The Unified Modelling Language (UML) in Cadastral System Development

Levi Shimi Mutambo
March, 2003
The Unified Modelling Language (UML) in Cadastral System Development

by

Levi Shimi Mutambo

Thesis submitted to the International Institute for Geo-information Science and Earth Observation (ITC) in partial fulfilment of the requirements for the degree of Master of Science in Geo-Information Management.

Degree Assessment Board

Chairman: Prof. Ir. Paul van der Molen
External Examiner: Dr. Ir. M. J. P.M Lemmens (Delft University of Technology)
Supervisors: Ir. Christiaan Lemmen
Arbind Tuladhar, MSc.

INTERNATIONAL INSTITUTE FOR GEO-INFORMATION SCIENCE AND EARTH OBSERVATION
ENSCHEDE, THE NETHERLANDS
Disclaimer

This document describes work undertaken as part of a programme of study at the International Institute for Geo-information Science and Earth Observation. All views and opinions expressed therein remain the sole responsibility of the author, and do not necessarily represent those of the institute.
Abstract

Cadastral Systems have been acknowledged to be a core component of land administration systems, yet they have been facing a number of challenges ranging from technological pressure to user requirement changes. On the other hand, a new modelling language, Unified Modelling Language (UML) has taken the world by storm and within a few years has become a widely accepted de facto industry standard and a draft ISO standard. The Unified Modelling Language has been described as a “Graphical language for visualising, specifying, constructing and documenting the artefacts of a software intensive system.” It is not necessarily restricted to software systems, but is intended for all application domains. Due to its wide acceptance and consequently the emerging number of UML based tools and technology and the apparent promises it seems to hold for some remedies for challenges in cadastral systems, this research was conducted to investigate what this UML really is and how it can be used in cadastral system development and the possible solutions it may have for the problems in the cadastral domain. The Zambian cadastral system was used as a basis for the evaluation - applying the UML via the GRAPPLE (Guidelines for Rapid Application Engineering) development process to address some challenges facing the cadastral surveying domain in Zambia and the challenges facing cadastral systems in general. It has been found that the emergence of the UML is more of a technological opportunity than a challenge to cadastral system development. The way it is applied in the context of a development methodology or process has been discovered through application. Its benefits to cadastral system development have been noted such as the ones arising from, its being based on the object-oriented paradigm which would lead cadastral system development benefiting from the paradigm which result in systems that are of a higher quality than the classical approaches, its being methodology independent providing the opportunity for the development of methodologies tailored for cadastral systems with their peculiar characteristics such as spatial information handling, its being widely accepted by industry opening doors for technology based on UML, which the cadastral domain may benefit from, its seamless communication in the development team and with the users gives greater probability of a cadastral system that better reflects the requirements of the users.

The UML therefore fits in well in the cadastral domain and its use in cadastral system development is bound to result in more optimal cadastral systems.

Keywords: Unified Modelling Language, Cadastral Systems, GRAPPLE, Object-oriented paradigm
Acknowledgements

First of all I give all glory and honour to the Sovereign Lord who in his mercy and grace has found it fitting that I carry out this challenging, but very interesting research. I return thanks to all his children at home, in Zambia, and in the Netherlands who relentlessly sought His face on my behalf as I laboured.

I return thanks to my parents who through their love have given me wings to reach this high in my academic progress. I give thanks to the rest of my family and friends for their love and support during my studies in the Netherlands.

Sincere thanks to my supervisors, Mr. Christiaan Lemmen and Mr. Tuladhar for their invaluable support, guidance and training in carrying out research. I also thank all the ITC staff for their individual contribution my acquiring of Geo-Information Management knowledge.

My gratitude also goes to Dr. Augustine Mulolwa for making himself available for consultation on my research topic and on the study area.

Special thanks also go Mr. Jose Santos for sacrificing his precious time of PhD research to explain some terms and concepts, which were too technical for a Geo-information Management student, but were a necessary bridge to reach the objectives of my research.

Thanks to the brethren at the students’ Christian fellowship for their encouragement and prayers.

I return thanks to the governments of The Netherlands and Zambia through whom I was able to acquire such invaluable knowledge and experience.

Thanks to you all!

L.S. Mutambo
March 2003
# Table of Contents

Abstract ................................................................................................................................................... i  
Acknowledgements ............................................................................................................................... ii  
Table of Contents ................................................................................................................................ iii  
List of Figures ....................................................................................................................................... vi  
List of Abbreviations ............................................................................................................................ viii  
1.  Introduction ....................................................................................................................................1  
   1.1. Background ............................................................................................................................1  
   1.2. Scope ......................................................................................................................................2  
   1.3. Research Objective ................................................................................................................3  
       1.3.1. Sub-Research Objectives ...............................................................................................3  
   1.4. Research Questions ................................................................................................................3  
       1.4.1. The UML and System Development ..............................................................................3  
       1.4.2. Cadastral Systems ..........................................................................................................3  
       1.4.3. Potentials of the UML ....................................................................................................3  
   1.5. Prior Work ..............................................................................................................................4  
   1.6. Research Methodology ...........................................................................................................4  
       1.6.1. Understanding the UML and its relation to System Development ..............................4  
       1.6.2. Analysis of the Cadastral System in Zambia .................................................................5  
     I. Field Work Preparation ...............................................................................................................5  
     II. Data Collection in Field through Interviews and Observations ..............................................5  
       1.6.3. Cadastral System modelling based on field work results (UML diagrams) ..................5  
       1.6.4. Analysis of the UML in Cadastral System Development ..............................................5  
   1.7. Structure of Thesis .................................................................................................................6  
2.  The UML and System Development ..............................................................................................8  
   2.1. Introduction ................................................................................................................................8  
   2.2. System Development Methodologies .....................................................................................8  
   2.3. Modelling ..................................................................................................................................9  
   2.4. Object Orientation ..................................................................................................................9  
   2.5. What is the UML? ..................................................................................................................11  
   2.6. UML views ..............................................................................................................................12  
       2.6.1. Static view ....................................................................................................................13  
       2.6.2. Use Case view .............................................................................................................13  
       2.6.3. Interaction view ............................................................................................................14  
       2.6.4. State Machine view ......................................................................................................17  
       2.6.5. Activity view ................................................................................................................17  
       2.6.6. Implementation view ....................................................................................................19  
       2.6.7. Deployment view ..........................................................................................................20
2.6.8. Management view: .................................................................20
2.6.9. Extensibility Construct ............................................................21
2.7. UML Tools .............................................................................21
2.8. UML for the Cadastral Surveying Domain View ..................22
2.9. Concluding Remarks .................................................................22
3. The Zambian Cadastral System ...............................................23
3.1. Introduction ............................................................................23
3.2. Ministry of Land ....................................................................23
3.3. Human Resources and Administration Department ...............26
3.4. Lands Department ..................................................................27
3.5. Lands & Deeds Department....................................................28
3.6. Survey Department ..................................................................29
3.7. External Organisations .............................................................32
3.7.1. Local Authorities (Councils) .................................................32
3.7.2. Land Use Planning Unit .......................................................32
3.7.3. Private Survey Firms ...........................................................32
3.7.4. Law Firms ..........................................................................33
3.7.5. Zambia Revenue Authority ................................................33
3.7.6. Utility Companies ...............................................................33
3.8. The Applicant, Leaseholder & General Public .......................34
3.9. Land Allocation Procedure ......................................................34
3.9.1. State Land ..........................................................................34
3.9.2. Customary Land (Reserves and Trust Lands) .......................35
3.10. Land Transfer .......................................................................36
3.11. Cadastral Surveying .............................................................37
3.12. Perspectives of the Cadastral System .....................................39
3.13. System Constraints (Surveyors’ Domain Perspective) ...........40
3.14. Concluding Remarks .............................................................41
4. Cadastral System Development with the UML .........................42
4.1. Introduction ..........................................................................42
4.2. GRAPPLE in Cadastral System Development ......................43
4.3. Requirements Gathering ........................................................44
4.3.1. Discover Business Process ..................................................45
4.3.2. Perform Domain Analysis ....................................................50
4.3.3. Identify Cooperating Systems ..............................................53
4.3.4. Discover Requirements ......................................................53
4.4. Analysis ................................................................................57
4.4.1. Understanding System Usage ..............................................57
4.4.2. Flesh Out Use Cases .........................................................59
4.4.3. Refine the Class Diagram ...................................................65
4.4.4. Analyse Changes of State in Objects ...................................67
4.4.5. Define the interactions Among Objects ...............................68
4.4.6. Design ...............................................................................70
4.5. Concluding Remarks .............................................................72
5. Analysis ...................................................................................73
List of Figures

Figure 1-1 Cadastral System perspectives ........................................................................................................2
Figure 1-2 Structure of Thesis ..........................................................................................................................6
Figure 2-1 Class Diagram showing Relationships ..........................................................................................13
Figure 2-2 Use Case Diagram of “Full transfer of ownership” (Tuladhar, 2002b) .............................................14
Figure 2-3 Sequence diagram for Submitting Deeds to Registration Office (Tuladhar, 2002b) ....................15
Figure 2-4 Collaboration diagram for Submitting Deeds to Registration Office ...........................................16
Figure 2-5 Statechart diagram of a parcel subdivision ...................................................................................17
Figure 2-6 Activity diagram for the process of creating a document (Tuladhar, 2002b) .................................18
Figure 2-7 Component diagram showing Applications in a Cadastral Systems ...........................................19
Figure 2-8 Deployment diagram showing an aspect of a Land Information System ..................................20
Figure 2-9 Packages of a Land Information System (LIS) model elements ...............................................20
Figure 3-1 Ministry of Lands Organisation Structure ...................................................................................24
Figure 3-2 Survey Department Organisation Structure ................................................................................30
Figure 4-1 Overview of chapter 4 showing the relationship between the two systems ................................43
Figure 4-2 Land Allocation (State Land) Activity Diagram ...........................................................................46
Figure 4-3 Land Allocation (Customary Land) Activity Diagram .................................................................47
Figure 4-4 Land Transfer Activity Diagram ................................................................................................48
Figure 4-5 Survey Activity Diagram ...........................................................................................................49
Figure 4-6 Lodgement Activity Diagram ....................................................................................................50
Figure 4-7 High-Level Class Diagram of initial Survey Objects ..................................................................52
Figure 4-8 High-Level Class Diagram of Employees ..................................................................................52
Figure 4-9 Deployment Diagram of Cooperating Systems .........................................................................53
Figure 4-10 Use Case Package for Ministry of Lands (High Level) ............................................................55
Figure 4-11 Use Case Package for Survey Department ...............................................................................55
Figure 4-12 Packages of functionality of LIMS .........................................................................................56
Figure 4-13 Use case Diagram of the Ministry of Lands ............................................................................58
Figure 4-14 Use cases Diagram of Regional Survey Office (Survey Department) ......................................59
Figure 4-15 Use case diagram for LIMS .....................................................................................................63
Figure 4-16 Detailed Package Diagram of LIMS functionality ....................................................................64
Figure 4-17 An overview of the application packages and their dependencies ..........................................64
Figure 4-18 Class Diagram of Cadastral System adapted from (Oosterom and Lemmen, 2002b) ...............66
Figure 4-19 State Diagram of Subject ..........................................................................................................67
Figure 4-20 State Diagram of Object ..........................................................................................................67
Figure 4-21 State Diagram of Site Plan .........................................................................................................67
Figure 4-22 Sequence Diagram for “Grant Survey Approval” use case ......................................................69
Figure 4-23 Deployment Diagram of proposed system architecture ...........................................................70
Figure 4-24 Proposed Activity Diagram for Lodgement .............................................................................71
Table 3-1 Ministry of Lands’ Clients and their general needs.............................................................25

Appendix A: Object Oriented Methodologies Graphical Notations.........................81
Appendix B: Land Circular No. 1 of 1985.................................................................88
Appendix C: Class Relationships.............................................................................92
### List of Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CASE</td>
<td>Computer Aided Software Engineering</td>
</tr>
<tr>
<td>CL</td>
<td>Commissioner of Lands</td>
</tr>
<tr>
<td>CR</td>
<td>Chief Registrar</td>
</tr>
<tr>
<td>Geo-ICT</td>
<td>Geo-Information &amp; Communication Technology</td>
</tr>
<tr>
<td>GIS</td>
<td>Geographic Information Systems</td>
</tr>
<tr>
<td>GUI</td>
<td>Graphical User Interface</td>
</tr>
<tr>
<td>GRAPPLE</td>
<td>Guidelines for Rapid Application Engineering</td>
</tr>
<tr>
<td>SG</td>
<td>Surveyor General</td>
</tr>
<tr>
<td>LIMS</td>
<td>Land Information &amp; Management System</td>
</tr>
<tr>
<td>MOL</td>
<td>Ministry of Lands</td>
</tr>
<tr>
<td>MDA</td>
<td>Model Driven Architecture</td>
</tr>
<tr>
<td>OMG</td>
<td>Object Management Group</td>
</tr>
<tr>
<td>OO</td>
<td>Object Orientation</td>
</tr>
<tr>
<td>UML</td>
<td>Unified Modelling Language</td>
</tr>
<tr>
<td>WAN</td>
<td>Wide Area Network</td>
</tr>
</tbody>
</table>
1. Introduction

1.1. Background

Cadastral systems have been acknowledged to be a core component of land administration systems and an important infrastructure, which facilitates the implementation of land policies (Williamson, 2002). The Cadastre 2014 (Kaufmann and Steudler, 2001) recognises that the tremendous technological progress, social change, globalisation and increasing interconnection of business relations with their legal and environmental consequences have put a strain on traditional cadastral systems. Their research reveals that they cannot adapt to all these developments as indicated by the many reforms that they are going through. In their article on the impact of recent Geographic Information & Communication (Geo-ICT) developments on cadastral systems, Oosterom and Lemmen (Oosterom and Lemmen, 2002), recognise the technologies not just as a challenge to existing systems, but more positively an opportunity created for development of more optimal new systems and improvement of the existing ones.

Among the technological developments is the Unified Modelling Language (UML). The UML has progressively become a de facto industry standard for modelling in the world of software system development. It seems to hold promise for some remedies to cadastral system development. Although the UML has been designed by and mainly for software engineers, “You can use UML for business modelling and modelling of other non-software systems too” (Object Management Group, 2002). It has been described, as a “Graphical language for visualising, specifying, constructing and documenting the artefacts of a software intensive system” (Booch et al., 1999). Many authors and system developers have highly recommended it as a modelling language that enables effective representation of a system by providing relevant views of the system to respective participants/stakeholders in its development and subsequent operation (Schmuller, 1999). Its popularity has been heightened by its being based on object technology, which is said to have many benefits in system development including the integration of data and processes (Hawryszkiewycz, 2001). Schmuller further says that with the UML, the stakeholders in system development i.e. the Clients, Users, Analysts and Developers are able to more accurately view the various aspects of the design view of the system beforehand thus enabling them to make necessary adjustments before deployment and also make it easier for future modifications.

The tools, such as Rational Rose and Microsoft Visio, that have been developed to support the UML may prove it to be useful even in the post deployment period vis-à-vis maintenance and upgrade of information systems.

It is in the light of such apparent promises that the UML seems to give and its emerging popularity, that this research has been undertaken to make an evaluation of the UML’s place in and the contribution it makes to cadastral system development.
In this thesis Cadastral System is defined as a system that includes Land Allocation, Land Registration, Cadastral Surveying & Mapping and the Land Information System that supports these activities.

A cadastral system can be looked at from at least four perspectives: Institutional, Domain experts’, Business and the Geo-ICT perspective (see Figure 1-1). This research will, therefore, evaluate the UML in cadastral system development in the context of the above perspectives.

When one looks at the institutional view of the system, the main concern is, as van der Molen has informally described, “the rules of the game”, whose players are the “organisations” (Molen, 2002). The domain experts’ perspective is the eye of the professionals in the environment in which the system being developed works, in this case lawyers, surveyors and registrars. Looking at the cadastral system from a business point of view is focusing on the processes and satisfaction of the customer’s need. The Geo-ICT perspective focuses on the technology that handles the information, both spatial and non-spatial.

Figure 1-1 Cadastral System perspectives

1.2. Scope

This research deals with two main subjects; the UML - an emerging modelling standard, and the Zambian cadastral system, focusing on the cadastral surveying domain, which mainly handles spatial information. The research endeavours to show the usage of the UML in cadastral system develop-
ment; it is not intended to result in a fully functional system, but to show the UML usage in the development process from analysis to a proposed solution.

1.3. **Research Objective**

The objective of this research is to determine how the UML can be used in Cadastral System Development and the potentials it holds.

1.3.1. **Sub-Research Objectives**

In order to achieve the main objective the following sub objectives are to be achieved:

i. To study the UML and its relation to system development (*UML Diagrams: Class Diagrams, Use Case Diagrams, State Transition Diagrams, Activity Diagrams, etc.*)

ii. To determine the operations of the cadastral system in Zambia and the challenges it faces.

iii. To consider the match between the challenge of developing a cadastral system and the UML’s support for the task.

1.4. **Research Questions**

1.4.1. **The UML and System Development**

i. What exactly is the UML?

ii. What are its major features?

iii. How does it relate to system development methodologies?

1.4.2. **Cadastral Systems**

i. What is a Cadastral System?

ii. What are the operations of Zambian Cadastral System?

iii. What are the challenges being faced by the cadastral system in Zambia?

1.4.3. **Potentials of the UML**

i. What are the potentials of the UML in cadastral system development?

ii. How does the task of developing a cadastral system compare with the UML’s support for the task?
1.5. Prior Work

Since the advent of the UML in the area of software development, other domains have began either testing its usage for their specific areas of operation or straightaway applying it and in the process discovering its usefulness and limitations, possibly due to the indications given by the Object Management Group of its usefulness in other application domains.

Kwon has used the UML in the redesign of Topographic mapping systems (Kwon, 2002). His focus was on re-designing of existing Topographic Mapping systems to one that takes advantage of the recent developments in ICT to meet the increasing diversity of customer needs.

Rutakyamirwa has also used the UML in business process modelling in distributed environment (Rutakyamirwa, 2002). Her focus was on performance improvement by modelling and she used the UML as the modelling tool.

Research has been carried in the cadastral domain as well, but using modelling notations other than the UML. A case in point is (Chimhamhiwa, 2001) who carried out performance analysis of the cadastral process in Zimbabwe focusing on the challenges of cross-organisational oriented processes. He modelled the various processes in the cadastral domain with a different modelling technique/graphical notation.

Tuladhar in his paper introduced the uses of the UML for describing cadastral information systems in terms of static and dynamic models (Tuladhar, 2002b).

This thesis builds on these ideas in the context of a system development process and based on a case study evaluating the UML for the Zambian case. It also addresses the significance of the UML’s emergence as a standard in cadastral system development.

1.6. Research Methodology

The approach for executing the research was to carry out the evaluation of the UML, based on the Zambian cadastral system, by following the system development process and seeing how the UML fits into the phases of the process as constraints are identified and solutions are proposed. And so the Zambian cadastral system was analysed in terms of its purpose, structure, processes, stakeholders/users & their requirements and the policies that regulate the system. This was preceded by a study of the UML, its features and concepts and based on the features and concepts and the significance of its standardisation to cadastral system.

1.6.1. Understanding the UML and its relation to System Development

Literature review was done to understand the UML and its relation to system development. An outline of system development methodologies is given in order to appreciate where the UML fits in and their relevance to cadastral system development. This was in answer to the questions raised in 1.4.1.
1.6.2. Analysis of the Cadastral System in Zambia

Field study was carried out in order to analyse the cadastral system in Zambia so as to provide a basis for the evaluation of the UML. The analysis was done with a view of identifying some constraints, particularly in the cadastral surveying domain, and propose some solutions. This effort was meant to deal with the issues raised in 1.4.2.

An Object-Oriented System development methodology was to be chosen and used to provide a guideline for steps to take, but not proceeding to implementation, which have required more time.

I. Field Work Preparation

Preliminary identification of stakeholders, preparation of questionnaire/interview guide and other logistical arrangements.

II. Data Collection in Field through Interviews and Observations

This task was executed in order to analyse the existing system and determine its purpose, structure, processes, stakeholders/users and their requirements and policies that regulate the system.

1.6.3. Cadastral System modelling based on field work results (UML diagrams)

The Zambian cadastral system was modelled based on the fieldwork results. The modelling was based on a chosen development process – Guidelines for Rapid Application Engineering (GRAPPLE).

1.6.4. Analysis of the UML in Cadastral System Development

Analysis of the results of the study of the UML and its application to cadastral systems was carried out so as to address questions raised in 1.4.3.
1.7. **Structure of Thesis**

The thesis is organised into six chapters and they are organised as follows:

![Diagram of thesis structure]

**Figure 1-2 Structure of Thesis**

**Chapter 1** introduces the research background, the research problem, objectives and research questions as well as the methodology used to achieve the objectives. It also includes summaries of prior research related to the UML and the cadastral domain.

**Chapter 2** gives an introduction to the UML and its relation to development methodologies. It goes on to put the UML in proper context by explaining the importance of modelling. It further gives a brief introduction to the object-orientation paradigm on which the UML is based. It also includes a note on the tools that are emerging along with the UML to support its use and ends with highlights of the UML’s relation to the cadastral surveying domain.

**Chapter 3** gives an overview of the cadastral system in Zambia based on fieldwork. It includes the purpose, structure, processes and stakeholders/users with their requirements. It goes into some detail on three processes of the cadastral system in the context of which the cadastral surveying domain falls i.e. Land Allocation, Land Transfer and Cadastral Surveying. It goes on to describe some constraints in the cadastral surveying domain. This chapter is the basis on which the models in chapter 4 were developed.
Chapter 4 seeks to bring the UML and the cadastral system together i.e. using the UML to describe the Zambian cadastral system and also to model proposed solutions to the constraints identified in chapter 4. The modelling or development process is carried out with the guidance of GRAPPLE – a development process and so in the process of modelling GRAPPLE is introduced and applied.

Chapter 5 considers, in detail, the UML in order to discover its essential features and their applicability to cadastral system development and benefits for the cadastral domain. This analysis is done from two perspectives - The UML’s artefacts and the UML’s being an emerging standard.

Chapter 6 summarises the conclusions drawn from the research and makes recommendations for future research.
2. The UML and System Development

2.1. Introduction

This chapter reviews concepts of the UML and its relation to system development methodologies. The UML being a modelling language has prompted the inclusion of a section on modelling in general, followed by a brief description of the Object-Oriented paradigm on which the UML is based. This section includes advantages of Object-Oriented System development methodologies compared to the Structural approach. And finally, the UML proper - its concepts and diagrams or artefacts, is addressed.

2.2. System Development Methodologies

A methodology can be defined as a collection of procedures, techniques, tools, and documentation aids which will help the system developers or business users in their efforts to implement a new information system (Avison and Fitzgerald, 1995). Avison and Fitzgerald, have added that a methodology consists of phases and sub-phases that guide the system developers in their choices of techniques that might be appropriate at each stage of the project and also help them plan, manage, control and evaluate information systems projects. A methodology represents a systematic way of developing an information system.

In the past information systems had been developed in a haphazard way with little or no documentation. Little attention was given to a proper understanding of the environment in which the system was being developed and the actual needs of the users. (Avison and Fitzgerald, 1995) have attributed this to the fact that system development was initially spearheaded by programmers who were not necessarily the best of communicators, a quality which is critical in transforming the needs of clients into appropriate systems to support their work processes. This led to systems that were technologically excellent, not adequately meeting the needs of the user and were very difficult to maintain due to the lack of proper documentation. Over the years the need of procedures and proper documentation was realised leading to a wide variety of and categories of methodologies. Some of the categories are: Soft Systems Methodologies, Structured System Methodologies, and Object-Oriented System Development Methodologies.

Now that Object-Oriented System Development methodologies have come with their advantages over the traditional or classic methodologies, it is expected that they will take the centre stage in the development of new cadastral systems. The UML as noted earlier is based on the Objected Oriented paradigm, which makes this subject of importance in this thesis. But before an introduction of the paradigm is made the following section will discuss modelling in general since it is an important commu-
nication tool in system development methodologies and specifically because the UML is actually a modelling tool.

2.3. Modelling

Simply put, “A model is a simplification of reality” (Booch et al., 1999). Expressed differently, a model is a representation capturing the important aspects of a certain point of view of reality simplifying or omitting the rest (Rumbaugh et al., 1999). Models are built to enable better understanding of a system as it is or the system being developed and the larger and more complex the system, the more important modelling becomes as it provides a means of understanding an otherwise incomprehensible system.

Models are meant to capture and precisely state requirements and knowledge to enable stakeholders understand and agree on them. They enable one to think about the design of a system and also open the possibility of exploring multiple solutions and master complex systems. Models consist of two major aspects (Rumbaugh et al., 1999) vis-à-vis semantic information (semantics) and visual representation (notations). The semantic aspect capturing the meaning of an application as a network of logical constructs such as classes, associations, states, use-cases, and messages, while the visual representation showing semantic information in a form that can be seen browsed and edited by humans.

(Booch et al., 1999) have summarised the aims of modelling as follows:

1. To visualise a system as it is or as we want it to be.
2. To enable us specify the structure or behaviour of a system.
3. To give us a template that guides us in constructing a system.
4. To document the decisions we have made.

There are two common approaches to modelling (Booch et al., 1999). The first is the algorithmic approach, which is the traditional one - Its main building blocks are procedures and functions. It deals with performing actions on data, focusing on issues of control and decomposition of larger algorithms into smaller ones (Functional decomposition). This approach results in systems that are brittle: very hard to maintain as requirements change and as the system expands. The second one is the Object-oriented approach whose main building blocks are objects or classes. This approach enables the modelling of all real world objects, which include processes, data, software and people. This is the approach discussed in the next section.

2.4. Object Orientation

Object orientation is a special approach to the construction of models of complex systems, in which a complex system is regarded as a set of objects (Jacobson et al., 1994) - the system consisting of a large number of occurrences. The relations between these occurrences are referred to as associations and their properties as attributes of the objects. The occurrences are also seen as having both static and dynamic characteristics and the occurrence that affects another when certain events take place is described as communication between the objects.
Object orientation sure has taken not just the software world by storm as (Schmuller, 1999) has acknowledged, but also the non-software world. Yes it has originated from the software world (Jacobson et al., 1994), but other disciplines are endeavouring to make use of its advantages. The object-oriented technique has been used to describe both organisations and systems constructed entirely of hardware. With respect to creating programs, (Schmuller, 1999) says it fosters a component-based approach to software development allowing the development of a system by first creating a set of objects. This approach makes it possible to expand the system by adding capabilities to components you have already made or by adding new components as opposed to having a monolithic system, which is difficult and is costly to maintain and improve.

Object orientation also allows reusing of the objects you create for the system when you build a new system, thus cutting down on system development time. (Schmuller, 1999) further says that the UML having been designed from the Object orientation approach allows you to build easy-to-use and easy-to-understand models of objects so that programmers can create them in software. The programmers are given a head start in their work by the modelling tools that have been developed.

Below are the key features of Object Orientation as described by the Object Management Group (Yourdon, 1994):

**Abstraction:** which defines a relationship between a group of object types such that one object type represents a set of characteristics, which are shared by other object types.

**Encapsulation:** which implies the packaging of operations and data together into an object type such that the data is only accessible through its interface.

**Reuse:** which is the ability to reuse object types during the design of a system and object classes within the implementation of a system.

**Specialisation:** which occurs when an object type inherits operations, attribute types and relationship types from one or more supertypes (with possible restrictions).

**Object communication:** which, in object orientation systems, takes the form of one object sending requests to other objects.

**Polymorphism:** which occurs when an operation can apply to several types. There are two main forms of polymorphism:

- Inherent polymorphism: where operations are inherited by every subtype
- Ad hoc polymorphism: where different operations on different types have the same name.

Further arguments for object-oriented methodologies against structured methodologies are summarised below (Yourdon, 1994):

- Structured methodologies separate the process (function) model from the data model and since the two models are often developed by separate teams of people, using separate CASE
tools. This results in a problem when it comes to combining the two. The models are found to be incompatible and contradictory.

- Productivity and speed: Object-oriented projects are said to achieve dramatically higher levels of productivities than older methodologies because of their extensive reuse of classes and objects. Reuse is regarded as the silver bullet of technologies for higher productivity through the libraries of classes and objects and in particular through the concept of inheritance.

- Prototyping: The classical waterfall methodology, in which the life-cycle activities are carried out sequentially over a long period of time, is typically ignored in object-oriented projects, which have an iterative approach. The iterative approach does not wait for the completion of one phase say, analysis, before moving to the next say, design and coding and subsequent testing. This enables quicker presentation of the prototype to all the parties involved in the development and so correction of errors can be made earlier and would therefore result in less cost.

- Quality: The aspect of quality addressed here is the absence of defects. Proponents of the Object-oriented approach argue that systems based on this approach are more likely to be error free and if they are to degrade, they would degrade more gracefully using the encapsulation feature through which objects can respond to messages by simply expressing their inability to process the message.

- Maintainability: Rather than basing the overall architecture of the system on the hierarchy of functions (which tends to be rather volatile, as end users change their ideas about what functions they want the system to carry out), the architecture is based on a network of collaborating object. Because of encapsulation, an object can be replaced with a new implementation without affecting the other objects.

Having put the UML into context, its concepts will now be discussed in the following section.

2.5. What is the UML?

The Unified Modelling Language (UML) maybe defined as a general-purpose visual modelling language for specifying, visualising, constructing and documenting the artefacts of a software system (Rumbaugh et al., 1999). It captures decisions and understanding about systems that must be constructed. It is used to understand, design, browse, configure, maintain, and control information about such systems. While most modelling notations have been associated with development methods (Brinkkemper et al., 1995), the UML is intended for use with all object-oriented development methods, lifecycle stages, application domains, and media. It is intended to be supported by interactive visual modelling tools that have code generators and report writers. As alluded to above, the UML does not define a standard process but is instead intended to be useful with an iterative development process.

Literature on the UML seems to always endeavour to point out that UML is a language and not a method. This emphasis must be due to the background of methods being associated with modelling languages. (Fowler and Scott, 1999) point out that most methods consists, at least in principle, of both a modelling language and a process, explaining that the modelling language is the notation that methods use to express designs while the process is their advice on what steps to take in doing the design.
Some of the existing object-oriented processes /methods are:

i. Object-Oriented Analysis (OOA) and Object-Oriented Design (OOD) by Coad and Yourdon,
ii. Object-Oriented Analysis Design (OOAD) Martin & Odell
iii. The Object Modelling Technique (OMT) by Rumbaugh et. al.
iv. Object-Oriented Software Engineering (OOSE) by Jacobson et. al.
v. Object-Oriented Analysis and Design with Applications (OOADA) by Booch
vii. Guidelines for Rapid Application Engineering (GRAPPLE) by (Schmuller, 1999).

Among the above, only the Rational Unified Process and GRAPPLE are designed with the UML specifically in mind, as for the others, a sample of their respective graphical notations (Brinkkemper et al., 1995) can be seen in Appendix A.

The goals stated by the designers of the UML are (Eriksson and Penker, 1997):

i. To model systems (and not just software) using object-oriented concepts.
ii. To establish an explicit coupling to conceptual as well as executable artefacts.
iii. To address the issues of scale inherent in complex, mission-critical systems.
iv. To create a modelling language usable by both humans and machines.

Since its introduction in November 1997, it has become the de facto standard modelling language for software development. Although, here and there, there is a mention of the application of UML for non-software systems as well, one reading through the literature on the UML is still left wondering to what extent it can be used outside software development. Thanks to (Penker and Eriksson, 2000) who have given a demonstration of its usefulness in modelling businesses, particularly the benefits of having the business modelled in the same language as the information systems that support the business. This practically exposes other perspectives of its use and gives motivation for application in the cadastral domain.

### 2.6. UML views

The UML concepts and constructs have been divided into several views (Rumbaugh et al., 1999) with each view presenting a different aspects of a system. A complete picture of the system can be achieved by combining all the views.

At top-level views have been divided into three areas:

i. **Structural Classification** - describing the things in the system and their relationships to other things. Classifiers include use-cases, components and nodes. They provide the basis on top of which dynamic behaviour is built. Classification views include the **static view, use-case view, and implementation view**.

ii. **Dynamic Behaviour** - describes the behaviour of a system over time. Behaviour being described as a series of snapshots of the system drawn from the static view. Dynamic behaviour views include the **state machine view, activity view, and interaction view**.

iii. **Model Management** – Model management describes the organisation of the models themselves into hierarchical units. The package is the organisation unit for the models. Special
packages include models and subsystems. The model *management view* crosses the other views and organises them for deployment work and configuration control.

### 2.6.1. Static view

The static view models concepts in the application domain, as well as internal concepts invented as part of the implementation of an application. *This view is static because it does not describe the time-dependent behaviour of the system, which is described in other views.*

The static view mainly consists of classes and their relationships: association, generalisation, and dependencies of various kinds. A class is referred to as the description of a concept from the application domain or the application solution. Classes and objects model what it is in the system we are trying to describe. The static view is displayed in *class diagrams.*

A class is represented by a rectangle, divided into three compartments: The name compartment, the attribute compartment and the operations compartment as shown in Figure 2-1. The relationship types are shown in Appendix C.

![Figure 2-1 Class Diagram showing Relationships](image)

### 2.6.2. Use Case view

The use case models the functionality of the system as perceived by outside users, called *actors.* They describe what a new system should do or what an existing system already does.

The purpose of the use case view is to list the actors and use cases and show which actors participate in which use case. The use case view is displayed in *use case diagrams.*
The primary components of a use case model are use cases - represented by an ellipse, actors – represented by a stick figure and the system modelled – represented by a box as shown in figure 2-2.

Figure 2-2 Use Case Diagram of “Full transfer of ownership” (Tuladhar, 2002b)

2.6.3. Interaction view

The interaction view describes sequences of message exchanges among roles (or objects) that implement behaviour of a system.

A classifier role is the description of an object that plays a particular part within an interaction, as distinguished from other objects of the same class. This view provides a holistic view of the behaviour in a system—that is, it shows the flow of control across many objects.

The interaction view is displayed in two diagrams focused on different aspects: sequence diagrams and collaboration diagrams.
i. A **Sequence Diagram** shows a set of messages arranged in time sequence. Each classifier role is shown as a lifeline. One use of a sequence diagram is to show the behaviour sequence of a use case. *When the behaviour is implemented, each message on a sequence diagram corresponds to an operation on a class or event trigger on a transition in a state machine.*

Sequence diagrams consist of two axes: a vertical axis showing **time** and a horizontal axis showing a set of **objects**. On the horizontal axis are objects, represented by rectangles with the respective object and/or class name underlined. While on the vertical axis are dashed lines extending downwards from each object. This line is referred to as the object’s **lifeline**. Along each lifeline is a narrow rectangle called an **activation** representing an execution of an operation the object carries out. The length of the rectangle indicates the activation’s duration (see figure 2-3).

![Sequence Diagram](image)

**Figure 2-3** Sequence diagram for Submitting Deeds to Registration Office (Tuladhar, 2002b)
Symbols for Messages in sequence diagram:

- **Simple:** A simple message transfer of control from one object to another.
- **Synchronous:** If an object sends a synchronous message, it waits for an answer to that message before it proceeds with its business.
- **Asynchronous:** If an object sends a message it does not wait for an answer before it proceeds.

ii. A collaboration diagram models the **objects and the links** that are meaningful within an interaction. The objects and the links are only meaningful in the context provided by the interaction. A **classifier role** describes an object and an **association role** describes a link within collaboration. A collaboration diagram shows the roles in the interaction as a geometric arrangement (or spatial layout). One use of a collaboration diagram is to show the implementation of an operation.

Collaboration diagrams are drawn in the same way as classes, but their names are underlined and they do not have the compartments that classes have. The links are shown with lines, which, look like associations. A message can be attached to the link defining among other things, a sequence number for the message (see figure 2-4).

![Collaboration Diagram for Submitting Deeds to Registration Office](image)
Both sequence diagrams and collaboration diagrams show interactions, but they emphasise different aspects.

A **sequence diagram** shows *time sequence* as a geometric dimension, but the relationships among roles are implicit (Implied or understood though not directly expressed). A **collaboration diagram** shows the *relationships among roles* geometrically (i.e. in space) and relates messages to the relationships, but time sequences are less clear because they are implied by the sequence numbers. Each diagram should be used when its main aspect is the focus of attention.

### 2.6.4. State Machine view

A state machine models the possible life histories of an object of a class. A state machine contains states connected by transitions. Each state models a period of time during the life of an object during which it *satisfies certain conditions*. When an **event** occurs, it may cause the firing of a **transition** that takes the object to a new state. When a transition fires, an action attached to the transition may be executed. State machines are shown as **state chart diagrams**.

State chart diagrams have a starting point and an end point. The starting point, which is the initial state is shown by a solid filled circle and the end point or final state is shown by a circle surrounding a smaller solid circle (a bull’s eye). A state is represented by rectangle with rounded corners and between the states are state transitions represented a line with an arrow from one state to another. This transition may be labelled with the event that is causing the change of state (see figure 2-5).

![Statechart diagram of a parcel subdivision](image)

**Figure 2-5 Statechart diagram of a parcel subdivision**

### 2.6.5. Activity view

An activity graph is a variant of a state machine and their purpose is to capture actions (or work and activities) that will be performed and their results in terms of object state changes. The states in the activity diagram (called action states or activity state) transition to the next stage directly when the action in the state is performed (without specifying any events as in the normal state diagram). The other way in which the activity diagram differs from the state diagram is in the sense that their activities can be placed in groups, with respect to who is responsible for them or where in an organisation they take place. These groups are referred to as **swimlanes**.
An activity graph describes both **sequential** and **concurrent** groups of activities. Activity graphs are shown on **activity diagrams**. Although activity diagrams are typically used to describe activities performed in an operation, they can also be used to describe other activity flows, such as a use case or an interaction.

Activity diagrams consists of a start point, shown by a solid filled circle, an end point shown by a circle surrounding a small solid circle, the activity states shown as rectangles with rounded corners and lines with an arrow from one activity state to another (see figure 2-6).

---

**Figure 2-6 Activity diagram for the process of creating a document (Tuladhar, 2002b)**

A diamond shaped symbol is used to show a decision point.

Bold lines show forks and joins of control to demonstrate a transition that is divided into several branches and the unification of the branches respectively.
2.6.6. **Implementation view**

The implementation view is the first of the two so-called Physical views, the other being the Deployment view. The views considered thus far model the concepts in the application from a logical viewpoint. The physical views model the implementation structure of the application itself, such as its organisation into components and its deployment onto run-time nodes. These views provide an opportunity to map classes onto implementation components and nodes.

The implementation view models the components in a system – that is, the software units from which the application is constructed - as well as the dependencies among components so that the impact of a proposed change can be assessed. It also models the assignment of classes and other model components. The implementation view is displayed on **component diagrams**.

The component diagram’s main icon a **rectangle** that has **two smaller rectangles** overlaid on its left side, with the name of the component written inside the large rectangle (see figure 2-7).

A **small circle** with a name is an interface – a coherent set of services.

A **solid line** from a component to an interface indicates that the component provides the services listed in the interface.

A **dashed arrow** from a component to an interface indicates that the component requires the services provided by the interface.

![Component diagram showing Applications in a Cadastral Systems](image-url)

**Figure 2-7 Component diagram showing Applications in a Cadastral Systems**
2.6.7. Deployment view

The Deployment view is the second of the Physical views. It represents the arrangement of run-time component instances on node instances. A node is a run-time resource, such as a computer, device, or memory. This view permits the consequences of distribution and resource allocation to be assessed. The deployment view is displayed on deployment diagrams.

A cube represents a node in UML. The components deployed on the node may be drawn inside the node as shown in figure 2-8.

![Deployment Diagram](image)

Figure 2-8 Deployment diagram showing an aspect of a Land Information System

2.6.8. Management view:

The model management view models the organisation of the model itself. A model comprises a set of packages that hold model elements, such as classes, state machines, and use cases. Packages may contain other packages: therefore, a model designates a root package that indirectly contains all the contents of the model.

![Package Diagram](image)

Figure 2-9 Packages of a Land Information System (LIS) model elements
Packages are units for manipulating the contents of a model, as well as units for access control and configuration control.

A model is a complete description of a system at a given precision from one viewpoint. There may be several models of a system from various viewpoints - for example, analysis model as well as a design model. A model is a special kind of package.

A subsystem is another special package. It represents a portion of a system, with a crisp interface that can be implemented as a distinct component.

2.6.9. Extensibility Construct

UML includes three main extensibility constructs: constraints, stereotypes, and tagged values.

A constraint is a textual statement of a semantic relationship expressed in some formal language or in natural language. Constraints are useful for making statements that can be expressed in text language but which are not directly supported by UML constructs.

A stereotype is a new kind of model element devised by the modeller and based on an existing kind of model element.

A tagged value is a named piece of information attached to any model element. Text values are especially useful for project management information and for code generation parameters. Most tagged values would be stored as pop-up information within an editing tool and would not usually be displayed on printed pictures.

These constructs permit many kinds of extensions to UML without requiring changes to the basic UML metamodel itself. They are used to create tailored versions of the UML for an application area.

2.7. UML Tools

The UML is a complex and extensive language—not in the sense of difficulty of use, but in the degree of development. Therefore using it as a modelling technique requires the support of tools (Eriksson and Penker, 1997). While initial stages of modelling may begin on paper (or manually), the work of maintaining, synchronising, and consistency checking of the diagrams is almost impossible without a tool. Among the functionalities of a modern CASE tool are; the support for drawing diagrams, translation of all information in the model into code skeletons (code generation) providing a head start to the implementation phase and reading existing code and producing models from it (reverse engineers), making it possible for the developer to iterate between working in the modelling tool and programming.

With the acceptance of UML, a new generation of tools and processes that use UML have also emerged. Among the modelling tools or CASE tools that have implemented support for the language are Rational Rose, Together, Visio and ArgoUML.
2.8. UML for the Cadastral Surveying Domain View

As mentioned in the first chapter, the cadastral system can be viewed from the institutional perspective, the Geo-ICT perspective, the business perspective and the domain experts’ perspective. The domain experts are the ones at the operational level using their expertise to carry out the business, which is defined at the institutional level, using the Geographical Information & Communication Technology to support their work. In this thesis it is the surveyors’ or cadastral surveying domain among domain experts, which is the point of focus and so the evaluation of the UML will be based mainly on its use in this domain.

The cadastral surveying domain is the domain in the cadastral system that is responsible for the production of spatial information. It has its own procedures and techniques for systematic collection, updating, processing and distribution of spatial data.

There are aspects of the UML when used in cadastral system development, which are bound to result in more optimal systems, as subsequent chapters will endeavour to show. The mere standardisation in itself is a breakthrough with respect to system development. Because of its standardisation, more opportunities are emerging from the perspective of tools for development, options of methodologies (since it is methodology independent) and development of flexible systems i.e. systems, which can put up with the fast changes in technology and user requirements. The OMG’s Model Driven Architecture (Object Management Group, 2002) is the concept that promises this flexibility.

The Model driven Approach (MDA), envisions systems that will be able to cope with the fast changes in technology specifically in communication standards. It is said to divorce implementation details from business functions, thus it will not be necessary to repeat the processes of modelling an application or system’s functionality and behaviour each time a new technology is introduced. But what is the role of UML in the MDA? Every application using the MDA is based on normative, Platform-Independent Model (PIM) which is in UML. This is where its being universally accepted (or its being a standard) comes out most strongly. MDA has used it to enable the creation of applications that are portable across and interoperable naturally across a broad spectrum of systems. Now a cadastral system modelled with the UML will harvest from what the OMG is sowing in the field of interoperability technology.

2.9. Concluding Remarks

The UML has been developed from software system development, but the aim was to make it usable for all application domains and including non-software systems. In itself it is independent of methodologies, giving systems developers a wider range of methodologies to select from at the same time benefiting from the communication power it offers for all stages of system development and their respective participants. This combination of qualities is bound to result in more optimal systems. As (Penker and Eriksson, 2000) has explored, the UML makes it possible to model the entire business, the information systems that support it and the software applications that enables the information system to operate.
3. The Zambian Cadastral System

3.1. Introduction

Having reviewed the concepts of the UML, this chapter proceeds to discuss the cadastral system in Zambia, which carries out land allocation, cadastral and land registration activities. The Zambian case will provide the basis for the evaluation of the UML for cadastral systems. Since the Ministry of Lands (MOL) spearheads land administration activities in Zambia, it will be the main centre of discussion, but will include the external organisations that interact with it in land administration. The discussion will look at the organisational/Institutional aspects where goals are set and roles and resources are allocated, the Business/processes for which the resources are allocated and then the Geo-ICT which supports the business processes. The major resources of the cadastral system are the professionals in land administration, which include planners, surveyors and registrars. Their input provides guidance in the use of Geo-ICT to support the area of their expertise. Cadastral systems include spatially referenced land information, which is produced and maintained mainly by the Survey Department and because its management has been identified as a major source of concern, it will be given greatest attention among the domain experts. The discussion will be based on three main processes i.e. Land Allocation, Land Transfer and Cadastral Surveying. Some problems in the existing system will be highlighted and solutions proposed. These solutions will be modelled with the UML in chapter 4. The source of the information in this chapter was interviews carried out in the study area, observation of processes and reports and forms collected during the field trip.

3.2. Ministry of Land

The Ministry of Lands is the government institution responsible for land administration in Zambia. Among the ministry’s functions are Land Policy Administration, Land Surveys and Mapping, Lands & Deeds Registration and Provisions of land for all purposes. Politically, it is headed by a cabinet Minister while administratively it is headed by the Permanent secretary. It has four departments namely: Human Resources and Administration Department, Lands Department, Surveys Department and Lands & Deeds Department (See Fig. 3-1). These departments are further divided into sections or units.
The Ministry’s key clients and their needs, in general, are summarised in Table 3.1 (Ministry of Lands, 2002). Not all these were interviewed during the interview and so the detailed information of the requirements of those interviewed are given in the following sections.
<table>
<thead>
<tr>
<th>No</th>
<th>Client</th>
<th>Needs</th>
</tr>
</thead>
</table>
| 1  | Prospective property Owners           | ▪ Provide information on land  
▪ Provide land  
▪ Provide cadastral survey services  
▪ Grant certificate of title  
▪ Resolve land disputes |
| 2  | Property Owners                       | ▪ Provide information on land  
▪ Provide cadastral survey services  
▪ Register Deeds & Encumbrances  
▪ Resolve land disputes  
▪ Correct errors  
▪ Facilitate change of ownership  
▪ Effect land alteration of boundaries |
| 3  | Law Firms, Investors                  | ▪ Provide information on land  
▪ Register securities and  
▪ Provide cadastral survey services |
| 4  | Local Authorities (Councils)          | ▪ Provide information on land  
▪ Resolve land disputes  
▪ Provide cadastral survey services  
▪ Grant approvals for land allocation  
▪ Number properties |
| 5  | Private Surveyors                     | ▪ Provide information on land  
▪ Grant survey approvals  
▪ Calibrate survey instruments |
| 6  | Traditional Rulers                    | ▪ Provide information on land  
▪ Resolve land disputes  
▪ Provide cadastral survey services |
| 7  | Government Ministries and Institutions | ▪ Provide information on land  
▪ Provide cadastral survey services  
▪ Ensure payment of property transfer tax  
▪ Approve layout plans |
| 8  | Estate Agents                         | ▪ Provide information on land |
| 9  | Consulting Firms and Contractors       | ▪ Provide information on land  
▪ Provide specialist and cadastral surveys |
| 10 | Utility companies                     | ▪ Provide information on land  
▪ Provide specialist and cadastral surveys  
▪ Register deeds and land |
| 11 | Mining Companies                      | ▪ Provide information on land  
▪ Provide land  
▪ Register deeds  
▪ Provide specialist and cadastral surveys |

Table 3-1 Ministry of Lands’ Clients and their general needs.
Mission Statement:
The draft strategic plan 2002-2006 (Ministry of Lands, 2002) includes the revised Mission Statement, justifying the fundamental purpose for the existence of the Ministry. It aims at providing a new vision of success to strive towards and the framework within which management decisions will be made and the programmes and activities that will be undertaken in the period covered. The revised mission statement is as follows:

“To efficiently, effectively and equitably deliver land, maintain up-to-date land records and provide land information in order to contribute to socio-economic development for the benefit of the Zambian people and the country”

Goal Statement:
The Ministry’s goal statement redefined in line with the revised mission statement is as follows:

“To decentralise the ministry’s operations to Regional, Provincial and District levels in order to facilitate easy access to land and land information.”

Objectives:
The strategic plan also outlines a number of objectives, strategies for implementation and output indicators.

The four departments into which the Ministry of Lands is structured and through which it aims carrying out its mandate are described in the following section.

3.3. Human Resources and Administration Department

Following the restructuring exercise, the Human Resources and Administration Department consists of the following units which all report to the Director Human Resource and Administration who in turn reports to the Permanent Secretary. This department is responsible for the overall provision of the necessary support services for the effective and efficient operation of the Ministry.

It is further divided into the following units which includes the Planning & Information Unit which is responsible for the Land Information & Management System (LIMS):

- General Administrative Services and Transport Unit
- Human Resources Management and Development Unit
- Planning and Information Unit
- Accounts and Internal Audit
- Procurement and Supplies Unit
- Registry Unit

The Planning & Information unit is responsible for the maintenance of the Ministry’s Land Information & Management System (LIMS). The unit is also responsible for the provision of general hardware maintenance services and the maintenance of the Local Area Network.
The computerisation of the Land Information & Management System was started in 1984 and in 1990 the main registers, i.e. the Property Register, the Lease Payment Register and the Lands Register, were computerised. The Registered are maintained by Survey Department, Lands Department & Lands & Deeds Department respectively. The system underwent renovation in between 1999 and 2001, a process which saw, among other things changes in the operating system, the database management system, the user interfaces and an increase in the number of work stations. The current system links the activities of the three departments of the ministry, each of which have restricted access to the database according to their respective areas of jurisdiction.

The renovation did not, however, include an integration of spatial data, produced by the survey department, with the existing administrative system, which only handles thematic data. This has led to loss of opportunities in the improvement of service provision, by making use of the ever-increasing technologies in Geo-information production and information technology in general.

Among other constraints, the system is not accessible to the regional offices, which have to phone or travel hundreds of kilometres to get the information they need for executing their respective mandates.

### 3.4. Lands Department

The Lands Department of is, in general, the custodian of all land in Zambia on behalf of the President of the Republic of Zambia. The President has delegated his powers to the Commissioner of Lands, who is the head of the department, to make and execute grants and dispositions of land subject to special or general directions of the Minister responsible for land.

The main functions of the department are:
- Identifying and allocating land to individuals and organisations
- Ensuring that land is developed in accordance with the lease conditions
- Generating revenue through ground rent.

In order to carry out its functions, the department has been divided into the following sections:

- Lands Administration Section
- Legal Section
- Estates & Valuation Section.

The Lands department is the only department, which has offices in all the nine provinces of Zambia.

The role of the Lands Department in the process of Land Allocation is to ensure that land is made available by ensuring that idle land is identified and planned by the relevant planning authorities and that leased land which is not being utilised is re-possessed and re-allocated.

This role is initiated through liaison with the local authorities for urban land and the Ministry of Agriculture & Co-operatives for rural land.
With respect to Land Transfer, the department is responsible for the grant of authority or consent to transfer land to individuals or organisations that want to transfer land. The Commissioner of Lands gives this consent through the Estates and Valuation Manger. This way the state ensures that land is transferred to people or organisations that qualify to hold it.

The party interested to carry out a transfer initiates this role by approaching the Commissioner of Lands with a filled in application form. Before the consent to transfer is granted, the Lands Register, administered by the Lands & Deeds Department, is checked to verify that the registered owner is the one making the application.

The Lands department is not directly involved in Cadastral Surveying except that it forwards approved plans to the Survey Department for numbering and subsequent execution of the cadastral survey.

This role is initiated when the planning authorities forward the plans to the department for scrutiny. The department needs to know the location of the land and the type of activity that a particular parcel of land will be used for (or the proposed land use of the parcel).

The forms used for land allocation (or alienation) are contained in the Land Circular No.1 of 1985 (See Appendix B).

3.5. Lands & Deeds Department

The Lands & Deeds Department is a new department originally a section of the Lands Department and now headed by the Chief Registrar. Among its principle functions are:

   v. Provide security of tenure.
   vi. Ensure speedy registration of all documents lodged.
   vii. Register documents in the Lands & Deeds Register.

The Lands and Deeds Department prepares Certificates of Title for both direct leases where the owner was allocated directly by the Ministry of Lands and in the case of transfer from another individual or organisation.

In the case of a direct lease the Lands & Deeds Department receives the Lease Agreement from the Lands Department together with the Survey Diagram (from Survey Department), which gives the geometric description of the property and registers them and prepares the Certificate of Title after having checked the lodged set of documents for completeness.

In the case of a transfer, there is no lease agreement involved as the new owner inherits the lease as originally agreed by the previous owner and the Commissioner of Lands, and so only a letter of consent to transfer or assign and the Deed of Transfer are attached. In case of a transfer involving a subdivision, a Survey Diagram of the separated portion is attached for preliminary registration. The Par-
ent Certificate of Title is sent to the Survey department for Marking Off of the separated portion before the final registration of the new Certificate of Title.

The Lands & Deeds Department also have an office in Ndola and so registration of documents can also be done there to cater for the northern region of the country.

3.6. Survey Department

The Survey Department is the national mapping and surveying agency. It is responsible for the production and revision of national maps of Zambia, the planning of aerial surveys and provision of national geodetic control. The department is headed by the Surveyor General who is assisted by three Assistant Surveyor Generals each of whom heads the three respective branches into which the department is divided namely:

- Cadastral Services
- Mapping Services
- Survey Services

The structure of the department is summarised in Figure 3.2.
Figure 3-2 Survey Department Organisation Structure
Among the branches of the Survey Department, the Cadastral Branch is the one that has a direct role in the processes of land allocation, transfer and survey. In this thesis, Cadastral Branch and Survey Department will be used interchangeably as the Cadastral Branch is the branch whose activities in the Survey Department are of major importance here. This branch deals with services related to the accurate fixation and recording of legal boundaries. It is structured in the following way:

**The Cadastral Drawing Office** whose function is the preparation of Survey Diagrams and Sketch plans, which are a constituent of the Certificate of Title, and preparation of Working Plans from Field Book data and General Plans. They are also responsible for the update of Cadastral Index Plans. The drawing office also carries out other functions like Marking Off, preparation of Certified True copies of Survey Diagrams (For issue of new Certificate of Title in case of loss), preparation Supersede Diagrams. They also carry out amendments to survey records lodged by private surveyors for examination if they are minor, rather than send them back for correction.

**The Examination Section**, which is responsible for the examination of all survey records lodged with the Survey department by both the government and private surveyors. The examination is carried out in order to verify that the lodged surveys were executed in accordance with the Land Survey Act and the Land Survey Regulations. This section manages the **Plan Room** where survey records are lodged and archived and the numbering of properties is done. The Plan Room is the contact point with the external environment of the Cadastral Branch.

**Regional Survey Offices**, which are responsible for carrying out surveys of property boundaries throughout the country for the acquisition of certificates of title. There are seven regional survey offices situated in seven of the nine provinces of Zambia. Of the seven regional offices, the Ndola Regional Survey Office has been authorised to do Examination and approval of survey records lodged by other regional offices near it and private surveyors, while the rest of the offices have to take their survey records to the Survey Department head office in the capital city, Lusaka.

The Branch’s role in land allocation is initiated by a request from the Lands Department for numbering of a site plan. This request comes via a standard form through the Plan Room. With respect to Land Transfer, it is only involved in the case of subdivision when a separate Survey Diagram is required and the Marking Off of the parent diagram. The request for this comes from the Lands & Deeds Department.
3.7. **External Organisations**

The following organisations outside the Ministry of Lands are party to the land delivery process and use of land information:

3.7.1. **Local Authorities (Councils)**

The Local Authorities are under the Ministry of Local Government & Housing. The ministry’s Department of Physical Planning and Housing (The Planning Authority) is responsible for the planning in the local authorities. City and Municipal councils are given freedom to develop layout plans on the understanding that they faithfully implement the Town & Country Planning Act Cap 283 of the Laws of Zambia. Where failure to do so is observed, the Planning Authority intervenes in their operations; otherwise they work with very limited oversight.

With respect to District Councils, however, the Planning Authority has direct oversight through the Authority’s respective Provincial Planning units.

The Local Authorities identify the need for development in an area, and identify new sights for possible development. This need and proposed sight are presented to the Planning Authority that is responsible for the preparation of layout plans and approval of the same.

The Local Authorities interact with the Ministry of Lands directly with the Lands Department and indirectly with the Survey Department. They send an approved site plan to the Lands Department to confirm the availability of the land proposed for development. They deal with the Survey Department indirectly in the sense that through the Lands Department, a request is made for the numbering of the proposed parcels before an invitation is made to the general public for application. It is the survey department who would later prepare the legal.

3.7.2. **Land Use Planning Unit**

The Land Use Planning unit is in the Ministry of Agriculture & Co-operatives – Land Husbandry section. Its role in land allocation is the planning and demarcation of agricultural lands based on resource surveying (soil, land capability and suitability classification surveys). The resource surveys (Field surveys) assist in determining viable sizes of farms. Based on these surveys they prepare layout plans in consultation with Local Authorities, and submit duly signed plans to the Commissioner of Lands for subsequent numbering and survey or preparation Sketch Plans.

The also unit makes recommendations to the Commissioner of Lands for proposed subdivisions and transfer of land in order to control land use. It also makes recommendations to the Commissioner of Lands, in liaison with the Local Authority, for repossession of farms that are not developed.

3.7.3. **Private Survey Firms**

Private licensed surveyors are authorised to carry out cadastral surveys, but they first receive instructions from Survey Department when the property has been numbered. They are also required to sub-
mit their work to the Survey Department in order that their surveys may be checked for conformity with then Land Survey Act and the Land Survey Regulations. The survey records, which include a field book and a map showing how the survey was executed, remain at the Survey Department for archive, while the approved Survey Diagrams are given to the surveyor, a copy remaining with the department. Private surveyors always make searches for reference information in the Survey Department archives before carrying out their surveys. And so the private surveyors play complimentary roles with the government surveyors with respect to their role in Land Allocation and Land Transfer.

3.7.4. **Law Firms**

The Lands & Deeds Registry Act stipulates the need for registration of documents with the Chief Registrar of Lands & Deeds at the Ministry of Lands for legal recognition. And so the lawyers come in mainly when there is a change of ownership using their competence to prepare the deed of transfer or assignment.

The Lands Act stipulates the need for obtaining Consent to transfer land from the Commissioner of Lands at the Ministry of Lands and so the lawyer also makes the application for consent on behalf of the client.

3.7.5. **Zambia Revenue Authority**

The Zambia Revenue Authority (ZRA) has an indirect interaction with the Ministry of Lands (MOL). The only thing that seems to bring them together is the fact that they have the same clients i.e. Lease holders and buyers. The law requires that these leaseholders intending to transfer their rights deal with the two institutions in the land transfer process.

The tax that establishes a relationship of Ministry of Lands with ZRA is the Property Transfer Tax stipulated in the Property Transfer Tax Act 1984 and the Income Tax Act. The Income Tax Act demands tax clearance on all property transactions to ensure that tax is paid where applicable. The Ministry of Lands enforces the Income Tax Act by insisting of the evidence that property transfer tax has been paid before the transaction is authorised. This clearance is given by ZRA once they assess the nature of the transfer, as some transfers say to a spouse or child may not be taxable.

If Tax is required on a transfer, ZRA levies 2.5% of what they refer to as the Realisable Value of the property that is the price at which it could, at the time of transfer, be sold on the open market.

3.7.6. **Utility Companies**

Utility companies are mainly users of cadastral information. The Lusaka Water and Sewerage Company (LWSC) for example, mostly collects Cadastral Plans (indicating property boundaries) from the Survey Department. These plans are used to geographically locate the clients to whom they provide services. They collect hard copies of maps from Survey Department.
Having fully introduced Geo-ICT, LWSC desires to have digital datasets from ZSD as the conversion of the analogue maps they currently collect consumes too much of their time.

The other problem that they face with the products and services of ZSD is the lack of uniformity in the coordinate systems of the different coordinate system.

It is the opinion of LWSC that Geo-ICT developments are moving too fast for Survey Department hence their lagging behind. They desire that Survey Department takes a lead role in the provision of digital maps, which should be updated annually.

3.8. The Applicant, Leaseholder & General Public

This category of players in the Land Allocation, Land Transfer and Cadastral Survey procedures are mainly beneficiaries of the cadastral system. They are the main target of the system as can be understood from the mission statement of the Ministry of Lands. They are the ones for whom the processes are mainly to ultimately benefit.

3.9. Land Allocation Procedure

This section shows the steps involved and how the various parties interact in the process of land allocation. Zambia has a dual tenure system: Customary and Statutory Tenure (or Leasehold Tenure). Customary Tenure applies in traditional land and is communal while Statutory Tenure applies in State Land. It is, however, possible to convert Customary Tenure to Statutory Tenure with the consent of the traditional ruler. The procedures for alienation of statutory land and the conversion of customary tenure to statutory tenure will be described in this section.

3.9.1. State Land

State land is mainly in two categories: Stands (for Residential, Commercial or Industrial use) and Farms or Smallholdings (for Agricultural & Residential purposes). The preparation of layout plans for agricultural land is carried in liaison with the Land Use Planning unit of the Ministry of Agriculture & Co-operatives. These steps refer Stands.

Step 1: Planning Authority identifies land, prepares layout plan and request commissioner to check for availability.

Step 2: Lands Department request for numbering is made to Survey Department and if land is available and site plan is numbered, Planning Authority advertises plots inviting developers.

Step 3: Survey Department checks and numbers the Site Plan and if it is Ok, enters the numbers in the Property Register of the Land Information and Management System (LIMS). Once this is done the numbered Site Plan is sent back to Lands Department who forwards copies to the Local Authority who uses it for advertisement to the public.
Step 4: Applicant fills in application forms.

Step 5: Planning Authority carries out interviews and sends the list of selected applicants to Lands Department recommending them for a parcel. This is sent together with the applicants’ letter of application.

Step 6: Lands Department receives the application and prepares an offer letter, which indicates the duration of the lease whether 14 or 99 years.

Step 7: The Applicant accepts offer by paying the lease charges stipulated on the offer within 30 days of receiving the offer.

Step 8: Lands Department makes request to Survey Department for Survey Diagram (for 99 year lease) or Sketch Plan (for 14 year lease).

Step 9: Survey Department prepares Survey Diagram or Sketch Plan (whichever case is applicable) and sends to Lands Department for preparation of Lease Agreement. For the Survey Diagram, a Cadastral Survey procedure is carried as described in section 3.11.

Step 10: Lands Department prepares Lease Agreement once the Survey Diagram or Sketch Plan is approved and both the Applicant and the Commissioner of Lands sign the agreement. The signed lease is then sent to the Lands & Deeds Department for registration and preparation of Certificate of Title.

Step 11: Lands & Deeds Department registers the Lease and other documents and prepares the Certificate of Title.

Step 12: The Chief Registrar sends the Certificate of Title to the Commissioner of Lands who informs the applicant.

Step 13: Applicant collects Certificate of Title.

These steps are modelled in Figure 4.2.

3.9.2. Customary Land (Reserves and Trust Lands)

Step 1: Applicant identifies land.

Step 2: Applicant consults chief for consent to convert the tenure from Customary to Leasehold Tenure).

Step 3: Applicant has Site Plan prepared usually based on topographic map.
Step 4: Applicant submits the chief’s consent and site plan to Local Authority together with an application form. The Local Authority sends applicants to the Commissioner of Lands.

Step 6: Application is received by Lands Department where the check of availability is made. If the land is not available, then the Local Authority is informed is rejected, if available then request for numbering is made to Survey Department.

Step 7: Survey Department checks and numbers the Site Plan, if it is Ok and enters the numbers in the Property Register of the Land Information and Management System (LIMS). Once this is done the Site Plan is sent back to Lands Department who sends numbered copies to the Local Authority and the Applicant.

Step 8: Lands Department prepares offer based on the given property number, indicating the duration of the lease.

Step 9: The Applicant accepts offer by paying the lease charges stipulated on the offer.

Step 10: Lands Department makes request to Survey Department for Survey Diagram (for 99 year lease) or Sketch Plan (for 14 year lease).

Step 11: Lands Department prepares Lease Agreement once the Survey Diagram or Sketch Plan is approved and both the Applicant and the Commissioner of Lands sign the agreement. The signed lease is then sent to the Lands & Deeds Department.

Step 12: Lands & Deeds Department registers the Lease and document and prepares the Certificate of Title.

Step 13: Chief Registrar sends the certificate of title to the Commissioner of Lands who informs applicant.

Step 14: Applicant collects Certificate of Title.

These steps are modelled in Figure 4.3

3.10. Land Transfer

Land, which has been already registered, is subject to change of Leaseholder. The changes can either be of the whole parcel or a part thereof. Below are the steps for land transfer in the case of a subdivision. The steps are similar for the transfer of the whole parcel except that some steps are omitted in the latter. Subdivision is only possible for land, which is on 99-year lease (Land on 14 year leases cannot be subdivided).

Step 1: Applicant has a Site Plan prepared and requests for approval.
Step 2: Planning Authority checks application-if Ok then approves.

Step 3: Applicant applies to Commissioner of Lands (Lands Department) for consent to subdivide.

Step 4: Lands Department checks—if Ok grants consent and requests Survey Department for numbering and survey.

Step 5: Applicant engages a Lawyer to draft a deed. Type of deed depends on whether it is a transfer, gift etc. Property transfer tax is paid at this moment at Zambia Revenue Authority.

Step 6: Zambia Revenue Authority receives payment and issues Tax Clearance certificate.

Step 7: Lawyer compiles Deed, Tax Clearance Certificate, Parent Certificate of Title and Survey Diagram. These documents are lodged with Lands & Deeds Department for registration and preparation of separate Certificate of Title and Marking off the subdivision from the Parent Certificate of Title.

Step 8: Lands & Deeds Department sends Parent Certificates of Title to Survey Department for Marking off.

Step 9: Survey Departments Marks off and returns to Lands & Deeds Department.

Step 10: Lands & Deeds Department registers the Deed document and prepares separate Certificate of Title for the subdivision.

Step 11: Chief Registrar sends copy to Commissioner of Lands and archives copy.

Step 12: Commissioner of Lands informs Lawyer is informed of the readiness of the Title.

Step 13: Lawyer collects Certificate of Title on behalf of the client.

In case of a transfer where there is no subdivision, some the procedure is similar to the above only that some steps are omitted. The omitted steps are the preparation of the Site Plan and its approval and the Marking off. The model of this process shown in Figure 4.4

3.11. Cadastral Surveying

As observed above, the Land Allocation and Land Transfer processes include Cadastral Surveying. Since the end of the two processes is the acquisition of a Certificate of Title and the geometric description being a major part of the documentation in the Title, Cadastral Surveying and the related procedures in the Survey Department are necessary.
The Survey Diagram or Sketch Plan is the end product of the survey department’s role in the land allocation and transfer processes and their production line is outlined below:

**Procedure for production of the Survey Diagram**

**Step 1:** Request for Survey Diagram is received from Lands Department. A letter is sent by Survey Department to the applicant to give him authority to have the parcel surveyed. The letter includes a list of Licensed Surveyors and Regional Survey Offices for the applicant to choose from.

**Step 2:** The applicant request a surveyor to execute the Cadastral Survey.

**Step 3:** The surveyor then checks the Topographic Index Map for the topographical map on which the site falls, then collects the map from the map library.

**Step 4:** The surveyor then prepares a survey quotation for the client.

**Step 5:** The Topographical Map is used for location of site and nearest control stations, access route, estimate of distance for fuel cost estimate, terrain to know type of equipment to carry, vegetation cover - whether to use GPS or conventional survey techniques, terrain for determination of type of vehicle to use (Four wheel drive or two wheel drive). All above data will enable preparation of survey quotation for the client.

**Step 6:** Data Collection - Once the terms of payment have been agreed and some advance amount paid, the surveyor begins his data collection. This data includes connecting data from old surveys, Controls Points and their coordinates, the Cadastral index map to check the nearest surveyed properties, the General Plan (larger scale cadastral plan with distances and bearings) for pre-computations.

**Step 7:** Mobilising Resources - The surveyor then mobilises all the required resources (Survey Team, Instruments and Vehicle) for the fieldwork.

**Step 8:** Field Survey & Computations - Theoretical coordinates are computed based on the site plan are done. The cadastral survey is then carried out implementing the theoretical computations. Post survey computations are carried out at the end of the survey for the areas, coordinate list and any deviations from the theoreticals etc. All these activities are carried out in accordance with the Land Survey Act and Regulations.

**Step 9:** Drawing - The surveyor then submits his field book and coordinate list to the Drawing Office where the Cartographers plot the Working Plan, General plan and Survey Diagrams.

**Step 10:** Lodgement – The survey is then lodged for examination through the Plan Room of the Survey Department.

**Step 11:** Survey Examination: The survey is checked for conformity with the Land Survey Act and Regulations.
Step 12: Approval of Survey Records - If the survey is found to have been carried out in conformity with the Land Survey Act, it is recommended for approval by the examination section and approved by a Government Surveyor working on behalf of the Surveyor General. If not it is returned to the surveyor for correction.

Step 13: Microfilming (Reprographic section) - The General Plan and Survey Diagrams are then sent to the Reprographic section for microfilming and archiving of microfilm.

Step 14: Archiving of Survey Records - The Survey Records sent back to examination section where they are archived for future reference (the examination section is also responsible for archive of survey records and cadastral plans).

Step 15: Collection of Survey Diagrams: Survey Diagrams are then collected by the clients who lodges then with Lands Department to prepare for the lease document and subsequent preparation of the Certificate of Title by the Chief Registrar. The model for this process is shown in 4.5

3.12. Perspectives of the Cadastral System

As mentioned in the introduction, cadastral system is regarded as a system encompassing both the official recording of legally recognised interests in land and the parcel based land information system containing records of interests in the land. It is also important to bear in mind that a system, at least as used here, encompasses people and the information technology they use in support the processes that define their work (Hawryszkiewycz, 2001).

There is an overall vision of the system and organisation describing the structure of the organisation and illustrating strategic plans and how goals are to be reached. Goals would include innovations to prepare for future, financial aspects to result in optimal systems, services & product to clients. They may include change of focus from production orientation, which leads to piling up of maps, to customer orientation, which results in producing what the customer needs. The goals may address the service delivery aspect of the cadastral system. These are issues that are dealt with at the institutional level.

It is a widely accepted and appreciated fact that computer based information systems are incomparably more efficient in today’s business world. As the technology has been advancing the computer based management of information has extended to spatial information as seen by the GIS packages that have emerged and the upcoming versions of spatially enhanced database management systems.

It should be borne in mind that this technology, however, is only a support of the core business of the system as they carry out operations to achieve their goals. The professionals in the business or the system or organisation, thus play a critical role in ensuring that their requirements as experts in the field are accurately translated to computer systems. This point shows the relationship between the
Geo-Information & Communication Technology (Geo-ICT) experts and the experts in the core business, which is land administration. Examples of these professionals are surveyors and registrars.

The role of computer systems, as (Hawryszkiewycz, 2001) has pointed out, is to support people in their work by using technology to provide ways to collect and use information and support their work processes, adding that any designer must look at ways of combining all these elements in ways that most effectively support the goals and work practices within the organisation.

The ministry of lands has a computer based Land Information & Management System that supports the processes of land allocation and land transfer. With respect to cadastral services or services provided by the Survey Department, it only has limited support as it does not support spatial information which is the main information that the Survey Department deals with.

### 3.13. System Constraints (Surveyors’ Domain Perspective)

Although the strengths of the Ministry of Lands noted in the 2002-2006 Strategic Plan, include qualified and skilled human resources, creation of the planning and information unit, computerisation of the operations and decentralisation of operations, the field observation indicated that their was still need for attention in the above mentioned strengths.

For example, the Information Technology Unit lacks adequately skilled manpower. The staff in that department are in need of upgrading their information technology knowledge to keep up with the fast advancement in technology, particularly in Geo-ICT and all the related technology such as GIS packages and spatially enhanced database management systems. In fact this rapid advancement of technology poses a great challenge for Zambia in the sense that a designed system may fail to cope with changes in the technology or user requirements. A solution for these issues, is therefore required.

The computerisation indicated is a good start, but as at now, it is only with respect to administrative data or attribute data. The spatial information that the ministry deals with is still in analogue form thus limiting the service provision and opportunities that digital spatial information offers. This should have actually been added as an opportunity in the SWOT analysis outlined in the strategic plan, because of the many possibilities that the digital spatial data provides.

With respect to decentralisation, there are some areas that would do with improvement. While there are seven regional offices of the Survey Department spread in different provinces, they still lack efficient access to cadastral information (both spatial and non-spatial), which is archived at the head office in the capital city. In order to execute their duties, they need the information as reference, but in order to access, they have to either try and get what is possible through the telephone or travel hundreds of kilometres which is not cost effective or as in most cases overburdens the clients who end up bearing the cost because of their desperation. Because of this the effect of the decentralisation is not of as much benefit as it can be. With proper support or development in the Geo-ICT, there can be better service provision to the users of cadastral information-both spatial and non-spatial. And with re-
spect to the system as a whole, the clients complain of having to make too many organisations to deal with before they obtain their ultimate requirement, which is the Certificate of Title.

And among the threats that should have been included the private sector, which as it is going way ahead of the survey department in the advancement of technology (in terms of data collection and processing equipment) and service provision to clients. As the national mapping & surveying agency it should be in the forefront-providing leadership to external organisations that use or produce cadastral information. Survey department is bound to lose its clients or allow a situation where failure to provide framework data in digital form leads to the private sector making an attempt in an unprofessional way.

In addition to identified Strengths, Weaknesses, Opportunities and threats other needs were identified, which the Ministry realised needed attention if improvement of performance was to be achieved. Among them were the Obsolete survey Equipment which the Survey department were currently using and the Outdated Land Survey Regulations on which their surveys were based. It was seen as important that the Ministry of Lands purchases and maintains the latest state of the art survey equipment if the survey department was to improve its services. The Land Survey Act as well, needed to be amended to align it with the developments, which have taken place in the survey field.

Improvement of processing procedures will be imperative in the event of acquiring the more efficient instruments as this would enable better utilisation of the available technology. Modelling the system would help better communicate the problems to decision makers and stakeholders and also identify and communicate solutions.

Since the draft of the draft of the 2002-2006 strategic plan was necessitated by the need of the Ministry to re-align itself with the changes in the environment and enable it to improve upon the quality of service delivery to its clients, the draft, addressing the issues raised above would be part of realising the alignment to the environment.

It is such observations as these that necessitates modelling either to clearly see the structure and behaviour of the existing system in order to more clearly identify the problems and/or in order to use the short comings of the existing system to design a more optimal one. The UML seems to have capacity to handles various models at different levels. And its standardisation holds promise for further opportunities.


In this chapter, operations of the system of cadastral system in Zambia were outlined, showing the different aspects of a cadastral system and as can be seen, there are many steps and players in the processes. The main processes of focus i.e. land allocation & land transfer, land surveying and registration have been described, thus providing a basis for applying the UML on a real system.
4. Cadastral System Development with the UML

4.1. Introduction

The objective of this chapter is to see how the UML can be applied in the development process of a cadastral system. Having used the Zambian cadastral system as the basis for this research, an attempt is made to apply the various artefacts and concepts of the UML and its general potentials to modelling the various aspects of an existing cadastral system and make some proposals for improvement in the cadastral surveying domain. As noted in chapter 2, the UML is a methodology independent tool; consequently its application in the development process requires the choice of a methodology. The importance of a methodology has been outlined in chapter 2 and in this case, GRAPPLE (Guidelines for Rapid Application Development) was opted for as the vehicle for the evaluation of the UML in cadastral system development.

GRAPPLE was chosen as the guideline because of its relative simplicity and flexibility. The other advantage of GRAPPLE is that it was developed with the UML in mind, thus making it easier to apply the modelling language and give due attention to its potentials rather that try to see how a given methodology fits in with it, which would have required more time.

It is important to draw the reader’s attention here to the fact that the bulk of the textual descriptions of the domain being analysed is documented in chapter 3. The separation was done made for clarity’s sake.

There are effectively two systems being dealt with in this chapter or better still the same system at two different levels of abstraction; first the Cadastral System as a whole, centred on the Ministry of Lands, and then the information system that supports the processes (Figure 4.1 illustrates this).
4.2. GRAPPLE in Cadastral System Development

GRAPPLE stands for Guidelines for Rapid APPLication Engineering (GRAPPLE). The author outlines the following points concerning the process (Schmuller, 1999):

- “Guidelines” is important in the word GRAPPLE: It is not a methodology written in stone, but a set of adaptable, flexible ideas.
- A simplified skeleton of a development process.
- A vehicle for showing the UML within a context.
- It leaves room for a creative project manager to add his own ideas about what will work in a particular organisation, and so subtract the built in steps that will not.

GRAPPLE has the following segments: Requirements Gathering, Analysis, Design, Development and Deployment. These will be discussed progressively in subsequent sub-sections of the chapter. But before delving into the segments, below is the structure of each segment:

ix. Requirement Gathering
- Discover Business Processes
- Perform Domain Analysis
- Identify Cooperating System
- Discover System Requirements
Present Results to Client

x. Analysis
- Understand System Usage
- Flesh Out Use Cases
- Refine the Class Diagrams
- Analyse Changes of State in Objects
- Define Interactions Among Objects
- Analyse Interaction with Cooperating Systems

xi. Design
- Develop and Refine Object Diagrams
- Develop Component Diagrams
- Plan for Deployment
- Design and Prototype User Interface
- Design Tests
- Begin Documentation

xii. Development
- Construct Code
- Test Code
- Construct User Interfaces, Connect to Code, and Test
- Complete Documentation

xiii. Deployment
- Plan for Backup and Recovery
- Install the finished System on Appropriate Hardware
- Test the Installed System

The development phases that will be covered will mainly be the Requirements Gathering and the Analysis and aspects of the Design as implementation is beyond the scope of this research.

4.3. Requirements Gathering

The first two actions (i.e. Discovering Business Process & Perform Domain Analysis) in GRAPPLE are concerned with the domain rather than with the system. No specific system is proposed at these two stages. This is just to know the specific processes that need to be enhanced and the nature of the world those processes operate in. Basically the essentials of the client’s domain and the problem to be solved are the issues of concern.
4.3.1. Discover Business Process

**Objective:**
The objective of this step is to gain an understanding of the business processes of the domain to be enhanced with a proposed system.

**Work Product:** A set of Activity Diagrams that capture the steps and decision points in the business processes.

The main processes identified in the Zambian cadastral system, as seen from the previous chapter, are Land Allocation, Land Transfer and Cadastral Surveying. Strictly speaking, though, Cadastral Surveying is a sub-process of the other two. Cadastral Surveying is a necessary part of the complete procedure for Land allocation (at least for 99-year leases) and so is it for the complete procedure of Land Transfer involving a subdivision. Cadastral Surveying will, however, be given separate attention to avoid congesting the models describing the previous two processes. The usage of Cadastral Surveying in this sense includes all the activities of the Cadastral Branch of the Survey Department that result in the preparation of Survey Diagrams and not just the fieldwork part of it as the phrase suggests.

The UML’s Activity Diagrams are ideal for modelling the business processes of an organisation. They help to have a good understanding of the processes that take place and the parties involved, thus giving a good overview of the system, which is to be understood and enhanced. The first process that will be given attention is the Land Allocation Process, which involves five parties: Applicant, Local Authority (Planner), Lands Department, Surveys Department and Lands & Deeds Department. Figure 4.2 shows the Land Allocation procedure for State Land while Figure 4.3 shows the procedure for Customary Land.

The Land Transfer Process involves at least seven parties: Leaseholder, Local Authority (Planners), Lands Department, Surveys Department, Lands & Deeds Department, Zambia Revenue Authority (ZRA), and Law Firm. The processes are modelled in Figure 4-4.

The Cadastral Survey procedures have been modelled in separate diagrams for clarity: One to show the survey procedure (Figure 4-5) and the other the lodgement procedure (Figure 4-6). The Lodgement procedure is the process undertaken by Private Surveyors and Regional Survey Offices in order to have their surveys approved resulting in approved Surveyor Diagrams, which are used for the preparation of Certificates of Title.
Figure 4-2 Land Allocation (State Land) Activity Diagram
Figure 4-3 Land Allocation (Customary Land) Activity Diagram
Figure 4-4 Land Transfer Activity Diagram
Figure 4-5 Survey Activity Diagram
4.3.2. Perform Domain Analysis

Objective:
The aim of this step is to improve the understanding of the domain by identifying the major entities in the system. All the entities or objects are identified and listed. Similarities are identified resulting their being grouped into classes. This list is just an initial list and is subject to modification as the development process progresses. This is a quality of the iterative development process, which allows interplay among stages of development. With deeper understanding, models assume different shapes and levels of details.

Work Product: A high-level class diagram.
Major Domain Entities:

At this stage the initial objects (entities) in the domain and their relationships are identified. An example of the result of this step is shown in (see examples in Figure 4-7 & 4-8)

**Survey Objects**
1. Parcel
2. Survey Diagram
3. General Plan
4. Working Plan
5. Cadastral Index Map
6. Field Book
7. Survey Records Jacket
8. Survey Report

**Employee Objects**
1. Surveyor General
2. Survey Examiner
3. Plan Room Officer
4. Draughtsman
5. Surveyor
6. Officer in Charge
7. Reprographic Officer

**Lands Document Objects**
1. Application Letter
2. Consent form
3. Lease Agreement
4. Offer Letter
5. Request form (e.g., for numbering)

**Employee Objects**
1. Commissioner of Lands
2. Lands Officer

**Lands & Deeds Document Objects**
1. Certificate of Title
2. Deed of Transfer

**Employee Objects**
1. Chief Registrar
2. Assistant Registrar
3. Registry Officer
These objects may be classified into various categories such as Documents, Employees and Cadastral Plans. This is the start of developing the building blocks since these are the objects, which will interact in different ways to realise use cases which describe what the system should do.

Figure 4-7 High-Level Class Diagram of initial Survey Objects

Figure 4-8 High-Level Class Diagram of Employees
4.3.3. **Identify Cooperating Systems**

**Objective:**
To Identify Cooperating Systems i.e. which other systems the new system would depend on and which systems will depend on it. The system engineer who is mainly responsible for deployment already begins to think of possibilities.

**Work Product:** A deployment diagram showing the system as nodes, with lines of communication, resident components, and intercomponent dependencies.

Cooperating system in the Zambian situation can be the National Registration Office, which keep records of citizens, the ministry of Commerce and Industry which keeps company registration information and the Local Authority’s office which would have its own database of building information while using parcel information from the Ministry of Lands. As at now there isn’t a computer link between the organisations, but this is just to show the organisations that produce information, which the Ministry of Lands uses would be related. These systems would be linked via an Internet service provider. Figure 4-9 shows the deployment diagram of this scenario, but does not include the resident components, as this is only an overview.

![Deployment Diagram](image)

Figure 4-9 Deployment Diagram of Cooperating Systems

4.3.4. **Discover Requirements**

**Objective:**
The aim of this step is to identify what the users of the system want the system to do.
Work Product: A package diagram with each package representing a high level area of system functionality.

While the previous steps dealt with conceptual issues about the domain from which business processes were derived and high level class diagrams generated, the following steps will deal with the system itself. It is time to develop a vision of the enhanced system. It is time to envision the computer based cadastral system, which handles spatial information which information is produced by the Survey Department.

The business process knowledge and the cadastral domain experts’ knowledge will be fused with the emerging Geo-ICT knowledge in order to enhance the cadastral processes.

Packages as mentioned in chapter two help in the management of models. In this case they help in grouping the system functionality (use cases) according to respective users (Actors) or respective sub-systems.

Developing the vision

The business process diagrams in section 4.3.1 reveal aspects of the system’s activities that can be enhanced with Geo-ICT. As indicated earlier the focus of this research are the activities of the survey department or the cadastral surveying domain, where geo-information (Survey Diagram, General Plans, Sketch Plans etc.) is produced as in put for the processes of Land Allocation and Land Transfer. Geo-ICT will definitely speed up movement of spatial information in these processes as it has been widely accepted to do. All the activities require information input before moving from one activity state to the next activity.

A computer based information system already exists in the Ministry of Lands to support information flow, but that is only administrative information. It is referred to as the Land Information & Management System (LIMS). In the desired system, there has to be spatial data handling which will cut down on draughting time, cadastral plans preparation and update, storage space, storage costs currently incurred during microfilming and generally speed up information exchange. There are a number of other opportunities that introduction of Geo-ICT tools would have to the cadastral system as detailed in chapter 3.

The problem of access to the new system by the regional offices, can be solved by a Wide Area Network (WAN) linking the head office information system to each regional office.

With the vision of the spatially enhanced LIMS, now it is time to build on the insights gathered so far by modelling the system from the users’ point of view. It is time to gather and document the system requirements. Normally the team that is involved in this exercise consists of: system users & domain experts, the development team consisting of analysts, designers, programmers and system engineers.

As mentioned earlier, there are two aspects of the cadastral system and so two levels of use case modelling will be used to describe the system. One capturing the cadastral system in general as perceived
by outside users (See Figure 4-10 & 4-11), while other one at a lower level will be derived from the higher level one, but will involve another system - the Land Information & Management System, which will help realise the higher level use cases. Note that the higher-level use cases are initiated by actors external to the Ministry of Lands, while those of the lower level are initiated within the Ministry of Lands by the respective domain experts.

**Figure 4-10 Use Case Package for Ministry of Lands (High Level)**

**Figure 4-11 Use Case Package for Survey Department**
With respect to the LIMS, there are three packages that can be modelled each package representing the use cases for each department: Lands, Surveys and Lands & Deeds, only the Surveys Department will be considered in detail as it is the department of focus. The overall package of LIMS is shown in Figure 4-12. The requirements gathered are modelled as use cases within the packages.

Figure 4-12 Packages of functionality of LIMS
4.4. Analysis

This segment is a progression from the Requirements segment and is meant to increase the understanding of the problem. The requirements gathered are going to be analysed in this segment and fleshed out into a system. The use cases provided the bridge in this movement from understanding the domain to understanding the aspects of the system to be enhanced showing that system development is use-case driven. The steps of the analysis segment are as follows:

- Understand System Usage
- Flesh Out Use Cases
- Refine the Class Diagrams
- Analyse Change of State in Object
- Define the interactions Among Objects
- Analyse Integration with Cooperating Systems

4.4.1. Understanding System Usage

Objective:
The aim of this step is to discover the actors who initiate each of the use cases identified in the Requirements step bearing in mind that an actor can be a system as well as person.

Work Product: A set of use case diagrams that show actors and any stereotyped dependencies (<<extends>> and <<includes>>) between use cases.

- Includes or Uses: enables one to reuse one use case’s steps inside another use case.
- Extends: allows you to create a new use case by adding steps to an existing use case.

Only the “uses” stereotyped dependency is used in this case.

As mentioned in section 4.3.4, system usage was modelled at two different levels: one at Ministry level i.e. the way actors view the Ministry of Lands followed by department level - the way they view the Survey Department.

The view of the whole of the Ministry of Lands reveals the following as actors:

i. Local Authority
ii. Utility Company
iii. Lawyer
iv. Private Surveyor
v. Public
vi. Applicant
vii. Offeree
viii. Property Owner

The above actors and the respective use cases they initiate have been modelled in Figure 4-13.
Zeroing in to the Survey Department, the following were the identified actors:

i. Regional survey Office
ii. Lands Department
iii. Lands & Deeds Department
iv. Local Authority
v. Utility Company
vi. Private surveyor
vii. Public
viii. Applicant
ix. Offeree
x. Property Owner

Figure 4-14 shows the use case model of the use cases and actors involved.
4.4.2. Flesh Out Use Cases

Objective:
To analyse the sequence of steps in each use case.

Work Product: A text description of the steps in each use case.

GRAPPLE advises that for each Scenario (for use cases with variances or alternative paths) a listing of the following information should be made:
A brief description of the scenario
Assumptions for the scenario
Actor who initiates the use case
 Preconditions for the use case
Steps in the scenario (An activity diagram can also be used to show the steps in a scenario)
Post conditions when the scenario is complete
Actor who benefits from the use case.

A **precondition** is a constraint that must be true when an operation is invoked.

A **postcondition** is a constraint that must be true at the completion of an operation.

The **Assumptions** indicate what conditions are assumed to be in existence to support the realisation of the use case. This implies that what is assumed must either also be developed/designed or acquired in a complete form. It therefore can initiate another process of design.

The “Grant Survey Approval” use case will be developed leading to the proposed solution to the current use case for granting survey approval at the Survey Department.

**Description:** A Surveyor submits the survey records after executing a survey in order to have the survey approved and signed Survey Diagrams issued to him.

**Assumptions:** Land Information & Management System including Spatial database and GIS applications, Wide Area Network to reach regional offices.

**Initiating Actor:** Surveyor.

**Pre-condition:**
- Cadastral Survey has been executed.
- Survey not approved.

**Post-condition:** Survey Approved, Survey Diagrams Approved.

**Steps:**

i. Plan Room Officer receives Survey Records from Surveyor and activates the Graphical User Interface (GUI) for Lodgement.

ii. He enters the Parcel Number on the Survey Records to retrieve the Parcel in the GIS Database through the Wide Area Network (WAN)

iii. The GIS Database retrieves the parcel and displays it on the GUI.

iv. Plan Room Officer begins to enter the Survey Record details through the GUI, which are transmitted, to the GIS through the WAN.

v. Plan Officer physically submits the Survey Records for Examination.
vi. Examiner checks the survey for conformity with the Land Survey Act and Regulations.

vii. If survey is ok he updates the GIS Database that Survey is OK

viii. Examiner physically sends Order for Modelling parcel (together with Survey Records) to Draughtsman.

ix. Draughtsman retrieves parcel information from GIS database through the WAN

x. Draughtsman begins to model parcel object based on the physical Survey Records coordinate information.

xi. Draughtsman updates GIS Database and sends notice to Examiner

xii. Examiner sends instructions to Plotter to plot print the parcel (Survey Diagram).

xiii. Examiner physically sends the hard copy Survey Diagram to Officer in Charge for approval.

xiv. On approval, Officer in Charge updates GIS Database and sends approved Survey Diagram to Plan Room Officer for on ward transmission to surveyor.

The sequence diagram of this use case is modelled in Figure 4-22. Note that it is a best case scenario model.

The other use cases can be developed and modelled in a similar way, but what is clear is that an spatial information system is needed to speed up the information exchange, to deal with the problem of archiving space and the save the time spent on manual drawing of cadastral plans. As mentioned earlier, the role of the “Assumptions” is to identify what still needs to be developed in order to have the system up and running.

What we see here is that the use cases are ultimately creating a path to the information system. In order for each player in the processes to realise the use cases, they need information—both spatial and non-spatial. Consequently the main players indicated in the activity diagrams (Figures 4-2, 4-3, 4-4, 4-5) i.e. Survey Department, Lands Department, Lands & Deeds Department, will now become the actors with respect to the information system for the benefit of the external users of the system such as Private Surveyor, Applicant, Lawyer and Local Authority. And so a lower use case analysis is initiated.

An important aspect of the use case analysis is that it reveals components of the system. These are found in the assumptions section of each use case analysis as mentioned earlier.

In the cadastral system software side, it is clear that a number of user interfaces will be required for respective Actors e.g. Surveyor General, Commissioner of Lands, Chief Registrar.

It is also obvious that a spatial database will be needed to contain both administrative and spatial information on objects of the system, such as parcel and property owner. A GIS package will be required for handling spatial information.

On the hardware side it will be necessary to have a wireless connection to the regional offices and all land offices to facilitate access to the central database. PCs will definitely be needed for respective actors.
Giving all required details of the future system would result into the design document that will be given to both the client and the programmers.

What is observed thus far is that use cases need to be delved into in greater detail, not just listing them. The details are what will reveal the components required hence the importance of detailing the scenarios.

The functionality of the system as perceived by the users of the LIMS is modelled in Figure 4-15, based on the use cases below:

Surveyor General
i. Lodge Survey
ii. Approve Survey or Sketch Plan
iii. Give property history
v. Number Property
vi. Enter Coordinate Information
vii. Cancel Property
viii. Monitor Movement of Records

Commissioner of Lands
i. Create Application
ii. Approve Application & Create Offer
iii. Create Lease Agreement
iv. Lodge Lease with Lands & Deeds Dept.
v. Maintain Consent Information

Chief Registrar
i. Lodge Documents
ii. Register Documents
iii. Prepare Certificate of Title
iv. Uplift Documents

The use cases are separated into packages according to the actor they serve as modelled in Figure 16. These use cases also serve as a basis for Graphical User Interface (GUI) design through the actors can access the database and GIS applications. Each of the identified sub-systems can be developed separately, but the sub-system of interest is the spatial database whose proposed structure is dealt with in section 4.4.3, Figure 4-17.
Figure 4-15 Use case diagram for LIMS
Figure 4-16 Detailed Package Diagram of LIMS functionality

Figure 4-17 An overview of the application packages and their dependencies
4.4.3. Refine the Class Diagram

Objective:
To fill in the names associations, abstract classes, multiplicities, generalisations, and aggregations.

Work Product: A refined class diagram.

It is at this stage that the high-level classes as in sub-section 4.3.2 are refined to show their relationships. Figure 4-18 shows the general for objects of the spatial database. This is the core model for the information access that is needed by each player in the realisation of use cases. It reveals the contents of the spatial data model package of Figure 4-17.
Figure 4-18 Class Diagram of Cadastral System adapted from (Oosterom and Lemmen, 2002b)
4.4.4. Analyse Changes of State in Objects

This section will identify how the parts of the cadastral system change state and when they do.

**Objective:** To show the changes of state of parts of the system.

**Work Product:** A state diagram.

The changes of state identified in the cadastral system are the subject who changes from mere member of the Public, to Applicant, Offeree and then Property Owner (see Figure 4-19). The parcel also does undergo changes during subdivision: from parent parcel, parent parcel undergoing subdivision, and then parent parcel subdivided (see Figure 4-20). Though at this stage the whole parcel dies resulting in two new parcels with separate identities. The site plan also does undergo changes as actions are taken on it. First it is an unapproved unnumbered site plan, and then an approved, but unnumbered site plan then an approved and numbered site plan (see Figure 4-21).

**Figure 4-19 State Diagram of Subject**

**Figure 4-20 State Diagram of Object**

**Figure 4-21 State Diagram of Site Plan**
4.4.5. Define the interactions Among Objects

**Objective:**
To define how objects interact.

**Work Product:** A set of sequence and/or collaboration diagrams depicting interaction.

This stage is meant to show how the objects interact to complete each use case. Sequence diagrams and/or collaboration diagrams are used to depict the interaction.

They help to show how the system parts interact in order to complete each use case. At the high level, the objects (Surveyor General, Commissioner of Lands, Chief Registrar, etc.) interact in completing the use cases Allocate Land and Transfer Land. Messages are sent between the objects and responses made to realise the use case.

At the lower level, i.e. in the Land Information & Management System, the objects are Graphical User Interfaces (GUI), the Spatial Database and the Wide Area Network (WAN). Messages are sent to and from the database through the GUIs. And if the message is from a regional office then there is interaction with the WAN.

After modelling interactions among components, the system is much closer to becoming a reality. A use case’s sequence diagram can be thought of as one view of a use case. The user interface takes the user into the sequence.
Figure 4-22 Sequence Diagram for “Grant Survey Approval” use case
The remaining segments of GRAPPLE are Design, Development and Deployment. These will, however, not be illustrated except for the deployment diagram of the proposed architecture for information exchange.

4.4.6. Design

Using the results of the Analysis segment the solution has been designed. Part of the solution is modelled in the sequence diagram in Figure 4-22. In this segment only the new arrangement of the nodes that will enable the use cases in the new system to be realised is modelled Figure 4-23. Figure 4-24 shows the new roles, via the activity diagram, in the realisation of the use case “Grant Survey Approval”.

Figure 4-23 Deployment Diagram of proposed system architecture
Figure 4-24 Proposed Activity Diagram for Lodgement
4.5. Concluding Remarks

This chapter has shown the application of the UML in cadastral system development based on the Zambian cadastral system. GRAPPLE was used as the vehicle for using the UML. It has shown how the various diagrams of the UML can be used to arrive at a desired system. In this case there have been two levels of analysis-the first being at the level where the system is the Ministry of Lands and the external users of the system being the actors. Use cases have been used to show how they view the system. Then there was a progression to the Land Information & Management System, which is an internal system to help realise the high-level use cases. At this level, the actors became the staff of the Ministry of Lands. Their respective use cases were outlined based on how the system should support them to realise the use cases of the external user. A spatial database model was assumed in the course of the use case analysis resulting in the progression to the design of the general structure of data model. The importance of the use case and delving into it has been demonstrated as it has clearly given a path to the desired situation.
5. Analysis

5.1. Introduction
This research has been focusing on the UML for cadastral application. Having observed the trends in the advancement of technology, which has resulted in the emergence of the UML as a de facto standard and an ISO draft standard, an effort has been made to evaluate and explore its application in cadastral system development and the benefits may bring. The UML has furthermore been used in the standardisation work within Geographic Information done by ISO TC211, an area of interest to the cadastral surveying domain, for modelling spatial objects like the parcel. For these reasons, a study has been done of the UML – its concepts and tools followed by a study of operations of a cadastral system based on the Zambian example. Having studied the UML and the cadastral system, the two were brought together in order to explore the UML’s use and potential in cadastral system development. In order to achieve this, the UML was fitted into a development process since in itself it is process independent. Guidelines for Rapid Application Engineering (GRAPPLE) was the selected vehicle for this exploration. This chapter therefore presents the analysis of this work in answer to the objective of the research. The analysis has been made from two perspectives: first directly from the UML artefacts and then indirectly from the fact of its emergence as a modelling standard.

5.2. The Artefacts of the UML
The section presents an analysis of the UML based on its artefacts and their relevance in cadastral system development

5.2.1. Activity Diagrams
The Activity diagrams clarify the business processes and clearly model the roles or resources in the processes. They enable the understanding of procedures which are mind constraining to grasp from written text as demonstrated by say the Land Allocation procedure stipulated in Circular No. 1 of 1985 (see Appendix B). This diagram provides clarity not just to the team trying to improve the system, but also to the clients, which the system endeavours to serve. In the Zambian case members of the public have complained of not knowing the procedures for Land Allocation, Land Transfer and Cadastral Surveying. They often do not know where to start and are not clear which parties are involved and cannot tell at which stage their job is. This information is important to the clients as it enables the justification of the costs they have to incur in receiving the requested services from the system. With this transparency the clients are given power as they can demand explanations for delayed delivery with confidence based on their knowledge and would contribute to the reduction of corrupt practices, which is among their complaints. Activity diagrams also enable more clear identification of the aspects of the system where Geo-ICT can be applied to improve service provision and income generation.
5.2.2. Use Case Diagrams

The Use Case Diagrams are the driving force towards developing or improvement of a system. With the use case diagrams the users of the system and what they expect it to do can be made plain as seem from the Zambian case.

With the cost recovery policy in the Ministry of Lands, this aspect of system development is important. Driving the development by the requirements of the users. The use cases show what the system should do. The UML diagrams provide development methodologies with the means of smooth progression from the expectations of the users to the system that will deliver what they require. If clients can get what they want, like the Lusaka Water & Sewerage Company (a utility company) have expressed, then they can pay for it and this will ensure sustainability of the improved system. This all starts with the use case, progressing to the sequence of steps that result in the realisation of the use case. Throughout the development process, as iterations are made, a check can be made whether the resulting system is satisfying the identified use cases.

This research has shown how the use case diagrams can be delved into deeper resulting in the identification of a needed system, which can also be modelled and its own actors or users identified. It has shown the progression from a situation where actors such as private surveyors, lawyers and land use planners are external to the Ministry of Lands as a System, to a lower level of abstraction where the Surveyor General, Chief Registrar and Commissioner of Lands become actors to an identified system within the Ministry of Lands - the Land Information and Management System.

5.2.3. Sequence Diagrams

The UML’s Sequence diagrams have been seen as useful diagrams to model the bottlenecks in the interaction processes. The Activation length enables the demonstration of the object, which takes the longest time in responding to the messages given by other objects. It also gives a comparative indication of how long it takes before a message is responded to. With respect to the example of the “Grant Survey Approval” use case, the length of the Plan Room Officer object’s activation gives a picture of how long it takes before the Survey Diagram is issued from the time the Survey submitted by the Surveyor is lodged. This diagram can be used both in the analysis and design phases of system development. With respect to the analysis, the Survey Examination process, which is a bone of contention in the Zambian system because of its rigorous nature and consequent time demand as the examiner ensures the correctness of the survey, can be modelled in the context of the other objects that interact in the Survey Process and the alarming time demand can be reflected in the compelling way that the UML’s sequence diagram does. The same is the case for the actual field survey which takes long because of the effort the surveyor has to make to meet the high level of accuracy demands and the distances he has to cover to reach the nearest of the scanty Survey Control network. Information presented in this way can be useful for making a case for improvement of the system to the management and the staff whose roles would have to be changed in the process of developing alternatives solutions.
5.2.4. Collaboration Diagrams
Though not applied in the Zambian case due to time limitation, but only described and illustrated in chapter two, Collaboration Diagrams can be applied to model interactions between objects relative to their geographical position. Much as the interactions are similarly modelled by the Sequence Diagrams, the exchange of messages between objects represented relative to space can bring out insights, which would otherwise be hidden by sequence diagrams which emphasises the time aspect of interaction. For example if the map of Zambia is drawn and all the interacting objects such as the regional offices, the head office which houses the Land Information & Management System and most of the Survey Records for the entire country and where most examination takes place, the interactions modelled with the Collaboration Diagram would show the great distances covered to access information and services an aspect which the sequence diagram does not bring out.

5.2.5. Class Diagrams
The Class Diagrams are the building blocks in the object-oriented paradigm. All the interactions that have been mentioned are between objects, all the state changes exemplified are state changes of objects and the use cases from which gives rise sequence and collaboration diagrams are realised by objects as they interact with each other. These objects as shown in chapter 4 are of a wide variety of classes, which classes can also be grouped in various categories or packages. They give the possibility of modelling both the aspects of the system which can be turned into programming code and those that will remain physical once the system is implemented, such as the human objects like the Examiner-these are all modelled in the same way, which would clearly bridge the gap between users and the Geo-ICT experts who are in the developing team. It is this communication, which will result in more accurate translation of user requirements into a running system that meet their requirements.

In a detailed design, the operations of a class are the ones that are indicated as messages between objects in the interaction diagrams. With these, we can see attributes of each identified object and the responsibility it has to the other objects as shown by the operations it has. In the cadastral domain the strength of these diagrams are best seen in the modelling the spatial database.

What these class diagrams are revealing is that even job descriptions for the human objects with respect to the cadastral system can be modelled using the same diagrams. These would appear in the operations segment of a class diagram. These details are not shown in the interaction diagrams to avoid clouding the diagram and consequently losing focus, and so the class diagrams are important, as they will show the details of each object that is playing a role in realising respective use cases.

5.2.6. State Transition Diagrams
Details such as state changes can show the changes that some objects in the cadastral surveying domain go through, thus giving deeper insight to the programmers to enable them develop appropriate code. The changes, through which a parcel goes for example, can be analysed with state transition diagrams, before hand when it comes to a more detailed design, which is beyond the scope of this research.
5.2.7. Component Diagrams and Deployment diagrams

The UML facilitates the modelling all the way to modelling software components and on which hardware they reside. Thus facilitating for the modelling of the entire development process with traceability from the early stages of development down to implementation. This makes it easier to identify sources of problems in the design and understand how a feature identified in the analysis phase is implemented.

5.3. The Standardisation of the UML

As noted in the Zambian situation one of the challenges in cadastral system development is the computerisation of spatial information. The UML is currently being used in the standardisation work within Geographic Information done by ISO TC211 and this is likely to help in the provision of better spatial data models. And so developing a system with the UML will really be of benefit as there will be no need of interpretation of models and already existing CASE tools case be used.

Some problems facing cadastral system have to do with the methodology of development, but with the UML being methodology independent, it leaves the cadastral domain with a wide range of methodologies to select from and even gives them the freedom to develop methodologies specific for cadastral system.

As mentioned in chapter 2, the MDA is system design approach that seems to heavily depend on the standardisation of the UML. The approach is an attempt to address the never-ending proliferation of platforms on the one hand and the changes of user requirements on the other hand. It attempts to allowing business requirements and technology to evolve at their own pace, without the one affecting the other. Cadastral systems are not exempt from this challenge as mentioned in the introduction and so the cadastral domain is bound to benefit from the approach as it uses the UML in its design.

5.4. Concluding remarks

The analysis of the UML findings of this research have been presented in this chapter in answer to the research questions raised. This has been done from the point of view of the UML’s artefacts and from the point of view of its emergence as a modelling standard. The respective artefacts of the UML have been analysed pointing out their relevance to the Zambian cadastral system and cadastral systems in general. The potentials of the UML with respect to its standarisation, has also been pointed out citing the work within the Geographic Information of ISO being a prospect, the emergence of UML based CASE tools and finally the Model Driven Architecture which counts on the wide acceptance of the UML.
6. Conclusion and Recommendations

This chapter summarises the conclusions of the research and makes recommendations for further research.

6.1. Conclusions

The thesis demonstrates how the UML can be used in cadastral system development. It shows how it fits into the development process and how each of the artefacts are used to describe the static and dynamic view of the cadastral system. Class, Use case and Deployment diagrams have been used to describe the static view of the cadastral system, while the Statechart (or State Transition), Sequence and Activity diagrams have been used to describe the dynamic view of the system. Package diagrams have also been used to show the management of the model. All this has been done in the context of system development using GRAPPLE (Guidelines for Rapid Application Engineering) as a guide.

Through the application of the UML in analysis and proposal of a solution for the Zambian case, the abilities of the UML have been shown. The UML has been used to describe proposed solutions to the challenges facing the cadastral surveying domain such as decentralisation, spatial information handling with roles and procedures. These have been done using the activity, use case, sequence, class and deployment diagrams.

The UML being based on the Object-oriented paradigm, leads the developers of cadastral systems to a development approach that results in benefits such as seamless communication in the development team which result in better systems due to correct interpretation of user requirements, an iterative approach which enables quicker presentation of results to users thus correcting any errors found at a less cost and improved maintainability due to the encapsulation which enables replacement of objects after implementation without affecting other objects. With the meagre resources available for cadastral systems which government run, like in the Zambian case, these benefits provide real opportunities.

And being methodology independent, the UML gives an opportunity for the cadastral domain experts to develop methodologies that are tailored for cadastral systems with their peculiar aspects such as spatial data handling through GIS packages.

Standardisation implies more opportunities with respect to UML based technology tools and design solutions like the OMG’s Model Driven Architecture (MDA).

The solution to the challenge of flexibility has not been modelled due to time limitation time. Though the source of the possible solution seems to lie in the MDA, which seems to utilise the strength of the
UML standardisation to tackle the problem of fast changing technology and user requirements facing the cadastral domain generally. This is a potential that actually needs further exploration.

The other contribution the UML makes to cadastral system development as alluded to above is by virtue of its standardisation. With the limited financial resources facing the Ministry of Lands as indicated by the cost recovery policy, utilisation of the above mentioned qualities of the UML in the development and maintenance of the Zambian cadastral system make it a modelling language to give attention to.

The findings of this research are that the UML is not a solution in itself, but is a promising supporting tool in the processes of addressing a problem. The findings above indicate is likely to improve cadastral system development and consequently the resulting cadastral systems.

6.2. Recommendations

The research has set an example for the application of the UML in the development process showing where which and how the UML diagrams are used to model various aspects of the cadastral system at various stages of system development. This demonstration sets a stage for a complete development cycle for future researchers.

It is recommended that further research be done up to design and implementation to further explore the applicability of the UML at implementation and maintenance level. Application of the developing Geographic Information ISO technical committee specification in the implementation would probably provide greater insight into the unity of the diagrams right from use case models.

It is also recommended that a research be carried out to clearly show the relationship between UML business model and the information system modelled with the UML. A case study would be an idea to demonstrate how the UML business model can help in the specification of the cadastral information system.

The Model Driven Architecture (MDA) has only been scratched on the surface in this research, and so it is recommended that further research be carried out to develop models for cadastral application that can provide deeper insight into the practicality of this OMG approach, which is based on UML models. This approach seems to hold promise to the threat of proliferation of technology on cadastral models, particularly in currents highly world, and so a detailed analysis of the exact problem solutions that can be improved by the application of the MDA.
References

Appendices

Appendix A: Object-oriented Methodologies Graphical Notations (Brinkkemper et al., 1995)

1. The Object-Oriented Analysis and Design (OOA/OOD) method by Coad & Yourdon
2. The Object Modelling Technique (OMT) by Rumbaugh et. al.

Dynamic model (continued)

```
Start State

Stop State

Superstate

Substate

Substate

Substate

State Nesting / Concurrent Subdiagrams

Splitting and Synchronization of Control

Functional model
```

Data store  Actor

Object
3. Object-Oriented Analysis and Design with Applications (OOADA) by Booch
ASSESSING THE USABILITY OF THE UML IN CADAstral SYSTEM DEVELOPMENT

Object diagram

Synchronization
- simple
- asynchronous
- blocking
- timeout
- asynchronous

Visibility
- global (G)
- protected (P)
- private (F)
- local (L)

State Transition Diagram

State icon
- state (s)
- initial (i)
- final (f)

History
- event (e)
- guard (g)
- action (a)

State transitions
- event guard / action
- start
- end

Nesting
- state 1
- state 2
- state 3

Interaction diagram

Module Diagram

Module Icons
- Subsystem
- Main program
- Specification
- Body

Process Diagram

Icons
- Processor
- Device

Connection
- level

85
4. Principles of Object-Oriented Analysis and Design (OOAD) by Martin & Odell
5. Object-Oriented Software Engineering (OOSE) by Jacobson et al.
Appendix B: Land Circular No. 1 of 1985

MINISTRY OF LANDS AND NATURAL RESOURCES

Procedure on Land Alienation

LAND CIRCULAR

No. 1 of 1985
INTRODUCTION

This Circular is intended to lay down general policy guidelines regarding the procedure all District Councils are expected to follow in the administration and allocation of land.

2. Your attention is drawn to the fact that all land in Zambia is vested absolutely in His Excellency the President who holds it in perpetuity for and on behalf of the people of Zambia. The powers of His Excellency the President to administer land are spelt out in the various legislations some of which are; The Zambia (State Land and Reserves) Orders, 1928 to 1964, the Zambia (Trust Land) Orders, 1947 to 1994, the Zambia (Gwembe District) Orders, 1939 and 1994 and the Land (Conversion of Titles) Act No. 20 of 1975 as amended. His Excellency the President has delegated the day-to-day administration of land matters to the public officer for the time being holding the office or exercising the duties of Commissioner of Lands. Under Statutory Instrument No. 7 of 1964 and Gazette Notice No. 1345 of 1975, the Commissioner of Lands is empowered by the President to make grants or dispositions of land to any person subject to the special or general directions of the Minister responsible for land matters.

3. Pursuant to the policy of decentralisation and the principle of participatory democracy it was decided that District Councils should participate in the administration of land. To this effect, all District Councils will be responsible, for and on behalf of the Commissioner of Lands, in the processing of applications, selecting of suitable candidates and making recommendations as may be decided upon by them. Such recommendations will be invariably accepted unless in cases where it becomes apparent that doing so would cause injustice to others or if a recommendation so made is contrary to national interest or public policy.

4. Accordingly, the following procedures have been laid down and it will be appreciated if you shall ensure that the provisions of this Circular are strictly adhered to.

A. PREPARATION OF LAYOUT PLANS

(i) The planning of stands for various uses is the responsibility of the appropriate planning authority of the area concerned. Once a chosen area has been properly zoned, the planning authority shall forward the approved layout plans to the Commissioner of Lands for scrutiny as to the availability of the land.

(ii) Upon being satisfied that the layout plans are in order, the Commissioner of Lands shall request the Surveyor-General to number and survey (or authorise private survey) the stands.

(iii) Thereafter, a copy of the layout plan showing the order of numbering shall be sent back to the District Council and the planning authority concerned.

B. ALLOCATION OF STANDS

(i) Stands recommended for allocation to the Commissioner of Lands will be assumed to have been fully serviced by the District Council concerned. If the stands are not serviced, the District Council shall give reasons for its inability to provide the necessary services before the recommendations can be considered.

(ii) Before stands are recommended, the District Council concerned may advertise them in the national press inviting prospective developers to make applications to the District Council in the form appended hereto and numbered as Annexure A.

(iii) On receipt of the applications the District Council concerned shall proceed to select the most suitable applicants for the stands and make its recommendations in writing to the Commissioner of Lands giving reasons in support of the recommendations in any case where there may have been more than one applicant for any particular stand, or where an applicant is recommended for more than one stand.

(iv) On receipt of the recommendation(s) from the District Council(s), the Commissioner of Lands shall consider such recommendation(s) and may make offer(s) to the successful applicant(s), sending copies of such offer(s) to the District Council(s) concerned.
(v) Where the District Council is not the planning authority, an applicant whose recommendation has been approved by the Commissioner of Lands shall be directed, in a letter of offer in principle, to apply for and obtain planning permission from the relevant planning authority before a lease can be granted.

(vi) If the District Council is aggrieved by the decision of the Commissioner of Lands, the matter shall be referred to the Minister of Lands and Natural Resources within a period of thirty days from the date the decision of the Commissioner of Lands is known, who will consider and decide on the appeal. The Minister’s decision on such an appeal shall be final.

(vii) No District Council shall have authority in any case to permit, authorise or suffer to permit or authorise any intending developer to enter upon or occupy any stand unless and until such developer shall have first received the letter of offer, paid lease fees and the development charges, and has obtained planning permission from the relevant planning authority.

(viii) Prior to the preparation of the direct lease, the District Council concerned shall inform the Commissioner of Lands the minimum building clause to be inserted in the lease.

(ix) Prompt written notification of the relevant particulars upon the issue of a certificate of title shall be given by the Commissioner of Lands to the District Council concerned.

C. UNSCHEDULED AGRICULTURAL LANDS

(i) Any State Land required for agricultural use shall be notified to the Commissioner of Lands so that its status and availability can be determined. Once the Commissioner of Lands is satisfied that the land in question is available the Department of Agriculture in consultation with the District Council shall be requested to plan the area into suitable agricultural units. The layout plans duly approved by both the Department of Agriculture and the District Council concerned shall be submitted to the Commissioner of Lands for survey and numbering.

(ii) Once the District Council is in possession of information from the Commissioner of Lands regarding the numbered farms or small-holdings the procedure outlined in paragraph 4(i) (i), (ii), (iii) and (iv) above shall apply. And the application form to be completed by the applicants shall be as per Annexure ‘’

(iii) No District Council shall have authority in any case to permit, authorise, or suffer to permit, or authorise any intending developer, to enter upon or occupy any agricultural farm or small-holding unless such developer shall have first received the letter of offer and has paid the lease fees.

D. RESERVES AND TRUST LANDS

(i) In the Reserves and Trust Lands, the powers of the President, in making grants or dispositions of land, are limited by the requirement to consult the local authorities affected by such grants or dispositions of land.

(ii) Local authority, in the Orders, has been administratively understood to mean the Chief and the District Council. This means, therefore, that the consents of the Chiefs and District Councils shall continue to be the basis for any approval of applications for land in the Reserves and Trust Lands.

(iii) As has been the practice before, to ensure that a local authority has been consulted, the Commissioner of Lands will insist that each recommendation is accompanied by the following:

(a) written consent of the chief under his hand;
(b) extracts of the minutes of the Committee of the Council responsible for land matters embodying the relevant resolution and showing who attended, duly authenticated by the Chairman of the Council and the District Executive Secretary;
(c) extracts of the minutes of the full Council with the relevant resolution and showing who attended, duly authenticated by the Chairman of the Council and the District Executive Secretary;
d) Four copies of the approved layout plan showing the site applied for, duly endorsed and stamped by the Chief, Chairman of the Council and the District Executive Secretary.

iv) The preparation of the layout plan showing the area applied for, should be done by persons possessing the cadastral know-how. At Annexure ‘B’ of this circular is a model layout plan which provides the necessary details for an acceptable layout plan.

v) It has been decided, for the time being, not to allocate more than 250 hectares of land for farming purposes in the Reserves and Trust Land areas. The District Councils are therefore advised not to recommend alienation of land on title in such areas in excess of 250 (two hundred and fifty) hectares as such recommendations would be difficult to consider. If the applicant’s request were to be agreed to by the Minister

vi) In each case recommended to the Commissioner of Lands, the recommending authority shall certify that it has physically inspected the land applied for and confirm that settlements and other persons’ interests and rights have not been affected by the approval of the application.

E. APPLICATIONS FOR LAND BY NON-ZAMBIANS

i) You are now aware that under the Land (Conversion of Titles) (Amendment) (No. 2) Act of 1983 no land can be alienated to a person who is not a Zambian. However, under the same Amendment, a non-Zambian can be granted a piece of land if his application has been approved in writing by His Excellency, the President.

ii) To obtain the approval of His Excellency, the President, a non-Zambian wishing to own a piece of land will be required, in the first place, to submit his application to the District Council concerned for scrutiny. In considering the application, the District Council will be at liberty to solicit for as much information as possible from the applicant about the intended development.

iii) When recommending the application to the Commissioner of Lands, the District Council shall be required to give full back-up information in support of or against the applicant in addition to the following:

(a) extracts of the minutes of the Committee of the Council responsible for land matters, embodying the relevant resolution and showing who attended the meeting duly authenticated by the Chairman of the Council and the District Executive Secretary;

(b) extracts of the minutes of the full Council, with the relevant resolution and showing who attended the meeting, duly authenticated by the Chairman of the Council and the District Executive Secretary; and

(c) four copies of the approved layout plan, showing the site applied for, duly stamped and endorsed by the Chairman of the Council and the District Executive Secretary where the site has not been numbered.

5. Consultations—Development projects of great significance both to the District and the nation shall be referred to the Provincial Authority for guidance before communicating the decision to the Commissioner of Lands.

6. Decentralisation of Land Department—Necessary plans to further decentralise the various aspects of land administration and alienation to the Provincial Headquarters have been made. These plans will be operational as soon as funds are available.

7. Reserved Powers—The Minister responsible for lands shall have the right in any case or cases or with respect to any category or categories of land, to modify, vary, suspend or dispense with the procedure outlined above or any aspect of same as he may see fit in the circumstances.

P. Chela,
Minister of Lands and Natural Resources

cc The Rt Hon. Prime Minister.
cc Hon. Chairman of the Rural Development Committee.
cc Administrative Secretary, Freedom House.
Appendix C: Class Relationships

![Diagram of class relationships]

**Association:** A structural relationship that describes a set of links, in which a link is a connection among objects.

**Aggregation:** A special kind of relationship that specifies a whole-part relationship between the aggregate (the whole) and a component (the part).

**Composition:** A form of aggregation with strong ownership and coincident lifetime of the parts by the whole.

**Generalisation:** A specialisation/generalisation relationship, in which objects of the specialised element (the child) are substitutable for objects of the generalised element (the parent).