires a complete inventory of the villages. The Handeni pilot study revealed first examples of maps. Standards for topographic data capture and mapping are urgently needed to streamline the process of land registration.

The UML modelling language allows the dynamic and functional view of the application. UML activity diagrams show the complex structure of registration processes. The registration of persons diagram highlights that frequent data and information exchange between local registries and the national database is necessary. Measures have to be taken especially during the implementation phase to minimize delay in the registration process. The registration of land rights and land objects offer different opportunities to register different kinds of land right documents. A decision tree explains how spatial data can be integrated to georeference land rights. Important is, that all relevant documents (e.g. extralegal documents, survey protocols) are transferred to attributes and scanned to keep the original document as a copy.

The ULR data model is based on the STDM developed in UML. The STDM is a specification of the CCDM, which supports modelling of land tenure relationships in developing countries with complex land rights. The ULR data model points to the importance of system metadata. The specification and classification of existing land rights is important to register land rights systematically. A categorization of survey methods, spatial accuracies and data sources is necessary to validate data for spatial analysis applications. System metadata guide the client, who uses the data for spatial analysis and land use planning. The metadata can further be used to define rules of spatial analysis so that overlapping land rights can be distinguished from disputed land. However, the implementation of the ULR requires a more detailed analysis of existing documents to define and specify system metadata and lookup tables to ensure the usability of the data for spatial analysis.

The ULR deployment model describes data replication and dissemination in the distributed ULR network. The weak communication network and unreliable electrification cause uncertainty the ULR implementation. Thus, this study proposes to carry out local registration offline, but frequent data exchange is mandatory for data verification and dissemination. Whereas the data replication between District Land Office and higher administrative levels is manageable, the major constraint can be the data transfer among local registries and districts in rural areas. Unconventional methods like the use of messengers carrying data storage devices might be an option in some areas but nevertheless, it complicates the data exchange and may lead to delays. A good LIS has to keep data up-to-date if it aims to serve a land market, which is one goal in Tanzania.

The UML diagrams, data model and the catalogued functions of the ULR developed in this thesis constitute the foundation for further application development. Schär (2008) presents in his dissertation ULR use cases, the logical view and the physical model. All UML diagrams combined deliver a view on the present stage of the ULR system development.

7 Outlook

This thesis develops a GIS-based application and architecture for a universal land registry for Tanzania. In combination with the technical specifications developed by Schär (2008) it constitutes the first project phase for the implementation of the system. As second phase a pilot study should be conducted to validate the functionality and usability of the ULR. This pilot study should encompass the following activities in order to extend the ULR approach to national usability based on national standards:

> *Customary practices*: Research extralegal archetypes in more detail and define national standards for customary practices and documentation as proposed by ILD (2005c).
>
> *Geographic names*: Develop a database containing geographic names and their nationally standardised spelling for central use by the registration unit.
>
> *Topographic mapping*: Develop standards in topographic mapping for the establishment of Village Land Use Plans.
>
> *Support of illiterate users*: Develop standardized measures (e.g. graphical visualisation of land rights) and procedures to ensure that illiterate land right owners are able to secure their land rights.

Seasonal aspects of land rights are modelled through attributes and different spatial representations. But many land rights are difficult to delineate and they further depend on weather patterns like prolonged droughts. Pastoralists for example are often forced to travel long distances with their cattle for pasture during dry seasons. The modelling of changing boundaries and fuzzy boundaries is not solved completely and requires more research during the pilot study. Further development of adequate system metadata to support the spatial analysis of such land rights is necessary.

The lack of person identification papers in Tanzania is a concern for the formalization of land rights as well as the formalisation of business transactions. Therefore, the process of person registration described in this thesis could be implemented and extended in the MKURABITA formalisation programme to support also the formalisation of extralegal and informal businesses in Tanzania.

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