# University of Nairobi

## School of Engineering

## DEVELOPMENT OF A LAND INFORMATION MANAGEMENT SYSTEM FOR BARINGO COUNTY

Research Project submitted in partial fulfillment for the Degree of Master of Science in Geographic Information Systems, in the Department of Geospatial and Space Technology of the University of Nairobi


**BY**

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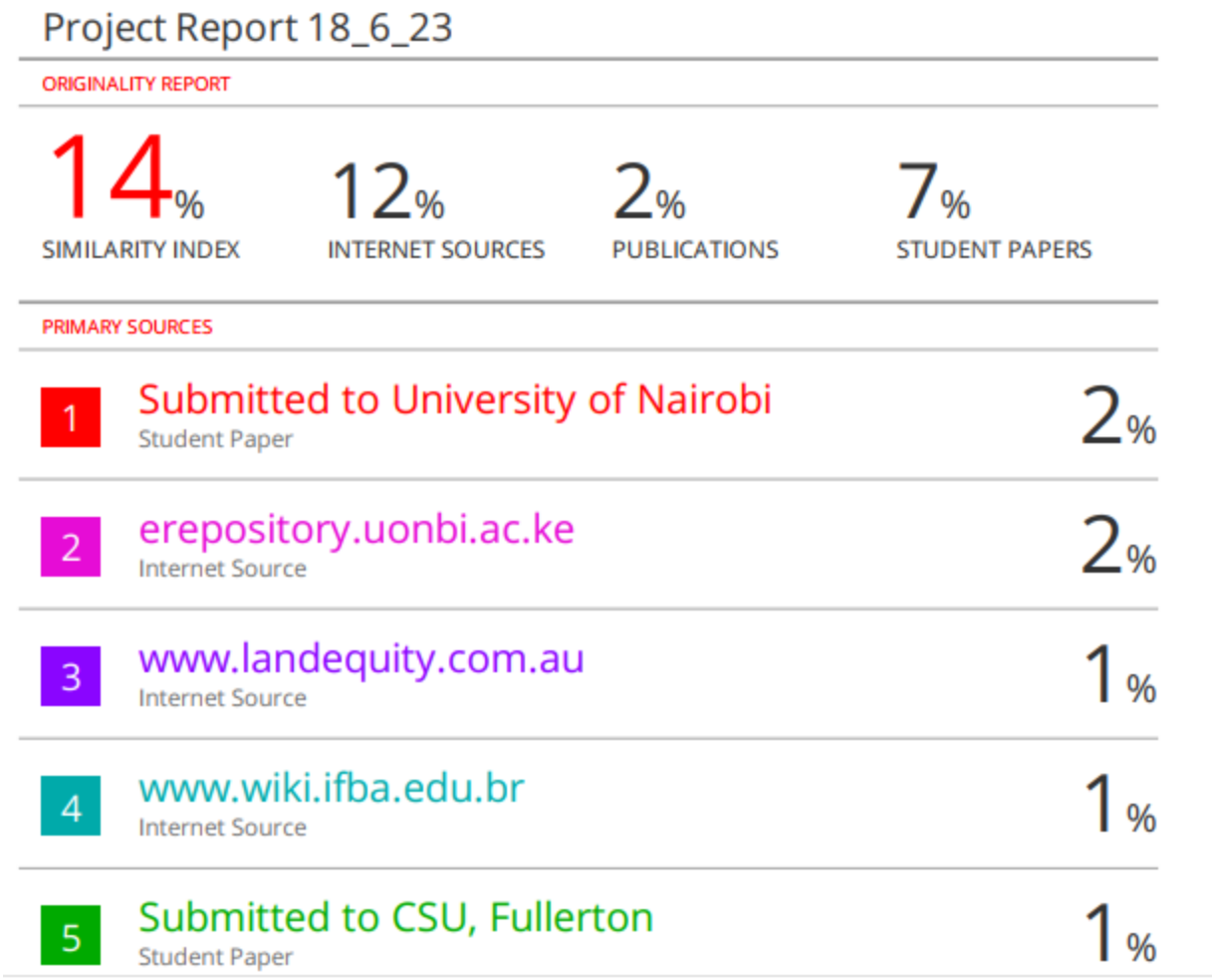

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## Abstract

National governments have continued to implement digital Land Information Management Systems (LIMS) to achieve accurate and up-to-date land information for efficient land-based services delivery; enhance good governance, decentralization, transparency in land administration and thus, contribute to sustainable socio-economic development. The benefits of digital LIMS include increased revenue generation; reduced multiple or unauthorized land allocations; curbed altering of land documents; increased accuracy, integrity and reliability of digital registry records; centralized system administration; real-time online transactions processing; and reduced fraudulent practices in the land sector.

In Baringo County, the existing paper-based land records at the department of Lands, Housing and Urban Development were voluminous, susceptible to damage, loss, duplication, often difficult to access leading to inefficiencies in land administration procedures, poor service delivery and high cost of doing business. On this basis, it was necessary to modernize data capture, storage and retrieval by designing and developing a digital land information management system to link the datasets and workflows in the department to support effective land administration. The project's sub-objectives were to document the existing datasets and workflows in the department, develop a system design for the LIMS and implement the LIMS software application. To achieve this, data collection was conducted using semi-structured interviews and questionnaires, followed by data analysis, system modelling, data modelling and system implementation. The study revealed information on the existing datasets and land administration workflows in the department; land categories; legal and administrative framework; and LIMS system requirements. Data collected was analyzed to derive business process descriptions, workflow diagrams, data models and system architectural design for the LIMS. To implement the LIMS, a web-based application was developed with functionalities for managing land information, and lodging and processing land transactions. To enhance the prototype Baringo LIMS software developed, the following are the key recommendations; documentation and integration of more datasets and workflows; incorporation of a Document Management System (DMS) and a map server; and integration of public portal to support the department in provision of online services through remote submission of applications by public users such as land owners, surveyors, lawyers, banks and estate agents

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| | |
|---|---|
| ADF | Application Development Framework |
| API | Application Programming Interface |
| BPMN | Business Process Modelling Notation |
| CEC | County Executive Committee |
| CECM | County Executive Committee Member |
| COTS | Commercial off the shelf |
| CRUD | Create Read Update Delete |
| CSS | Cascading Style Sheets |
| DBMS | Database Management System |
| ERD | Entity Relationship Diagram |
| FAO | Food and Agriculture Organization |
| FOSS | Free and Open-Source Software |
| GIS | Geographic Information System |
| HTML | Hypertext Markup Language |
| ICT | Information Communication Technology |
| ID | Identity Document |
| IFAD | International Fund for Agricultural Development |
| IP | Intellectual Property |
| ISO | International Standards Organization |
| IUDP | Integrated Urban Development Plan |
| JVM | Java Virtual Machine |
| KRA | Kenya Revenue Authority |
| LADM | Land Administration Domain Model |
| LCB | Land Control Board |
| LEI | Land Equity International |
| LIMS | Land Information Management System |
| LIS | Land Information System |
| MVC | Model View Controller |
| NEMA | National Environment Management Authority |
| OMG | Object Management Group |
| ORM | Object Relational Mapping |
| PPA | Physical Planning Act |
| RIM | Registry Index Map |
| RRRs | Rights Responsibilities and Restrictions |
| SOA | Service Oriented Architecture |
| SOLA | Solutions for Open Land Administration |
| UI | User Interface |
| UML | Unified Modelling Language |
| URL | Uniform Resource Locator |
| UTM | Universal Transverse Mercator |
| VPN | Virtual Private Network |

## CHAPTER 1: INTRODUCTION

# 1.1 Background

Baringo is a county in Kenya located in the Rift Valley region. Neighboring counties include, Samburu and Turkana to the north, Elgeyo-Marakwet and West Pokot to the west, Kericho and Nakuru to the south, Laikipia to the east and Uasin Gishu to the southwest. It is located between latitudes 0.10 degrees south and 1.40 degrees north, and longitudes 35.30 and 36.30 degrees East. Baringo county covers a total area of 11,015.3 sq.km including three lakes – Lake Bogoria, Lake Baringo and Lake Kamnarok covering 165sq.km of surface water. Figure 1.1 displays the Baringo county base map indicating neighboring counties, major towns, rivers, roads and lakes.

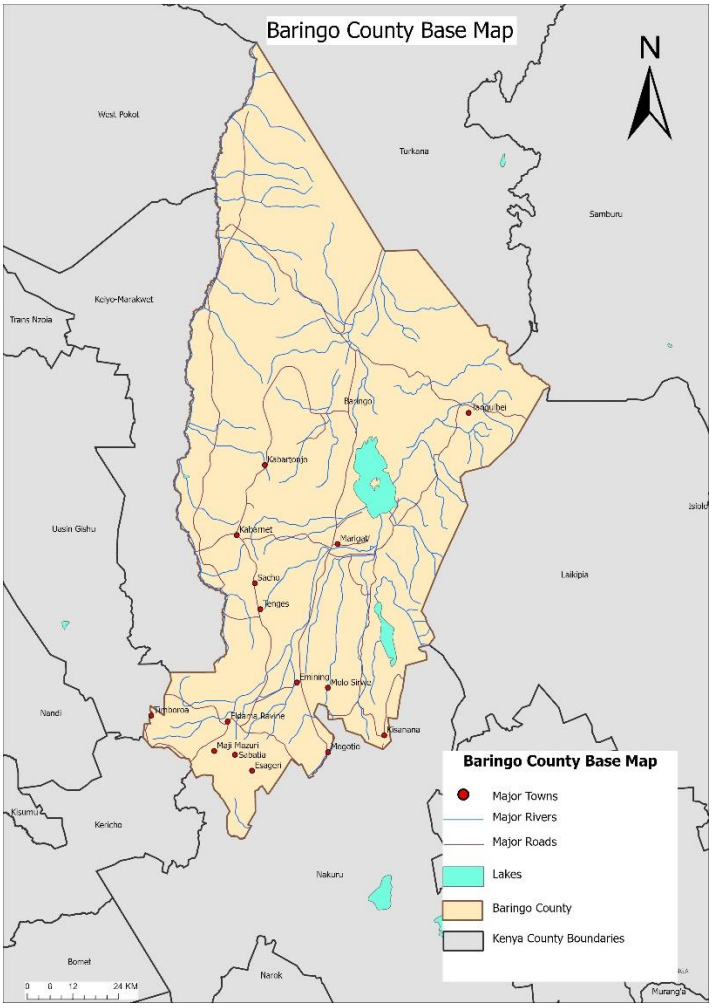



*Figure 1.1 Baringo county base map*

Baringo county has six sub-counties, which are further divided into thirty wards and a hundred and sixteen locations. Table 1.1 displays the sub-counties within Baringo county and number of divisions, locations, sub-locations and villages in each sub-county.

*Table 1.1 Administrative units in Baringo county, Source: KNBS, 2017*

| Sub County | No. of Divisions | No. of Locations | No. Sub-Locations | No. Villages |
|---|---|---|---|---|
| **Baringo central** | 4 | 21 | 53 | 284 |
| **Baringo North** | 4 | 14 | 44 | 355 |
| **Marigat** | 3 | 18 | 37 | 348 |
| **Mogotio** | 5 | 23 | 50 | 216 |
| **Koibatek** | 4 | 18 | 36 | 225 |
| **East Pokot** | 7 | 27 | 61 | 568 |
| Baringo County | **27** | **121** | **281** | **1996** |

Majority of land in Baringo County is community land, predominantly in sub-counties of Baringo North, Baringo South and Tiaty. Group ranches are found mostly in Bartum, Eldume, Kimalel, Kokwa Island, Marigat, Ngaratuko, Sabor and Salabani locations. Conservancies also form part of community land in Baringo County, these are land set aside by the community, groups of owners, individuals or companies for purposes of wildlife conservation. These include: Kabarion, Ruko, Kaptuya, Ngenyin, Morop Tarambus, Kimngochoch, Kiborgoch, Chuine, Irong, Kiborit and Kiplombe conservancies. Private land tenure is dominant in town centers such as Eldama Ravine, Mogotio, and in the highlands of Baringo North and Baringo Central. Public land in the county refers to land governed by the national and county governments including gazetted forests, national reserves, lake reserves and public land in town centers.

In the county government, the Lands, Housing and Urban Development department's mandate is to spearhead the establishment, regulation, growth of urban centers in the county. It manages the land administration procedures such as land adjudication and demarcation, and oversees the issuing of relevant land ownership documents. To discharge its mandate, the department works closely with national government agencies such as the Ministry of Lands, Public Works, Housing and Urban Development, the National Housing Corporation, the National Land Commission as well as other stakeholders in the land sector. Within the county government, the department liaises with other departments including: Industry, Commerce, Enterprise and Cooperative Development,

and Agriculture, Livestock Development and Fisheries. Since land is a primary factor of production, proper land management and administration is crucial to achieve maximum returns and development. The department's role is to ensure public utilities in commercial, residential and industries areas are provided and maintained. On housing, the department strives to develop cheap, quality and affordable housing for residents through collaboration with public and private sector stakeholders.

## 1.2 Problem Statement

The existing land records consist of a series of paper-based files and maps kept at the Lands, Housing and Urban Development department offices in designated places often under poor storage conditions. The analogue file system is not sustainable as the paper records are voluminous and susceptible to damage. The vulnerability of records to loss is high and often they are very difficult to access leading to inefficiencies in the land administrative procedures and the system is prone to abuse through corruption. Insufficient indexing and organization of the archives has also led to duplication and loss of records. While much effort might be put into the proper storage of records, the overwhelming number of records and transactions make it difficult to be organized and this leads to poor service delivery and high cost of doing business. On this basis, it is necessary to modernize data capture, storage and retrieval systems by designing and developing an integrated electronic land information management system that will automate the land administration and management services in Baringo.

## 1.3 Objectives

Main Objective

The main objective of the study is to develop a digital land information management system that will link workflows and datasets in the Lands, Housing and Urban Development department as well as other stakeholders to support land administration.

The specific objectives include:

- Document the existing datasets and workflows in the department

- Develop a system design for the LIMS
- Implement the LIMS software programs

## 1.4 Justification for the Study

Over the years, the department of Lands, Housing and Urban Development in Baringo County has accumulated massive land information records which are in manual format (paper-based) and a susceptible to manipulation, lose, misplacement, dilapidation, wear and tear, hence causing delays during retrieval of these records. This has inconvenienced residents who seek services from the department. Land administration procedures in the department are also characterized by time consuming, inefficient and expensive procedures; lack of transparency; and low public confidence.

Searching for information is cumbersome and time consuming due to the requirement of going through different file systems. With the manual systems, information such as when land leases are expiring or due for renewal can only be retrieved by going through the land records, hence many lessees are staying with expired leases therefore denying the county government much needed land revenue. There is no mechanism to notify land owners on the status and progress of land applications. Residents have to travel physically to the land offices for updates on their applications and in the process, they incur huge travel expenses especially those coming from far flung locations.

Payments in the manual system are cumbersome due to a single payment point for land services, this forces residents to incur huge travel expenses. A seamless payment system will enable payments to be done through different options such as bank deposits, online and mobile payments.

In Baringo, there is a lot of revenue losses in the land sector, since most plots are not documented, hence a lot of rental developments do not pay land rates. Revenue leakages are common due to lack of accountability and inefficiency of existing manual processes. The proposed Land Information Management System (LIMS) can assist in revealing areas lacking land ownership documents and plots that are not paying property taxes hence support collection of critical revenue by the county.

The proposed Baringo LIMS will serve as an integrated and unified platform across the entire Lands, Housing and Urban Development department. The LIMS will have modules and workflows

for land administration, valuation, physical planning and surveys; and will be aligned with the requirements of the County Integrated Development Plan in regards to the registration and management of land. The system design will include modules to manage workflows and access databases and will incorporate accessibility by interested stakeholders.

The proposed LIMS for Baringo County will provide benefits such as: availability of accurate and timely land information, digital archiving of land ownership documents, reduction in data redundancy and duplication, streamlined land administration procedures leading to improved revenue collection for the county government.

## 1.5 Scope and Limitations of the Study

The scope for this study is to develop a robust, secure, digital Land Information Management System which is integrated, scalable and sustainable technically, using international standards, and can be customized and upgraded to the Lands, Housing and Urban Development department's needs.

The study will focus on the Lands, Housing and Urban Development department and will entail development of a LIMS data model, system design, database design and LIMS software.

## CHAPTER 2: LITERATURE REVIEW

# 2.1 Introduction

Land is central to the development and transformation of Africa's economies. Land is the primary natural capital asset for sustainable development. If well governed and appropriately managed, land is an excellent means to enhance productivity, prosperous investment and economic growth. Wordsworth Odame (Larbi, 2016) emphasizes the importance of efficient land administration as being key to sustainable development. Land information management is the core of effective land administration.

Some sub-Saharan countries such as Kenya, Uganda, Tanzania, Rwanda, Ghana, Botswana, Lesotho, Mauritius, Namibia and Zambia have embraced Information Communication Technology (ICT) as an efficient tool in land management and are computerizing land administration with assistance of development partners. For example, the electronic Uganda National Land Information Management System (UgNLIS) has demonstrated substantial improvements in accountability and service delivery resulting in significant reduction in backdoor transactions, forgeries, grafts and challenges associated with missing land records (Oput, 2019). This has further strengthened the operation of a free land market and has encouraged investment to promote sustainable development in Uganda.

# 2.2 About LIMS

Land Information Management System (LIMS) is a computerized system for collection, management, storage, analysis and retrieval of land records and information. It consists of a database and a collection of modules that support land administration procedures in a given jurisdiction. Many land administration systems in Africa are characterized by paper-based and manual procedures which are slow, expensive and inefficient. Governments are slowly adopting electronic systems in the land administration sector in line with their e-governance efforts. Through projects with development partners, initiatives are being undertaken to digitize the existing paper records and develop digital land databases. Digitization consists of scanning the paper records and managing the digital files in electronic document management systems. Automation of some business processes are also being undertaken, though at a slow pace, mainly driven by the need to reduce the cost of doing business in a country/region.

LIMS consists of the following components that enable it to function well within land administration; datasets, processes/procedures related to data acquisition, processing, storage, maintenance, analysis and dissemination, hardware, software, communication networks and people

Land information system (LIS) is defined as a system for acquiring, processing, storing and distributing information about land (Williamson, Rajabifard, Enemark, & Wallace, 2010). Land information can be stacked as a set of data layers for decision making. Such layers include administrative areas, rights, use and restrictions, ownership and tax records; parcel framework; base maps.

Land information is core to effective land administration and is therefore crucial to be managed efficiently. In addition, land information is vital for promotion of good land governance contributing to sustainable development and poverty reduction. Information empowers people and thus strengthens democracy (Antonio et al 2016).

According to Byamugisha (2013), the expected benefits of a properly implemented Land Information Management System for governments, businesses and citizens include: improved security of land ownership documents and reduced transaction times; greater transparency and trackability of land transactions; reduced fraud and non-formal land transactions; increased timely, accurate and reliable land information; increased public confidence in the land administration system.

## 2.3 LIMS Implementations in Africa

In Rwanda, the Land Administration Information System (LAIS) was deployed in 2012 to maintain the land register created during the nationwide Land Tenure Regularization (LTR) programme which enabled over 8 million land parcels to be registered in the country. LAIS is an electronic land registry and maintenance system accessible to all 30 districts in Rwanda. LAIS is also linked to banks through the electronic Mortgage Registration System (e-MRS), as well as the Agricultural Land Information System (ALIS). Further integration is with the Rwanda Revenue Authority, Kigali City Construction Permitting System and the Land Query Notifications System (LQNS). Through integration with Irembo platform, the one-stop-shop for e-Government services,

citizens can submit online applications for: transfer of land, subdivision, amalgamation, fees payment, title details update, land document replacement, sporadic registration and change of land use. Core to LAIS is the linkage between the spatial and legal components of the land register, thus moving towards full automation of the land register, and improvement of land tenure security and land use management. A mobile application has also been developed to enable online checking of land information and sizes.

In an effort to improve land information management, the Department of Surveys and Mapping in Botswana developed a Land Information System (LIS) integrated with other government systems such as: National Identity Registration Database, Election Management System (EMS), Government Accounting and Budgeting System (GABS), and accounting/billing system. The LIS consists of deed registry and mapping modules that support uploading survey records and updating of the land register. In addition, Botswana is also implementing the e-Government strategy that seeks to enable online access for the following services at the Ministry of Lands and Water Affairs; application for state land allocation, application for tribal land allocation, public deeds search, land transfer, plot consolidation, sub-division, change of use and application for sub-lease. This is expected to expedite and enhance service delivery, and to further reduce turnaround time for land transactions

In 2021, Kenya launched a parcel based National Land Information Management System (NLIMS) dubbed "ArdhiSasa" aimed at improving land administration service delivery. The NLIMS project included computerization of workflows at the Ministry of Lands, and conversion and cataloguing of existing cadastral and topographical maps into digital databases. Additionally, the NLIMS supports digital land transactions through online access to the ArdhiSasa portal by land owners. ArdhiSasa seeks to remedy chronic problems facing land administration in Kenya such as: lengthy/fraudulent transactions, poorly stored physical land records and loss of records.

Mauritius, an Indian Ocean Island nation, implemented the Land Administration Valuation and Information Management System (LAVIMS), which has greatly assisted in property valuation of all residential and commercial properties. LAVIMS has enabled establishment of a digital cadastre and parcel-based deeds registration system, and further reduced fraudulent practices in the land sector. LAVIMS contains a web-based index map showing all land parcels and ownership details in a digital format allowing daily updates. Besides being a tool for better land management, the

establishment of a digital cadastre has contributed to secure land registration and transactions. LAVIMS has also enabled quality and accuracy audits, thus locking out unethical middlemen from the land sector and reduced errors in notarial deeds.

To modernize land registration, cadastral procedures, land valuation, physical planning as well as land management for efficient service delivery, Tanzania implemented the Integrated Land Management Information System (ILMIS), beginning with rollout in the Dar es Salaam region. ILMIS goal is to significantly enhance land market transparency, thereby lowering transaction costs and enabling the government to increase revenue collections. ILMIS supports cadastral survey activities such as planning, checking and approval of survey works, land administration and registration.

The main objective of the Zambia Integrated Land Management Information System (ZILMIS), developed in 2014, is to implement an electronic land administration system with centralized system administration functionality and real time transaction processing. The system includes an integrated Geospatial Information System (GIS) component that enables connectivity between the registration and cadastral information. Before ZILMIS, Zambia faced many challenges of encroachments and difficulties in accessing cadastral data due to storage of data in paper-based formats. The overall goal of ZILMIS is to achieve a comprehensive, accurate and reliable database of all land parcels in Zambia in order to enhance good governance, decentralization, transparency in land administration and thus contribute to sustainable socio-economic development.

## 2.4 LIMS Development Trends

Land Equity International (2020) reviews trends in Land Information Management Systems design and development, and reveals the following patterns in approaches since 2000;

- Software development options adopted range from in-house development, custom development, commercial development and open-source development.
- Agile software development methodologies seem to be preferred in comparison to the traditional waterfall development approach. The agile approach requires close involvement with the national land agency.

- Most common software architecture implemented in LIMS development include the Service Oriented Architecture (SOA) and microservices architecture.
- Compliance to the ISO standard Land Administration Domain Model (LADM) is becoming common place.
- Governments are implementing e-government strategies aimed at delivering services online through one-stop-shop public portals, integration of LIMS with other government systems such as revenue systems and national identity systems is becoming crucial during LIMS development.

### 2.4.1 LIMS Software Architecture

LEI (2020) defines software architecture as the fundamental structure of a software systems. LEI (2020) further describes the major software architecture models and the merits and demerits of implementing the different models in the context of LIMS. These are:

- The monolith architecture referred to as a layered architecture whereby software is designed as interconnected components organized in 3 layers namely: presentation layer, business later and data layer. The presentation layer provides the user interface through which users interact with the system, the business layer incorporates application logic and business rules, and the data layer stores and manages the database for the system
- Service Oriented Architecture (SOA) involves the deployment of discrete modules/services that perform a specific function and can easily be reused. The services communicate using a common protocol and gateway commonly referred to as a service bus.
- Microservices architecture is used to modernize existing monolith systems are consists of a collection of small autonomous services which can be deployed separately. Functionality in a microservice architecture is delivered through Application Programming Interfaces (API)

On factors influencing type of software architecture to be adopted during LIMS development, LEI (2020) mentions: degree of existing computerization within the land agency and whether the LIMS is a first or subsequent version; degree of interoperability that needs to be supported;

availability of reliable internet connectivity; availability and affordability of skilled software developers; and likelihood of further services to be provided by the LIMS

### 2.4.2 LIMS Software Development Methodologies

The traditional waterfall software development approach involves progression from one distinct development phase to the next as displayed in *Figure 2.1*.

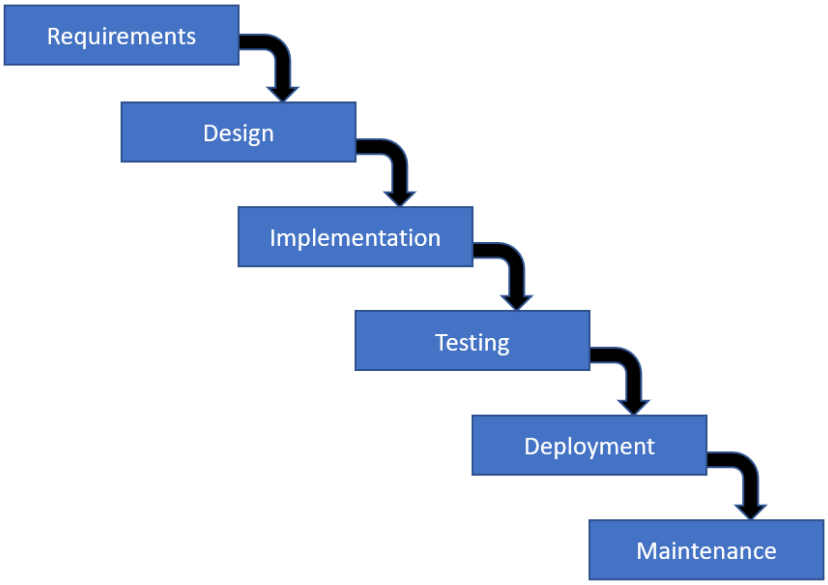



*Figure 2.1 Waterfall model*

Vital for the waterfall approach to work well is that crucial information be available at each stage such as during requirement specification, all user and system requirements need to be defined at that stage and have to remain constant as the development progresses through each phase. To remedy weaknesses in the waterfall development methodology, agile methodologies in different forms e.g Scrum, Lean Development, Extreme Programming, have been developed to ensure development occurs through different iterations and constant feedback is provided through each phase. Figure 2.2 displays different Agile model activities.


*Figure 2.2 Agile model*

LEI (2020) prescribes that the choice of development methodology adopted depends on familiarity of the software development team with a particular approach. However, agile methodologies are better suited for modern microservice system development as the modules/services can be developed separately by distinct development teams.

### 2.4.3 LIMS Components

LIMS comprises of subsystems integrated in a central database, and working together to support efficient delivery of computerized land administration services. Components core to LIMS include:

- Workflow management system whose role is to enable automation of business processes in the lands agency. Using the workflow management system, officers from departments of Lands, Surveys and Physical planning are able to process applications submitted by clients seeking land administration services.
- Document management system handles all scanned and digital documents comprising of land ownership documents, registry maps, layout plans, etc. Associated documents are

stored in an electronic archive and linked with particular transaction and land record. Features provided by the document management system include capability to create/upload new files, search, view and manage documents.

- Digital cadastre stores and manages all the georeferenced data in a spatial database containing land owner details, Rights, Responsibilities, Restrictions (RRRs), land parcel details, cadastral survey data, topographical maps.
- Reporting module generates user and system reports on land information statistics in a digital dashboard format displaying tables, charts, graphs, etc. Reporting module also supports export of tabular and graphical data in different formats.
- E-Government portal is a web enabled public portal through which land owners are able to login and submit applications for services such as land transfers, subdivision, registration, land rate payment, land search, etc. The E-Gov portal supports digital land transactions thus improving service delivery at the lands agency.
- Database Management System (DBMS) enables a relational or object relational database for storage and management of all land information. The DBMS can either be a centralized or distributed system and will handle both spatial and attribute data in the land register. The DBMS also supports create, read, update, delete (CRUD) operations on the data in a secure and efficient framework.

### 2.4.5 LIMS Development Approaches

During LIMS implementation, different approaches are available to develop the LIMS software. LEI (2020) highlights the following:

- Inhouse development whereby the lands agency will rely on its own staff to design, develop, deploy and maintain the LIMS software. This approach requires availability of skilled software developers employed and retained by the lands agency. This approach when successful enables the lands agency to own the intellectual property (IP) to the source code and ensures long term sustainability of the LIMS platform. This approach works well in countries having relatively advanced IT industries where highly skilled IT personnel are readily available.
- Bespoke development involves the lands agency procuring services of external IT consultants and solutions providers to design, develop, deploy and maintain the LIMS

software. This results in outsourcing of the LIMS development and provides flexibility and access to national and international skilled personnel. This approach is associated with high upfront costs for the LIMS and recurrent expenditure in maintaining the system through support contracts with the external firm.

- Commercial Off-The Shelf (COTS) solution approach enables the land agency to implement the LIMS in the shortest timeframe using the latest proprietary LIMS solutions available in the market. This approach requires the COTS solution provider to customize the solution according to the needs of the lands agency. COTS solutions come with annual software licensing and support fees that impact on the long term sustainability of the LIMS. The main advantage is the lands agency will leverage on state-of-the-art technology available for LIMS implementation since the solution provider has already invested resources in developing the solution.

### 2.4.6 Open-source LIMS

There exists Free and Open-Source Software (FOSS) packages, libraries and applications suitable for LIMS development. These include open-source databases, web application frameworks, programming languages, map servers, operating systems, etc. The most notable open-source suite developed specifically for LIMS implementation is the Solutions for Open Land Administration (SOLA) developed by the Food and Agriculture Organization (FAO). SOLA consists of packages such as Registry, Open Tenure, Systematic Registration, and State Land, which support formal land registration and management of the land register by a lands agency. Open-source software ensures lower upfront cost during LIMS development while facilitating customization of the software to fit the needs of the lands agency. The downside is that for maintenance of the software to be assured, an active software community has to be existing to provide constant updates and improvements to the software. Open-source software also requires external support during customization, deployment and maintenance phases of the LIMS.

### 2.4.7 Commercial LIMS Solutions

Examples of proprietary software solutions suitable for LIMS implementation include Trimble Landfolio, Innola Platform, among others. These are web-based solutions providing functionalities

for business process automation, land records management, digital cadastre, reporting and public land information portal, supporting digital land administration and management services.

### 2.4.8 LIMS External Systems

IFAD (2023) while reviewing innovative solutions to address tenure security, found that technologies are rarely used in isolation, thus to derive maximum benefits out of LIMS, integration and interoperability is required with external systems such as; taxation/revenue services, national identity system, company registry, valuation/rating system, etc. This is in line with government strategies of providing e-Government services via one-stop-shop public portals, giving citizens access to essential services without making physical visits to the government office. Example of e-Government platforms that have been successfully implemented in Sub-Saharan Africa include Kenya's eCitizen portal and Rwanda's Irembo platform.

## CHAPTER 3: MATERIALS AND METHODS

The goal of this study is to develop a prototype Land Information Management System (LIMS) for Baringo County. Figure 3.1 represents the methodological process used in this study.

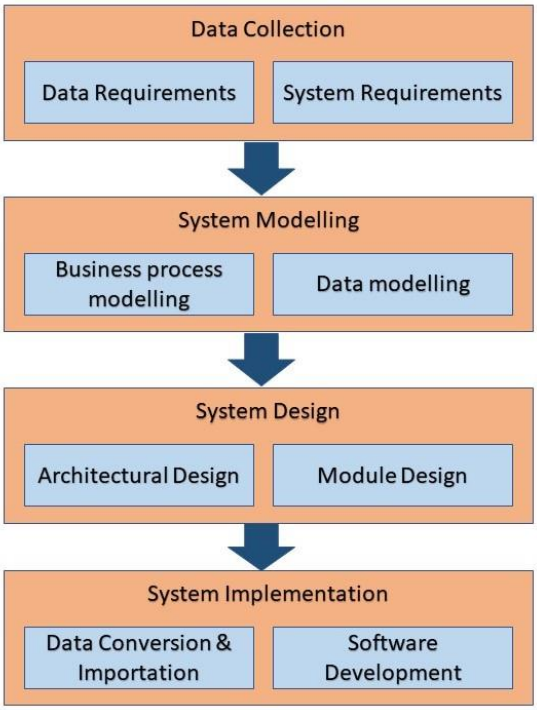



*Figure 3.1 Flow chart of project activities*

# 3.1 Data Collection

Elicitation of LIMS technical requirements was done through administering questionnaires to the representatives in the main technical department of Lands, Housing and Urban Development. Requirements are categorized into two; user and system requirements. User requirements are plain description of features to be included in the LIMS. System requirements include functional and non-functional requirements. The requirements definition questionnaire also contained aspects on the current data management in the department. This was geared towards getting information on the data types being managed, their formats and volumes. This greatly assisted in modeling the database during the system design phase.

Workflow discovery included getting descriptions of the different workflows handled by the department of Lands, Housing and Urban Development. Descriptions included the workflow steps,

inputs, outputs, actors, required conditions to start the workflows and decisions taken in the course of the workflow.

## 3.2 System Modeling

System modelling involves creating an abstract model of a system by analyzing different views or perspectives of a system and representing them in form of a model. To model a system, a graphical notation was used to depict different components of a model. The most prominent modelling notation used by system modelers is the Unified Modelling Language (UML) specification maintained by the Object Management Group (OMG).

### 3.2.1 Business Process Modelling

This entailed representing workflows graphically through a workflow diagram, flowchart, process model or modelling notation. Business process models were developed from descriptions provided by users and were used in subsequent phases of system design and development. The Business Process Modelling Notation (BPMN) specification developed by the Business Process Management Initiative, and maintained by the Object Management Group, is a common way for depicting workflows in different domains.

#### *3.2.1.1 Business Process Modelling Notation (BPMN)*

The BPMN specification is a graphical notation for representing business processes in a business process diagram. The goal of the specification is to enable process modelling using a notation that is comprehensible by different members in the system development team such as system analysts and system developers. BPMN enables depiction of elements in a business process diagram such as; events, activities, gateways, sequence flows, message flows, pools and swim lanes.

#### *3.2.1.2 Business Process Modelling Tools*

The following available tools can be used for business process modeling:

Activiti Process Modeller - this is an open-source process modeling application that supports BPMN 2.0 standard. It is developed with the help of the Alfresco Application Development

Framework (ADF) and can be used to define and validate business process models. Output files from Activiti can be executed in various workflow engines.

Signavio Process Manager - is a web-based modeling tool enabling a user to document, model, design and simulate business processes. Being a cloud-based application implies one does not need to install the application but accesses online via a web browser in a software-as-a-service model. It incorporates an intuitive user interface and supports BPMN 2.0 standard.

Camunda Modeller - this is a free and easy to use desktop application for defining and editing business process diagrams, decision tables and forms. It gives users powerful features for designing manual and automated workflow diagrams including the capability to create forms using a drag and drop interface.

jBPM Process Designer - is an integrated environment enabling design, validation and simulation of business processes. The process designer has six distinct parts; object library, process canvas, properties editor, toolbar, process validation screen and metadata.

### 3.2.2 Data Modelling

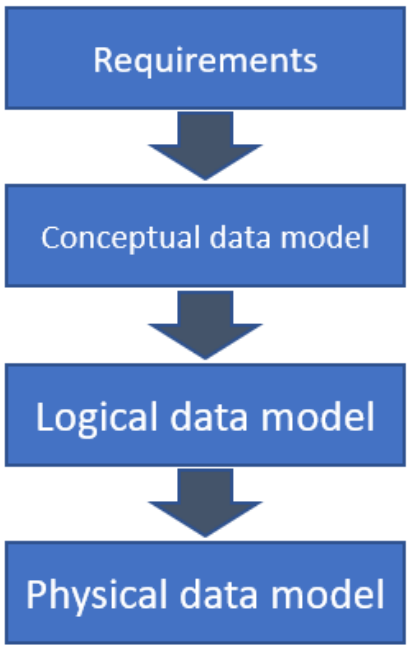



*Figure 3.2 Data modelling stages*

As depicted in Figure 3.2, the first stage in the data modelling process was requirements collection whereby prospective users were interviewed to capture and understand their data requirements. In

addition to data requirements, functional requirements of a system were also collected to assist in specifying the different operations such as retrieval and updates to be applied to the data. After collection and analysis of requirements, conceptual design followed, this included creation of a conceptual model for the database. The conceptual model has descriptions of major entities, relationships and constraints found in the data requirements. Logical design was the next step whereby the structure of data elements was established. Components of a logical data model include entities, relationships and attributes. Physical design was the last step which involves identifying the internal file systems, storage structures, memory specifications and indexes for the database.

## 3.3 System Design

System design involves depicting how a system should be structured and representing the overall organization of a system. During system implementation, system design provides a crucial connection between the requirements and the development, and shows the major structural components within a system and the linkages between them.

Architectural design provides the overall structure of the system to be developed. Its goal is to encapsulate the design decisions made and convey architecturally vital facets of a system. Architectural design provides the system development team with an integrated perspective of the system design details to be observed when developing the individual components.

## 3.4 System Implementation

Implementation involves developing programs in high- or low-level languages or adapting generic, off-the-shelf systems to meet the system requirements. System implementation uses the structure created during the architectural design to construct system elements that meet the system requirements. The architectural design was implemented into source code, modules tested, combined and built into executable code which was then deployed in a host environment.

A software development framework refers to a platform that can be used to develop software applications. It provides foundations programmers will use to develop software following a distinct architectural pattern, such as Model-View-Controller (MVC) pattern. Frameworks uses predefined elements existing as classes and modules that can handle common tasks like processing input and

interacting with services. Having pre-written functionalities and code structures streamlines the system implementation phase making it quicker and more efficient. Examples of software development frameworks are:

### 3.4.1 Django

This is a python-based web application framework that focuses on robustness and reusability and includes a model layer, view layer, template layer and a URL router. The model layer provides object-relational mapping (ORM) which simplifies dealing with data and the database. The view layer handles the business logic and is responsible for processing user input and sending back responses. The template layer is used to separate the data from the way it is presented and viewed by the user.

### 3.4.2 Spring Framework

This is an open-source Java-based software development framework for developing production-grade enterprise applications running on the Java Virtual Machine (JVM). Spring Boot makes creating web-based applications and microservices using the Spring framework seamless through autoconfiguration. Autoconfiguration is achieved through initializing applications with pre-set dependencies that do not need manual configuration. Spring framework provides dependency injection capability which enable objects to define their own dependencies that are later injected into the objects. This makes it possible to develop modular applications composed of loosely coupled components ideal for microservices. In addition, the Spring framework provides built-in support for methods that an application typically needs such as: type conversion, resource/event management, exception handling, validation and type conversion.

## CHAPTER 4: RESULTS AND DISCUSSION

# 4.1 Data Collection Findings

This section presents findings from the review of the current land administration and management framework within the county. The findings were sourced from key informants in the department consisting of officers and managers in the key technical directorates of lands, surveys and physical planning. The findings are categorized into topics namely; laws and regulations; land categories; departmental organogram; data; coordinate systems; land administration functions; existing forms; communication methods; current bottlenecks; existing systems; external users; and LIMS system requirements. The findings are expounded in the following sub-sections.

### 4.1.1. Laws and Regulations

L**egal documents** that are used by the Lands, Housing and Urban Development department in its mandate include:

- The Physical and Land Use Planning Act, 2019
- Survey Act
- Housing Act
- Land Act
- Urban Areas and Cities Act
- County Government Act
- Public Finance Management Act

The Baringo County Finance Act 2019 contains all fees and charges levied by department. Fees include development control fee, approval fees, survey fees

### 4.1.2 Land Categories

The categories and classes of land administered by the department are as follows: Public land including leasehold parcels allocated by the county and the former local authority, land classified as public utilities in municipalities, towns and trading centers; Private land registered to individuals under freehold tenure; Community land held by the county on behalf of the community pending registration according to the Community Land Act 2016

### 4.1.3 Departmental Organogram

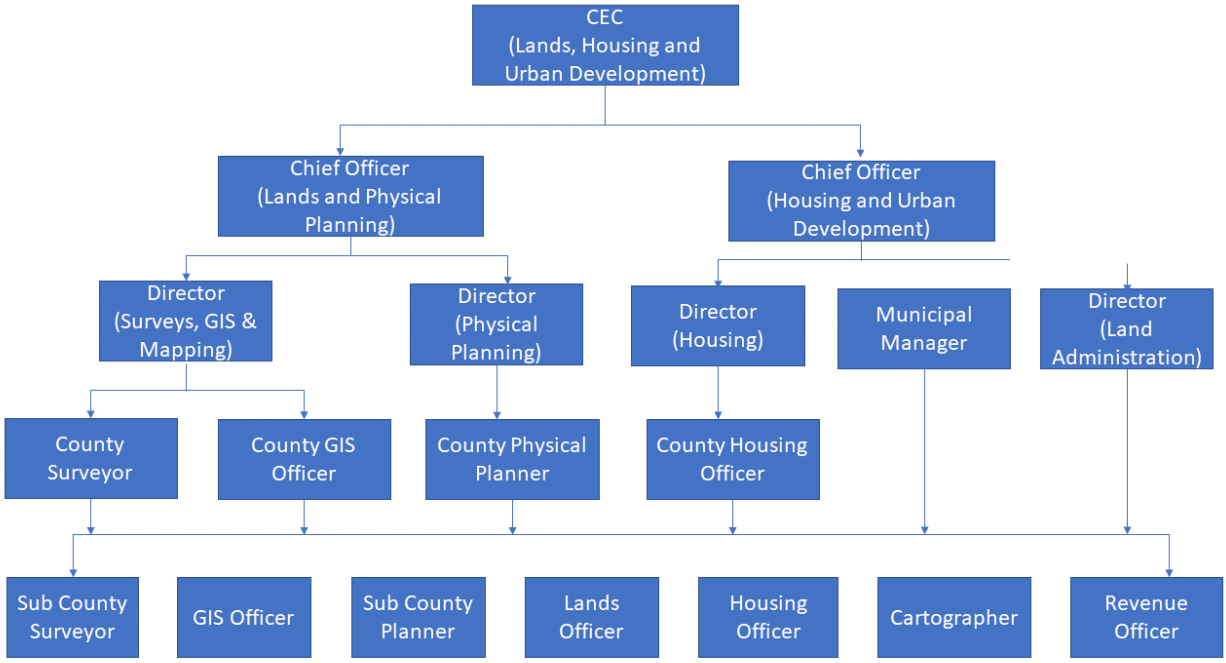



*Figure 4.1 High-level departmental organogram*

Department is organized into four directorates – Physical planning, surveys, housing and urban development, headed by directors and chief officers. The directorates have officers such as physical planners, land surveyors, land valuers and GIS officers. Towns and municipalities headed by town administrators and municipality managers respectively, depend on the directorates for day-to-day operations. Sections within towns and municipalities structures include surveys, physical planning, development control and revenue management. Figure 4.1 displays the high-level departmental organogram.

Baringo county has one municipality – Kabarnet and 10 towns/market centers.

### 4.1.4 Data

The department depends on the Baringo Lands and Surveys offices and do not maintain separate registries for lands or surveys data. 95% of data is in hard copy format, including physical development plans, survey plans, Registry Index Maps (RIM) and center plot registers. Development plans are estimated to be 200 plans with approx. 100 plots per plan. The plans are mostly analogue, a few have been digitized. Cadastral data for the 10 market centers in Baringo

exists as both paper-based plans and AutoCAD files. Cadastral data for new surveys is sent to Survey of Kenya for approval and maintenance.

There are approximately 2000 leasehold plots in the county supported by allotment letters. Land rates payment records are maintained by the respective county and sub-county revenue offices. Records on land owners is not centralized but maintained at the sub-county level.

Data in digital format includes digital land use plans for new urban areas, county spatial plan and Integrated Urban Development Plan (IUDP) for two towns.

### 4.1.5 Coordinate Systems

Cadastral surveys and plans in Baringo county (similar to the rest of Kenya) are based on Cassini coordinate system with Clarke 1858 used as reference ellipsoid and the unit of measurement is meters. Conversion parameters between Cassini to UTM projection are provided by Survey of Kenya. The department also maintains digital geospatial data in WGS84 and UTM Arc1960 spatial reference.

### 4.1.6 Land Administration Functions

Surveying functions undertaken by the department include cadastral and topographical surveys of centers, demarcation surveys for public institutions and surveys to resolve boundary disputes between land owners. The department manages plot records for county urban areas and administers plot transfers. Physical planning functions include planning of trading centers, regional and sub-regional plans, development approvals and control, subdivision approvals (consent to subdivide). Valuation services are also provided through government valuers.

Physical planning workflows:

- Application and processing for change of user, extension of user, extension of lease
- Processing of application for subdivision
- Processing of building plans
- Issuance of compliance certificate

- Preparation of site plan
- Application for consent for subdivision of land/plot
- Preparation of land/plot lease
- Consent to transfer property
- Application for consent to sublease
- Development application
- Amendment of PPAII
- Approval of site board onsite advertisement
- Preparation and processing of part development plans
- Selling of master plan
- Review of NEMA reports

### 4.1.7 Forms

Paper-based forms include application forms filled when seeking different services in the department. Forms are prescribed by the relevant legislation such as Physical Planning Act and are available on public government website for download. Accompanying documents include original title deed/lease document, allotment letter, original ID card and proof of rate payment. Requirements for Plot transfer include ID copy, KRA pin, passport, allotment letter and rate payment receipt. ID copy, copy of title and building plans are needed during application for development permission.

### 4.1.8 Communication

Communication methods used within the department include memos, letters and email communication using both official and personal email addresses.

### 4.1.9 Bottlenecks

Major bottlenecks experienced in the department include land information not easily found since it’s scattered everywhere and information is not up to date.

### 4.1.10 Existing Systems

Existing software in use in the department include AutoCAD, QGIS and ArcGIS Desktop. The department has a GIS lab with desktop and server equipment. An electronic payment platform has been procured by the County government to handle payments for parking, land rates and other services.

### 4.1.11 External Users

Besides other departments in the county government, land owners, developers, business owners, sub county and ward administrators form the bulk of potential external users for the proposed LIMS.

### 4.1.12 LIMS System Requirements

The following functional and non-functional requirements highlight the core LIMS requirements for the department of Lands, Housing and Urban Development.

Functional requirements

- Workflow management – automate land administration workflows such as application for development permission and circulation (building plans submission and payments), change of user application, plot transfer
- Integration with revenue management system
- Manage parcel information – plot numbers, owner information, land tenure, historical transactions and associated documents
- Manage spatial units (parcels) – support subdivision, amalgamation and redefining of parcels
- Map spatial information – search and view spatially defined cadastral data, display other map layers
- Document management – scan, upload and link documents supporting transactions, search and retrieve documents historic documents
- Reporting – auto-generate email/sms notifications to applicant/owner when key milestones of transactions are completed, generate progress report for a service, generate office transaction processing metrics reports
- Land information portal requirements – updated details about each plot, plot records, owner information, land rates and rent payments option

- System administration requirements – editing and updating functions to be performed by system administrators, multiple user functions to be used by department staff to view and suggest edits, client access.

Non-functional requirements

- System security – user authentication and user role management including controlled access to perform certain functions and view specific database details, logging of all changes to critical data elements, auditing database changes, system access and encryption.
- Software maintainability

# 4.2 System Modeling

## 4.2.1 Business Process Modelling

This entails representing workflows graphically through a workflow diagram, flowchart, process model or modelling notation. Business process models are developed from descriptions provided by users and are used in subsequent phases of system design and development. The Business Process Modelling Notation (BPMN) specification developed by the Business Process Management Initiative, and maintained by the Object Management Group, is a common way for depicting workflows in different domains.

### *4.2.1.1 Business Processes Identification*

Table 4.1 outlines the business processes identified from key informant interviews and administering questionnaires in the directorates of physical planning, lands and surveys.

*Table 4.1 Business processes in the department of Lands, Housing and Urban Development*

| **Directorate** | **Business Process** |
|---|---|
| Physical planning | Development application |
| Physical planning | Consent for subdivision |
| Physical planning | Application for change of user |
| Physical planning | Application for extension of user |
| Physical planning | Application for extension of lease |
| Physical planning | Application for subdivision |
| Physical planning | Processing of building plan |
| Physical planning | Processing of environmental impact assessment and audit report |
| Physical planning | Issuance of compliance certificate |
| Physical planning | Preparation of site plan |
| Physical planning | Preparation of land lease |
| Physical planning | Consent to transfer property |
| Physical planning | Application for consent to sub-lease |
| Physical planning | Amendment of PPAII |
| Physical planning | Approval of site board on-site advertisement |
| Physical planning | Preparation of part development plan |
| Lands | Renewal of lease |
| Lands | Plot search |
| Lands | Consent to charge |
| Lands | Plot transfer |

#### *4.2.1.2 Business Processes Description*

After identifying and categorizing business processes into their respective directories, each process was decomposed into the main steps in the process, actions involved, descriptions of the actions and roles/responsible officers who are assigned according to respective legal provision and departmental procedures. The descriptions are detailed in Tables 4.2 to 4.6

*Table 4.2 Development permission process mapping*

| No. | Process Mapping | Actions | Description | Role / Responsible Office |
|---|---|---|---|---|
| 1 | **Application** | Submit Application | Applicant submits development application | Applicant |
| | | Receive Application | Department receives application | Department |
| | | Issue submission certificate | County Director issues applicant with submission certificate through Form PLUPA/DC/5 | Director |
| 2 | **Make Payment** | Make Payment | Payment of prescribed fees by the applicant | Applicant |
| 3 | **Register application** | Register Application | County Director registers the application in the development applications register | Director |
| 4 | **Circulation** | Circulate Application | County Director circulates application for review and comments, 7 days after receiving application | Director |
| | | Review and Comment | Technical officers review and comment on application | Technical Officers |
| 5 | **Report** | Prepare Report | County Director analyzes the comments received and prepares a report for submission to the CECM | Director |
| | | Submit Report | County Director submits report to CECM | Director |
| | | Receive Report | CECM receives report | CECM |
| 6 | **Decision** | CECM Decision | The CECM grants (with or without conditions), defer or refuses application with reasons and authorizes the county director to communicate decision to the applicant | CECM |
| | | Notice of Decision | County Director transmits decision to applicant | Director |
| 7 | **Recirculation** | Recirculate Application | County Director recirculates deferred applications to relevant authority for further review | Director |
| 8 | **Appeal** | Make Appeal | Aggrieved party appeals to the County Liason Committee within 14 Days | Applicant |

*Table 4.3 Consent to subdivide process mapping*

| No. | Process Mapping | Actions | Description | Role / Responsible Office |
|---|---|---|---|---|
| 1 | **Application** | Submit Application Form | Submit approved application from LCB | County Land Office |
| | | Create File | County lands officer creates a file for the subdivision | Lands Officer |
| 2 | **Valuation** | Request Valuation | Lands officer requests for valuation of subdivided portion from valuation department | Lands Officer |
| | | Submit Valuation | Valuation department submits valuation report | Valuation department |
| 3 | **Payment** | Make Payment | Client makes payment (stamp duty is 2 percent for agricultural land, 4 percent for commercial) | Client |
| 4 | **Registration** | Initiate Registration | Lands officer initiates registration of title using approved transfer form from LCB | Lands Officer |
| | | Prepare Title | Lands officer prepares title | |
| | | Forward Title | Lands officer forwards prepared title to Land Registrar for registration | Lands Officer |

*Table 4.4 Change of user process mapping*

| No. | Process Mapping | Actions | Description | Role / Responsible Office |
|---|---|---|---|---|
| 1 | **Application** | Submit Application | Client through registered physical planner applies for change of user | Client |
| | | Receive Application | Application is received by physical planning department | Physical Planning dept |
| 2 | **Gazettement** | Gazette Intention | Physical planning department gazettes the intention to change user | Physical Planning dept |
| 3 | **Payment** | Make Payment | After 30 days, client through physical planner pays for the application | Client |
| 4 | **Review** | Review Application | Physical planning department reviews application | Physical Planning dept |
| 5 | **Approval** | Give Approval | Physical planning department gives approval of application | Physical Planning dept |
| | | Decline Approval | If there are issues at stage 2 or 4, department declines application | Physical Planning dept |

*Table 4.5 Extension of user process mapping*

| No. | Process Mapping | Actions | Description | Role / Responsible Office |
|---|---|---|---|---|
| 1 | **Application** | Submit Application | Client through registered physical planner applies for extension of user | Client |
| | | Receive Application | Application is received by physical planning department | Physical Planning dept |
| 2 | **Payment** | Make Payment | After 30 days, client through physical planner pays for the application | Client |
| 3 | **Review** | Review Application | Physical planning department reviews application | Physical Planning dept |
| 4 | **Approval** | Give Approval | Physical planning department gives approval of application | Physical Planning dept |
| | | Decline Approval | If there are issues at stage 3, department declines application | Physical Planning dept |

*Table 4.6 Renewal of lease process mapping*

| No. | Process Mapping | Actions | Description | Role / Responsible Office |
|---|---|---|---|---|
| 1 | **Application** | Submit Application | Client applies to county land office for renewal 3 months before expiry | Client |
| | | Receive Application | County lands office receives application | County Land Office |
| | | Forward Application | Lands office forwards request to land administration department for consideration | County Land Office |
| 2 | **Review** | Review Application | Land administration will review application | Land Administration |
| | | Give Feedback | Land administration will give feedback to land office allowing renewal or reservation of renewal | Land Administration |
| 3 | **Letter of Renewal** | Issue Letter of Renewal | Land administration will give letter of renewal to client through Lands office | County Land Office |
| 4 | **Letter of Rejection** | Issue Letter of Rejection | Land administration will give letter of rejection to client through Lands office | County Land Office |

### *4.2.1.3 Workflow diagrams*

From the detailed business process descriptions, workflow diagrams were generated to model the steps from end to end using the Business Process Modelling Notation (BPMN). This was done in the Activiti Modeler, an open-source software application enabling creation and manipulation of BPMN workflow diagrams. Activiti Modeler includes functionality to export workflow diagrams to BPMN file formats that enables importation of the process definitions into workflow engines.

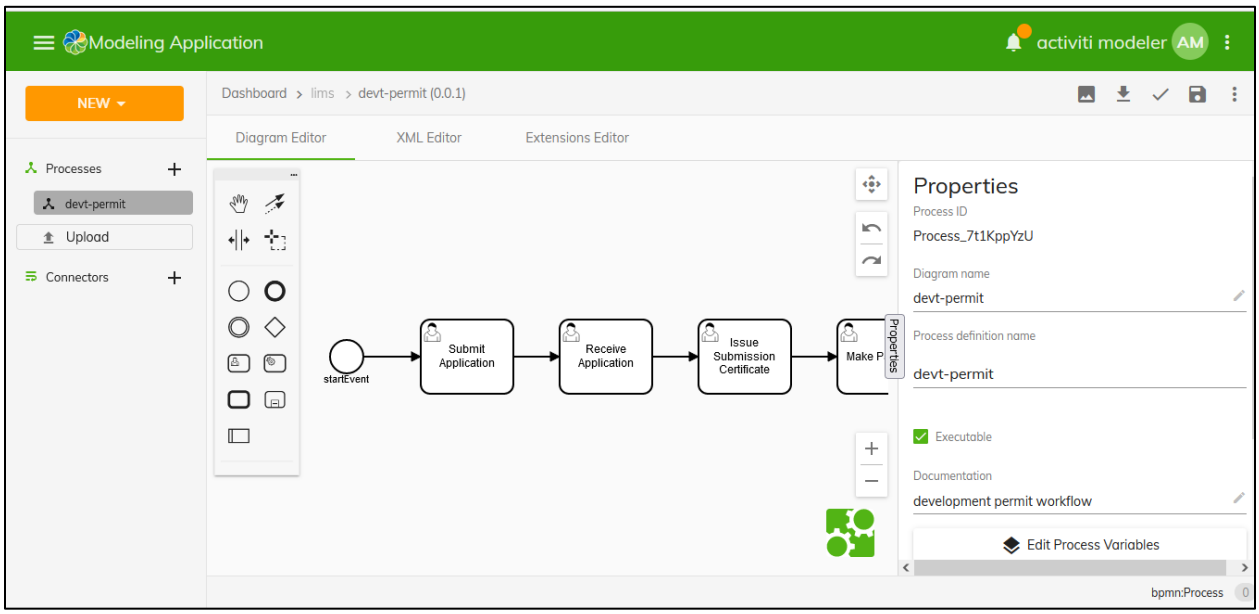



*Figure 4.2 Activiti Modeler window*

Figure 4.2 displays the Activiti Modeler user interface (UI) through which one can define process start and end events, tasks, gateways, sequences, assignees and process variables. Besides the diagram editor, one can also edit properties of each element such as the task names and condition expressions. Optionally, the XML editor indicated by Figure 4.3 is also present to allow editing of the BPMN process definition in an XML-based format. Figures 4.4 to 4.7 displays the different workflow diagrams generated from the process descriptions.

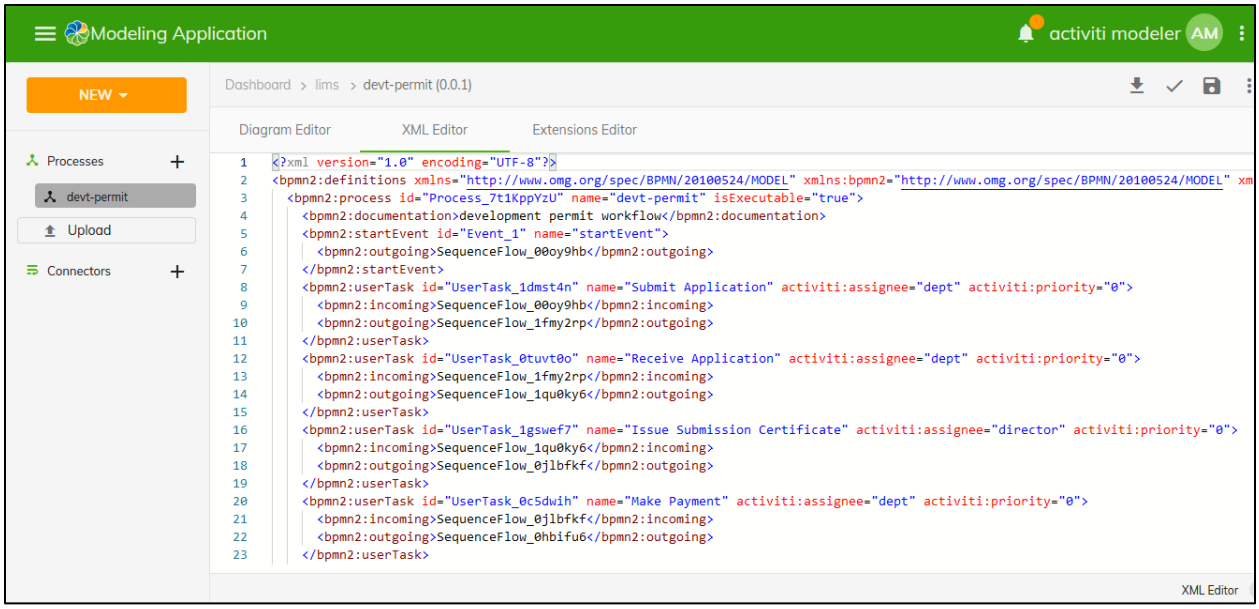



*Figure 4.3 XML Editor*

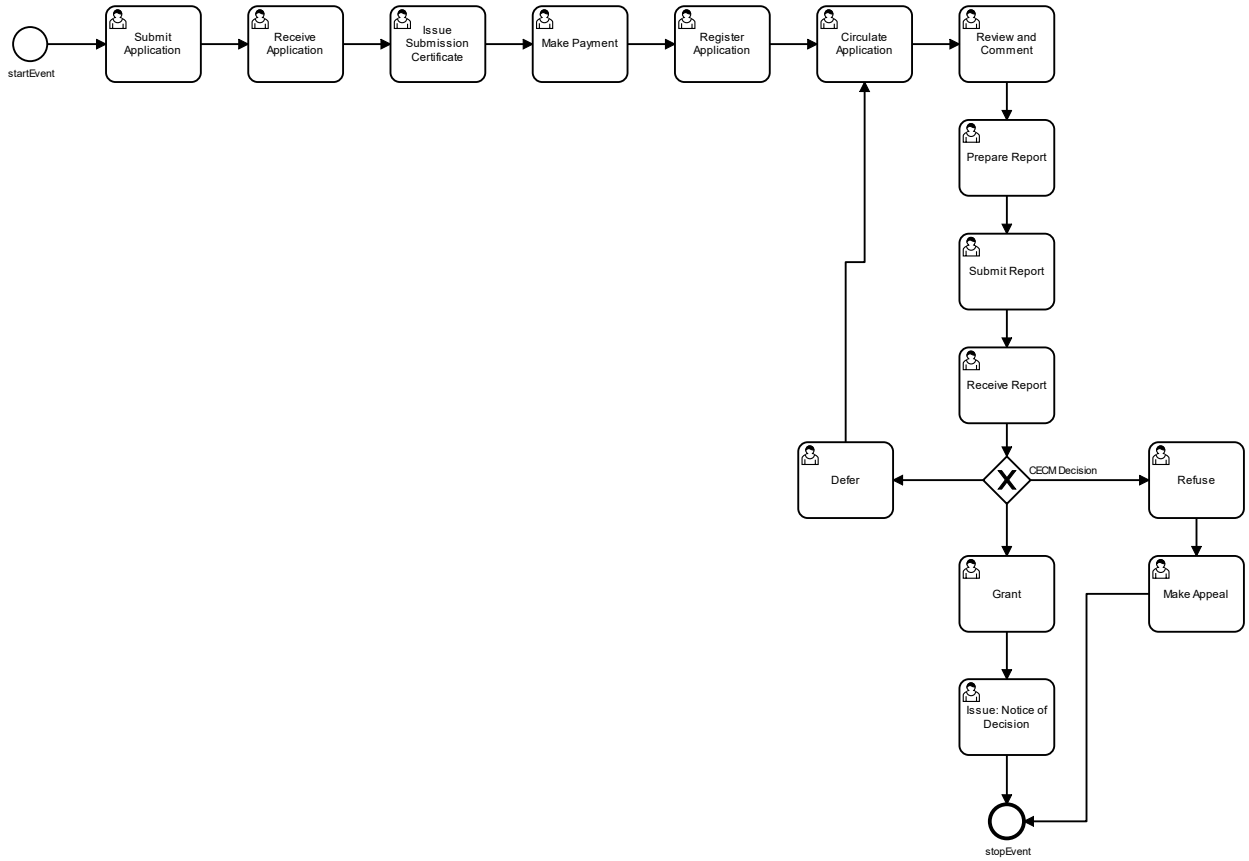



*Figure 4.4 Development permission workflow diagram*

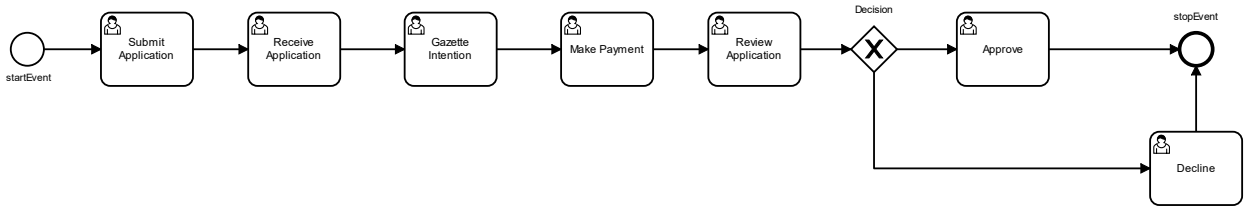



*Figure 4.5 Change of user workflow diagram*

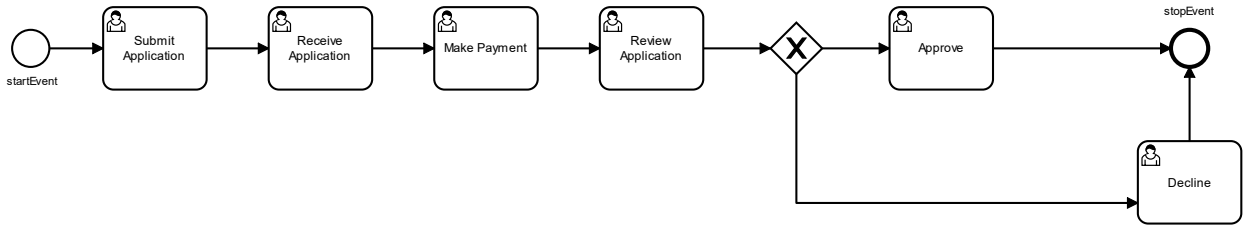



*Figure 4.6 Extension of user workflow diagram*

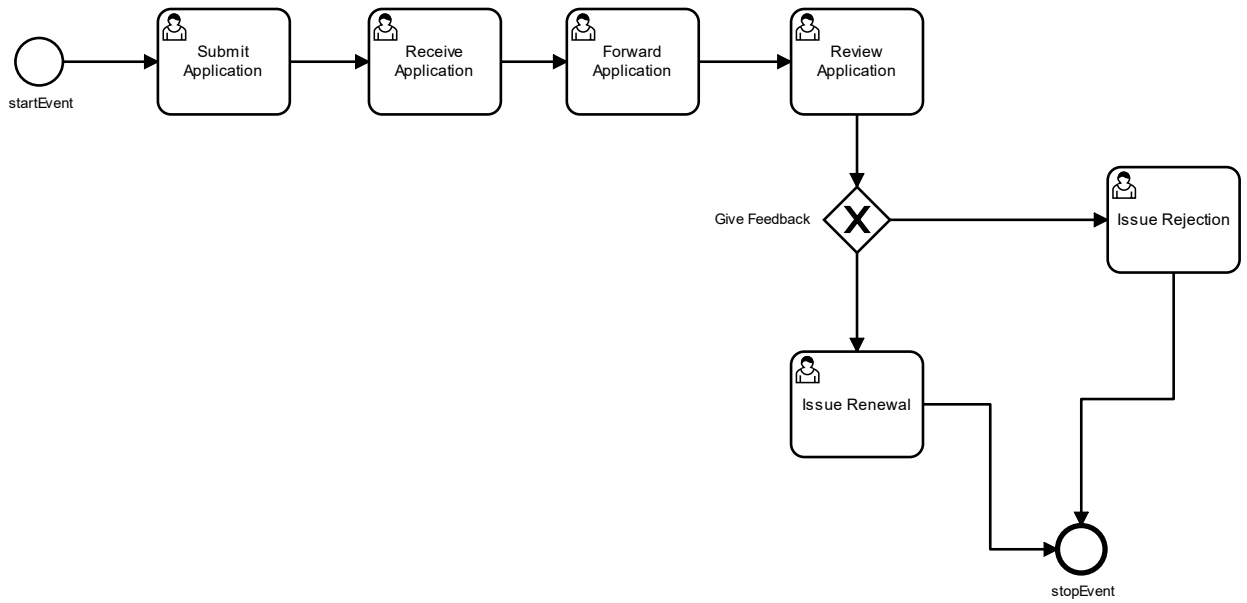



*Figure 4.7 Renewal of lease workflow diagram*

### 4.2.2 Data Modelling

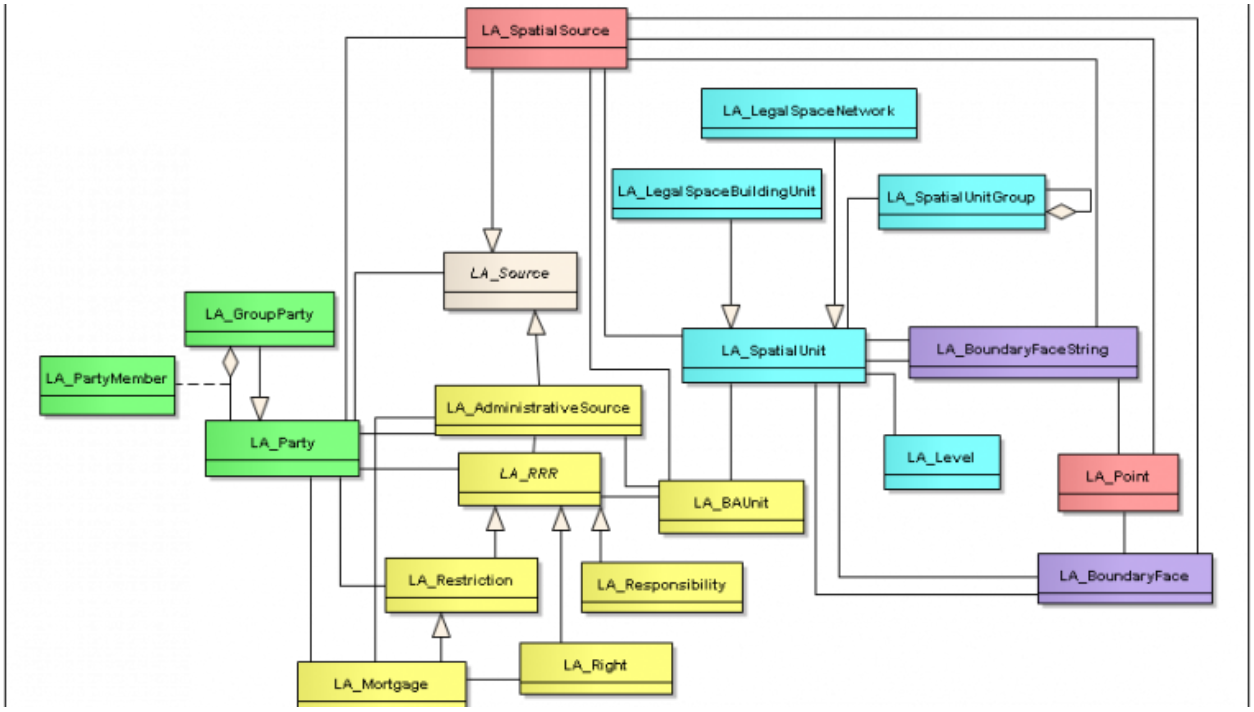



*Figure 4.8 LADM Class Diagram*

Figure 4.8 displays an overview of the Land Administration Domain Model (LADM ISO 19152), a conceptual data model covering the width of land administration, integrating spatial parts (geometry, topology, surveying) and legal/administrative components. LADM is a reference model used as a basis for national and regional profiles and specializations, which contain parts relevant to a specific country. So far there are about 45 country profiles in different phases – research, prototype and production.

Basic LADM packages are: party, legal/administrative and spatial unit packages implemented using four core classes; LA_Party, LA_RRR, LA_BAUnit, LA_SpatialUnit. The LADM was adapted to form the conceptual data model used in the proposed Baringo LIMS. Table 4.7 displays the mapping of the LADM basic classes to the Baringo LIMS data model, while Figure 4.9 shows the resultant relational schema.

*Table 4.7 Mapping LADM classes to Baringo LIMS*

| LADM Classes | Baringo LIMS Classes | Description |
|---|---|---|
| LA_Party | Party | Stores information on land owners – personal and contact details |
| LA_SpatialUnit | Parcel | Stores information on land parcels/plots |
| LA_RRR | RRRs | Stores information about all rights, responsibilities and restrictions linking persons to land parcels. |
| extApplication | Application | Stores information on all transactions lodged on the LIMS |
| extStaff | User | Store information about land officers assigned to process land transactions |

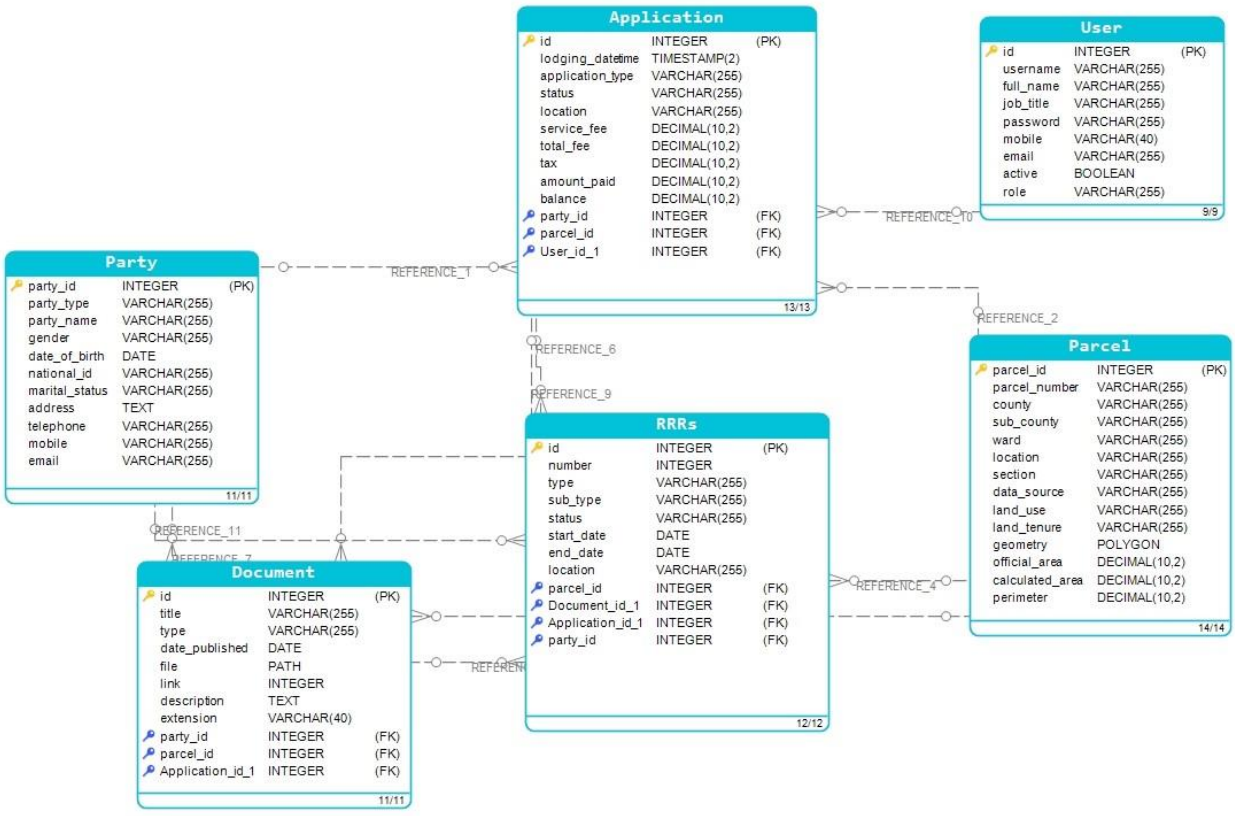



*Figure 4.9 Entity Relationship Diagram (ERD)*

## 4.3 System Design

System architectural design provides the overall structure of the system to be developed. Its goal is to encapsulate the design decisions made and convey architecturally vital facets of a system. Architectural design provides the system development team with an integrated perspective of the system design details to be observed when developing the individual components.

### 4.3.1 Context View

The context view of the system describes the relationships, dependencies and interactions between the system and its environment (the people, systems and external entities that it interacts with).

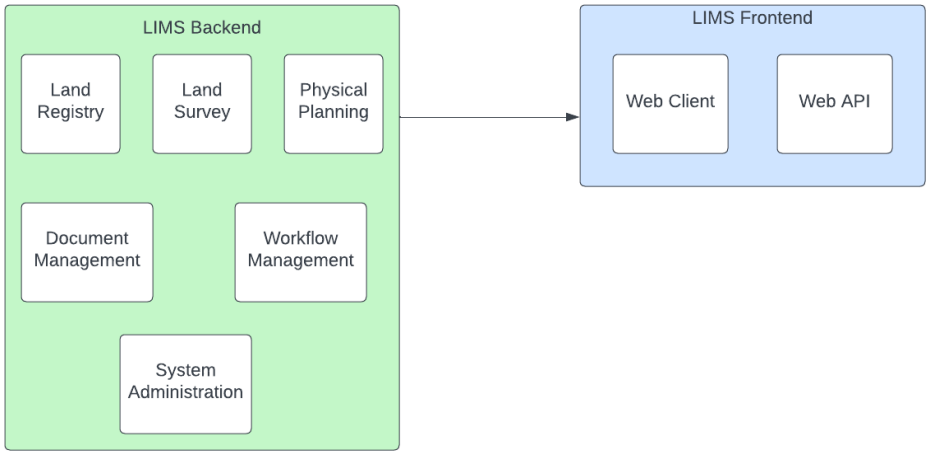



*Figure 4.10 Context Diagram*

The context diagram displayed by Figure 4.10 gives an overview of the LIMS and its interactions with other components within the LIMS system architecture. The diagram displays the expected inputs and outputs from the LIMS to and from various external entities.

### 4.3.2 Functional View

The functional view of the system defines the system's architecturally significant functional elements, the responsibilities of each, the interfaces they offer and the dependencies between elements.

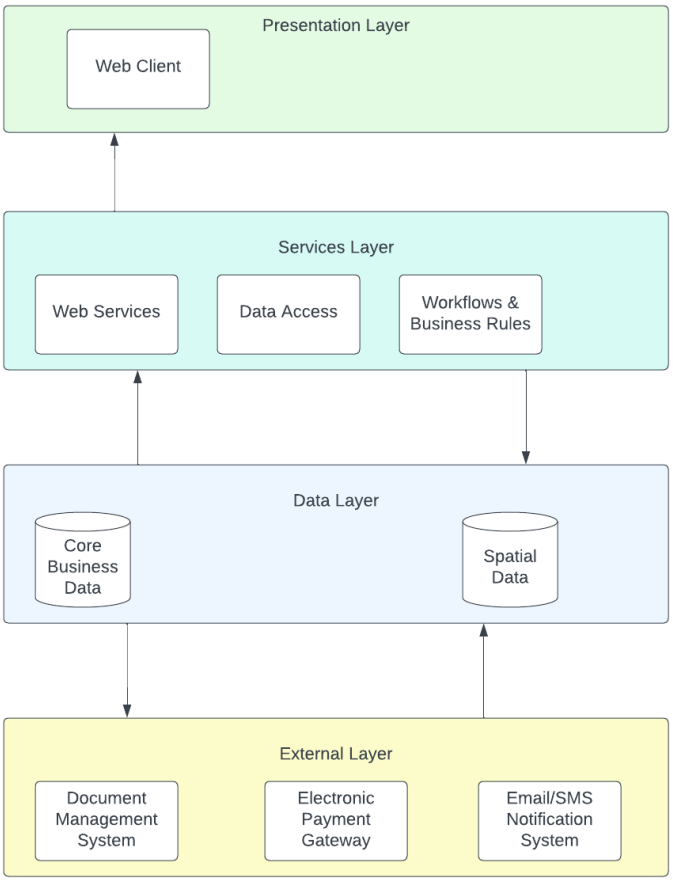



*Figure 4.11 Functional diagram*

The Figure 4.11 depicts a layered functional view illustrating the different tiers and main functional elements within each tier.

Presentation tier consists of the web frontend application delivered to end users using web 2.0 technologies - HTML5, JavaScript and CSS. The frontend supports user login, visualization and export of information. User interface (UI) elements include dashboards, panels, legends and visualization options - graphs, charts, tables, etc.

Logic tier consists of the system logic providing user authentication and management capabilities, data querying and filtering. Through web services the logic tier uses data access connectors to integrate with external systems.

Data tier consists of the embedded database used to store user information and system configurations for the LIMS.

### 4.3.3 Deployment View

The Deployment view of the system defines the important characteristics of the system's operational deployment environment. This view includes the details of the processing nodes that the system requires for its installation (i.e., its runtime platform), the software dependencies on each node (such as required libraries) and details of the underlying network that the system will require.

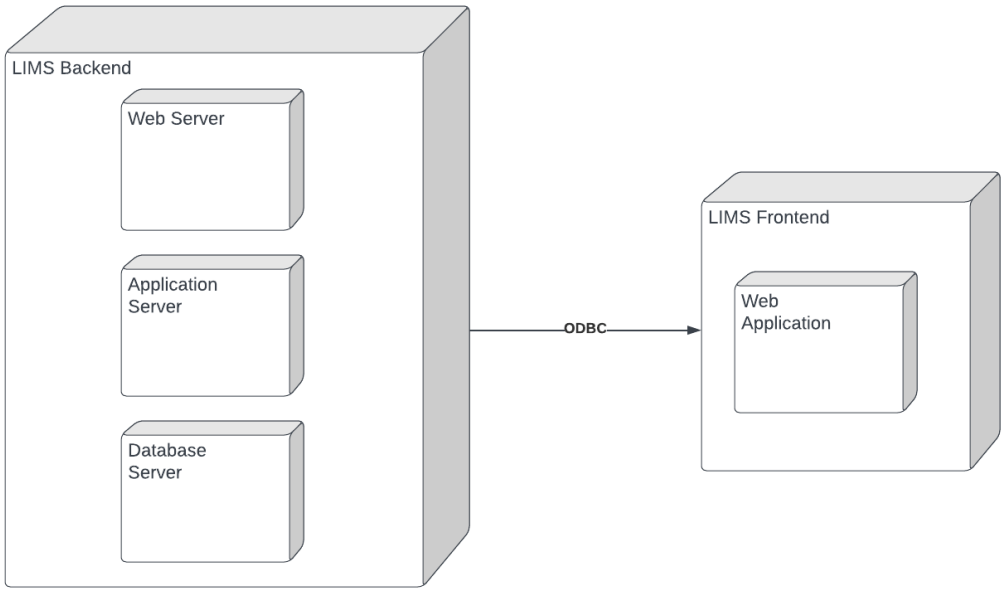



*Figure 4.12 Deployment diagram*

The deployment diagram displayed by Figure 4.12 depicts the different nodes, execution environments and devices involved in the LIMS deployment. The arcs represent communication protocols between the nodes.

### 4.3.4 Operational View

The Operational view defines how the system will be installed into its production environment, how data and users will be migrated to it and how it will be configured, managed, monitored, controlled and supported once this is achieved. The aim of the information in this view is to show

how the operational environment is to be created and maintained, rather than to define detailed instructions or procedures.

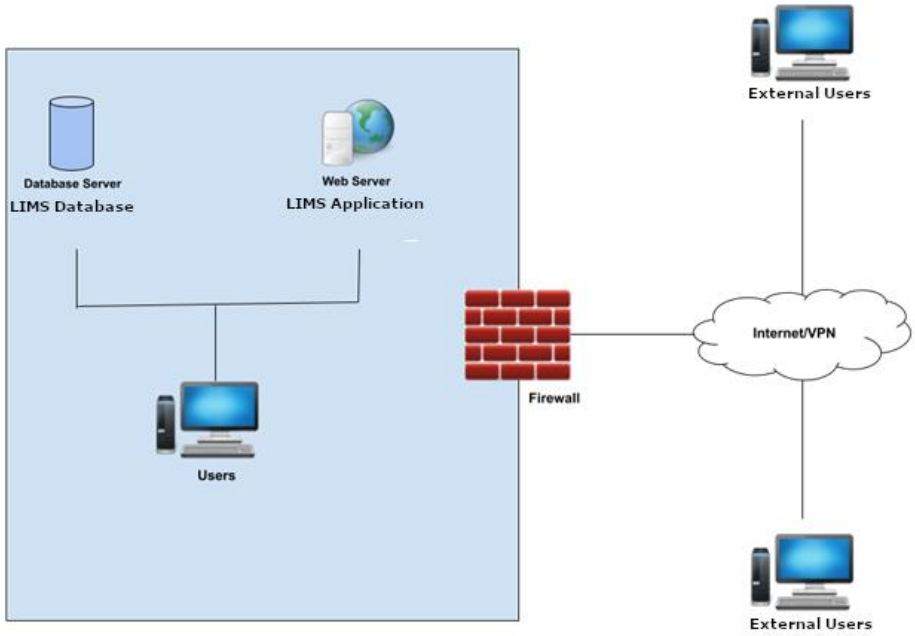



*Figure 4.13 Operational diagram*

The operational diagram displayed by Figure 4.13 depicts the LIMS components to be deployed in the production environment. Essentially, the LIMS application is a full stack application consisting of a frontend and backend deployed on the same server.

# 4.4 System Implementation

## 4.4.1 Data Conversion

Spatial and attribute data collected was converted into digital file formats suitable for importation into the LIMS database. The cadastral survey plans displayed in Figure 4.14 were first check to confirm that the beacons matched those in the corresponding coordinate lists. The coordinate pairs

were then entered into a spreadsheet and then converted from Cassini to UTM using conversion parameters provided by Survey of Kenya. Figure 4.15 displays the coordinate transformation parameters spreadsheet. After conversion, the spreadsheet was imported into ArcGIS Pro desktop GIS software as point data as displayed in Figure 4.16. Parcel polygons were then generated from the point data and labelled according to the cadastral survey plans. ArcGIS Pro loaded with the Parcel Fabric extension enabled organization of the spatial data into a geodatabase, feature dataset, Parcel Fabric and feature classes. Figures 4.17 and 4.18 displays the ArcGIS Pro geodatabase structure and parcel map respectively.

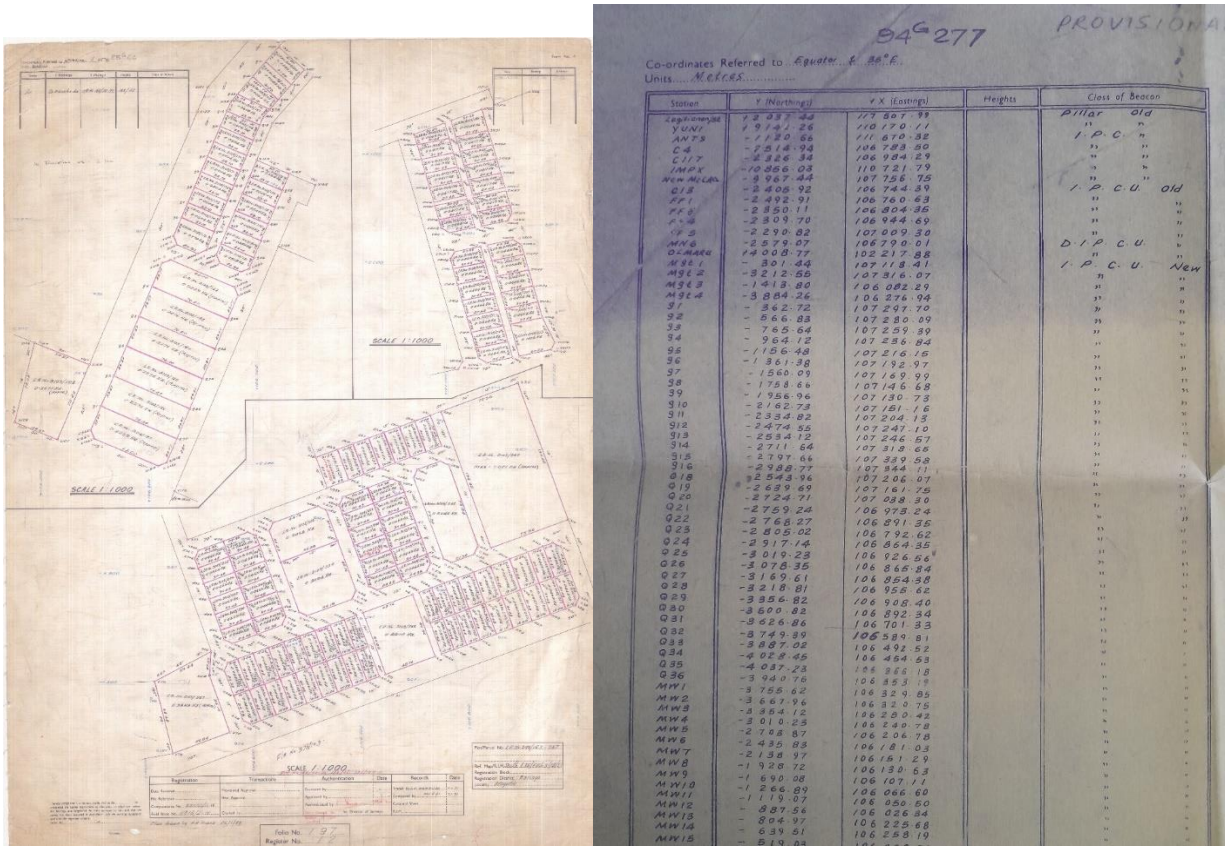
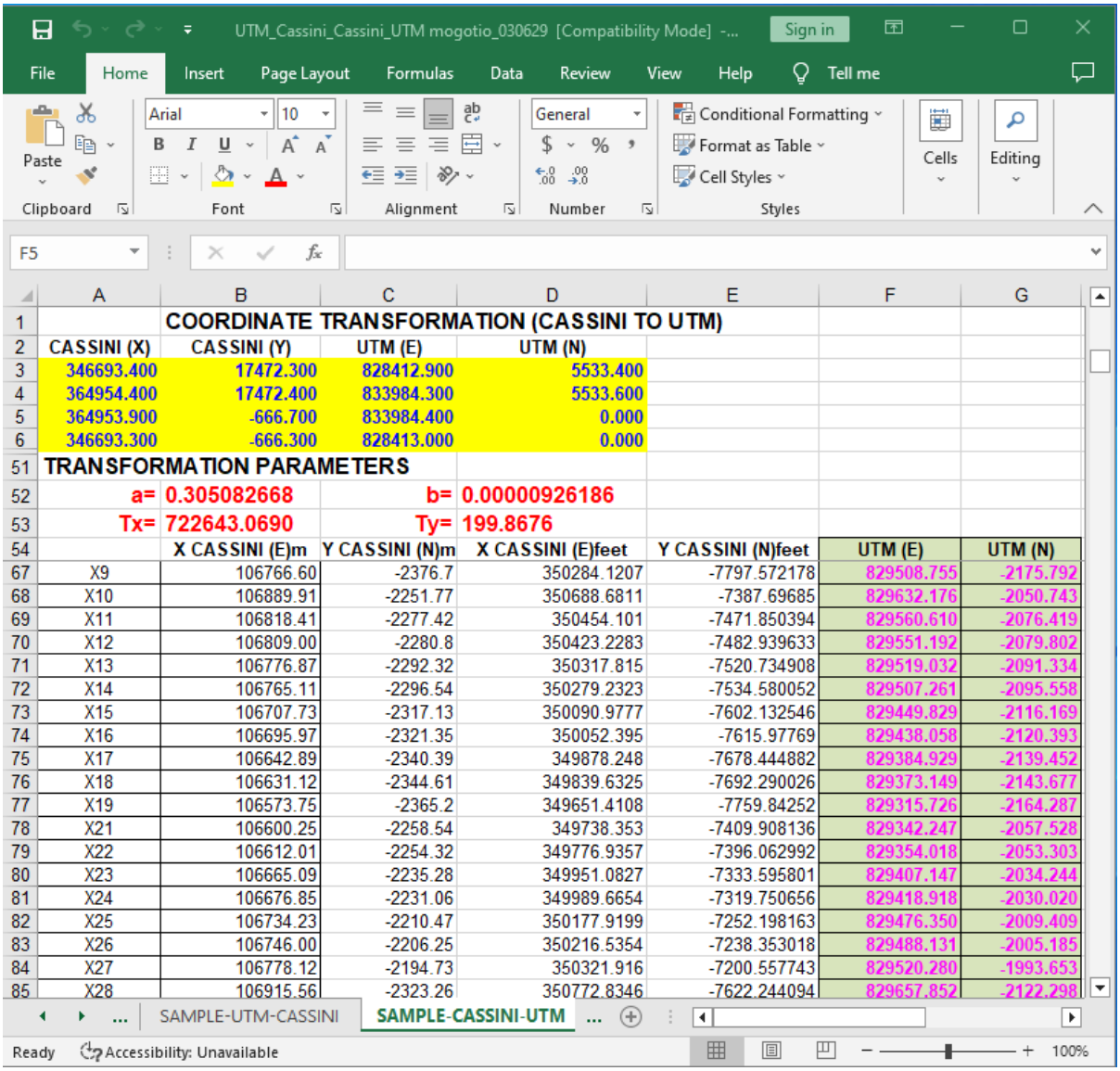



*Figure 4.14 Cadastral survey plan*



| | A | B | C | D | E | F | G |
|---|---|---|---|---|---|---|---|
| 1 | | COORDINATE TRANSFORMATION (CASSINI TO UTM) | | | | | |
| 2 | CASSINI (X) | CASSINI (Y) | UTM (E) | UTM (N) | | | |
| 3 | 346693.400 | 17472.300 | 828412.900 | 5533.400 | | | |
| 4 | 364954.400 | 17472.400 | 833984.300 | 5533.600 | | | |
| 5 | 364953.900 | -666.700 | 833984.400 | 0.000 | | | |
| 6 | 346693.300 | -666.300 | 828413.000 | 0.000 | | | |
| 51 | TRANSFORMATION PARAMETERS | | | | | | |
| 52 | a= | 0.305082668 | b= | 0.00000926186 | | | |
| 53 | Tx= | 722643.0690 | Ty= | 199.8676 | | | |
| 54 | | X CASSINI (E)m | Y CASSINI (N)m | X CASSINI (E)feet | Y CASSINI (N)feet | UTM (E) | UTM (N) |
| 67 | X9 | 106766.60 | -2376.7 | 350284.1207 | -7797.572178 | 829508.755 | -2175.792 |
| 68 | X10 | 106889.91 | -2251.77 | 350688.6811 | -7387.69685 | 829632.176 | -2050.743 |
| 69 | X11 | 106818.41 | -2277.42 | 350454.101 | -7471.850394 | 829560.610 | -2076.419 |
| 70 | X12 | 106809.00 | -2280.8 | 350423.2283 | -7482.939633 | 829551.192 | -2079.802 |
| 71 | X13 | 106776.87 | -2292.32 | 350317.815 | -7520.734908 | 829519.032 | -2091.334 |
| 72 | X14 | 106765.11 | -2296.54 | 350279.2323 | -7534.580052 | 829507.261 | -2095.558 |
| 73 | X15 | 106707.73 | -2317.13 | 350090.9777 | -7602.132546 | 829449.829 | -2116.169 |
| 74 | X16 | 106695.97 | -2321.35 | 350052.395 | -7615.97769 | 829438.058 | -2120.393 |
| 75 | X17 | 106642.89 | -2340.39 | 349878.248 | -7678.444882 | 829384.929 | -2139.452 |
| 76 | X18 | 106631.12 | -2344.61 | 349839.6325 | -7692.290026 | 829373.149 | -2143.677 |
| 77 | X19 | 106573.75 | -2365.2 | 349651.4108 | -7759.84252 | 829315.726 | -2164.287 |
| 78 | X21 | 106600.25 | -2258.54 | 349738.353 | -7409.908136 | 829342.247 | -2057.528 |
| 79 | X22 | 106612.01 | -2254.32 | 349776.9357 | -7396.062992 | 829354.018 | -2053.303 |
| 80 | X23 | 106665.09 | -2235.28 | 349951.0827 | -7333.595801 | 829407.147 | -2034.244 |
| 81 | X24 | 106676.85 | -2231.06 | 349989.6654 | -7319.750656 | 829418.918 | -2030.020 |
| 82 | X25 | 106734.23 | -2210.47 | 350177.9199 | -7252.198163 | 829476.350 | -2009.409 |
| 83 | X26 | 106746.00 | -2206.25 | 350216.5354 | -7238.353018 | 829488.131 | -2005.185 |
| 84 | X27 | 106778.12 | -2194.73 | 350321.916 | -7200.557743 | 829520.280 | -1993.653 |
| 85 | X28 | 106915.56 | -2323.26 | 350772.8346 | -7622.244094 | 829657.852 | -2122.298 |

*Figure 4.15 Coordinate Transformation (Cassini to UTM)*

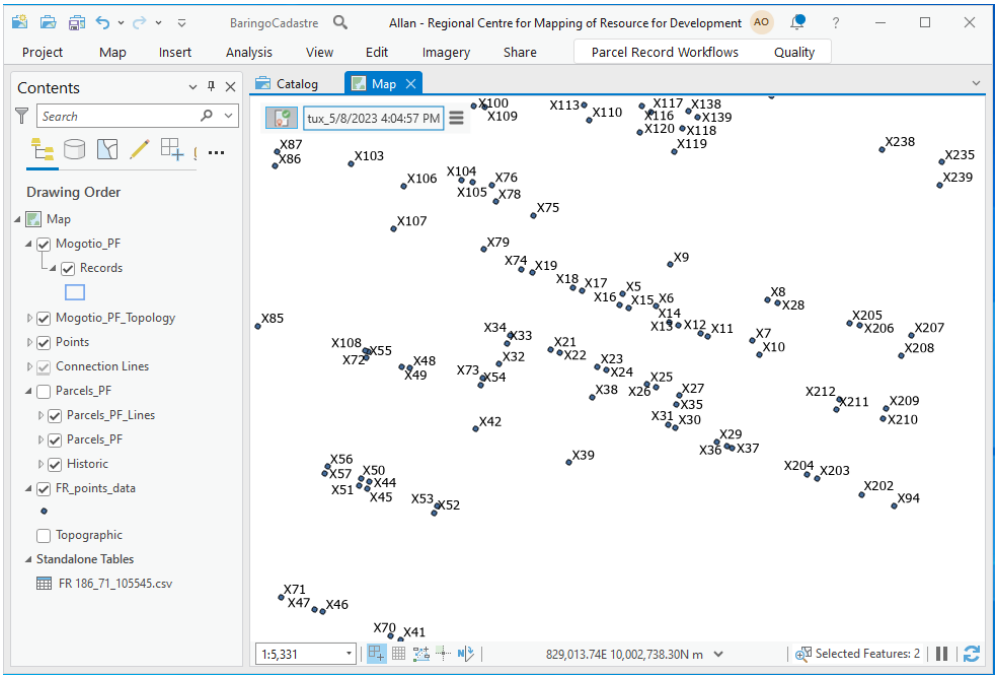



*Figure 4.16 Point data*

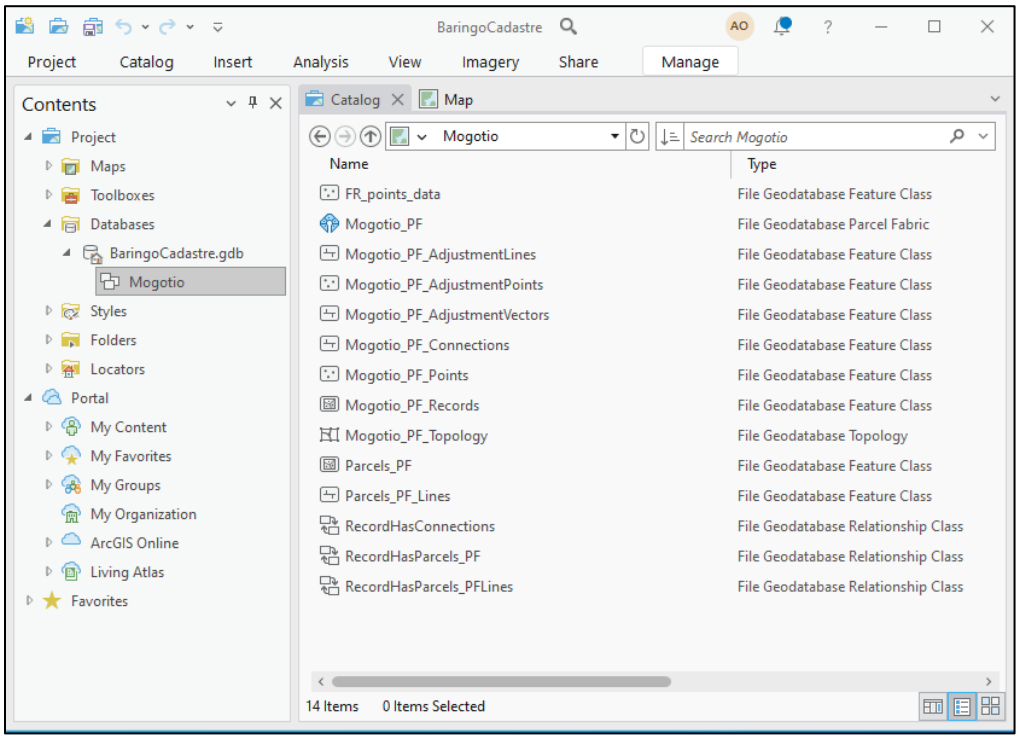



*Figure 4.17 ArcGIS Pro geodatabase structure*

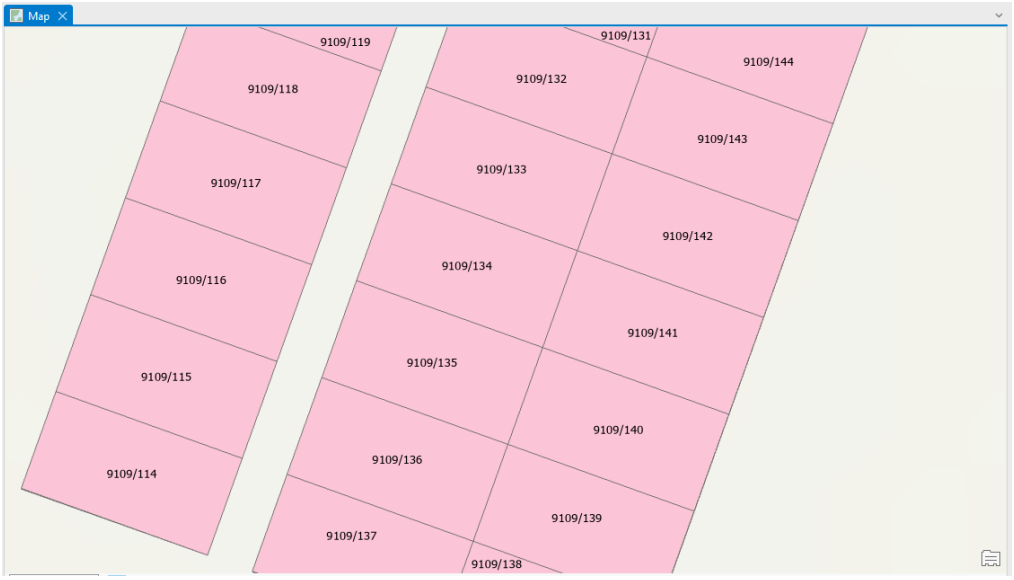
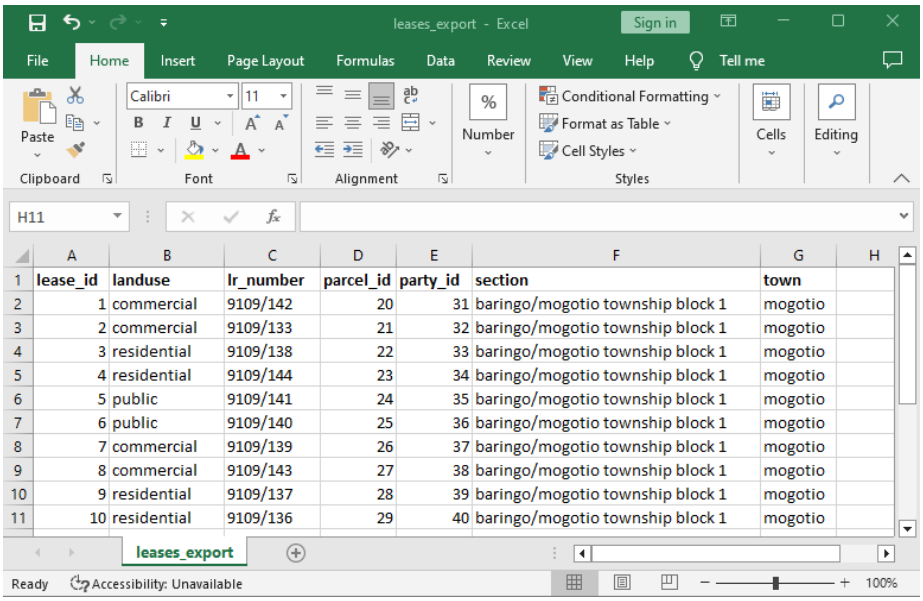



*Figure 4.18 Parcel map in ArcGIS Pro*

### *Attribute data entry*

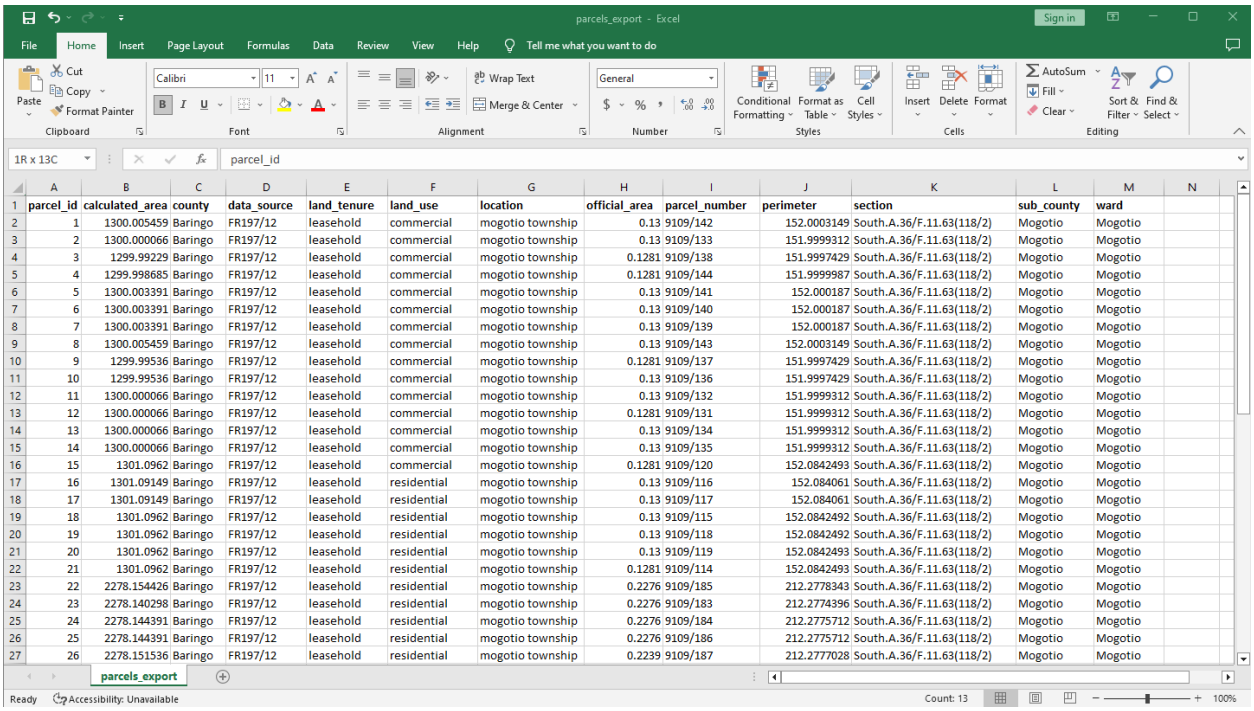
Attribute data collected was entered into a spreadsheet with fields according to the LIMS data model, this included leasehold data, parcel attribute data and land owners' data, as displayed by Figure 4.19 to 4.21.



leases_export - Excel

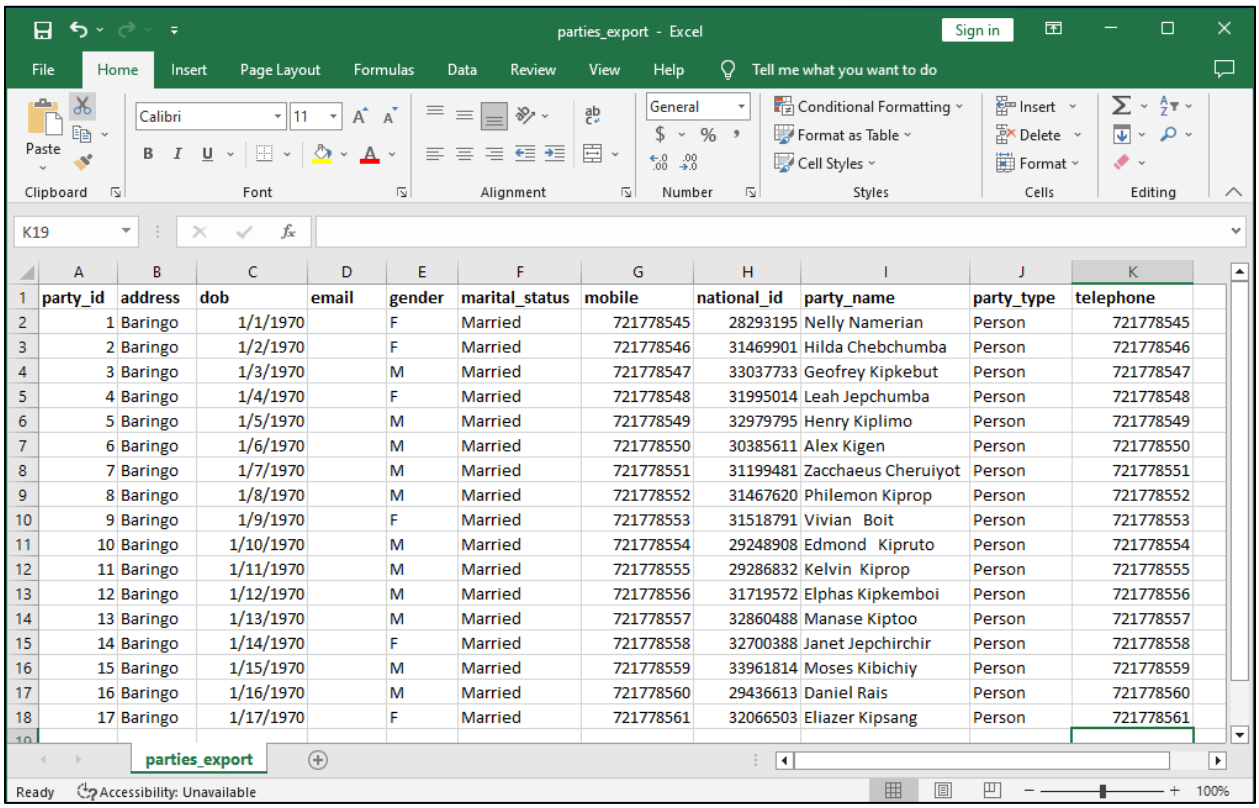
| lease_id | landuse | lr_number | parcel_id | party_id | section | town |
|---|---|---|---|---|---|---|
| 1 | commercial | 9109/142 | 20 | 31 | baringo/mogotio township block 1 | mogotio |
| 2 | commercial | 9109/133 | 21 | 32 | baringo/mogotio township block 1 | mogotio |
| 3 | residential | 9109/138 | 22 | 33 | baringo/mogotio township block 1 | mogotio |
| 4 | residential | 9109/144 | 23 | 34 | baringo/mogotio township block 1 | mogotio |
| 5 | public | 9109/141 | 24 | 35 | baringo/mogotio township block 1 | mogotio |
| 6 | public | 9109/140 | 25 | 36 | baringo/mogotio township block 1 | mogotio |
| 7 | commercial | 9109/139 | 26 | 37 | baringo/mogotio township block 1 | mogotio |
| 8 | commercial | 9109/143 | 27 | 38 | baringo/mogotio township block 1 | mogotio |
| 9 | residential | 9109/137 | 28 | 39 | baringo/mogotio township block 1 | mogotio |
| 10 | residential | 9109/136 | 29 | 40 | baringo/mogotio township block 1 | mogotio |

*Figure 4.19 Mogotio township leasehold data*



| parcel_id | calculated_area | county | data_source | land_tenure | land_use | location | official_area | parcel_number | perimeter | section | sub_county | ward |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1300.005459 | Baringo | FR197/12 | leasehold | commercial | mogotio township | 0.13 | 9109/142 | 152.0003149 | South.A.36/F.11.63(118/2) | Mogotio | Mogotio |
| 2 | 1300.000066 | Baringo | FR197/12 | leasehold | commercial | mogotio township | 0.13 | 9109/133 | 151.9999312 | South.A.36/F.11.63(118/2) | Mogotio | Mogotio |
| 3 | 1299.99229 | Baringo | FR197/12 | leasehold | commercial | mogotio township | 0.1281 | 9109/138 | 151.9997429 | South.A.36/F.11.63(118/2) | Mogotio | Mogotio |
| 4 | 1299.998685 | Baringo | FR197/12 | leasehold | commercial | mogotio township | 0.1281 | 9109/144 | 151.9999987 | South.A.36/F.11.63(118/2) | Mogotio | Mogotio |
| 5 | 1300.003391 | Baringo | FR197/12 | leasehold | commercial | mogotio township | 0.13 | 9109/141 | 152.000187 | South.A.36/F.11.63(118/2) | Mogotio | Mogotio |
| 6 | 1300.003391 | Baringo | FR197/12 | leasehold | commercial | mogotio township | 0.13 | 9109/140 | 152.000187 | South.A.36/F.11.63(118/2) | Mogotio | Mogotio |
| 7 | 1300.003391 | Baringo | FR197/12 | leasehold | commercial | mogotio township | 0.13 | 9109/139 | 152.000187 | South.A.36/F.11.63(118/2) | Mogotio | Mogotio |
| 8 | 1300.005459 | Baringo | FR197/12 | leasehold | commercial | mogotio township | 0.13 | 9109/143 | 152.0003149 | South.A.36/F.11.63(118/2) | Mogotio | Mogotio |
| 9 | 1299.99536 | Baringo | FR197/12 | leasehold | commercial | mogotio township | 0.1281 | 9109/137 | 151.9997429 | South.A.36/F.11.63(118/2) | Mogotio | Mogotio |
| 10 | 1299.99536 | Baringo | FR197/12 | leasehold | commercial | mogotio township | 0.13 | 9109/136 | 151.9997429 | South.A.36/F.11.63(118/2) | Mogotio | Mogotio |
| 11 | 1300.000066 | Baringo | FR197/12 | leasehold | commercial | mogotio township | 0.13 | 9109/132 | 151.9999312 | South.A.36/F.11.63(118/2) | Mogotio | Mogotio |
| 12 | 1300.000066 | Baringo | FR197/12 | leasehold | commercial | mogotio township | 0.1281 | 9109/131 | 151.9999312 | South.A.36/F.11.63(118/2) | Mogotio | Mogotio |
| 13 | 1300.000066 | Baringo | FR197/12 | leasehold | commercial | mogotio township | 0.13 | 9109/134 | 151.9999312 | South.A.36/F.11.63(118/2) | Mogotio | Mogotio |
| 14 | 1300.000066 | Baringo | FR197/12 | leasehold | commercial | mogotio township | 0.13 | 9109/135 | 151.9999312 | South.A.36/F.11.63(118/2) | Mogotio | Mogotio |
| 15 | 1301.0962 | Baringo | FR197/12 | leasehold | commercial | mogotio township | 0.1281 | 9109/120 | 152.0842493 | South.A.36/F.11.63(118/2) | Mogotio | Mogotio |
| 16 | 1301.09149 | Baringo | FR197/12 | leasehold | residential | mogotio township | 0.13 | 9109/116 | 152.084061 | South.A.36/F.11.63(118/2) | Mogotio | Mogotio |
| 17 | 1301.09149 | Baringo | FR197/12 | leasehold | residential | mogotio township | 0.13 | 9109/117 | 152.084061 | South.A.36/F.11.63(118/2) | Mogotio | Mogotio |
| 18 | 1301.0962 | Baringo | FR197/12 | leasehold | residential | mogotio township | 0.13 | 9109/115 | 152.0842492 | South.A.36/F.11.63(118/2) | Mogotio | Mogotio |
| 19 | 1301.0962 | Baringo | FR197/12 | leasehold | residential | mogotio township | 0.13 | 9109/118 | 152.0842492 | South.A.36/F.11.63(118/2) | Mogotio | Mogotio |
| 20 | 1301.0962 | Baringo | FR197/12 | leasehold | residential | mogotio township | 0.13 | 9109/119 | 152.0842493 | South.A.36/F.11.63(118/2) | Mogotio | Mogotio |
| 21 | 1301.0962 | Baringo | FR197/12 | leasehold | residential | mogotio township | 0.1281 | 9109/114 | 152.0842493 | South.A.36/F.11.63(118/2) | Mogotio | Mogotio |
| 22 | 2278.154426 | Baringo | FR197/12 | leasehold | residential | mogotio township | 0.2276 | 9109/185 | 212.2778343 | South.A.36/F.11.63(118/2) | Mogotio | Mogotio |
| 23 | 2278.140298 | Baringo | FR197/12 | leasehold | residential | mogotio township | 0.2276 | 9109/183 | 212.2774396 | South.A.36/F.11.63(118/2) | Mogotio | Mogotio |
| 24 | 2278.144391 | Baringo | FR197/12 | leasehold | residential | mogotio township | 0.2276 | 9109/184 | 212.2775712 | South.A.36/F.11.63(118/2) | Mogotio | Mogotio |
| 25 | 2278.144391 | Baringo | FR197/12 | leasehold | residential | mogotio township | 0.2276 | 9109/186 | 212.2775712 | South.A.36/F.11.63(118/2) | Mogotio | Mogotio |
| 26 | 2278.151536 | Baringo | FR197/12 | leasehold | residential | mogotio township | 0.2239 | 9109/187 | 212.2777028 | South.A.36/F.11.63(118/2) | Mogotio | Mogotio |

*Figure 4.20 Mogotio township parcels attribute data*



| party_id | address | dob | email | gender | marital_status | mobile | national_id | party_name | party_type | telephone |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Baringo | 1/1/1970 | | F | Married | 721778545 | 28293195 | Nelly Namerian | Person | 721778545 |
| 2 | Baringo | 1/2/1970 | | F | Married | 721778546 | 31469901 | Hilda Chebchumba | Person | 721778546 |
| 3 | Baringo | 1/3/1970 | | M | Married | 721778547 | 33037733 | Geofrey Kipkebut | Person | 721778547 |
| 4 | Baringo | 1/4/1970 | | F | Married | 721778548 | 31995014 | Leah Jepchumba | Person | 721778548 |
| 5 | Baringo | 1/5/1970 | | M | Married | 721778549 | 32979795 | Henry Kiplimo | Person | 721778549 |
| 6 | Baringo | 1/6/1970 | | M | Married | 721778550 | 30385611 | Alex Kigen | Person | 721778550 |
| 7 | Baringo | 1/7/1970 | | M | Married | 721778551 | 31199481 | Zacchaeus Cheruiyot | Person | 721778551 |
| 8 | Baringo | 1/8/1970 | | M | Married | 721778552 | 31467620 | Philemon Kiprop | Person | 721778552 |
| 9 | Baringo | 1/9/1970 | | F | Married | 721778553 | 31518791 | Vivian  Boit | Person | 721778553 |
| 10 | Baringo | 1/10/1970 | | M | Married | 721778554 | 29248908 | Edmond  Kipruto | Person | 721778554 |
| 11 | Baringo | 1/11/1970 | | M | Married | 721778555 | 29286832 | Kelvin  Kiprop | Person | 721778555 |
| 12 | Baringo | 1/12/1970 | | M | Married | 721778556 | 31719572 | Elphas Kipkemboi | Person | 721778556 |
| 13 | Baringo | 1/13/1970 | | M | Married | 721778557 | 32860488 | Manase Kiptoo | Person | 721778557 |
| 14 | Baringo | 1/14/1970 | | F | Married | 721778558 | 32700388 | Janet Jepchirchir | Person | 721778558 |
| 15 | Baringo | 1/15/1970 | | M | Married | 721778559 | 33961814 | Moses Kibichiy | Person | 721778559 |
| 16 | Baringo | 1/16/1970 | | M | Married | 721778560 | 29436613 | Daniel Rais | Person | 721778560 |
| 17 | Baringo | 1/17/1970 | | F | Married | 721778561 | 32066503 | Eliazer Kipsang | Person | 721778561 |

*Figure 4.21 Mogotio township lesees attribute data*

### 4.4.2 Data importation

Spatial and attribute data was imported into the LIMS relational database using the open-source database administration tool – pgAdmin. Prior to importation, tables were created in the database following the physical schema. To import data, pgAdmin has to connect to the PostgreSQL database server where the database is running. Figure 4.22 to 4.23 display the pgAdmin window and import dialogs.

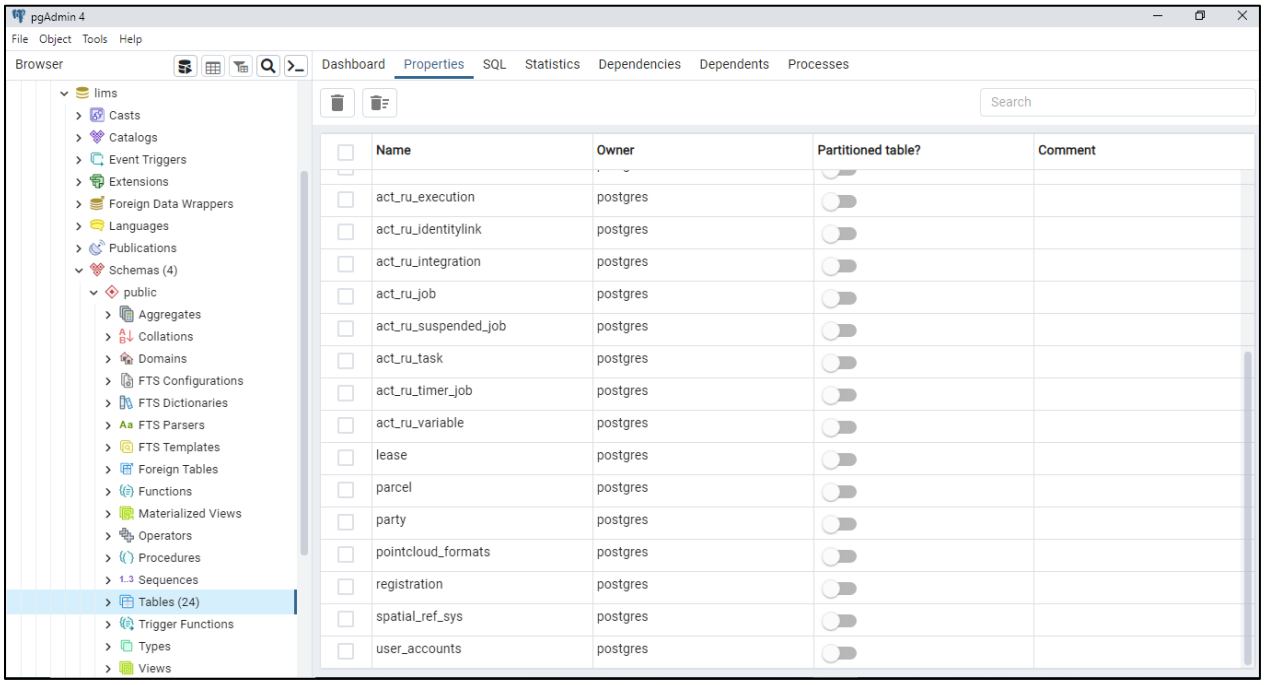



*Figure 4.22 pgAdmin 4*

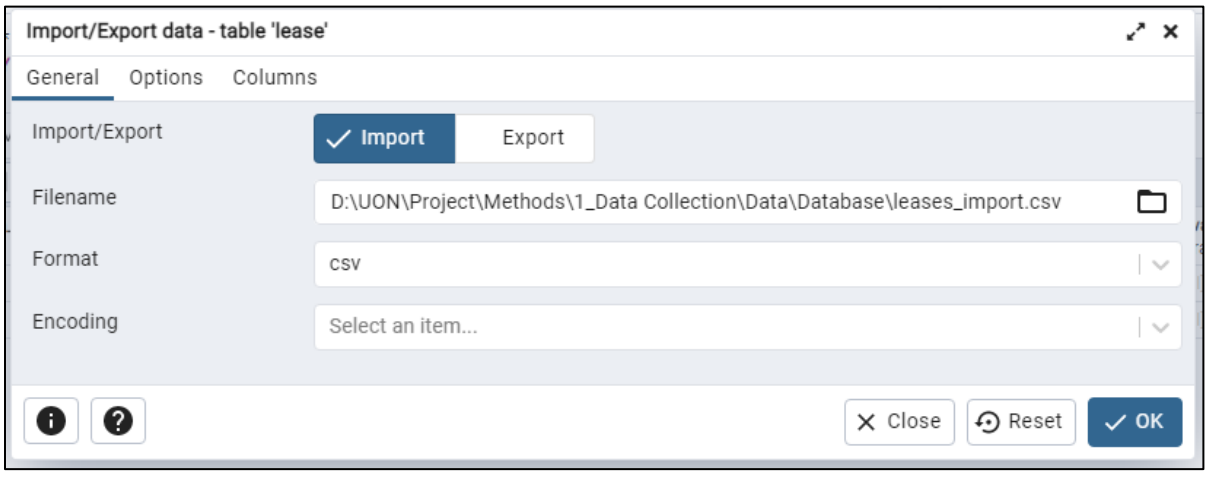



*Figure 4.23 pgAdmin 4 Import data*

### 4.4.3 Software Development

The LIMS software application was implemented in the Java programming language using the Spring Boot open-source Java-based framework. Spring Boot provided a robust platform to develop an enterprise web-based application with minimal configuration and easy deployment. The other criteria for selecting Spring Boot were the inbuilt compatibility with the Activiti workflow engine which enabled automation of LIMS business processes. The Java Persistence API (JPA) enabled implementation of object-relational-mapping (ORM) while GeoTools provided tools for geospatial data manipulation. Spring Boot was integrated with Thymeleaf, a Java template engine, to implement HTML pages on the front-end user interface. In addition, Bootstrap framework provided the HTML/CSS design templates for typography, forms, buttons, tables and navigation. To achieve seamless development, testing and deployment, Spring Tool Suite (STS) was used as the Integrated Development Environment (IDE). Figure 4.24 displays the STS IDE on Windows 11.

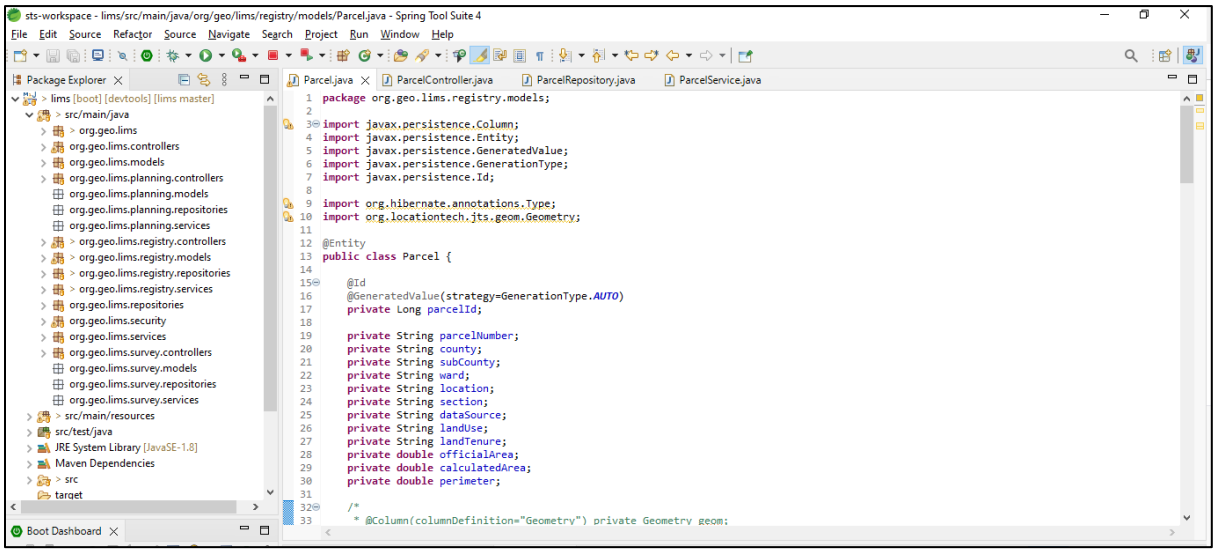



*Figure 4.24 Spring Tool Suite 4 Integrated Development Environment (IDE)*

### 4.4.4 Baringo LIMS Interface

The Baringo LIMS application comprises of a home page enabling authorized users in the department of Lands, Housing and Urban department, to access land information and initiate land transactions in a digital environment. Figure 4.25 displays the home page.

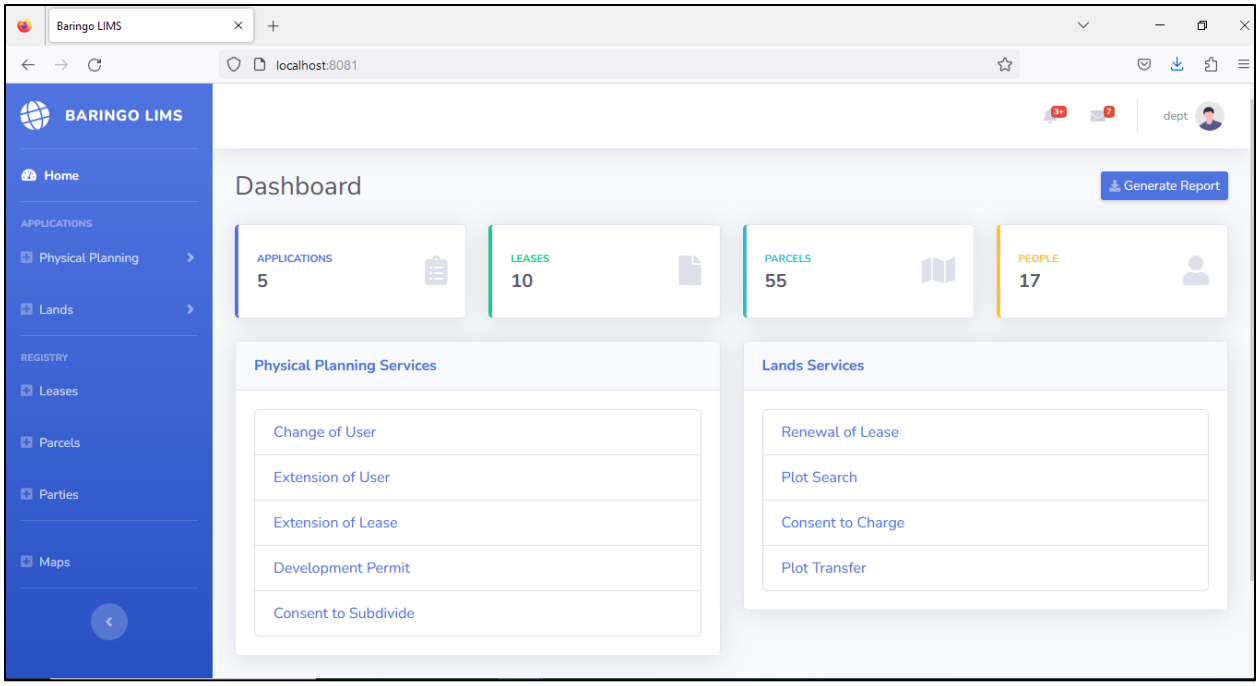



*Figure 4.25 LIMS home page*

After login, a user is able to browse and view land information such as Leases, Parcels and Parties. Figures 4.26 to 4.28 displays the different list pages.

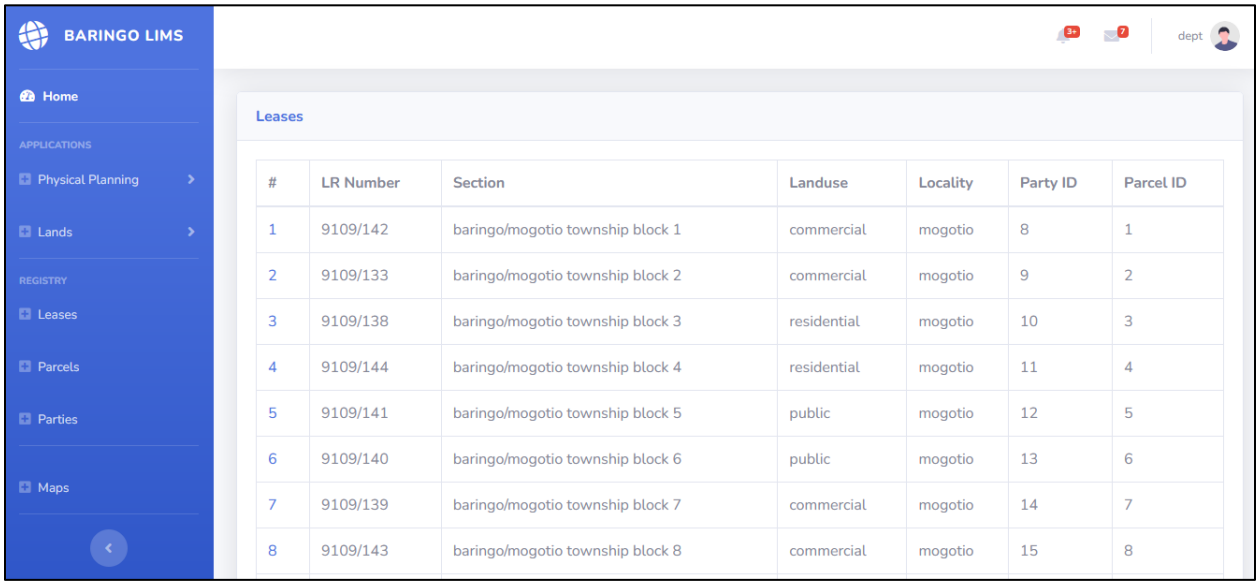
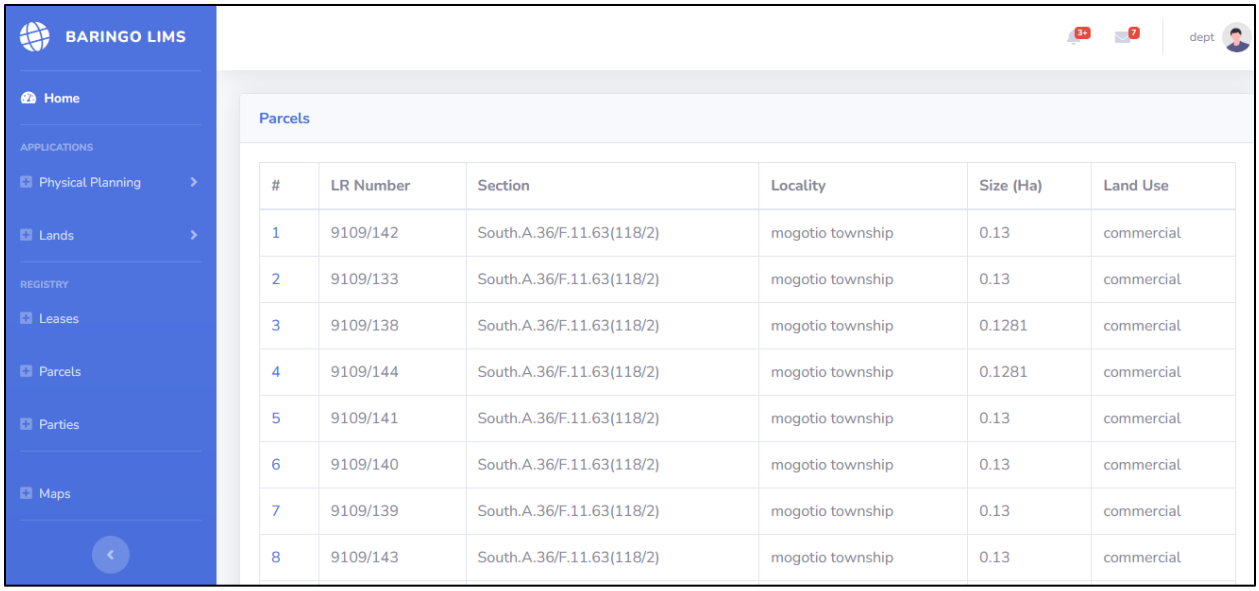
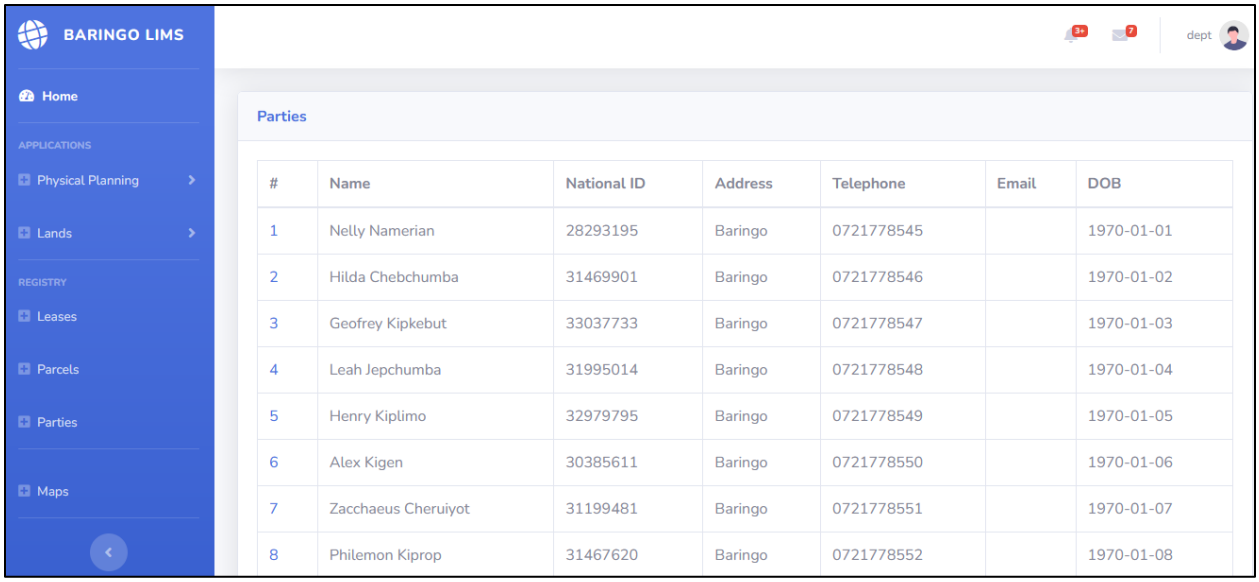



*Figure 4.26 Leases list page*




| # | LR Number | Section | Locality | Size (Ha) | Land Use |
|---|---|---|---|---|---|
| 1 | 9109/142 | South.A.36/F.11.63(118/2) | mogotio township | 0.13 | commercial |
| 2 | 9109/133 | South.A.36/F.11.63(118/2) | mogotio township | 0.13 | commercial |
| 3 | 9109/138 | South.A.36/F.11.63(118/2) | mogotio township | 0.1281 | commercial |
| 4 | 9109/144 | South.A.36/F.11.63(118/2) | mogotio township | 0.1281 | commercial |
| 5 | 9109/141 | South.A.36/F.11.63(118/2) | mogotio township | 0.13 | commercial |
| 6 | 9109/140 | South.A.36/F.11.63(118/2) | mogotio township | 0.13 | commercial |
| 7 | 9109/139 | South.A.36/F.11.63(118/2) | mogotio township | 0.13 | commercial |
| 8 | 9109/143 | South.A.36/F.11.63(118/2) | mogotio township | 0.13 | commercial |

*Figure 4.27 Parcels list page*




| # | Name | National ID | Address | Telephone | Email | DOB |
|---|---|---|---|---|---|---|
| 1 | Nelly Namerian | 28293195 | Baringo | 0721778545 | | 1970-01-01 |
| 2 | Hilda Chebchumba | 31469901 | Baringo | 0721778546 | | 1970-01-02 |
| 3 | Geofrey Kipkebut | 33037733 | Baringo | 0721778547 | | 1970-01-03 |
| 4 | Leah Jepchumba | 31995014 | Baringo | 0721778548 | | 1970-01-04 |
| 5 | Henry Kiplimo | 32979795 | Baringo | 0721778549 | | 1970-01-05 |
| 6 | Alex Kigen | 30385611 | Baringo | 0721778550 | | 1970-01-06 |
| 7 | Zacchaeus Cheruiyot | 31199481 | Baringo | 0721778551 | | 1970-01-07 |
| 8 | Philemon Kiprop | 31467620 | Baringo | 0721778552 | | 1970-01-08 |

*Figure 4.28 Parties list page*

From the list view, a user is able to select a Lease, Parcel or Party and view the details page. Figures 4.29 to 4.31 displays the detail pages.

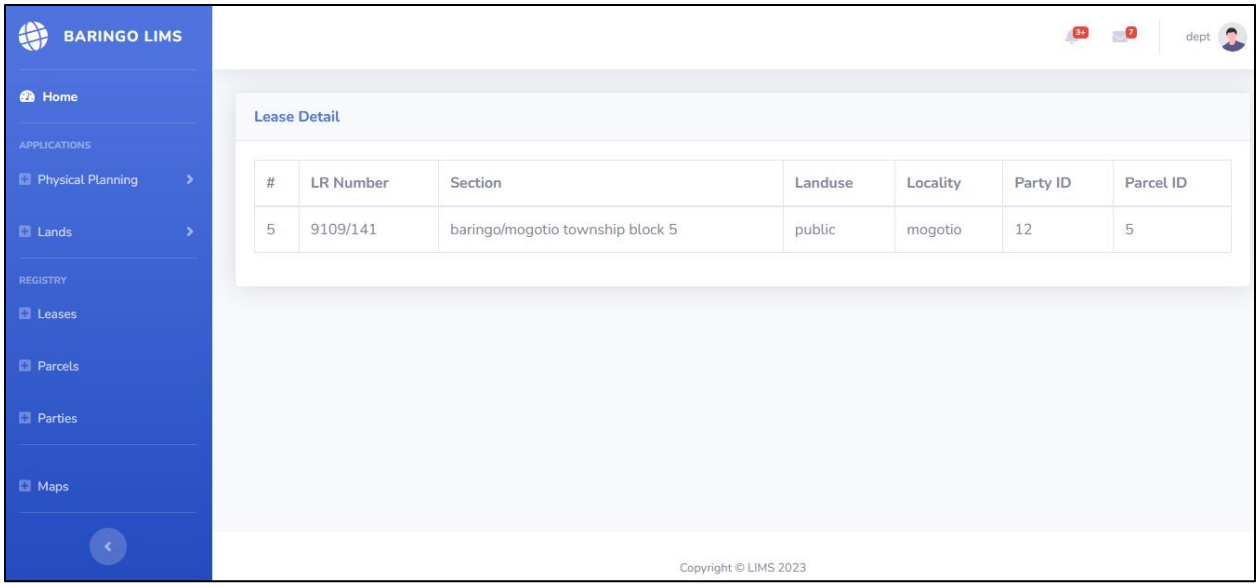



*Figure 4.29 Lease detail page*

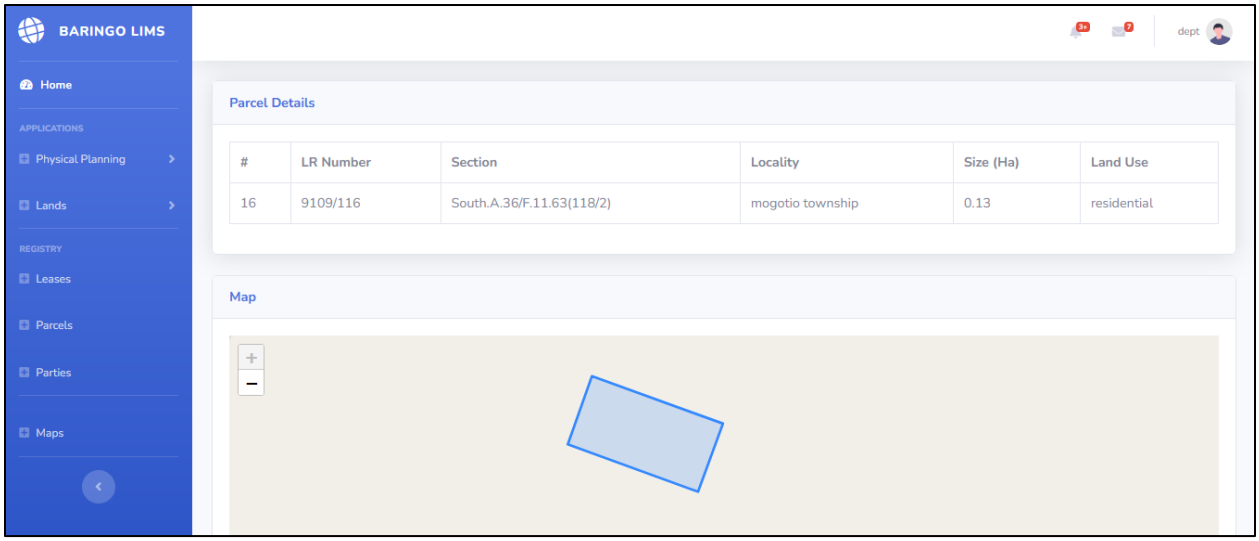



*Figure 4.30 Parcel detail page*

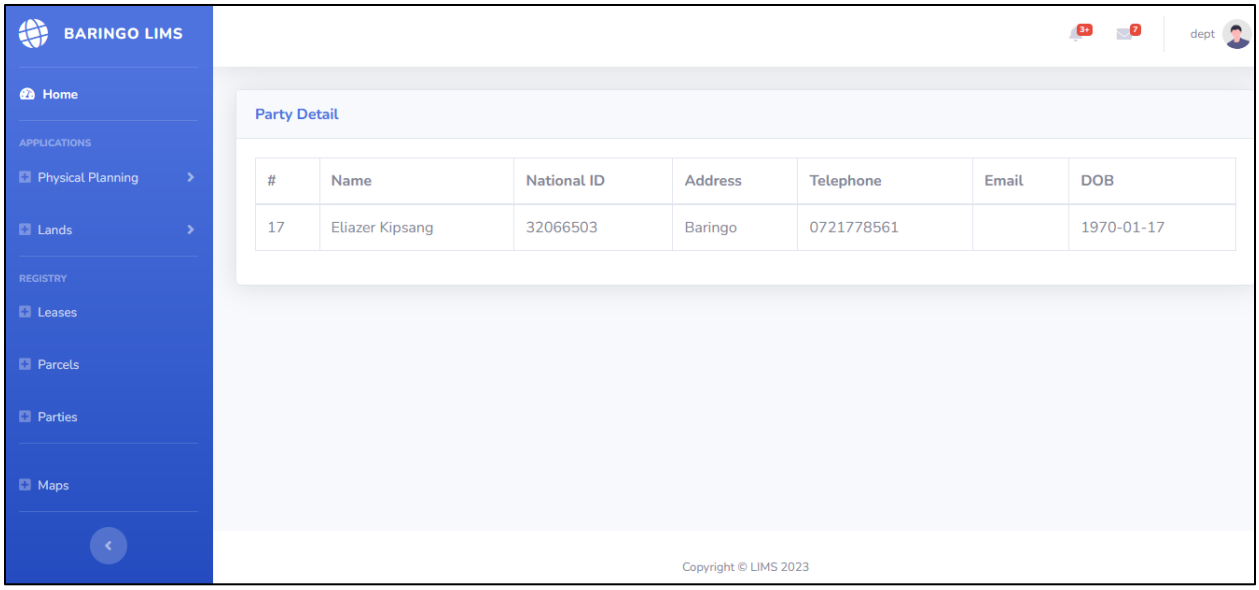



*Figure 4.31 Party detail page*

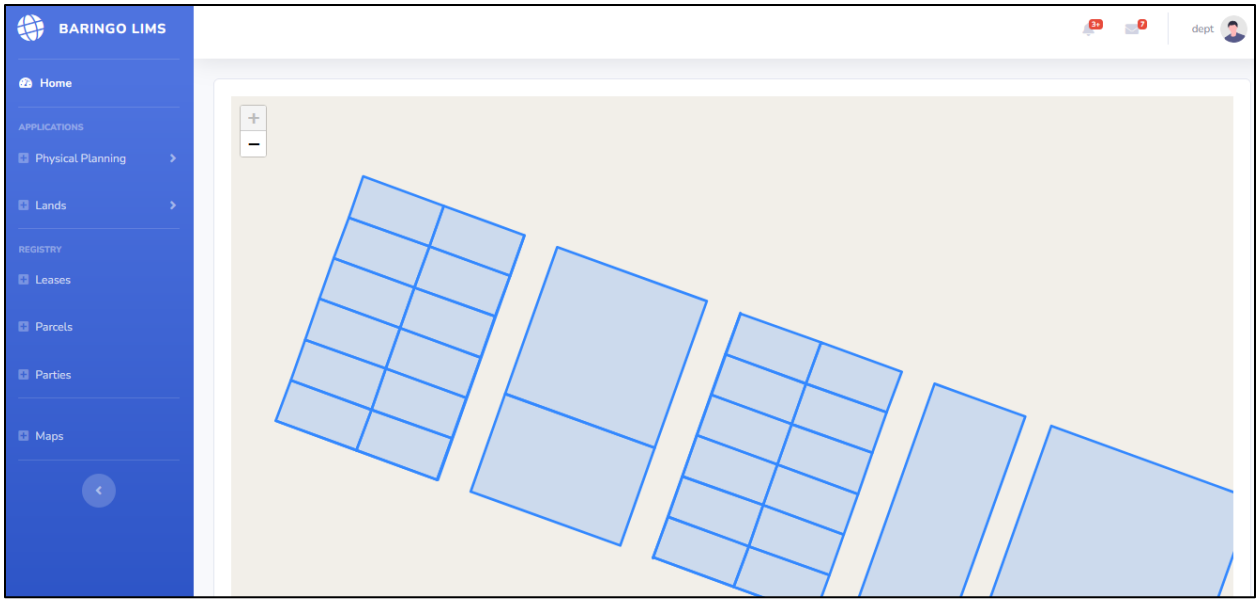



*Figure 4.32 Maps page*

Figure 4.32 displays the Maps page containing land parcels in a web map viewer. The home page also displays a dashboard indicating item summaries such as number of applications, leases, parcels and parties. From the home page, a user is able to select a service to submit an application and process the application as per the workflow. Figures 4.33 to 4.38 displays the different pages a user will go through during submission and processing Change of User applications.

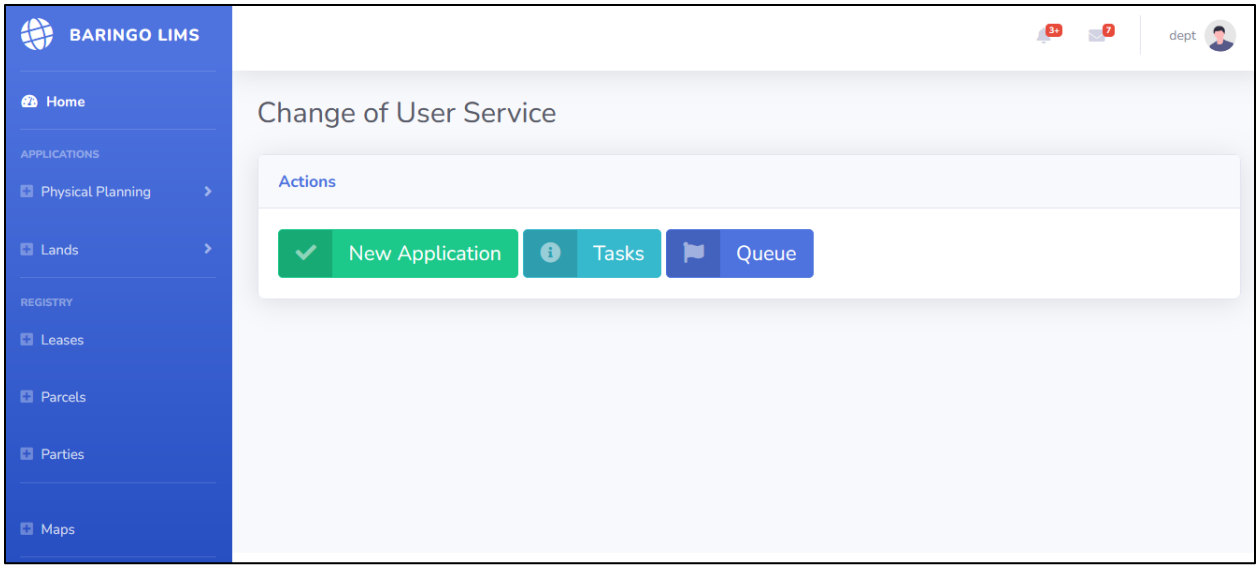



*Figure 4.33 Change of User page*

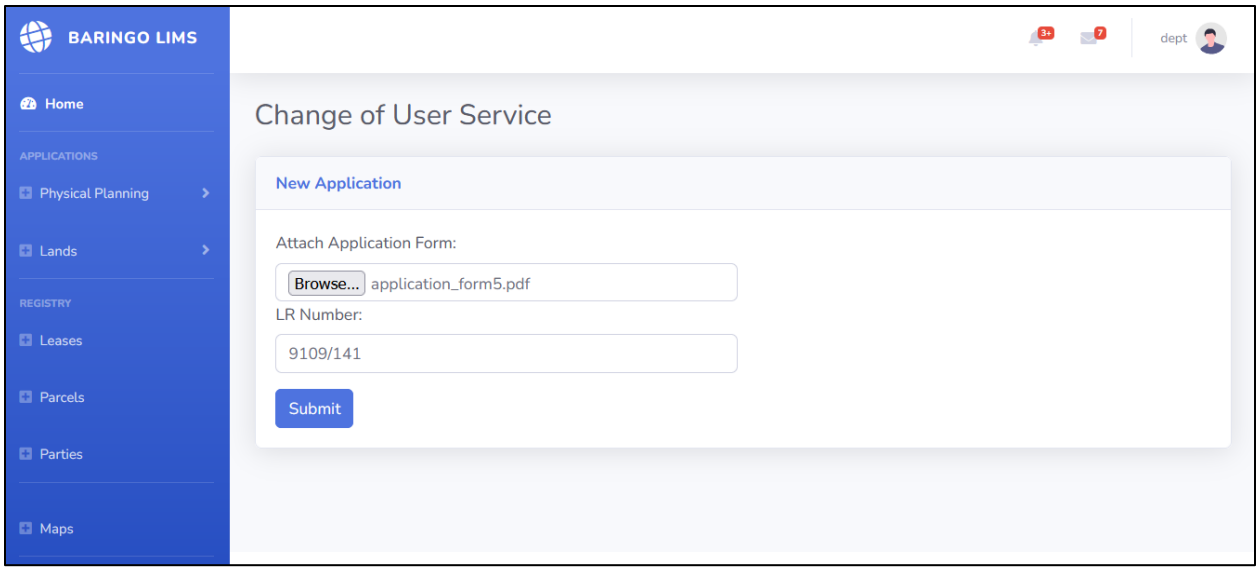



*Figure 4.34 Change of User new application page*

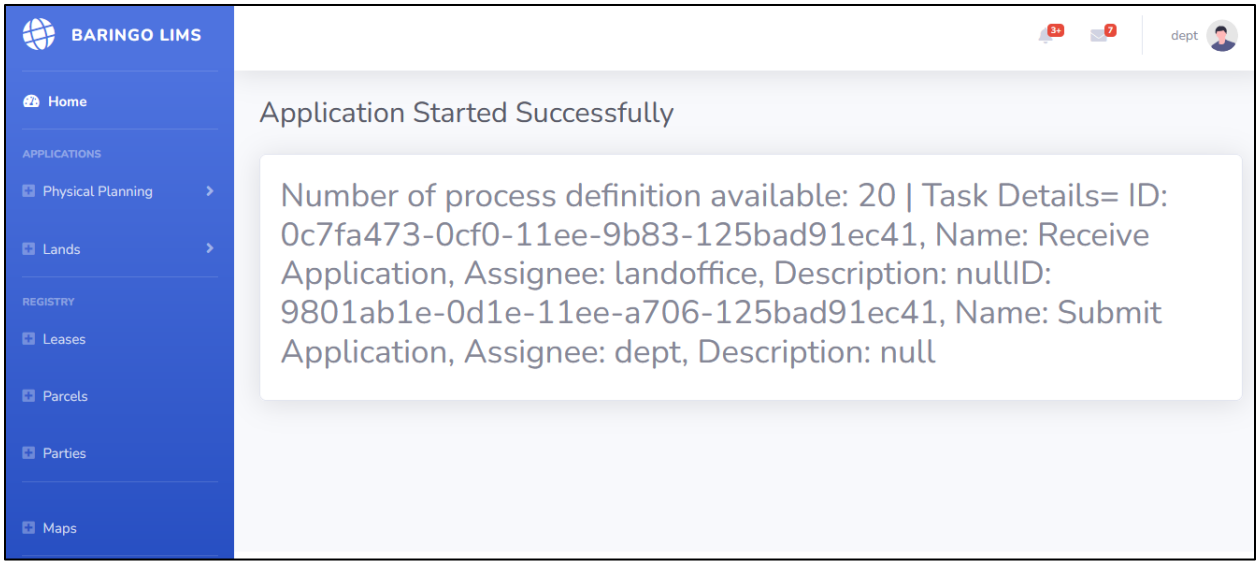



*Figure 4.35 Change of User application started page*

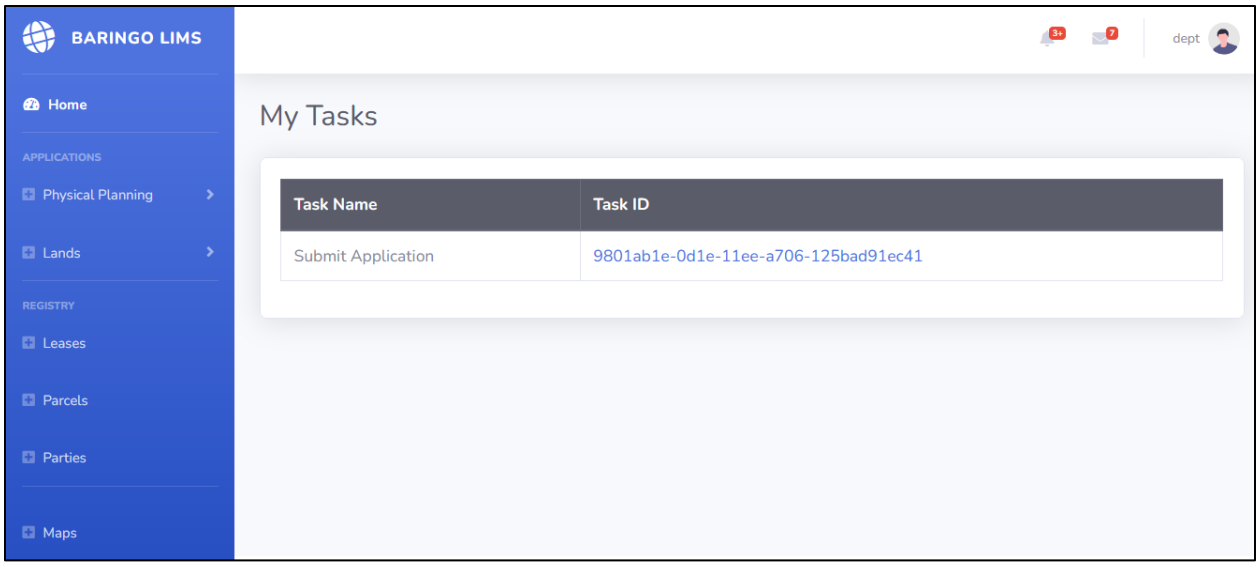



*Figure 4.36 Change of User tasks page*

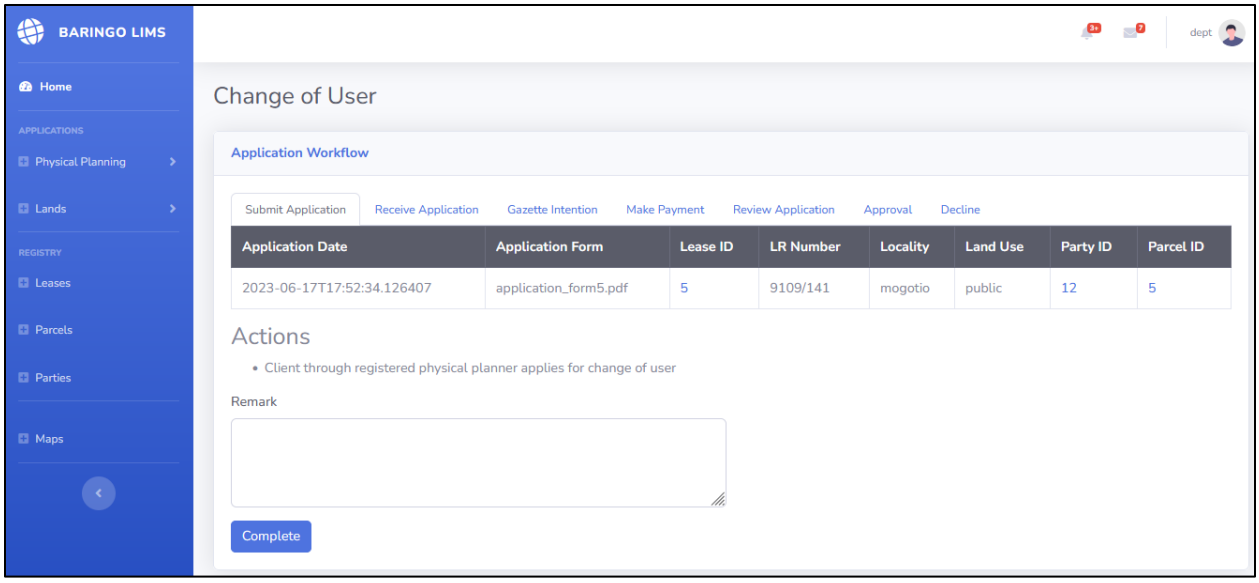



*Figure 4.37 Change of User application processing page*

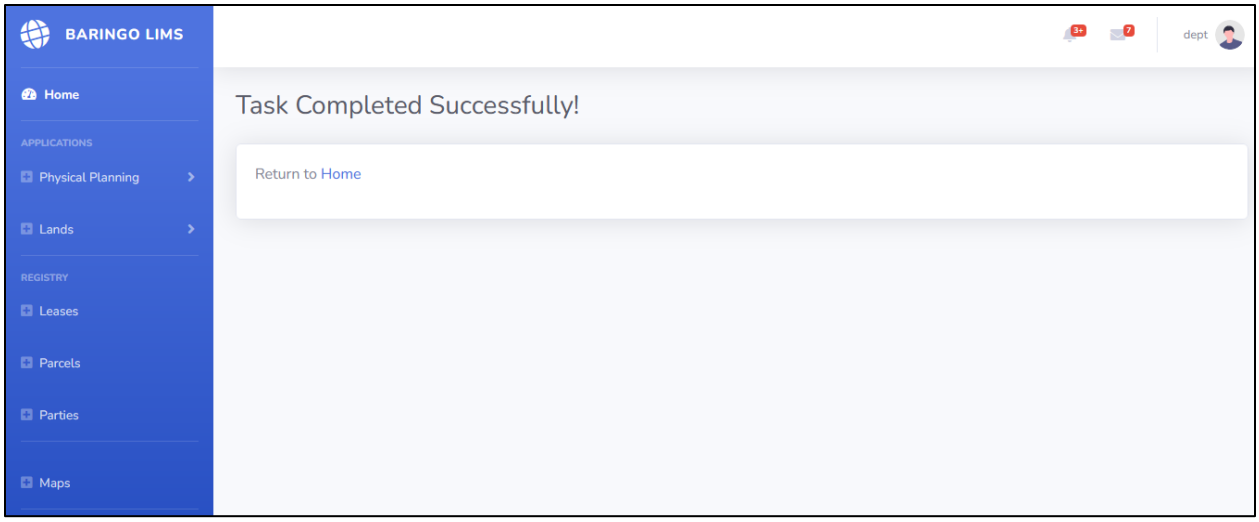



*Figure 4.38 Change of User task completed page*

# CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

This chapter presents the conclusion of the project's findings based on the objectives outlined in chapter one. Furthermore, a set of recommendations based on the results and discussion in chapter four is presented in this chapter. The project's limitations and areas for further research are also presented.

## 5.1 Conclusions

The project aimed to develop a digital land information management system that links workflows and datasets in the Baringo county department of Lands, Housing and Urban Development. To achieve this objective, the project used semi-structured interviews and questionnaire administration based on software development methodology to gather the relevant data. Following the data collection, system modelling, system design and system implementation, the results and discussion are presented in chapter four. The subsequent subsections present the conclusion of the project outcome under the three sub-objectives of the project.

### 5.1.1 Document the existing datasets and workflows in the department of Lands, Housing and Urban Development

The first sub-objective focused on reviewing and documenting the current datasets and business processes in the department. This was achieved by conducting key informant interviews and administering questionnaires to managers and technical officers in the department. Information gathered from the respondents revealed the state of manual and digital datasets in the department and existing land administration processes. The data collected and analyzed provided a basis for achieving subsequent sub-objectives in the project.

### 5.1.2 Develop a system design for the LIMS

This sub-objective focused on developing a system design for the Baringo county LIMS. This was achieved by first analyzing the functional and non-functional system requirements specified during data collection, followed by business process modelling, data modelling and finally architecting an overall structure of the system to be developed. The architectural design adheres to the Service Oriented Architecture (SOA) design pattern and is described by context, functional, deployment and operational views.

### 5.1.3 Implement the LIMS software programs

This sub-objective focused on implementing the system design developed in sub-objective two into a functional LIMS software application. This was achieved by programming a Java-based web application with functionalities for managing land information, and lodging and processing land transactions. This LIMS software developed leveraged on the open-source Activiti workflow engine to automate three main workflows in the department. Automation of all workflows in the department was constrained due to missing data on some workflows such as those in the land surveys directorate.

## 5.2 Recommendation and Areas for further research

The Baringo LIMS was developed to a prototype level and will require documenting and integrating more datasets and workflows to make it production-grade. Incorporation of a Document Management System (DMS) will be vital in storing scanned documents in an electronic archive and linking to transactions and interests (leases, etc.) on land. Furthermore, the LIMS requires integration with a web map server to handle spatial data manipulation and rendering. A public portal/website will also support the department in provision of online services through remote submission of applications by public users such as land owners, surveyors, lawyers, banks, estate agents and the general public.

During system implementation, it was identified that automation of workflows requires hard-coding the process definitions in the software, therefore, further research on implementing workflow automation without hard-coding in software is recommended. This is vital as the workflows might change due to revisions in the legal framework and administrative procedures.

## LIST OF REFERENCES


Byamugisha, F. (2013). *Securing Africa's Land for Shared Prosperity.* Washington DC: The World Bank.

IFAD. (2023). *Frontier Technologies for Securing Tenure: A review of concepts, uses and challenges.* Rome: IFAD.

Larbi, W. O. (2016). Developing Effective Land Administration Systems in Africa. *Training on Effective Land Administration.* Nairobi: RCMRD.

LEI. (2020). *Land Administration Information and Transaction Systems: State of Practice and Decision Tools for Future Investment.* Wollongong: Land Equity International.

Oput, R. (2019). The National Land Information System (NLIS) in Uganda: Improvements in Land Governance and Transparency. *Conference on Land Policy in Africa.* Abidjan: Africa Land Policy Centre.

Williamson, I. P., Rajabifard, A., Enemark, S., & Wallace, J. (2010). *Land Administration for Sustainable Development.* Redlands: ESRI .

Barney, L., Mark, G., Aurelie, M., Carol, R., Christopher, B (2019). Implementation of an Integrated Land Management Information System for Tanzania [Paper presentation]. World Bank Conference on Land and Poverty, Washington DC, USA. https://www.conftool.com/landandpoverty2019/sessions.php

Deininger, K., Augustinus, C., Enemark, S., Munro-Faure, P. (2010). "Innovations in Land Rights Recognition, Administration and Governance", Proceedings from the Annual Conference on Land Policy and Administration, Washington DC, USA.

Barney, L., Apollo, L., Milledrogues, A., Roffer, C., Burke, C(2018). "Developing and Integrated Land Management Information System for Tanzania", Proceedings 2018 World Bank Conference on Land and Poverty, March 19-23 2018, Washington DC, USA.

Mwathane, I., Musyoka, S., Karanja, F. (2012). Pilot Project to establish a Pro-Poor Land Information Management System for part of Thika Municipality

Roffer, C., Lizenko, S., Kalyta, M. (2017). "Agile Collaboration as the Way to Build Uganda National Information System", Proceedings 2017 World Bank Conference on Land and Poverty, March 20-24 2018, Washington DC, USA.

UN-Habitat (2012). Designing a Land Records System for the Poor, Nairobi

# APPENDIX

## Department of Lands, Housing and Urban Development

## Land Information Management System (LIMS)

## Data Collection Questionnaire

Respondent Name: _____

Position: _____

Date: _____

## 1. General Section

### 1.1. Project Scope

The project will focus on the automation of the main land administration services, carried out by the **Lands**, **Housing** and **Urban Development Department** of the County Government of Baringo.

### 1.2. Project Activities

The below list outlines the **project activities** with associated time periods.

- Data Collection (1 month)
- System Modelling (1 month)
- System Design (1 month)
- System Implementation (1 month)

### 1.3. Laws and Regulations

List the **legal documents** that are used by the department in its mandate.

Provide a copy of the latest **gazetted fees**. Clarify how often the fees are revised?

### 1.4. Land Categories

Clarify the **categories and classes** of land administered by the department.

- Public

- Private

## 2. Departmental Section

### 2.1. Organogram

Capture the high-level departmental **organogram** outlining the sections involved.

### 2.2. Data

Note the **datasets and databases** maintained by the department. Also estimate the number of digital vs. hardcopy records.

### 2.3. Coordinate Systems *[only applicable to the Surveys section]*

Note the different **coordinate / survey systems** used by the department. Note the conversion parameters in place.

### 2.4. Land Administration Functions

What core **land administration functions** are undertaken within the department?

## 2.5. Forms

What **paper-based forms** are required to be completed by the public when applying or seeking services within the department? Also, what items are required to accompany applications e.g., identification documents, etc.?

Provide copies of the relevant forms.

## 2.6. Communication

What are the current **communication methods** used between the different departments to share information? Please provide examples.

## 2.7. Bottlenecks

Note the current **bottlenecks** experienced when performing land administration tasks?

## 2.8. Existing Systems

Clarify the **existing systems/software** used by the department.

## 2.9. External Users

Clarify the potential **external users** of the LIMS.

## 3. Land Information Management System Modules Section

Ensure that below sections accurately capture the **high-level LIMS requirements** for each module.

### 3.1. Cadastre Requirements

Clarify, and add to below list, all the required **land survey and cadastre functions**. Please capture a high-level description for each function.

### 3.2. Physical Planning Requirements

Clarify, and add to below list, all the required **physical planning functions**. Please capture a high-level description for each function.

### 3.3. Land Information Portal Requirements

Clarify, and add to below list, all the required **land information portal functions**. Please capture a high-level description for each function.

### 3.4. Document Management Requirements

Clarify, and add to below list, all the required **document management functions**. Please capture a high-level description for each function.

### 3.5. Workflow Management Requirements

Clarify, and add to below list, all the required **workflow management functions**. Please capture a high-level description for each function.

## 3.6. Reporting Requirements

Clarify, and add to below list, all the required **reporting functions**. Please capture a high-level description for each function.

## 3.7. Notification Requirements

Clarify, and add to below list, all the required **notification functions**. Please capture a high-level description for each function.

## 3.8. System Administration Requirements

Clarify, and add to below list, all the required **system administration functions**. Please capture a high-level description for each function.