University of Nairobi

School of Engineering

DEPARTMENT OF GEOSPATIAL AND SPACE TECHNOLOGY

CREATING A LAND INFORMATION SYSTEM FOR A SECTIONAL PROPERTY

CASE STUDY: LR 1870/1/218, WESTLANDS, NAIROBI

BY

LAWRENCE OKUMU MURAYA

F56/6826/2017

A Project submitted in partial fulfilment of the requirements for the Degree of Master of Science in Geographic Information System, in the Department of Geospatial and Space Technology of the University of Nairobi.

December 2019

Declaration of Originality

Name of student:	Lawrence Okumu Muraya
Registration:	F56/6826/2017
College:	Collage of Architecture and Engineering
Faculty/School/Institute:	School of Engineering
Department:	Geospatial and Space Technology
Course Name:	Master of Science in Geographic Information System
Title of work:	Creating a Land Information System for a Sectional Property

1. I understand what plagiarism is and I am aware of the university policy in this regard.
2. I declare that this research report is my original work and has not been submitted elsewhere for any examination, award of a degree or publication. Where other works or my own work has been used, this has properly been acknowledged and referenced in accordance with the University of Nairobi's requirements.
3. I have not sought or used the services of any professional agencies to produce this work
4. I have not allowed, and shall not allow anyone to copy my work with the intention of passing it off as his/her work.
5. I understand that any false claim in respect of this work shall result in disciplinary action in accordance with University of Nairobi anti-plagiarism policy.

Signature:

Date:

Declaration

I **Lawrence O. Muraya** declare that this report is my original work. To the best of my knowledge, the work presented here has not been presented for a degree in any other institution of higher learning.

Signature..... Date.....

This project has been submitted for examination with my approval as University Supervisor.

Signature..... Date.....

Mr. Jasper N. Mwenda

Dedication

I dedicate this project to my family for the moral and material support they offered throughout this period.

Acknowledgement

This project would not have been possible without the strength, knowledge and opportunity accorded to me by the Almighty God, individuals and organizations who came to assist in different ways.

I distinctly acknowledge the support, advice and guidance of my supervisor Mr. Mwenda J. N. of the Department of Geospatial and Space Technology, University of Nairobi, throughout this project and all others lecturers during this course.

I owe a great deal to colleagues and friends of the University of Nairobi and my work mates, whom helped in different ways, especially Mr Opicho.

I must not forget my mum, dear wife, and wonderful children who stood by me during this busy period.

Abstract

The general trend of urbanization, population growth and industrialization is asserting more pressure on land, depending on various human activities and land use. Since the supply of land is inelastic and fixed in quantity, there is need to maximise the use of available land. Due to the rising need for further developments, it is becoming necessary to construct tall complex buildings, run cables and other facilities underground or in space, in order to maximise on use of available land.

A general lack of efficient and comprehensive geospatial information in digital form in Kenya has brought about a number of problems and challenges such as loss of land documents, corruption, and intrusion of middlemen in the Survey and Lands offices especially during the land search process or when looking for maps in Lands Offices. These challenges in Lands and Survey offices can be eliminated by setting up a centralized, up-to-date geodatabase that can be accessed easily. Digital Land Information Management is now globally accepted as the best way to enhance the operation and management of land information in cities.

In this project, a sectional property in parcel LR 1870/1/218, Ring Road, Westlands, Nairobi, which has forty one (41) units was mapped and a database was created to expedite the search of the information in relation to ownership and rights, responsibilities and restrictions (3Rs) in relation to the property.

The sectional property data was collected for analysis and application of the geodatabase technology in processing, analysing, storing, dissemination and archiving of the data in a computer based system through a geodatabase system that would aid the information retrieval to relevant people or authorities. This prototype system provides a platform and a system that managers and the government department would use for data management.

Table of contents

List of Figures

List of Tables

CHAPTER 1: INTRODUCTION

1.1 Background

All over the world space for development is becoming less due to rapid urbanization and population increase. Modern cities have been trying to meet their needs for space by not only using surface structures but also considering vertical space use. According to UN Urbanisation Prospect from the studies done by United Nations in 2014 *"Globally, more people live in urban areas than in rural areas, with 54 per cent of the world's population residing in urban areas in 2014. In 1950, 30 per cent of the world's population was urban, and by 2050, 66 per cent of the world's population is projected to be urban"* (UN, 2014).

Urbanisation and industrialisation have led to subdivision of land into smaller portions to the extent that there is no more increasing space for expansion. New structures have been positioned under and above each other to make use of the available space. 3D Cadastre is increasingly gaining prominence in any cities. Examples of existing 3D situations are: infrastructure under and above the ground, building constructed above each other and increasing number of cables and pipes under different ownership underground and above the ground. It is expected that 3D cadastre will address registration issues that are not available in 2D cadastre. As illustrated in figure 1.1 land use should be considered above and below the ground surfaces. In reality, there is no way of expanding space as land has a fixed supply, therefore people have to resort to utilisation of space underground or in the space above the ground. Utilities like water pipes, sewer pipes, data cables, and power cables mostly are constructed underground, whereas more building spaces are secured both below land surface and extend into the space above.

The Government of Kenya has expressed the need to modernize the Land Information System in order to facilitate better and modern land administration, support the development of an integrated Land Information Management System and a National Spatial Data Infrastructure. However, a major impediment is unwillingness to embrace technological advancement by staff and stakeholders. In 2013 digitization of the Land records started under the authority of the section 9 and 10 of Land Registration Act 2012 which gives the Ministry of Lands and Physical Planning mandate to maintain the register of the property and parcels in an electronic register to enable information security and accessibility (Government of Kenya, 2012).

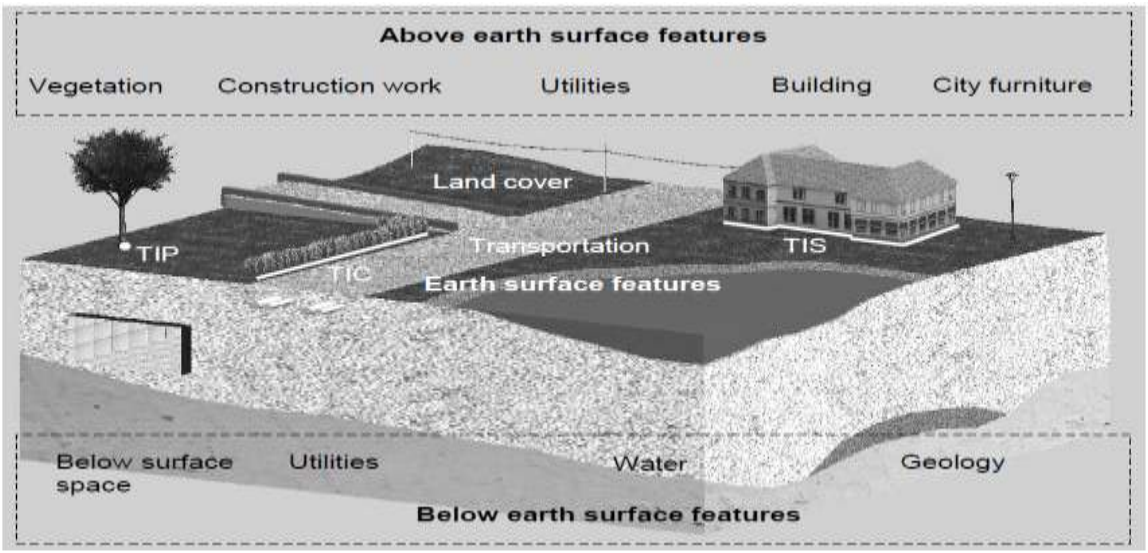


Figure 1.1 Thematic semantic subdivision of features (Zlatanova, (2004).

In Kenya, the current land registration is good enough for property registration such as land ownership rights, responsibilities and restrictions and objects in parcel-based Cadastre (classical 2D-Cadastre) where Survey Plans, Deed Plans, Registry Index Maps (RIMs) and Preliminary Index Diagram (PIDs) are used to support registration of title to land. However land right registrations are continuously confronted with a number of precincts of the present registration that would register spatially multifaceted property rights. Most importantly is to guarantee an efficient, secure and sustainable registration system in the future and that would take care of the forms of Cadastre; either 2D or 3D Cadastre (Wayumba, 2013). Both the technical and legal aspects of 3D cadastre are lacking. The closest approach to this property definition is the Sectional Property Act (No. 21 of 1987).

These physical 3D objects normally don't relate to legal objects that are obviously defined in a register, therefore, they cannot be defined as a cadastral object in the cadastral map (2D) and cannot be used as a base for registration, this appeal for the review of the law that would address the protection of the owners right, responsibility and restrictions on the properties and the general public as a whole. As indicated in Oosterom, (2018), best practices that 3D cadastre should be built on are legal foundation, initial registration, 3D Cadastral information Modelling, 3D Spatial Database Management System (DBMS) for 3D cadastres and lastly Visualizations and new opportunities.

The current developments are moving from the bungalows and maisonettes to flats and apartments and ownership of units in a flat or apartments. This has been made possible by the provision of the Act of Parliament known as Sectional Properties Act 1987 which provides for

the subdivision of building into units owned by the individuals and share in the ownership of the common properties.

1.2 Problem Statement

The Ministry of Lands and Physical Planning whom has been charged with the responsibility of collecting, storing, disseminating and archiving land information for the public access. Ministry of Lands and Physical Planning still has a lot of their data in hard copy (paper based Cadastre). Missing files, damaged maps, missing maps and even inaccessible and unavailable information is still very common due to poor record keeping, handling and management.

The Land attributes information is stored separately in different departments; that is land registration department and the Survey department. This has brought a lot of inconveniences to citizens interested in the data and information about land. Therefore it is important to link the spatial information to the land attributes to ensure effective and efficient access to land data.

Registration of a Sectional Plan is done under the Land Registration Act, 2012. The land on which the housing units or house are erected should be under freehold or leasehold from the government with an unexpired lease duration of not less than 45 years; otherwise it is registered under RDA (Registration of Documents Act). Sectional Property is a unique form of ownership where there is a co-ownership with other people in regards to Common Property.

1.3 Objective

The main objective of this project is to map sectional properties and to formulate digital land records and develop a Land Information System that can demonstrate and support the search, registration, management, updating and archiving the land records and maintain Land information system.

The specific objectives include:

a) To develop a prototype Land Information System that can register and map sectional property units as they are in survey plans to the correct geographical coordinates.
b) To analyse Sectional Property rights, restriction and responsibility for registered units and common properties like stairs, walls, parking and their management in a geodatabase.

1.4 Justification for the Study

With the growing pressure on land, especially in major urban centres, there is a need to embrace 3D Property Rights in infrastructure development, such as apartments, telecommunication cables, underground and aerial electrical cables.

This research project will be useful to developers and investors in real estate, infrastructure utilization of limited space for highest and best use through registration a sectional property and demonstration of right, responsibility and restriction (RRRs) through 2D projection of plots. The Sectional Property Act provides a foundation for mapping properties in 3D but displays them in 2D which doesn't describe complex, intersecting and overlapping real property records, therefore it will be necessary to amend the Act to deal with three-dimensional (3D) space, where most of the cabling and piping takes place. The difference between 3D real property implications on law and its 2D Cadastre registration and documentation has been emphasized with the increasing number of developments in urban areas where there are tall buildings and, complex structures in space, and underground infrastructures. The rights, restrictions and responsibilities associated with cadastral objects may relate to spaces or/ and below the Earth's surface.

3D Cadastre is necessary for the government and the public in the following areas; fiscal, legal support and territory management, property Cadastre information is usually managed by one or more agencies of the government (Stoter, 2014).

1.5 Scope of work

This project will review the literature and other relevant legal frameworks that would establish the legal framework for the strata properties, looking at their loopholes, especially the Sectional Properties Act and proposed ways by which they can be improved and give confidence to members of the public to purchase properties governed by this Act such as units of flats or a part of a building or an office floor.

The scope of this project goes further to development of a Land Information System whereby a spatial database system that helps in the search, input, manipulation and storing the spatial information as well as its attributes. The study will be restricted to LR 1870/1/218 Ring Road, Westlands, Nairobi, which is portioned from Block A to G and containing 41 units.

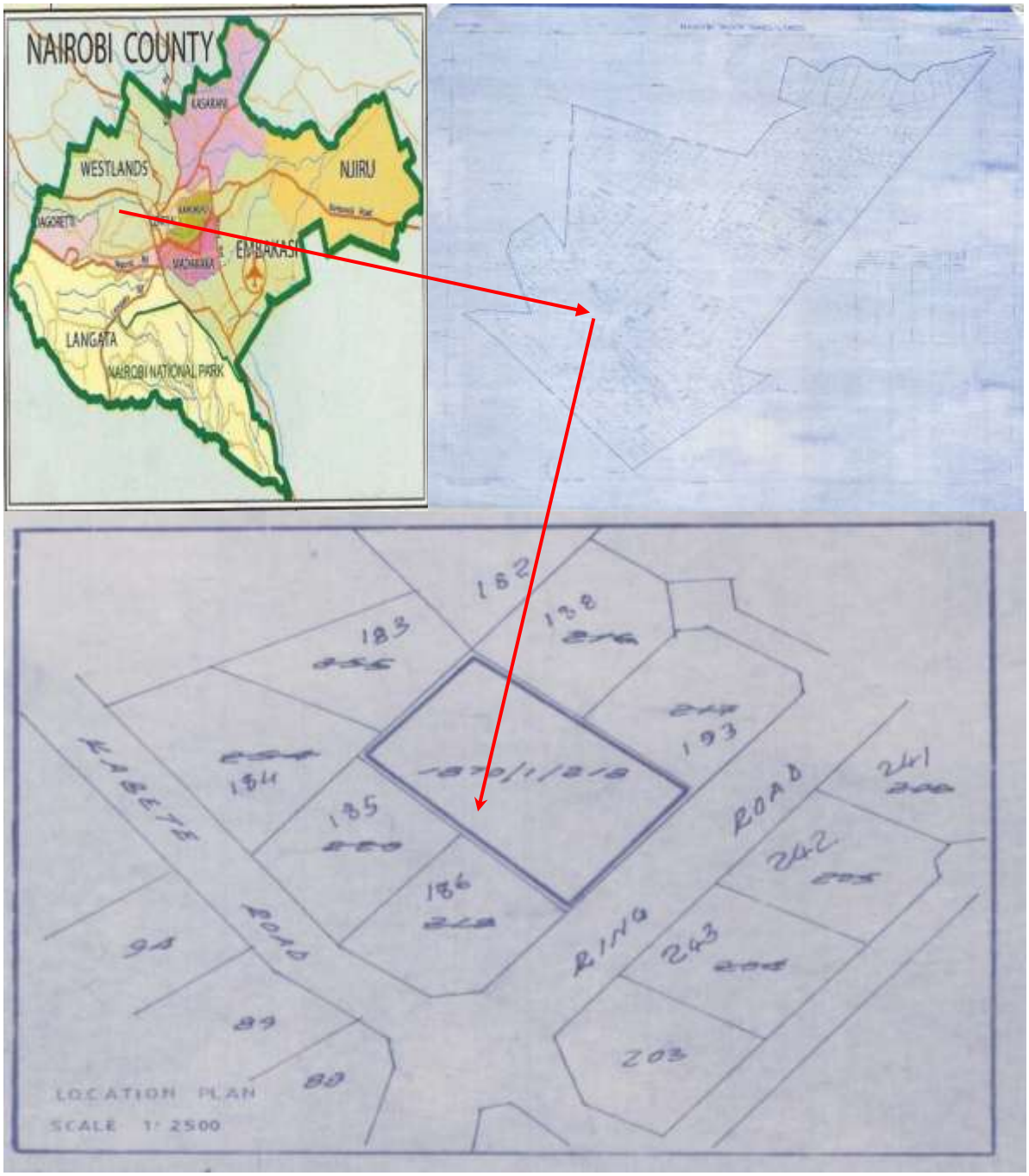


Figure 1.2 Study Area LR 1870/1/218 Ring Road, Westlands, Nairobi.

1.6 Organisation of the Report

The report is organised into five chapters, the first chapter is an introduction chapter, which introduces the concepts of sectional properties and land information system, the registration of a sectional property and the problems encountered in the data access and why it is important to formulate and design a database system to manage land information. Finally, the chapter concludes with the objective and the scope of the project and project justification.

The Second chapter deals with literature review. In that chapter the regulations, laws and jurisdictions with sectional properties and related practice worldwide such as 3D Cadastre are discussed. The efforts in the legislation review, practice advancement, success and limitations are discussed. Chapter Three discusses the methodology and deals with data identification, acquisition and processing of the data and the procedures used in the mapping and development of database which are key to this project and to achieve the main goal of storing data and management of sectional properties. Chapter Four discusses the results and analysis of the results. Chapter Five gives the conclusion and recommendations of the study.

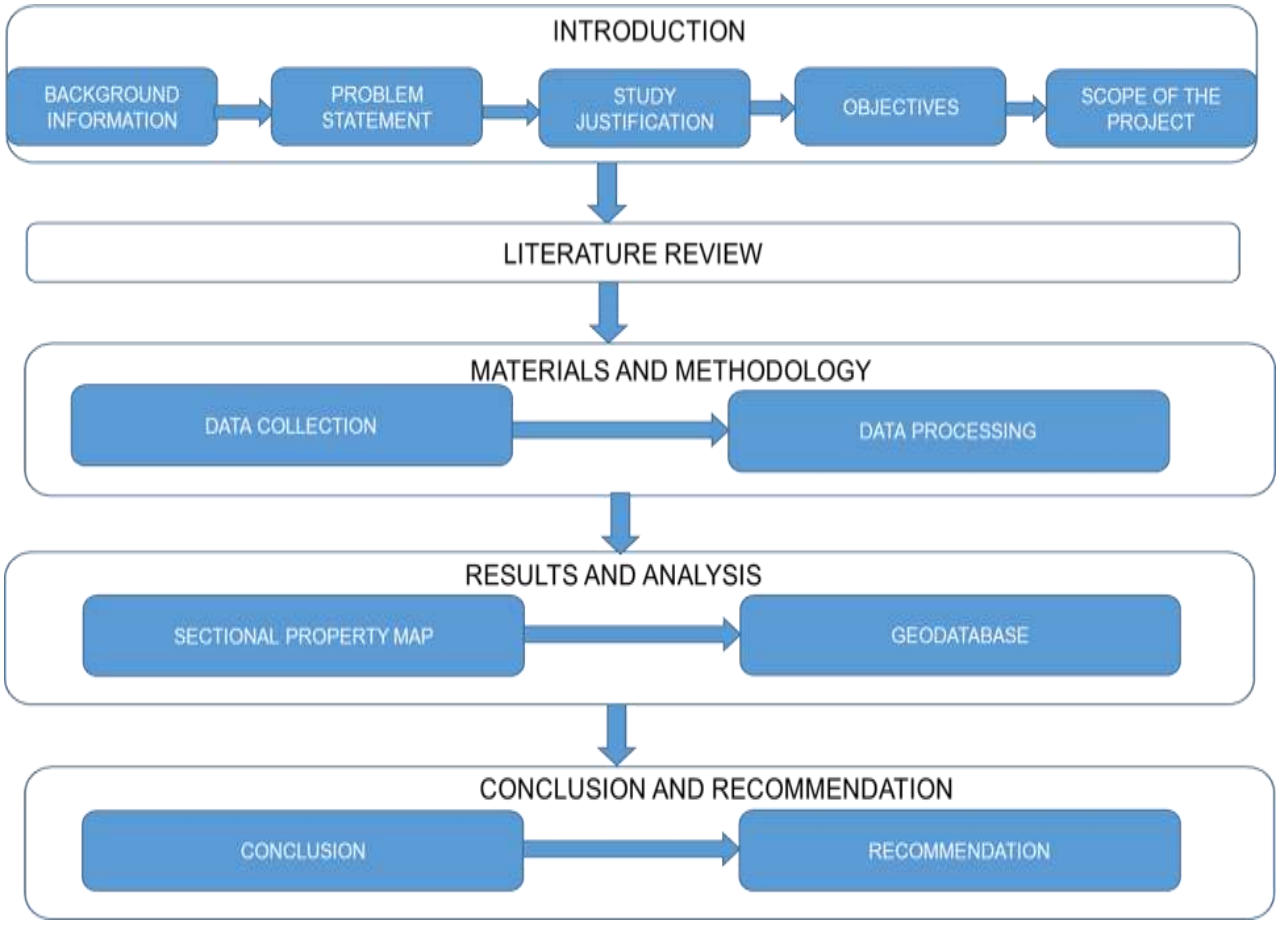


Figure 1.3 The organisation of the Report

CHAPTER 2: LITERATURE REVIEW

This chapter looks into general aspects of 3D property rights, private property rights in land and real property resources that are fundamental to modern societies. The division of land into property units and the establishment of exclusive, individual ownership rights will devolve both the cost of resource utilisation and the proceeds of management measures on the individual property owner. It also illustrates various forms of possible 3D property rights registration alternatives and formulation of the prototype database for storing and dissemination of the land related information.

2.1 Land Registration practice in Kenya

This is a process by which matters concerning land in possession, ownership and rights in land are recorded by the government of Kenya to facilitate transactions in land, protect against fraudulent activities on land and provide evidence of title and prevent the unlawful disposal.

2.1.1 Registration of Documents Act (No 26 of 1902)

This is an act of parliament legislated in 1901 in support of the white settlers for registration of ownership in land with or without a support of survey plan or a deed plan. The statute was also used for registration of other documents which are not related to land such as marriage agreements, architectural plans, building plans, change of names documents and many others. This statute was based on deeds registration and posed a challenge in locating the position of the parcel in geographical location.

2.1.2 Registration of Titles Act Cap 281,

The Registration of Titles Act was essential to provide the legal tools for a land registration system (Title) as opposed to the deeds registration, which was practiced under the Registration of Documents Act and Land Titles Act. This act was developed from the Torrens system of Australia and the English common law. This status was repealed as others in the year 2012.

2.1.3 Registered Land Act (Cap 300, Laws of Kenya)

The RLA (Registered Land Act) Cap 300 was passed purposely to deal with areas that had been surveyed under general boundary for the purpose of land registration. This law was to supersede Native Land Registration Ordinances and Special Areas Ordinance of 1959 and 1960 respectively. The Government constituted this Act of Parliament to replace other Laws that dealt with land registration by the time it was enacted in 1963. As noted in Mburu (2017),

"*this legislation covers a majority of Kenya's land registration where most of registries across the country totalling to over 50 percent"*. The land register under the Registered Land Act encompasses of green and white card for each parcel and parcel files. The cards register a chronology of transactions touching on the parcels while in the files, original transaction instruments are filed. This Act was repealed by the Land Registration Act (LRA) in the year 2012.

2.1.4 Land Registration Act 2012

This an Act of Parliament is meant to revise, consolidate and rationalize land registration, to principally give authority to the devolved government and national government authority on land registration matters and have an interconnected purpose.

The Land Registration Act includes the regulations and laws that are necessary for creating property rights and the associated restrictions and requirements imposed by the state or the community, for registering and subsequently transferring them, for resolving disputes, taxation purposes, and the equitable resumption of these rights. They must be responsive to local requirements and conditions, and be capable of evolving over time to deal with different needs and priorities. These institutions must also be open and transparent. The Act was enacted to revise, merge and streamline the registration rights on land, to effectively enable two government levels (National and County) to manage and carry out all their devolved functions of government pertaining land in land registration.

According to Section 104 of 1 of Land Registration Act provides that "*A register maintained under any of the repealed Acts shall, on the commencement of LRA, be deemed to be the land register for the corresponding registration unit established under this Act.*" (Government of Kenya, 2012)

2.1.5 The Sectional Properties Act 1987

This act was enacted to provide register sectional properties such as flats, offices, apartments, maisonettes, and any properties that has been developed on land. It is possible for anybody to own a unit in a building or a part of building without necessarily owning the whole building or owning the land which the property stands. On registration of a sectional plan, the registrar shall registers these rights where two or more units are in a particular parcel and closes the register of the parcel described in it and opens a separate register for each unit described in the plan.

Sectional Property Act No. 21 of 1987 provides a good footprint for 3D Cadastre development. However, institutional, technological and legal framework need to be improved for a sectional properties Act to provide a legislation for 3D Cadastre. In this law, units in a building are coordinated in 2D and the rest of the vertical units are coordinated based on the vertical projection where this assumption is not always true.

2.2 2D Cadastre

According to FIG, (International Federation of Surveyors) "*A Cadastre is a parcel based, and up-to-date, land information system containing a record of interests in land (e.g. rights, restrictions and responsibilities). It usually includes a geometric description of land parcels linked to other records describing the nature of the interests, the ownership or control of those interests, and often the value of the parcel and its improvements. It may be established for fiscal purposes (e.g. Valuation and equitable taxation), legal purposes (Conveyancing), to assist in the management of land and land use (e.g. for planning and other administrative purposes), and enables sustainable development and environmental protection"*. (FIG, 1995).

The current effort of creating a digital Cadastre has not culminated in the development of a comprehensive cadastral model as the parcel information contained therein is only spatial information in the traditional Cadastre without attributes interlinked. The separation of land registry (land attributes information) and the land survey information (spatial information) as well as the handling, storing, retrieval and management of the land information have become a great problem and a challenge to the security of land ownership and management.

According to Osundwa (2014) the land legal object contains four main groups: Parcel, Encumbrance, Owner, Property and Separated Right. The Property group provides a clear description of the land, and how it describes its vertical parcel in the space as a sub-class, and is connected to title reference. The owner parcel group describes the name and address of the owner, additional it should also contain information on any inhibition, caution, or restriction that would affect the right of disposition or acquisition. The group is also related to the title reference. The encumbrance group describes information on every burden adversely affecting the land; easements, charges, leases and restrictive covenants. The attributes could be the same as in the original model, which is the legal area, and the area type, encumbrance type and owner, land objects, corner coordinate, with some of the feature attributes as: first order, second order survey and third order survey as survey order classes grouping, the age of the monument, coordinate system and the type of the monument.

2.3 3D Cadastre

In the desire by citizens to have more land for development, land has been subdivided into many smaller portions and need for more space has led to the creation of infrastructure below the earth's surface and in the space and which has been encouraged and embraced. Construction of structures in space and under the surface, has resulted in the need for identification of property rights, restrictions and responsibility, especially in cities with dense population. In 3D Cadastre there should be a documentation of regulations and guidelines that show how every right should be protected. To manage this 3D space above and below the surface becomes an uphill task for the government and authorities working in this sector. Therefore it is important to develop a representation or modelling of these 3D infrastructure with geometrical model representation as "solid" in a computer environment and to put in place the database management that helps in the recording, retrieval, storing and displaying and querying the information.

The following factors directly affect the growing interest for 3D cadastre registration in many cities in the world:

i. Considerable increase in property value both land and the infrastructures on it.
ii. Developers interested and dealing with underground cables, tunnels, pipelines and space cables, especially for electricity, telephone, TV cables.
iii. Desire for more spaces by creating underground parking places, shopping malls, buildings above, roads/railways and other cases of multilevel buildings has grown considerably in the last forty years.
iv. Technological advancement, particularly in 3D approach in other domains (3D GIS, 3D Planning) which makes a 3D approach of the cadastral registrations attainable.

2.3.1 3D Legal foundations.

Many African countries are struggling with a legal framework, institutional framework and technical development of the 3D Cadastre; however South Africa has a functioning system ahead of other African countries. Investigation of 3D real property aspects in countries that are in the process of its implementation, starts by providing information on general characteristics of national real property legislation in the form of the following questions:

i. Why is it necessary to introduce a 3D system?
ii. What is the current status of the 3D Cadastre?

iii. What is the legal understanding of 3D objects and what are the possibilities for delimitations?
iv. What types of rights, responsibility and restrictions that can be registered in 3D?

According to Oosterom (2018), the above would be addressed in the following aspects:

i. How is real property defined in law (Land Code, Civil Code, or any other legal document in each country that defines land)? Is the third dimension implied/clearly defined in the legal definition?
ii. What are the 3D object situations (including every situation regardless if it is recording in Cadastre, or if it is defined by law)? - What are the 3D objects recorded in national registries and how are they recorded (e.g. 2D plans and floor number, 3D objects, 2D projections etc.)?
iii. Which registries are used to record these objects?
iv. Are there any restrictions or responsibilities implying 3D aspects (or directly defined in 3D) defined by law?
v. How is a 3D space separated from land ownership in case of underground/above ground infrastructures such as real property stratification, specific legislation and servitude establishment?

There are two kinds of private properties namely properties by nature, which is the land and other things incorporated to it by man or under the ground but without human intervention, and property by accession which are things immobilized by adhesion to the ground. In both cases, it could be said that the third (3^{rd}) dimension is implicit.

The concept of 3D property rights also varies depending on the national legal system. According to Abbas et al, (2014), 3D property right should be addressed in legislation: and which differs from one country to another on how it is practiced. There are four main types of 3D property rights that can be identified. First, an independent 3D property type, also known as public 3D property type, which is a model of sharing nature, intervening in the parties' ability to share their property units as they wish, and imposing a certain framework on them, having an inevitable measure of co-ownership. And secondly is the condominium where one has ownership right, users' right and leasehold rights. Then indirect ownership, which deals with tenants, limited companies and Housing Cooperation and lastly the grant rights which cover servitudes, leasehold and other right.

Kind of rights that can be registered in 3D cadastre

a) **Horizontal Property**

This is a right that mainly deals with cooperatives and condominiums and can be exercised over a property of its own. It gives to the owner the powers of use, and disposition. It can be exercised over private parts and over the common parts of a building. In accordance, the established respective regulations of horizontal property of different countries. The registration of rights in the areas of a building is possible and clear in the cadastral map of horizontal properties. This is mostly applied in sectional properties in the Kenyan law.

b) **Surface Right**

Surface rights refer to those ownership rights in a parcel of real estate that are limited to the surface. It does not include air rights or subsurface rights. It grants to the owner, the right of use, enjoyment and material and legal right to plant, forge or build, or planted, forested or constructed on the land, the air space or underground, according to the modalities of its exercise and term of duration established in the title and is sufficient in its constitution and within the provisions of this title and the special laws.

c) **Rivers and Lakes Boundaries**

The riparian line is a boundary that divides the public and private property rights, separating river (public domain) of land (private domain). In many jurisdictions it is determined from the average highest water level vertical surface.

d) Aeronautic Code/ Aviation Regulations

This regulation describes and defines the limitations to property owners with regards to their location, particularly to those in the way path of the flight or adjacent to airports. It defines the limits to which structures would obstruct airspace in airports or airstrips and their surrounding environment for the aircraft, to ensure the safe landing and take-off of aircrafts. These obstacles are by nature volumetric bodies such as infrastructure and buildings, they are represented by their projections on the representation surface.

According to the aviation the Civil Aviation Act No. 21 of 2013 Government of Kenya, (2013) "Notwithstanding the provisions of any written law, or the terms of any deed, grant, lease or licence concerning the use and occupation of land, the Minister for the time being responsible for matters relating to aerodromes may, where he considers it to be necessary in the interests of the safety of air navigation, by order published in the

Gazette, prohibit the erection within a declared area of any building or structure above a height specified in the order".

The 3D Rights Registration Alternatives

As stated by Stoter (2002) there are three possible ways of registering 3D cadastre, namely:-

a) The Full 3D Cadastre Registration

The 3D space in the cadastre universe is subdivided into parcels in vertical (3D parcel) without overlaps or gaps, this refers to the volumetric partitioning. The concept of 3D cadastre is realised where property is viewed as a block of volume where the cadastral registration in support of conveyance of 3D right is registered and the legal basis, real estate transacti'2on protocols. Practically, it seems best to maintain the classical way of registration particularly 2D parcel as default, and use the full 3D parcel in complex 3D structure situations.

b) The Hybrid Solution

Registering 3D physical objects within the 2D cadastral registration system when there is a legal reason for such registration. The resultant method of this 2D parcel registration works only when there is a legal registration situation and the registration of 3D physical objects which represent the actual 3D objects. An obvious relationship between the physical objects (3D Objects) and the piece of land affected are maintained. The parcels and 3D physical objects are also maintained.

c) 3D Cadastre tags in the current cadastral registration system

In this situation 2D registration processes is maintained in a classical process with the linkage of the external attributes to define the 3D Cadastre registration process. Complex registration situations in 3D Cadastre are done using the necessary data.

The reference of the spatial objects and the attributes can be done in various ways; the simplest way to tag 3D registration to the current system is by using the administrative register and cadastre plans and tag to the information from the land registry and appending the third component to describe this situation. A more advanced option in this situation is to add an attribute reference to a digital 3D description in the registration. The explanation may be available in analogue or digital form. In the latter case the information might even be included in the digital database. The projected outlines of the 3D (physical) object could also be registered in the cadastral map.

Preferred Alternative Registration

Stoter et al. (2001), observe that, "*both the cadastral and the technical viewpoint were observed as requirements of a 3D cadastre and concluded that for but that for the medium-long term hybrid approach is the most optimum choice for implementing 3D cadastre whereas the long-term future a full 3D cadastre is the preferred alternative*".

Therefore, any Cadastre would ensure that complex status quo like in 3D Cadastre and in a straightforward manner and is done correctly so that registration would provide an insight on the kind of registration provide real and a true representation of the legal in a simple, candid in a sustainable manner. Generally full 3D Cadastre is complex to present rights, responsibility and restrictions defined in 3D situation and a change in the civil regulation.

Forms of 3D Property Rights

It is observed by Paulsson (2007) that *"different forms of how to own or use a part of a building or other space that is three-dimensionally delimited. A categorisation of various theories of the structures of such rights would be very complex, due to a large extent to the fact that the structures are linked to the wording of each statute upon which such systems are built, but an attempt at such a classification is made" (*see in table 2.1).

Even though a grouping has been made subdividing the forms into specific types, it is important to emphasize here that there are no clear boundaries between certain of the forms. For example, it is difficult to draw a clear dividing line between indirect ownership forms and leased residential forms. The full range of 3D property rights in the broadest sense is given here, even including grants rights and leases.

However, the focus lies on the two main forms, independent 3D property and condominium, which can be considered as the real forms of 3D property. The other forms are described briefly in order to provide a wider picture. The table 2.1, Forms of 3D Property Rights.

Table 2.1 Different 3D Spaces in 3D cadastre (Paulsson, 2007)

Granted rights	Leasehold Servitude Other rights
Condominium	Condominium ownership Condominium user right Condominium leasehold
Indirect ownership	Tenant-ownership Limited company Housing cooperative
Independent 3D Property	3D Construction property Air-Space parcel

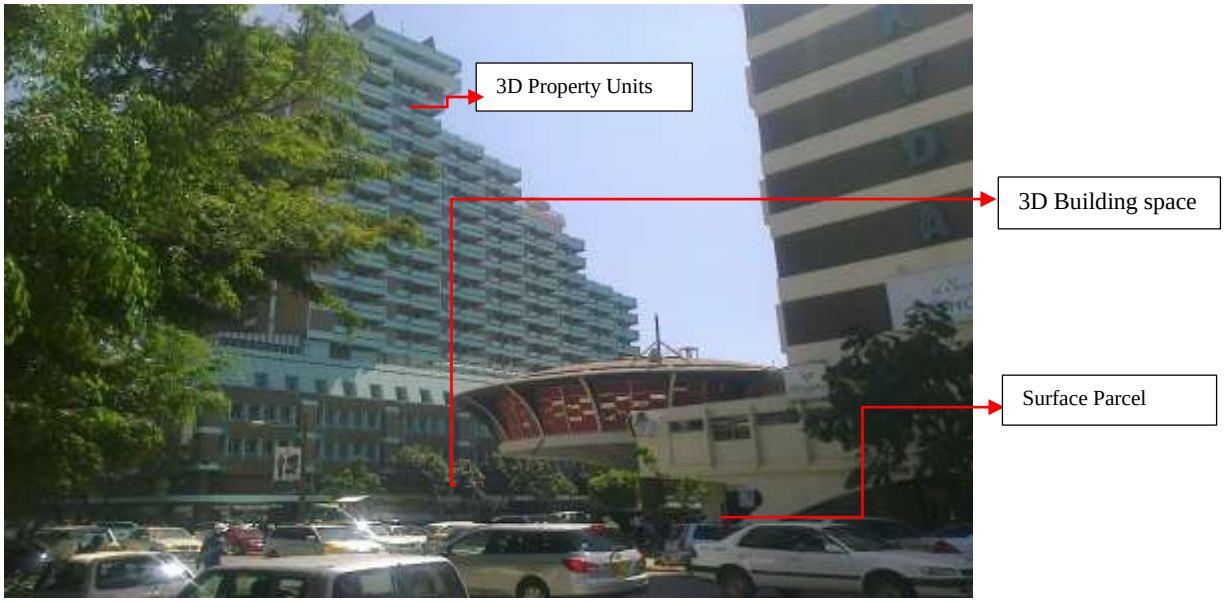


Figure 2.1 Different 3D spaces in 3D cadastre

A city plans and maps are generally described into 2D, and most of them are 3D infrastructure, this information is presented in plans to shows the extent in form of 2D maps. Complex states of the structures at the time of design where new ideas and styles comes, during constructions these designs are implemented and structures takes different shapes and styles. With the pressure of land most of the structures are done to utilise the spaces horizontally and vertically. This results in 3D situations where underground infrastructure such as garages, tunnels and space infrastructure such as surface apartments, monuments, and polluted areas. These

situations share the third dimension and this should be recorded during registration and any relevant information when registering the legal status. Apart from apartments and the office units there are no official regulations for registering the legal position, the geographical location (2D or 3D), or the extent of these 3D physical objects and Spatial DBMS for 3D Cadastres. As illustrated by Mwenda (2001) the fixed boundary survey should be carried out on the plot (in Kenya) and the site plan produced and floor plans follow as floor and unit descriptions.

2.3.3 Building Information Models for 3D Cadastre

3D Cadastre considers boundary of each property unit in three dimensions and their spatial and attribute relationships. A definition of a building or a section of a building in a geographical space and description of ownership or possession of this space is a basic right of the owner. The cadastral space depends on the property itself or parcel of land. The building is a whole inseparable box with or without any partition therefore there are many methods related to the site and locational plan or digital 2D drawings with the exception of 3D building constructions based on design images or CAD plans.

To design a unified Building Model all classes of features are collected from models while omitting their relationships. This is carried out by merging objects where the outdoor and indoor features are captured where their relationships are later redefined to produce a final Unified Building Model

According to El-Mekawy (2017) "*Building Information Models and geospatial technologies offer 3D data models that provide infothe surrounding environment and surrounding environment. The Industry Foundation Classes (IFC) and CityGML are today the two most prominent*"

(Yang et al. (2011), mentions that "*All the 3D cadastral units generated are described as separate objects and the connectivity among them must be created"*. Cadastral locational space representation is done with geometry by linking to adjacency of the objects.

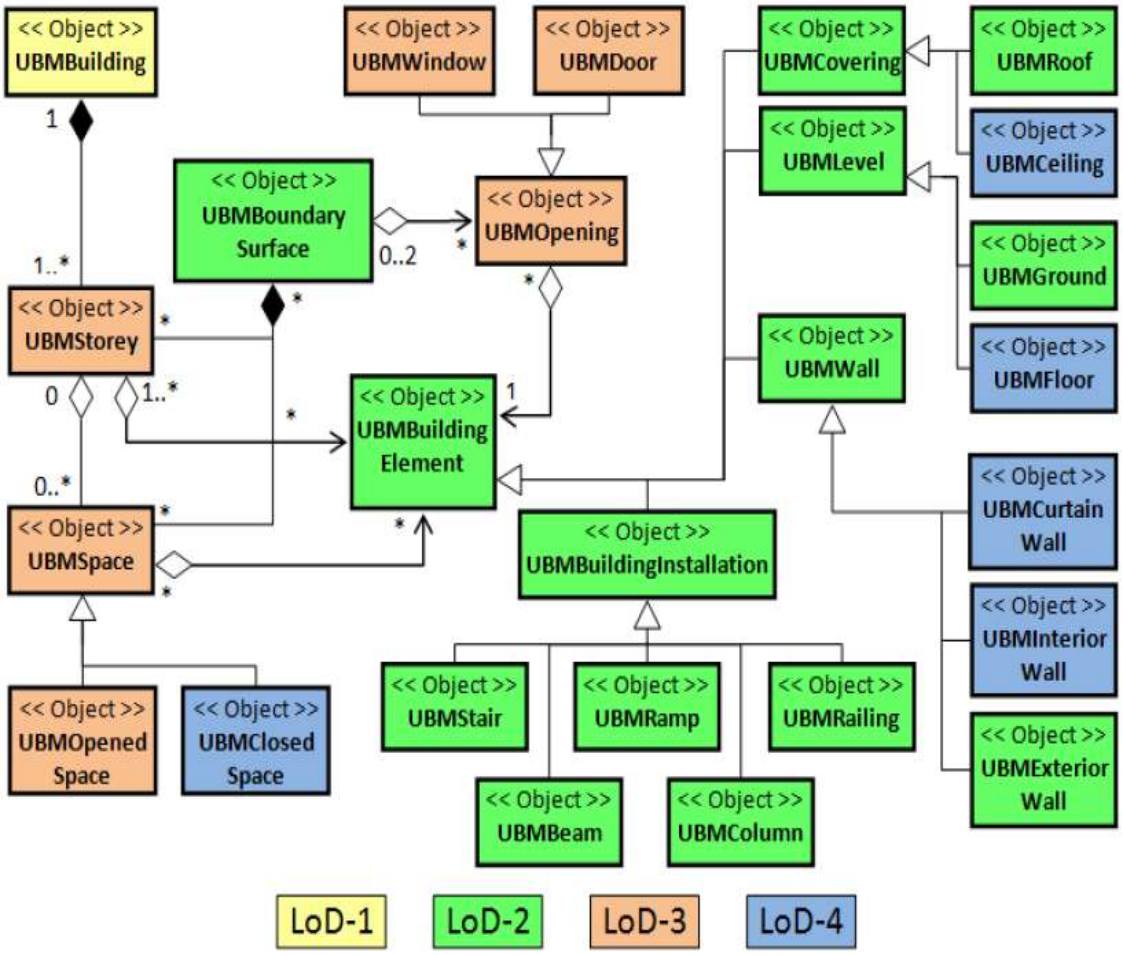


Figure 2. 2 The Unified Building Model (UBM) (El-Mekawy, 2012)

2.4 Database

Database is a collection of information organised that can easily be managed and updated. A spatial database is a database that stores and query data that represents geometric objects and space. Most of these geometric objects are represented in the form of points, lines and polygons.

2.4.1 Database Design

The database design basically follows the process of conceptual, logical and physical stages of design developed for storing and querying data that represents objects that describe geometric space. Some spatial databases handle more complex structures such as 3D objects, topological coverages, and linear networks.

Database design is the process of identifying the data that will go into the GIS database and how it will be represented. The database forms the foundation of all activities that will be performed using the GIS, such as map creation, data retrieval and spatial analysis and modelling. A good database design results in a well-constructed, functionally and operationally efficient database that:

a) Satisfies user requirements and objectives
b) Contains all necessary data, but no redundant data, unless some is explicitly planned for and properly documented.
c) Has an efficient data structures and retrieval mechanisms
d) Supports maximum data sharing
e) Accommodates different user views of the data
f) Is easy to update and maintain

In summary, the process of database design consists of the following steps:

i. Needs assessment
ii. Conceptual design
iii. Logical design
iv. Physical design
v. Pilot implementation
vi. Full implementation
vii. Operational GIS database

2.4.2 Database Management System

The spatial data types in a digital geographic data consist of two kinds of spatial information formats namely raster and vector. These spatial data can demonstrate spatial properties of geographic entities that require mapping to include geometry of the objects such as shape, size, orientation, dimension and topology and how they relate to other entities. Also geographic properties can be described by the attributes which is the non-spatial information, thematic attributes describe quantitative and qualitative properties and traits in the form of text, numbers, symbols, texture, images, graphic symbols video records, shape and many more. To represent some important features in the world, the spatial database must be modelled and developed to store, manipulate and appropriate organize all these data about geographic entities constituting this geographical aspect.

There are many modern software and hardware capabilities for the capture and utilisation of large point clouds is one of the major drivers to consider Spatial Database Management Systems in 3D situation. Topology and 3D relationship of the data models are important parts of 3D spatial data management. The Spatial data management systems should enable data models that handle a variety of 3D objects, perform automated data quality checks, search and analysis, data archiving, rapid data dissemination, 3D rendering, visualisation with close linkages to standards, ensure the data security of the data and the system.

3D Cadastre database Management is useful in the following areas of land planning and management:

- The desire to utilize the surveying boundaries to generate the 3D cadastral objects;
- The desire to store the 3D body surface of the 3D cadastral objects, and attributes explicitly and separately from the objects;
- The need for rapid topological queries to provide for user interaction and management. Comprehensive land administrative model is essential to build the cadastral management system.

According to Land Administration Domain Model (LADM) requirement, topological information alone is not enough to define a three-dimensional (3D) object, geometrical information must also be linked to topological information. Design of Prototype system model will describe and store the topological and geometric relationships of 3D cadastral units, as well as the entities, as shown Figure 2:1.

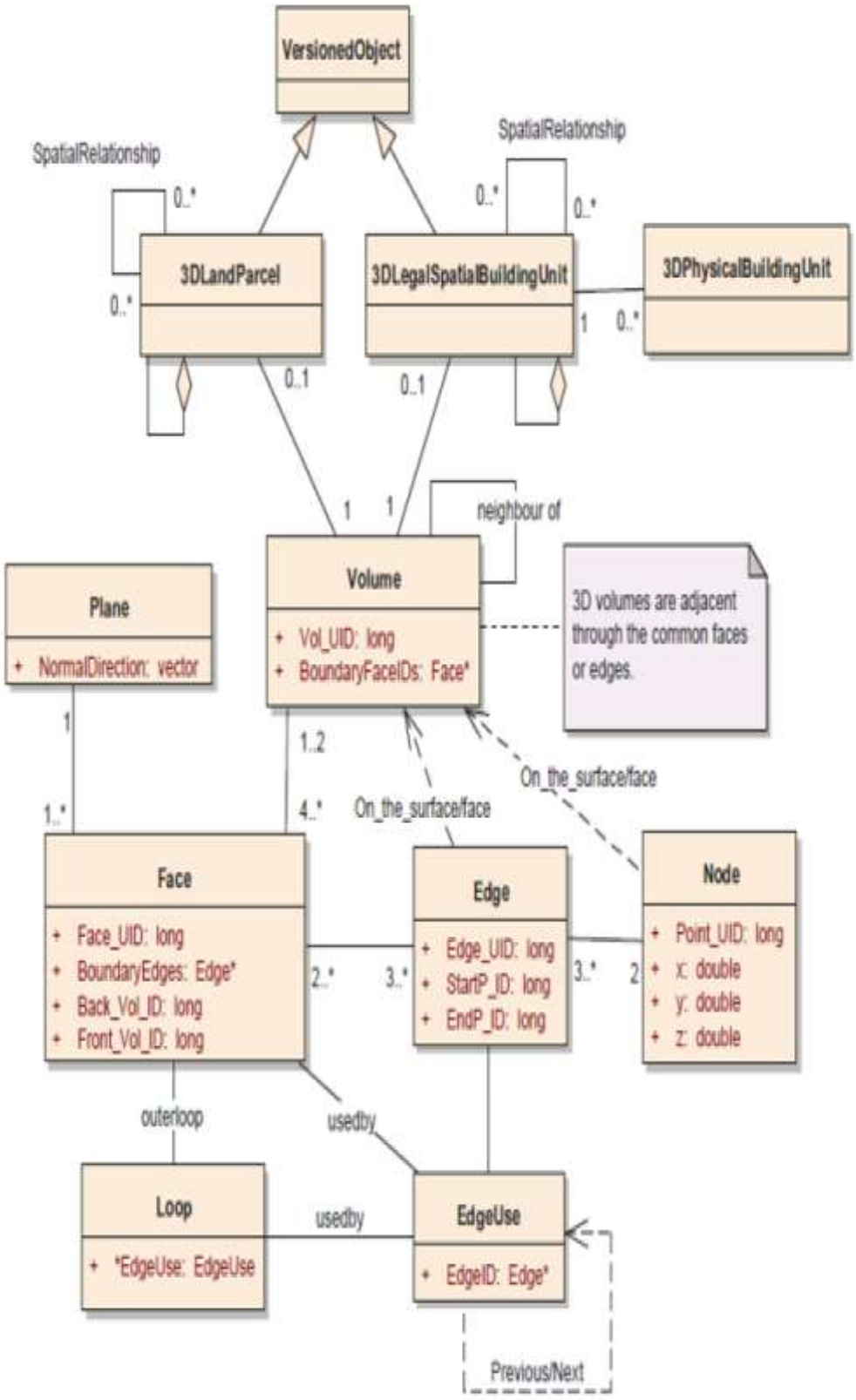


Figure 2.3 The INSPIRE 3D cadastre model based on the LADM

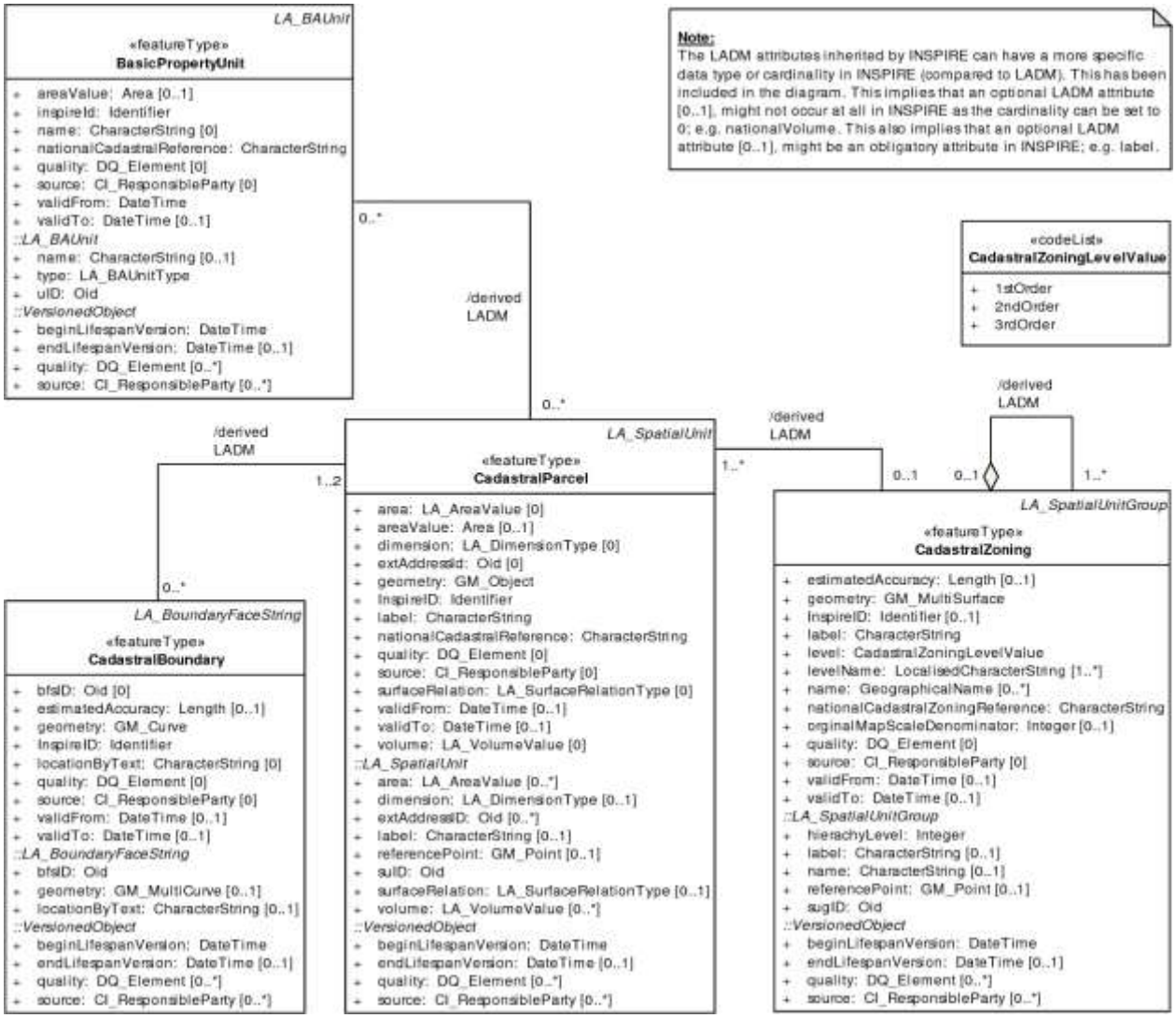


Figure 2.4 The INSPIRE cadastral parcel model based on the LADM (from Annex G, ISO 19152)

Three dimensional objects, geometric coordinates are recorded by node, and topological elements such as edge, face and body. Two conceptual classes that describe the 3D objects are parcels of land on which the land stands and 3D legal space of a unit in a building are defined to describe the 3D space representation of a solid 3D block.

2.5 Rights, Responsibilities and Restrictions

Property rights internationally varies in relation to different kinds of properties and legal system of a country. In Kenya Sectional Property rights extend from the internal area of the unit to the external area, where common properties look into in relation to the unit factor. The rights, responsibilities and restrictions (3Rs) in Sectional Properties are usually managed by the

Corporation that is constituted in a Sectional Property to manage common properties and ensure that all regulations are adhered to.

2.5.1 Owner Responsibility

According to the Sectional Properties Act there are rights, obligation and restriction to the owner of the unit and the Corporation. The owners' responsibility to the corporation are as follows: -

a) Allow the agents and the corporation staff to inspect the unit;
b) Constructing, maintaining, repairing or replacing cables, wires, and ducts for the existing system for the access and enjoyment or other units and common properties
c) Allows access for the maintaining, cleaning or replacing the common properties
d) To ensure every unit owner adhere to the rules and regulation that governs the property
e) Carry out all the tasks required by the public authority, local authority and even the corporation
f) Maintain his/her unit in a desirable in a good condition
g) Report to the corporation, any intention to repair, change ownership or change registration of postal address or carry out electrical, mechanical alteration in his unit or common property and give a notice about fourteen days in writing.

2.5.2 Owner Restrictions

The specific restriction to the owner of the units are as follows: -

a) The occupant of the unit shall only enjoy the use of the properties to the fullest so long as it doesn't interfere unreasonably with other users.
b) Use the unit in a rightful manner that would not cause any nuisance or cause any hazard to the rest of the occupants or other unit owners
c) Use the unit for the legal reason and avoid any activities that may injure the reputation of the residents of the plot
d) The unit owner should not rear the animal in his unit or in common property after the period allowed by the corporation for such activities elapse.
e) The unit owner should not use his unit for other reasons other than indicated, for example, residential unit should not be used for business reasons.
f) The unit owner is restricted to the corporate property or common property on any activities that can in any way increase the risk of fire and or raise the premium for insurance payable by the corporation

g) Place any movable property on your unit or common property that would be unpleasant or viewed as not aesthetically pleasant when viewed from outside
h) The owner is restricted from using the structures and other facilities like a sinks, toilets, and drains, for other reasons other than the reason they were meant for.
i) Obstruct other users from sidewalks, driveway, passage, parking areas and many other from egress or ingress to their facility.
j) Manage the refuse and the rubbish both in the units and common property and maintain the refuse bins.

2.5.3 Owner Rights

As stipulated in the Constitution in article 65 *"Every person has the right, either individually or in association with others, to acquire and own property"* Government of Kenya, (2010) the right extends to sectional property where units are owned and their rights are protected the same way as any property ownership.

The owners should enjoy the access to anything beneficial on his property such as appurtenant to the unit, an easement above or below it or on a common property. They also enjoy use of some basic commodities such as water, sewerage, radio, television, garbage and drainage through by the use of pipes, cables or wires or ducts.

CHAPTER 3: MATERIALS AND METHODOLOGY

3.1 Hardware and Software

3.1.1 Hardware

Computer Processor Core i7 CPU 2.4GHz, Memory 4GB or of a higher specification.

Scanner - Scanner of a high resolution scanner that is able to scan A0 Map.

Plotter - That is able to print A0 Papers

3.1.2 Software

Microsoft Office, ArcMap, Paint, Erdas Imagine and Global Mapper, Python, Microsoft-Access

3.1.3 Data

Table 3.1 Data and their sources

Data	Sources	Data Type and Characteristics
RIM	Survey of Kenya	Hard Copy of Parcel boundary which was compiled and approved 2005. Nairobi Block 7, Westlands
Survey Plan	Survey of Kenya	Hard Copy of the Parcel, which was compiled and approved in 2005, Mapping done in Cassini Soldner coordinate system. FR No. 331/13 to 331/15
Floor Plan	Survey of Kenya	Hard Copy the floors in this Parcel, which was compiled and approved in 2005, Mapping coordinated at the Cassini Soldner system The floor plans signed by the surveyor and architect. FR No. 331/16 to 331/19
Road Network	KeNHa	Shapefiles

3.2 Methodology Flow Diagram

The figure 3.1 illustrates the methodological procedure carried out in this project from the data collection to the final stage.

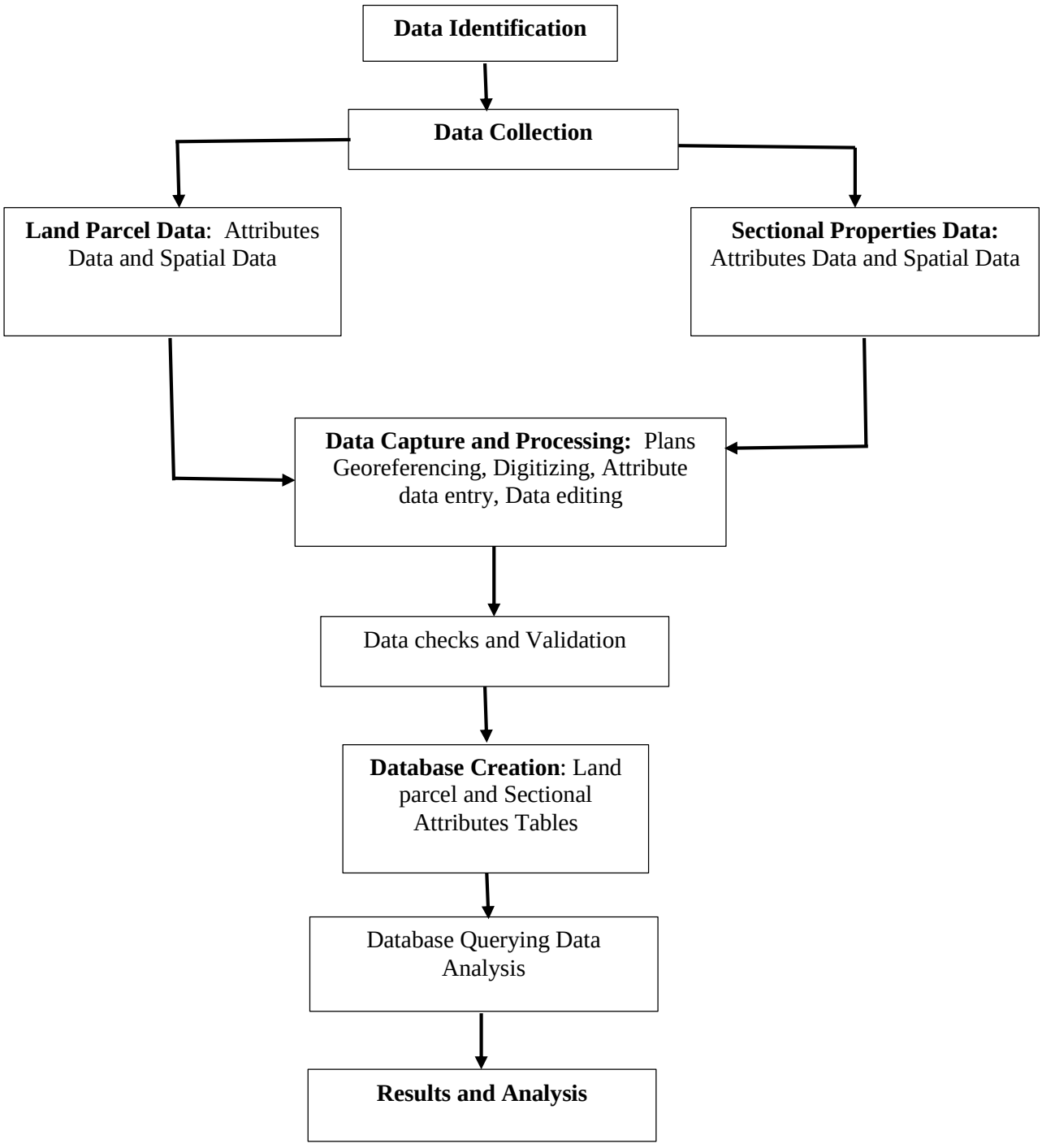


Figure 3.1 Project work flow Chart

3.3 Mapping of Sectional Property

3.3.1 Reconnaissance

The objective of the initial survey exercise was to;

i. Familiarize with the site and verify the units represented in the sectional plans.

ii. Identification of the parcel numbers of the property of study.

iii. Engaging the management of the property for the permission to collect ownership information, Corporation rules and regulations for Cadastre database development.

3.3.2 Sectional plans

The necessary approvals for Sectional Plans are obtained from relevant authority, especially for buildings and subdivision of the land to proceed as requirements for the registration of the individual units. The architect who designed the units should sign the plans to certify that buildings were constructed as per his or her design, and lastly to obtain the County government approvals stating that the proposed division of the units has been implemented as per the plan

3.3.3 Site and Building locational plan

Site and Building locational plan delineates the perimeter of the parcel and defines the location of any units to be erected on the parcel of land, it shows the number of building within the internal perimeter of the parcel and where necessary easements and other rights, restrictions and responsibility are granted before registration. Site and Building Location plans should show the immovable structures like shades, garage etc. The common properties within the parcel are well mapped as stipulated in Survey Act (Cap 299) whereby tie distances and offsets from parcel beacons or to some defined boundary lines are used.

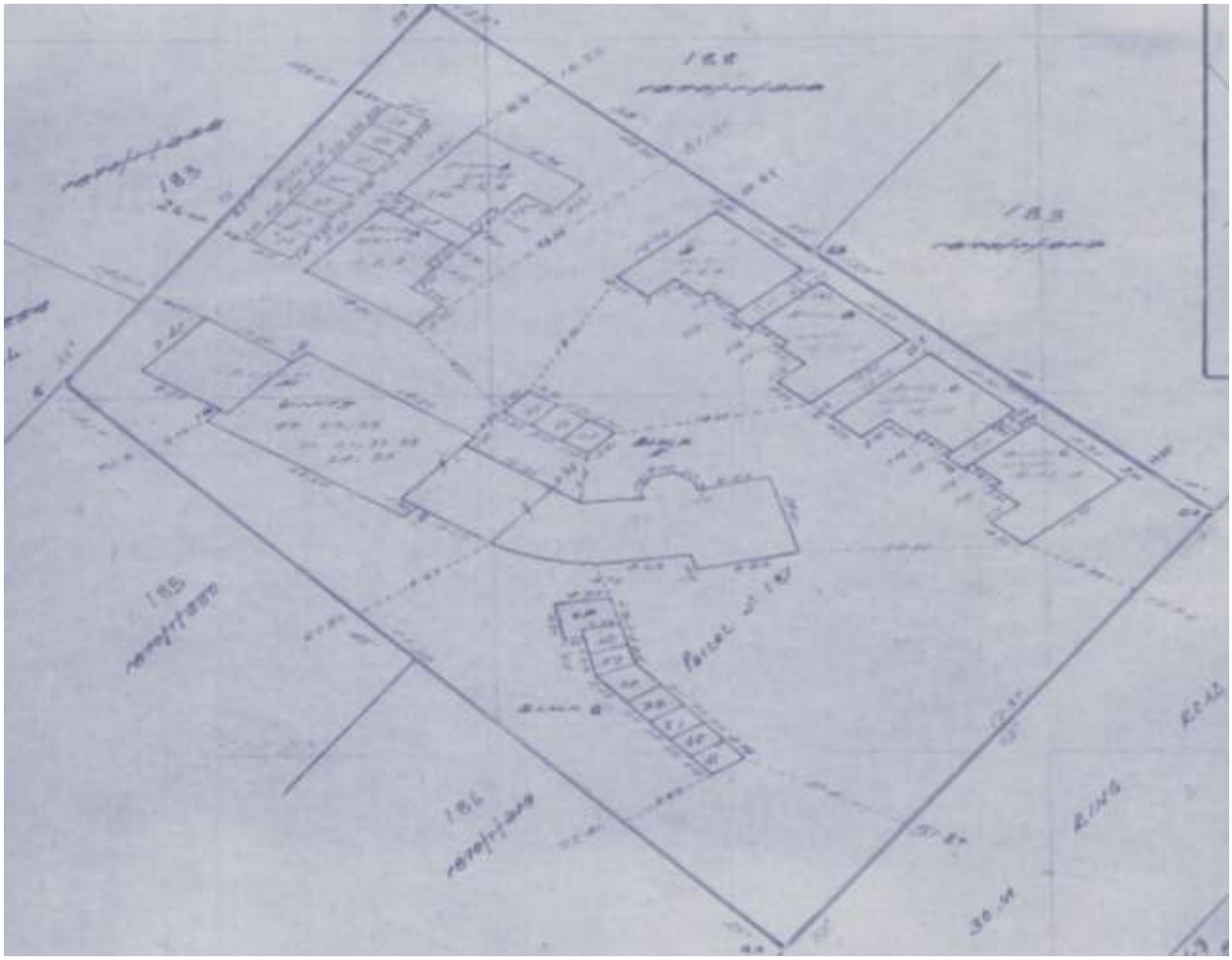


Figure 3.2 Site and Building Locational Plan

The individual unit were digitised to create a geodatabase that would answer to the registration issues and corporation management issues.

3.3.4 Floor Plans

Floor Plans show the boundaries of individual sectional units; they are described by the internal boundaries of the units, such as floors, walls, ceiling, windows and doors. The linen tape is mostly used for measurements and the architectural plan acts as a guide during measurements. Floor areas are given in square metres and linear measurements are made to the nearest centimetre (0.01m)

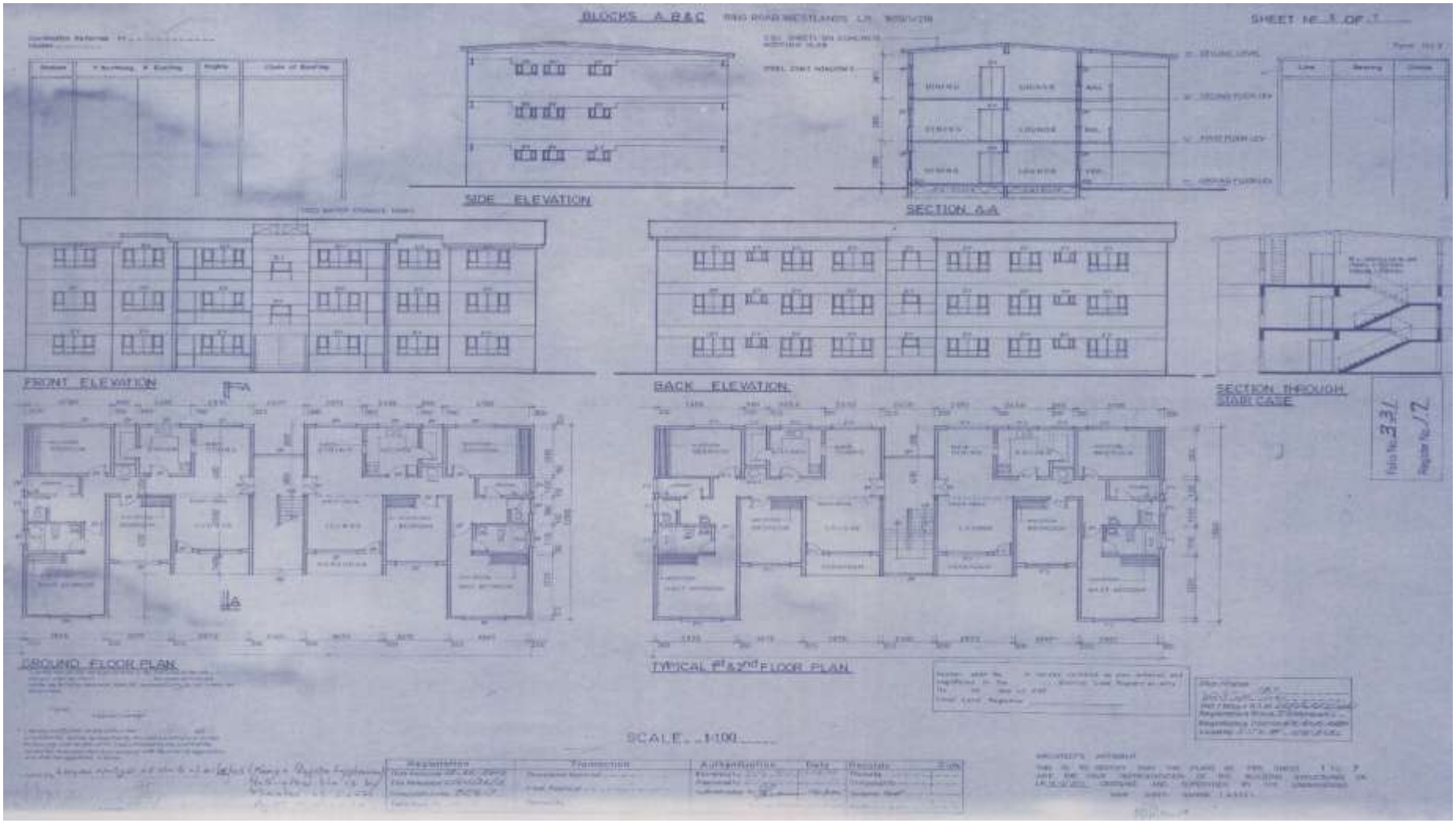


Figure 3.3 Floor Plans

3.3.5 Georeferencing

This is the process of assigning real world coordinates with the reference to datum to the image pixels or vector vertices, these coordinates may be obtained through ground survey or from the already georeferenced map. Most of the maps used in this project were based on Cassini coordinate system, after transformation the map were assigned the UTM coordinates Arc 1960 datum for easy data exchange and uniformity.

3.3.6 Unit Factor

A Unit factor is the representation of shares per unit owner in relation to Common property. Unit factor would be referred as unit entitlement which would be determined by unit floor area on the selling price or value factor of the unit or on the position of the unit or a combination of these factors is made equitable.

This the formula used to compute the unit factor: -

$$Unit\ 1 = \frac{a}{\sum A} x\ 10{,}000$$

Where 'a' is the floor area of the unit in m^2

'A' is the total floor area of all units in the sectional property in m^2

10,000 is a multiplication scalar used to convert a unit factor into a whole number

All the units are mapped and a unique number generated named OBJECTID which is used to identify all these features from ground floor, first floor and second floor. ArcMap software was used to compute each individual unit factor by using the equation 3.2 as shown in the figure 3.7.

Table 3.3 is derived from the ArcMap where the areas and perimeters are computed as per the size of the unit, Table 3.4 and Table 3.5 shows areas of the units, whereas Table 3.6 summarize the Total areas in each floor.

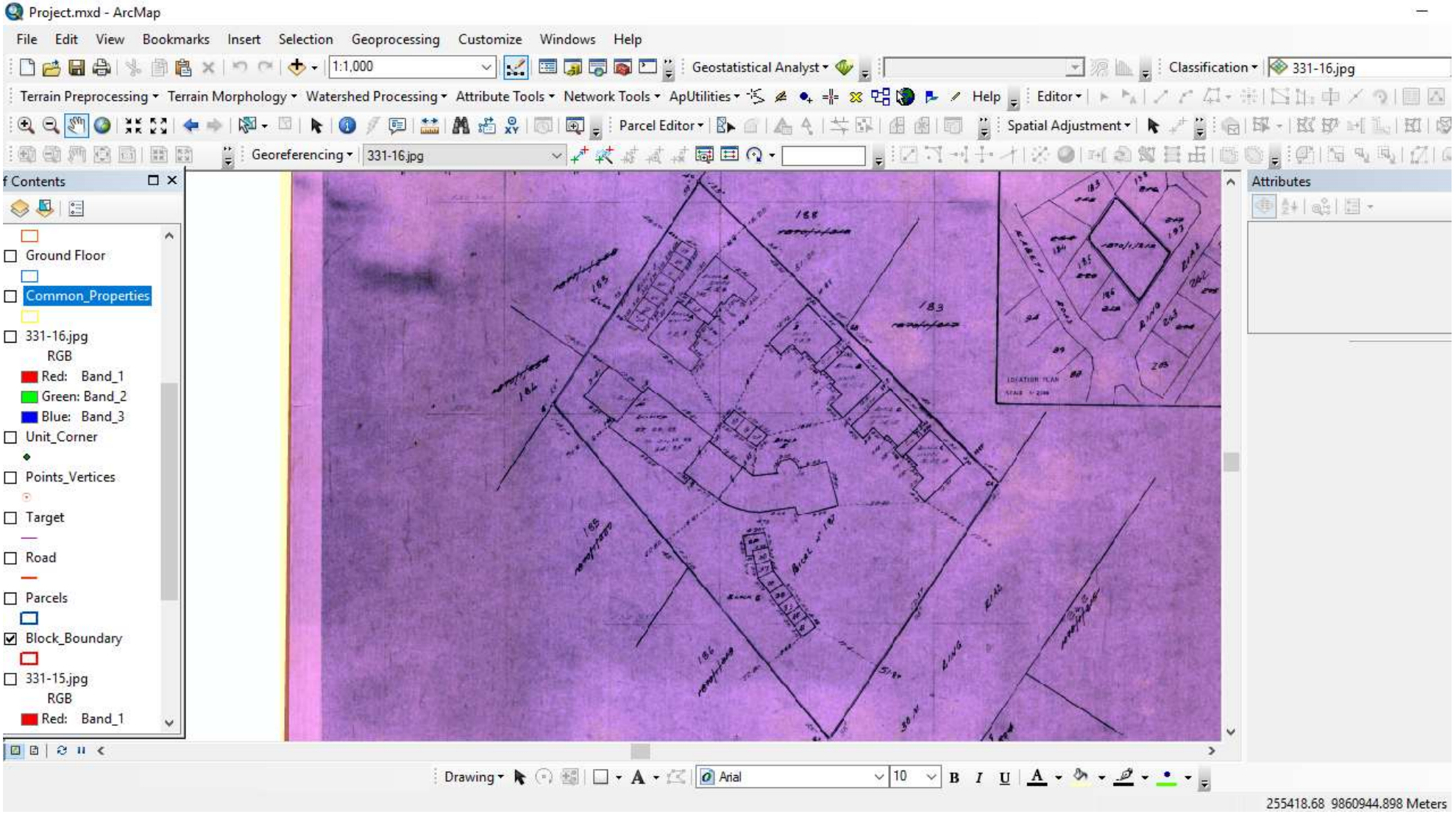


Figure 3. 4 Georeferenced Building and locational Plan

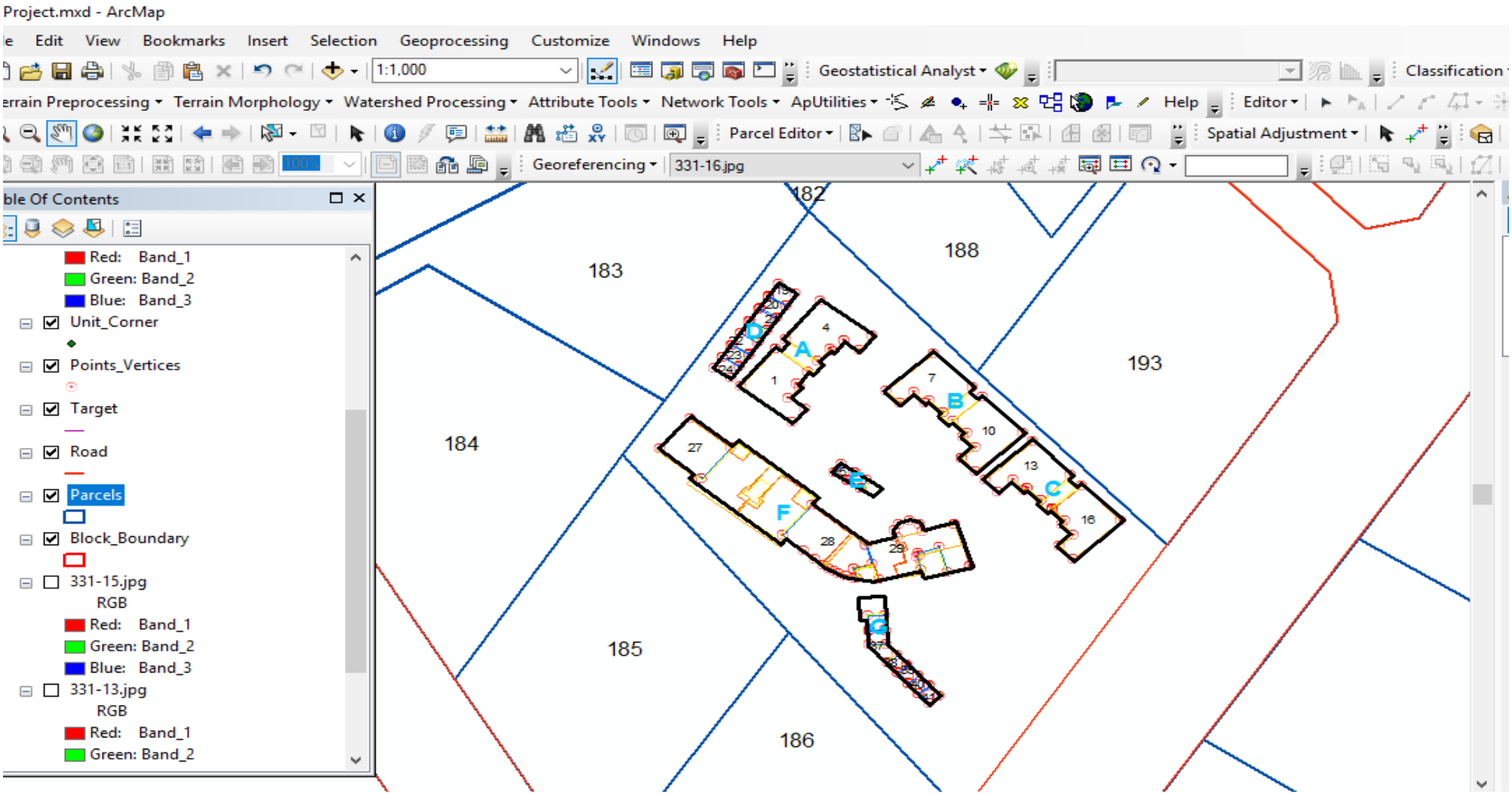


Figure 3. 5 Digitised Site and Building Location and Floor Plans.

Table 3.2 Ground floor computed Areas and Unit Factor

GROUND FLOOR CALCULATED UNIT FACTOR					
OBJECTID	**Area**	**Perimeter**	**Unit Factor**	**Unit No**	**Block**
24	11	13.17	30	24	D
25	11	13.58	32	23	D
26	11	13.48	32	22	D
28	12	13.72	33	21	D
29	11	13.59	32	20	D
30	11	13.55	32	19	D
31	6	9.86	17	26	E
32	6	10.19	18	25	E
33	9	11.86	25	37	G
34	10	12.39	27	35	G
35	7	10.47	19	38	G
36	7	10.53	20	39	G
37	7	10.63	20	40	G
38	7	10.59	20	41	G
39	102	45.79	290	7	B
40	105	46.28	297	10	B
41	102	45.70	291	13	B
42	104	46.21	296	16	B
43	106	46.37	302	4	B
44	103	46.11	293	1	A
45	89	37.87	254	27	F
46	142	66.06	404	29	F
47	133	49.59	379	28	F
Total	**1113**		**3,164**		

Table 3.3 Computed First Floor Areas and Unit Factor

FIRST FLOOR CALCULATED UNIT FACTOR					
OBJECTID	Area	Perimeter	Unit_Factor	Unit_No	Block_No
10	102	45.79	290	8	B
11	105	46.28	297	11	B
12	102	45.67	291	14	C
13	104	46.21	296	17	C
14	106	46.37	302	5	A
15	103	46.11	293	2	A
16	181	66.24	515	30	F
17	173	66.80	492	31	F
19	122	52.86	348	29	F
20	93	51.13	265	32	F
Total	1192		3,389		

Table 3.4 Second Floor Computed Areas and Unit Factor

FIRST FLOOR CALCULATED UNIT FACTOR					
OBJECTID	Area	Perimeter	Unit_Factor	Unit_No	Block
7	169	66.34	481	35	F
8	209	66.79	594	34	F
9	212	66.89	602	33	F
10	102	45.70	291	15	C
11	105	46.28	297	12	B
12	102	45.79	290	9	B
13	106	46.37	302	6	A
14	103	46.11	293	3	A
15	104	46.18	296	18	C
Total	**1212**		**3,446**		

Table 3.5 Summary of the summation of unit areas.

SUMMERY		
Floor	Total areas	Unit Factor
Ground	1113	3164
First	1192	3390
Second	1212	3446
Grand Total	**3,517**	**10,000**

Table 3.6 acts as a check to the calculations of the unit factor, in any arithmetic it is important to carry out checks to a certain any calculation.

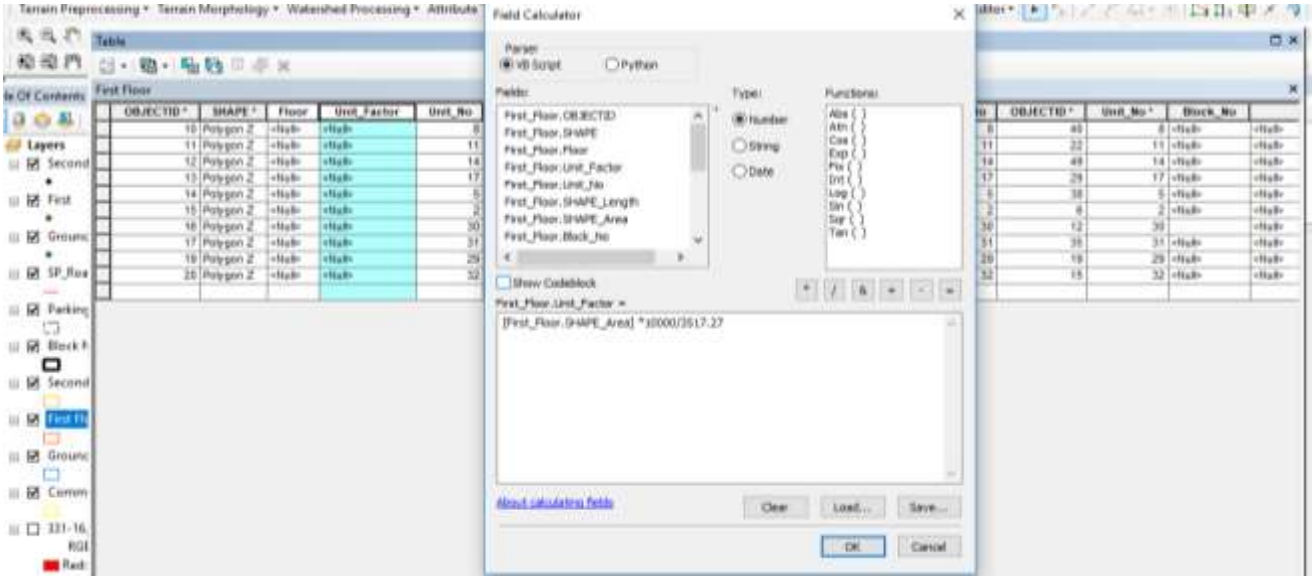


Figure 3.6 Using ArcMap to compute Unit Factor

3.4 Database

Geodatabase structural components are in a data formats, such as feature class which has spatial representation by the geographical coordinates of the features like points, lines and polygons with a descriptive tabular data appended to it. Object class and raster datasets.

In this project, the database will register a parcel of land link to the units developed on it and further to ownership and create relationships between different sets of data.

3.4.1 External Modelling (User's need Assessment)

This is a conceptual phase where user's requirements are taken into consideration through user needs assessment, for any database design, it's important to evaluate the requirement and needs of GIS system users, data types and data requirement. The users of this Land Information System (LIS) include the county governments, land professional officers, and sectional property managers, potential investors, financial institutions, land brokers and real estate companies. The data required to satisfy the users includes plot numbers, ownership details, unit area, unit Floor, plot taxation, encumbrances.

The objective of external modelling is to ensure a common interest between the design team and those who have a vested interest in the setup of the system. The end result of external modelling is a user needs assessment report.

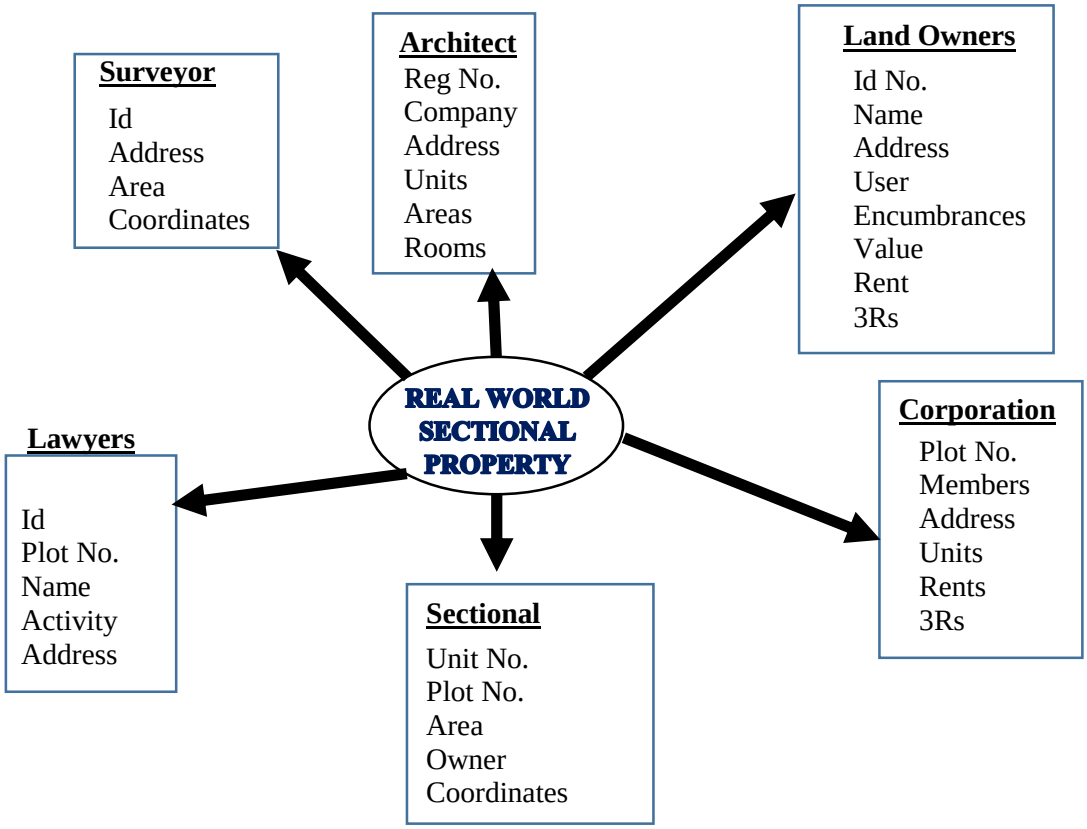


Figure 3.7 Sectional Property External Model

3.4.2 Conceptual modelling

Conceptual modelling is the synthesis of all the external models into an E-R diagram showing all the entities involved, their attributes and relationships. The E-R model is based on the fundamental concepts of entities, attributes, domains, relationships and mapping (cardinalities). E-R diagram defines the entities, their relationship with each other and the constraints.

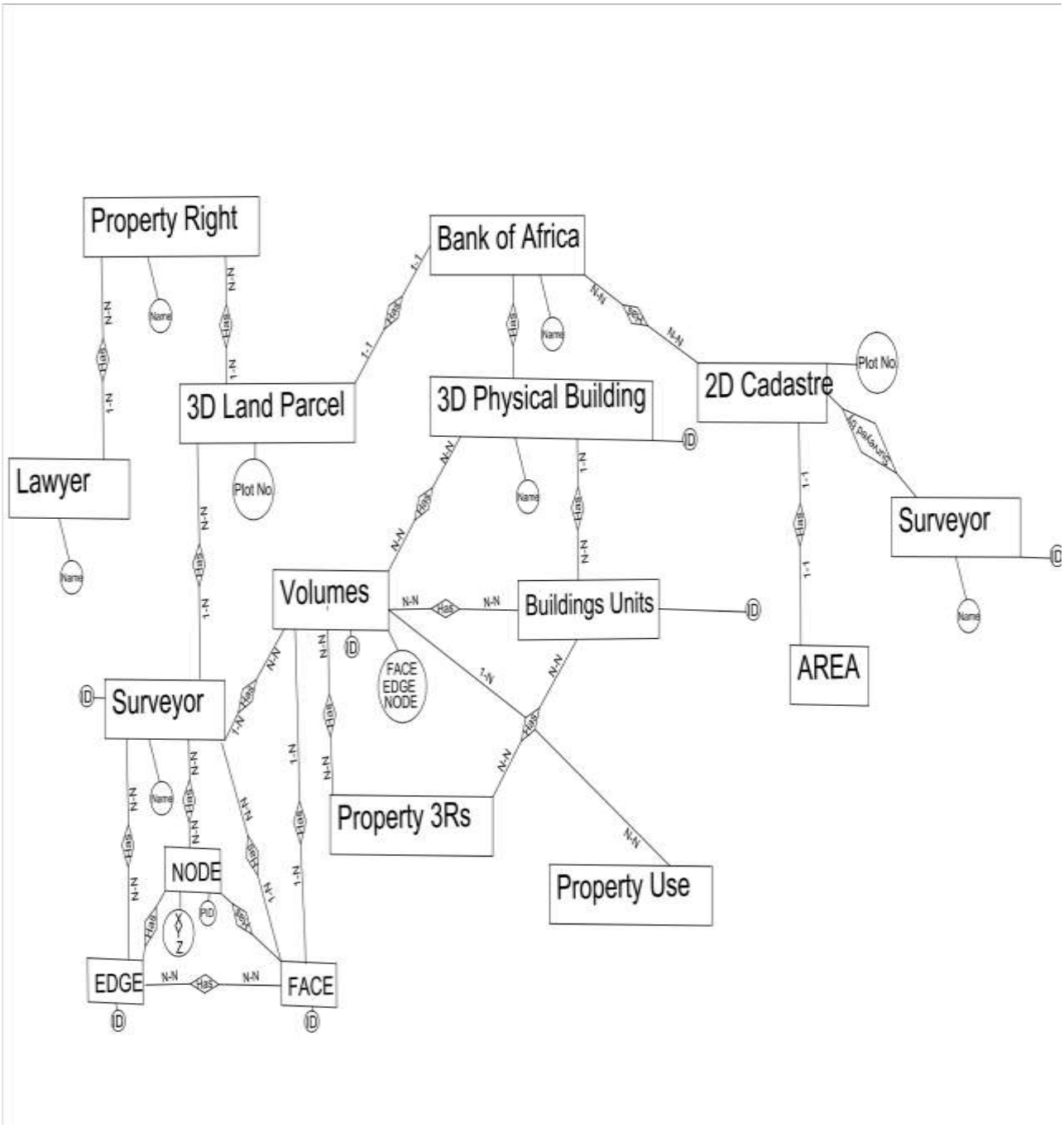


Figure 3.8 Entity Relational Diagram (ER)

3.4.3 Logical Modelling

Logical modelling consists of the mapping of the conceptual design onto the logical model DBMS. Logical modelling comprises the design and normalization of the relational tables according to the entities, attributes and relations identified from conceptual modelling; several

iterations will be necessary. Logical modelling is software dependent, but it is still hardware independent.

In this phase, data is identified and grouped in the table as it is required for the job completion and data relation, for example unit property relation to parcel number. It mainly involves the geographic entities that describe the objects or the process that helps in analysing data in details.

In this geodatabase design elements are defined based on the user requirement as entities in the conceptual phase. This phase describes the data specification, topology rules, relational properties and data structure that would require the development of relationships of the datasets and their properties

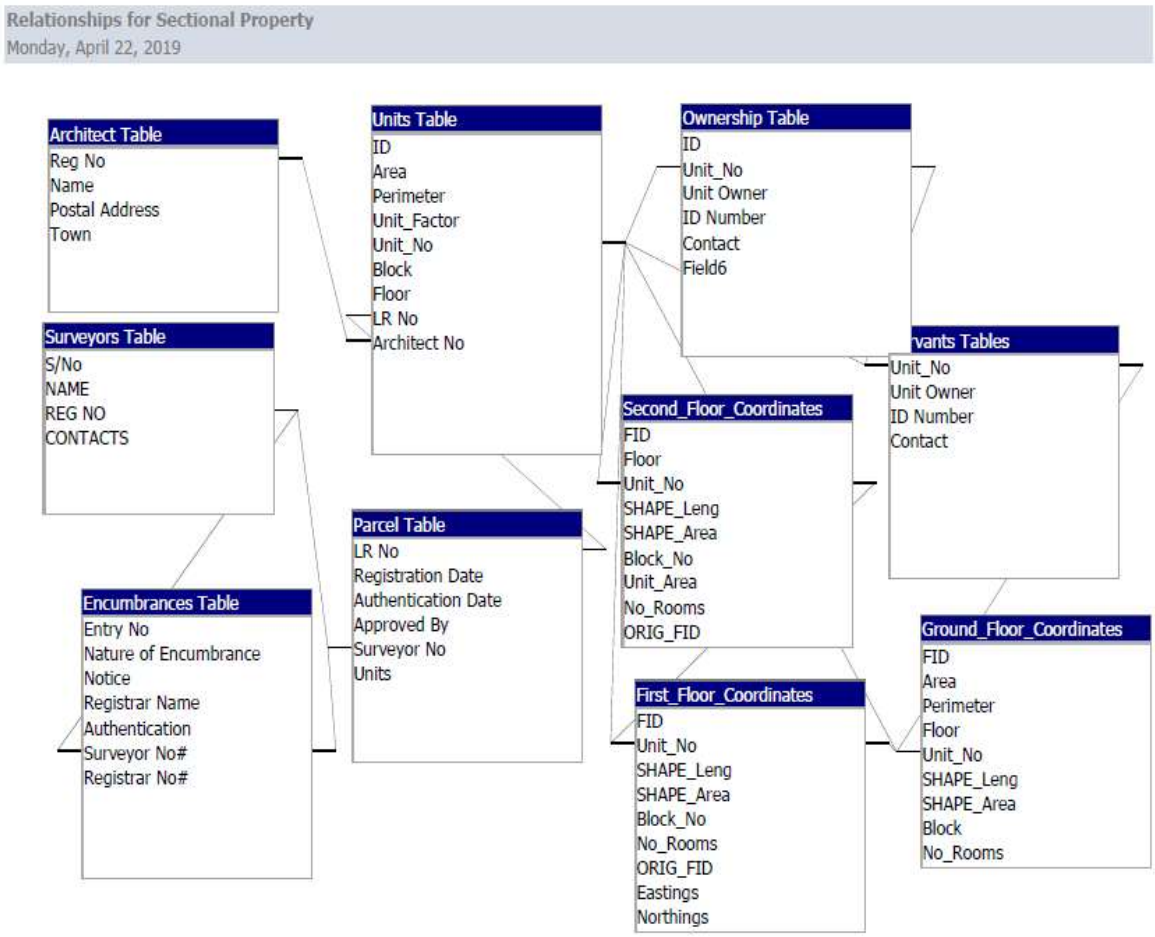


Figure 3.9 Relationship of the feature class in database

A relationship in a database allows linking of the different tables where primary key and the foreign key from the other table are linked and information is gathered from different source tables to enlarge the size of the table, the relationship above explains how this project will link tables from the main parcel to individual plots and relate it to unit ownership. It also would be linked to the survey works, building design and the rights, restrictions and responsibilities.

3.4.4 Physical Modelling

This is the design of efficient physical data storage structures for the data (e.g. Arrays, trees, stacks, queues, etc.) where the data will actually reside on disc and also how the data may be efficiently accessed. The DBMS it mostly handles this process. Physical modelling is both software and hardware dependent.

3.5 Database Query

To retrieve information from the database, SQL statements were used. SQL is a query language that enables data retrieval from relational databases. The syntax of SQL requires the specification of what attributes is to be retrieved, the relation involved, and any condition governing the retrieval. Such a condition is called a predicate.

One can prompt the software to save the query result.

The basic components of the SQL statement:

***Select**: <attribute name>*

***From**: <table names>*

***Where**: <condition to pick rows>*

CHAPTER 4: RESULTS AND ANALYSIS

4.1 Sectional Properties mapping

The set objective of this project was achieved, the units were mapped UTM Arc 1960 and the vertex coordinates of the corners, especially for Block A, B and C units that are directly above one another and therefore the units are similar as projected from the ground directly above each other to second floor. Blocks D, E, and G are occupied by servants/employees of owners of in Block A, B, C and F.

Block F units are not of the same size and design those in Blocks A, B and C. Figures 4.1, 4.2 and 4.3 show the units on ground, first and second floors.

Block F contain ten units, whereas the ground floor has a free space of nineteen metres provided for parking, therefore the design of the building on the first floor and the second floor are different as opposed to Blocks A, B, and C which have the same design from the ground floor to second floor.

4.2 Database Query and Analysis

The Database quarry can be used to identify the location or the position of the units in form of coordinates which was extracted from the units' corner vertices. The access quarry design shown below give the coordinates of each unit in block F.

The SQL query command is as below,

SELECT [Ownership Table].[Unit Owner], Ground_Floor_Coordinates.Eastings, Ground_Floor_Coordinates.Northings, Ground_Floor_Coordinates.Elevation, [Ownership Table].Unit_No, [Units Table].Block

FROM (Ground_Floor_Coordinates INNER JOIN [Ownership Table] ON Ground_Floor_Coordinates.Unit_No = [Ownership Table].Unit_No) INNER JOIN [Units Table] ON ([Ownership Table].Unit_No = [Units Table].Unit_No) AND (Ground_Floor_Coordinates.Unit_No = [Units Table].Unit_No)

WHERE ((([Ownership Table].[Unit Owner])="Sammy Kirumba Njuguna") AND (([Units Table].Block)="F"));

.

.

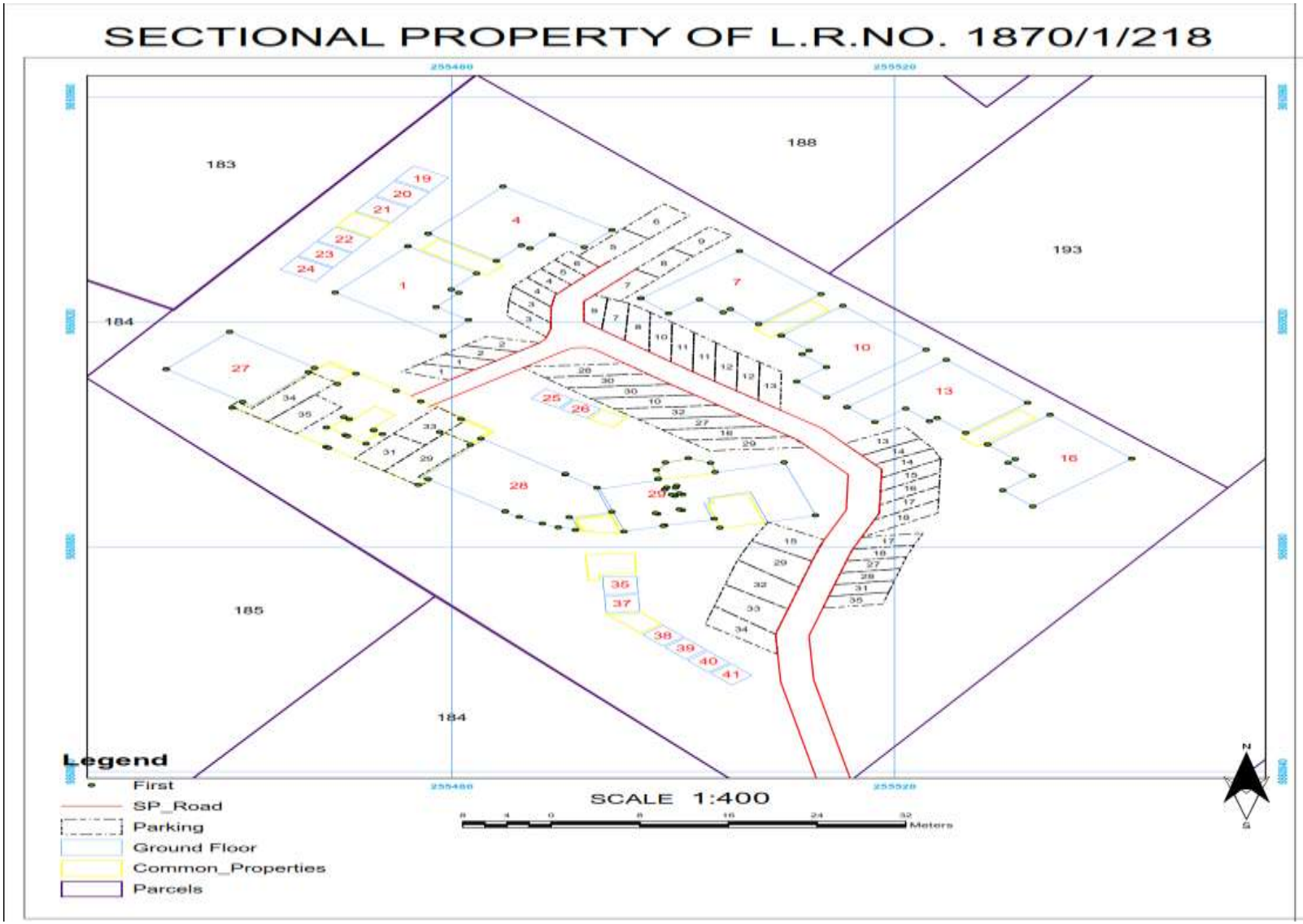


Figure 4.1 Ground Floor Units

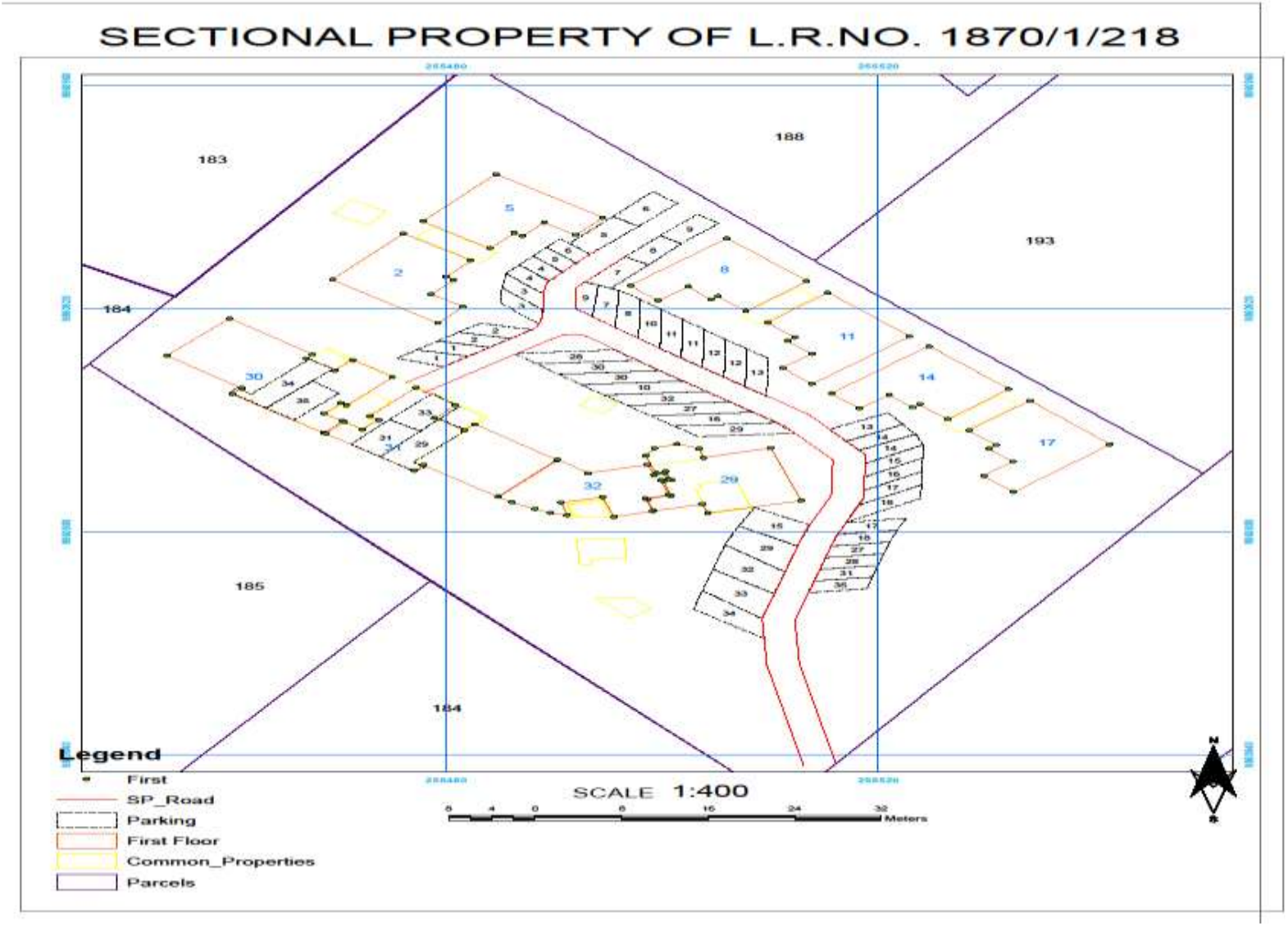


Figure 4.2 First Floor Units

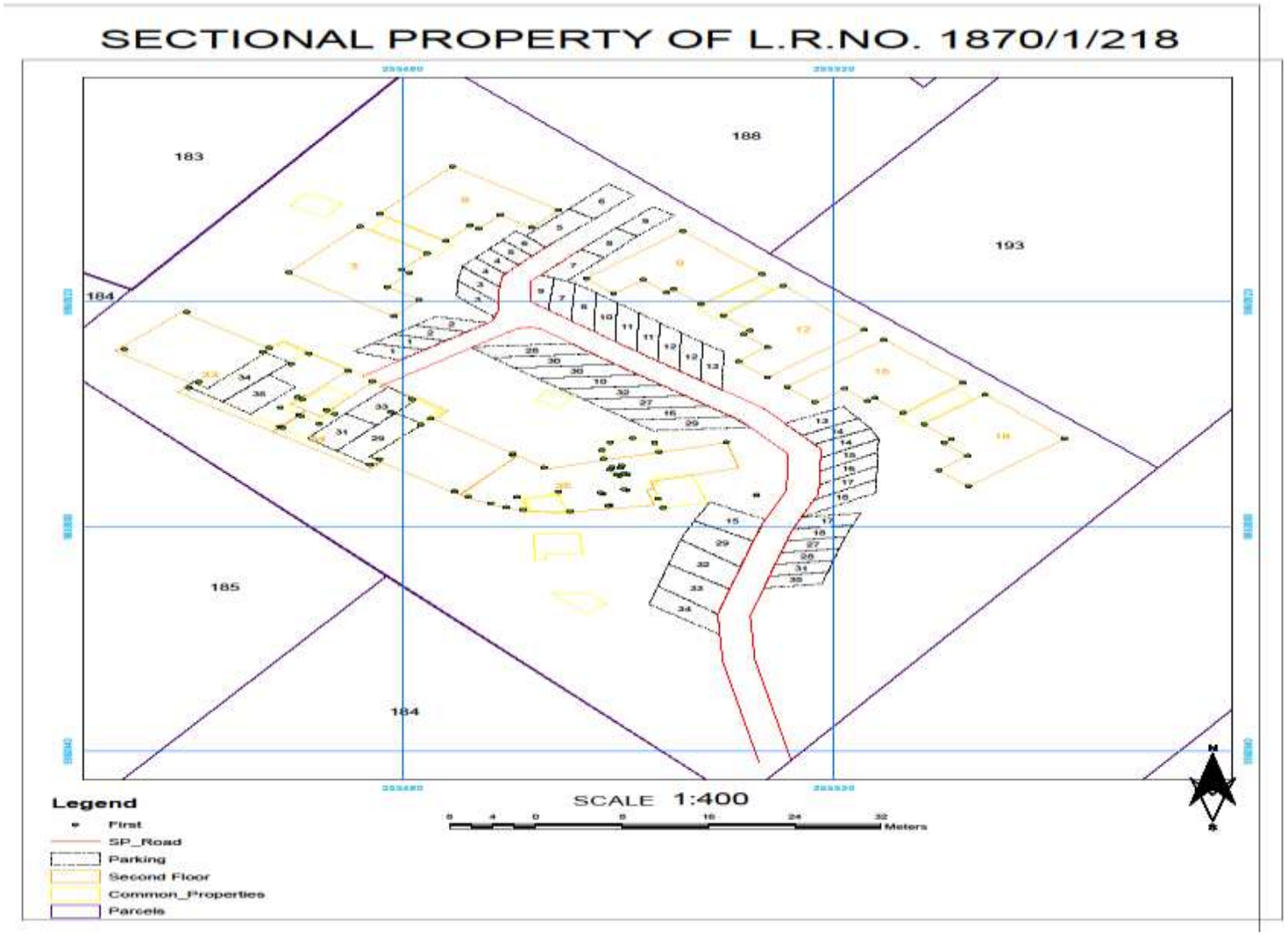


Figure 4.3 Second Floor Units

Table 4.1 Coordinates defining the Sammy Unit in block F

Query1					
Unit Owner	**Eastings**	**Northings**	**Elevation**	**Unit_No**	**Block**
Sammy Kirumba Njuguna	255494.29	9860886.08	1697.20	28	F
	255490.87	9860885.14	1697.20	28	F
	255491.53	9860883.00	1697.20	28	F
	255490.99	9860883.11	1697.20	28	F
	255489.34	9860883.60	1697.20	28	F
	255488.09	9860884.08	1697.20	28	F
	255487.22	9860884.49	1697.20	28	F
	255486.23	9860885.07	1697.20	28	F
	255485.24	9860885.85	1697.20	28	F
	255483.52	9860887.32	1697.20	28	F
	255481.35	9860889.13	1697.20	28	F
	255477.36	9860892.49	1697.20	28	F
	255482.93	9860899.07	1697.20	28	F
	255493.08	9860890.51	1697.20	28	F
	255494.29	9860886.08	1697.20	28	F

The query above specifically request the coordinate of the unit owned by Sammy Kirumba Njuguna in the block F

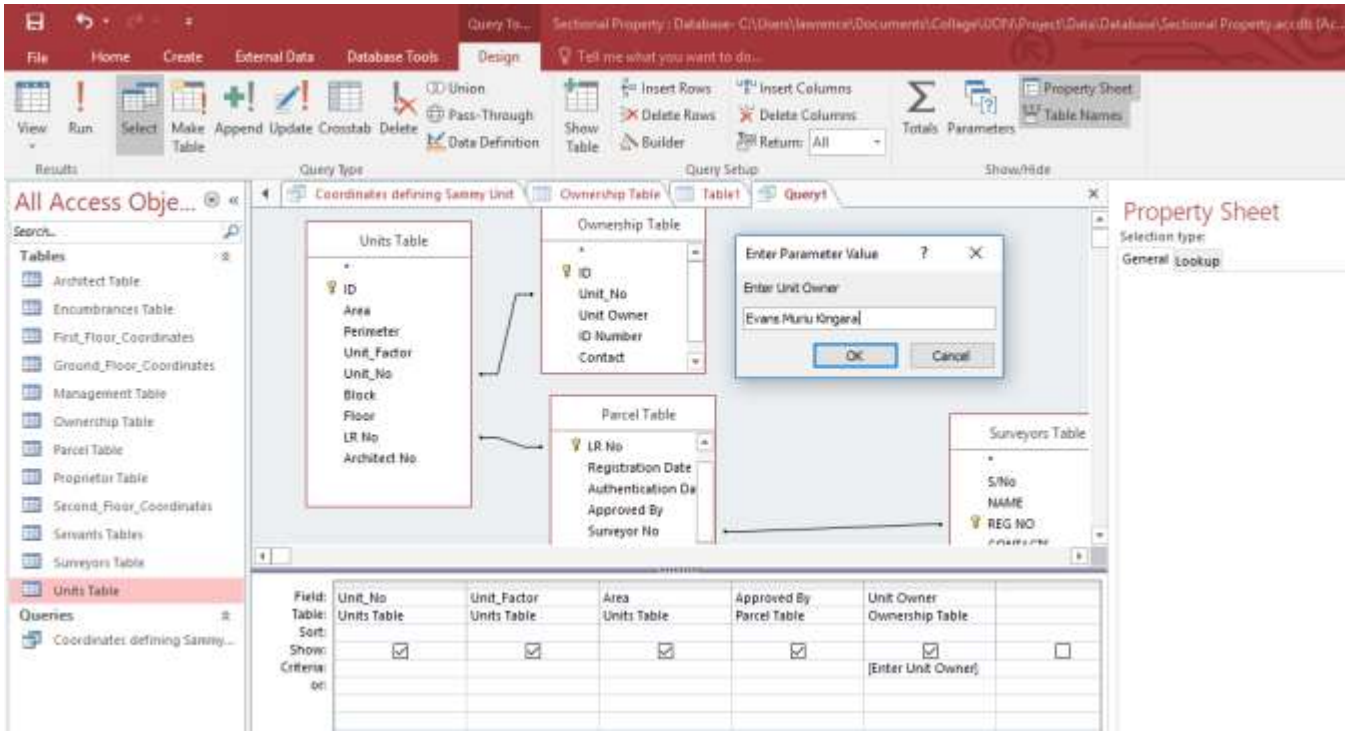


Figure 4.4 Creating a popup message "Enter Unit Number"

In the query design, one can custom search tool for many of the databases, access has the capability of creating a pop up search tool especially for this case the popup search tool to enter the Unit Owner at the criteria column.

Table 4.2 Search result for Unit Owner

Query1					
LR No	**Unit_No**	**Unit_Factor**	**Area**	**Approved By**	**Unit Owner**
1870/1/218	14	291	102.388	Muchori William	Evans Muriu Kingara

In all cases all properties have rights, responsibility and restrictions the system would easily identify these rights, for example, in the figure 4.5 where parking allocation for every unit would be searched and verified as in the case of unit 29 as selected.

The units in this sectional property are main units and servant units. Some main units are allocated servant unit whereas some other have no servant units. In this particular case there are fourteen servant units implying that there are twenty seven (27) units without servant units that are attached to them. This system can query how many main units on ground floor have servant units and who these servants are and their employers as illustrated in figure 4.6.

Block	Rooms	No_Rooms	ID	Unit_No	Unit Owner	ID Number	Contact	Unit_No	Servant Name	ID Number	Contact	Main Unit
B	<Raster>	6	7	7	William Njurumba	-	0791016357	<Null>	<Null>	<Null>	<Null>	<Null>
B	<Raster>	6	10	10	Beatrice Wambui	964955	0725804558	<Null>	<Null>	<Null>	<Null>	<Null>
C	<Raster>	6	13	13	Kungu Muiru	968313	0726568284	<Null>	<Null>	<Null>	<Null>	<Null>
C	<Raster>	6	16	16	Victor Wafula Munyau	20963589	0721673610	<Null>	<Null>	<Null>	<Null>	<Null>
F	<Raster>	4	27	27	Stephen Kiruthia Muturi	3596636	0722464915	<Null>	<Null>	<Null>	<Null>	<Null>
A	<Raster>	6	1	1	Francis Irungu Mwangi	435898	0722835563	24	Samson Welweta	30125041	<Null>	1
A	<Raster>	6	4	4	Andrew Okello Managu	924868	0724566722	21	Mary Nyakio Kimani	9986421	<Null>	4
F	<Raster>	5	28	28	Sammy Kirumba Njuguna	3597528	0714681732	40	Eunice Nabiswa	7485424	<Null>	28
F	<Raster>	6	29	29	Wilson Kiema Matara	<Null>	0722365412	41	Dina Ombogi	22587419	<Null>	29

(4 out of 23 Selected)

Figure 4.5 Servant units owned by ground floor main units

4.3 Analysis of results

Querying the Geo-database provides an easy way of accessing the records that would relate to ownership, size, location and other information with a single click of button as compared to the classical methods of keeping records and information. As in the Table 4.2 above Microsoft Access provides a platform that searches the data in a database and pulls out the required information as requested.

As illustrated in the Table 4.1, it provides an easier way of identifying the spatial location of the specific property in relation to the parcel and other units. The coordinate list shown has, Eastings, Northings and Elevation which describe the unit position in relation to the floor as the ground level units. The height of ground floor units, to first floor and second floor units were maintained at an average of 2.8 m.

ArcGIS is able create layers of all units regardless as to whether they fall on the same spatial position or have the same shape and dimension. Each layer can be switched on and off for viewing the overlap units as shown in fig 4.1, 4.2 and 4.3 from ground floor, first floor and second floor respectively.

CHAPTER 5: CONCLUSION AND RECOMMENDATION

5.1 Conclusion

1. The project utilised MS-Access as database software and GIS for mapping and data analysis, geo-referencing of the sectional property plans and creation of the database in MS-Access at the same time linking the tables in MS Access for easy data query, access. Retrieval, manipulation and interpretation were made easier by the use of the software.
2. Sectional Properties Act and property management are important and strategic components of planning, development and land registration. Most countries are moving towards the development of the 3D Cadastre, and Kenya needs to expedite the effort in digitizing land data which is mostly in paper form.
3. The Sectional Properties Act 1987 in the present form supports one of the Agenda Four objectives in a providing a housing to citizens and allows individuals to secure a rights, responsibilities and restrictions over the property.
4. The application of the Sectional Properties Act as now constituted is only applicable to buildings and their units which leaves a very big gap for its application in 3D cadastre. According the Sectional Property Act survey and property registration only deals with the floor, ceiling, walls and common properties. However properties beneath or above the surface are not adequately described: it is therefore necessary to change the law to allow for descriptions that make reference to areas as well as volumes of units. These surfaces and volumes are not adequately described: it is therefore to change the law to allow for descriptions that make reference to areas as well as volumes of units.

5.2 Recommendations

1. The consolidation of a 3D Cadastre, which registers 3D parcels and infrastructure constructed above or below the surface should be mapped in 3D indicating the position of the infrastructure either underground or above the ground to enable effective environmental and infrastructure network planning. This could prevent future damage to the existing infrastructure while carrying out other works.
2. 3D Cadastre can be used by government agencies for property registration and by private organisations for the management of the units and common properties and the facilities registered as Sectional properties.

3. The Sectional Properties Act should be amended to address the utilities and infrastructure developed on the land, underneath and in pace so that, positioning and registration of the sewer lines, water pipelines and power lines (which are underground and in space) can be registered and documented in terms of volume space, beyond the current approach.

REFERENCES

1. Abbas Rajabifard, Jantien Stoter and Mohsen Kalantari. (2014). legal barriers to 3D cadastre implementation: what is the issue? land use policy Journal, Department of Infrastructure Engineering, University of Melbourne, Australia.
2. Stoter Jantien, Oosterom Peter J.M., Hendrk D. Ploeger and Henri J.G Aalder (2004): Conceptual 3D Cadastral Model Applied in Several Countries Journal. Neitherlands.
3. El-Mekawy Mohamed and Sobih Aly. (2012). Feasibility of Building Information Models for 3D Cadastre in Unified City Models International Journal of E- Planning Research Vol 1. Stockholm University, Sweden.
4. Willimson Ian P. ,(2000) Best practice for land AdministrationSystem in the Developing Countries, International Conference of land policy Reform, Washington DC USA.
5. Gacoki, T. (2018). Polynomial transformation of cassini coordinates to UTM on the excel, FIG Congress XXVI, Intanbul,Turkey.
6. Government of Kenya. (2010). Constitution of Kenya. Nairobi: Government Press. Nairobi, Kenya
7. Government of Kenya. (2012). Land Registration Act Revised 2012. Nairobi, Kenya: National Council for Law Reporting. Retrieved from www.kenyalaw.org
8. Government of Kenya. (1987). Sectional Properties Act. Nairobi: Published by the National Council for Law Reporting.
9. Government of Kenya. (2012). The Water Act, Revised 2012. Nairobi, Kenya: National Council for Law Reporting. Retrieved from www.kenyalaw.org
10. Government of Kenya. (2013). The Civil Aviation Act, Revised 2013. Nairobi, Kenya: National Council for Law Reporting. Retrieved from www.kenyalaw.org.
11. Mburu Peter, Lizahmy Ntonjira and Jane Njeri (2017). Responsible Land Governance toward an evidence based Approach. Annual World Bank on Land and Poverty, Washington.

12. Mwenda, J. (2001). Registration of properties of strata in Kenya. 3D Cadastre.FIG conference Land Development ang Governance Institute. Nairobi , kenya.

13. Oosterom Peter J.M. (2018). Best Practices 3D Cadastres-Extended Version. Copenhagen, Denmark: FIG Publications.

14. James Osundwa, Eric Nyadimo and David Siriba (2014). Challenges in the Establishment of a NCDM for Kenya, FIG Working Week 2005 and GSDI-8, Cairo, Egypt .

15. Paulsson Jenny. (2007). 3D Property – Types of Rights and Management Factors. FIG Working Week, Integrating Generations, Stalkhod, Sweden.

16. Rainsford, H. F. (1968). Survey Adjustments and Least Squares. Constable Company, orange street UK.

17. Stoter Martin A. Salzmann, Van Oosterom and Van Der Molen. (2002). Towards a 3D Cadastre. Washington: FIG XXII International Congress.

18. Alias Abdul-Rahman, Sisi Zlataniva and Volker Coor. (2014). Innovations in 3D Geo-Information System, Published: Heidelberg: Springer, Switzerland.

19. United Nation. (10th July 2014). World Urbanisation Prospect Economic and Social Affairs, 1-2. Retrieved from https://doi.org/10.18356/527e5125-en. New York

20. Wayumba, G. O. (2013). An evaluation of the cadastral system in kenya and a strategy for its modernization, Thesis for Doctor of Philosophy in the University of Nairobi, Nairobi, Kenya.

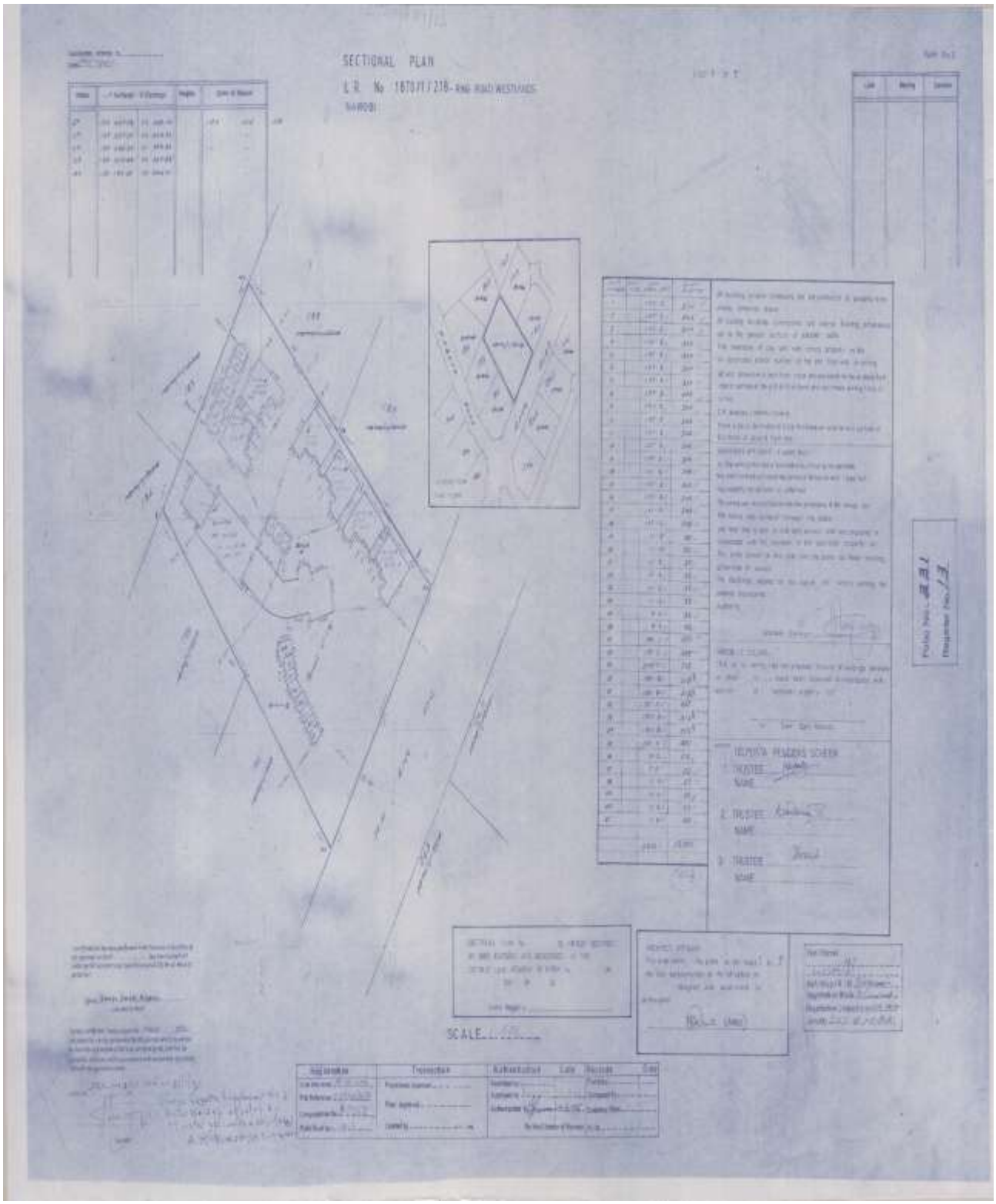
21. Williamson Ian and Don Grant. (1999). FIG Bathurst Declaration on Land Administration for Sustainable Development. FIG Publication No.21. New South Wales, Australia.

22. Zlatanova S. and Emgard L. (2004). Design of an Integrated 3D Information Model. GISt, OTB, Delft University of Technology, Delft, Netherlands.

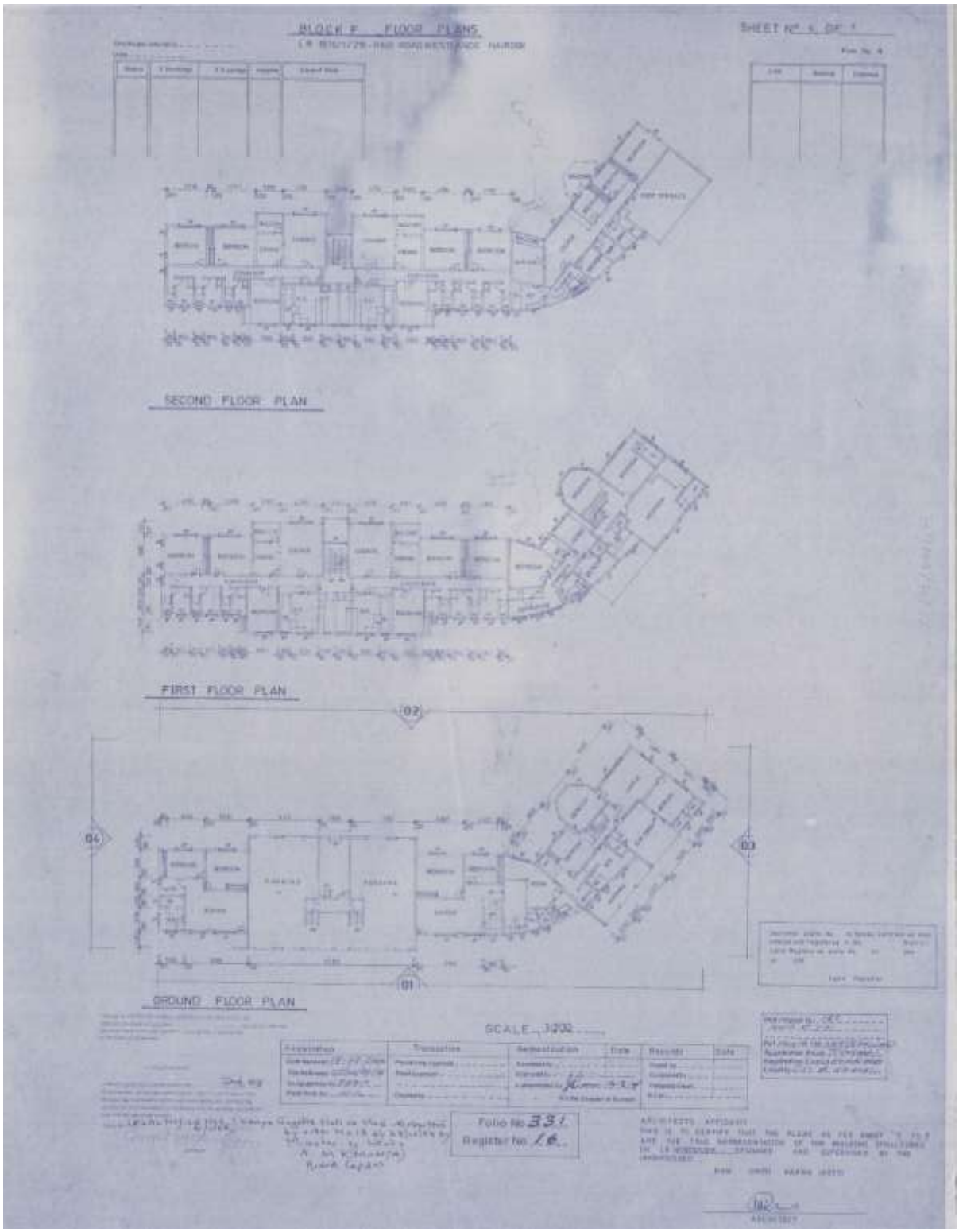
APPENDICES

Appendix A: Block 7 Westlands, NAIROBI (Locational Plan)

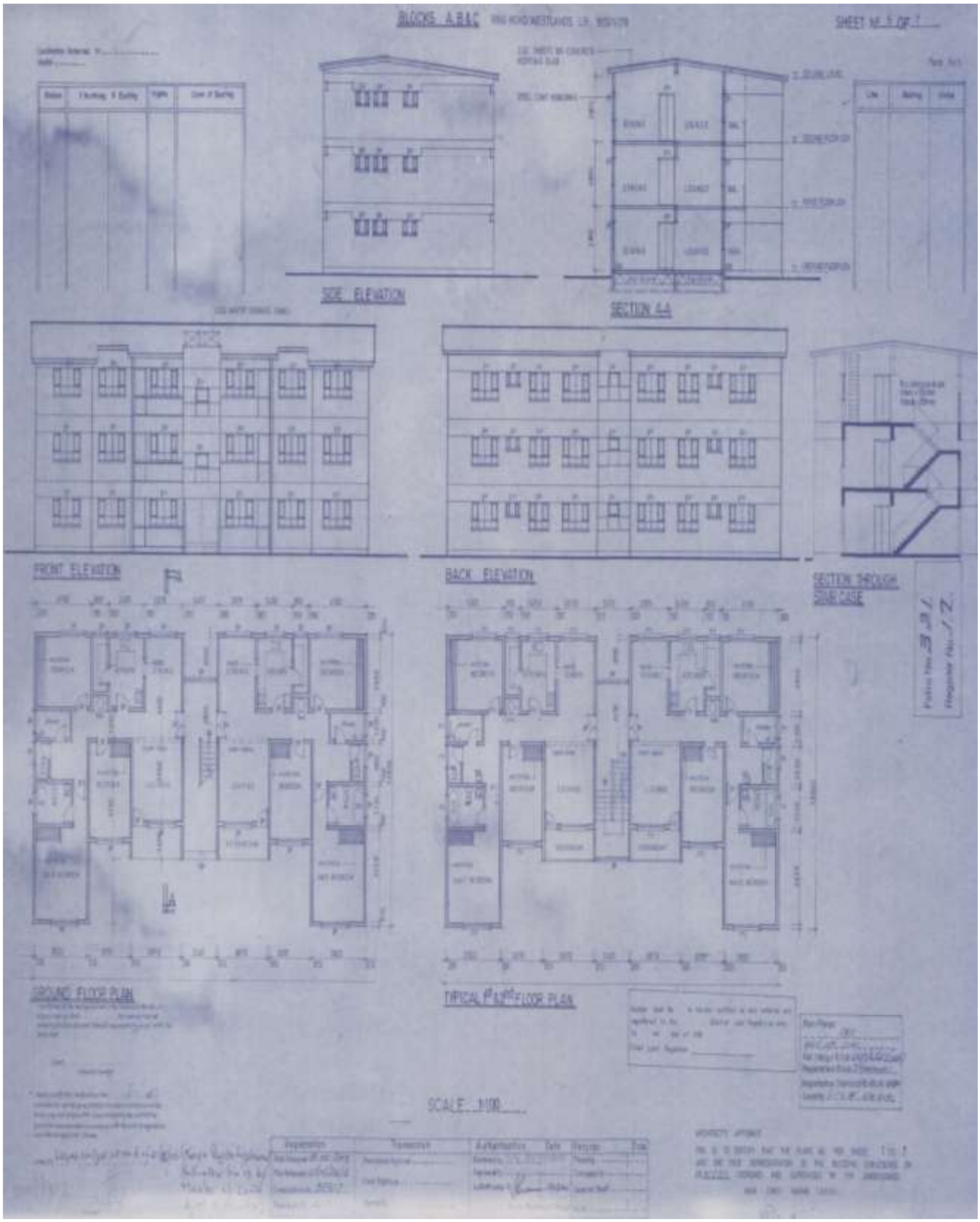
Appendix B: Site and Building Locational Plan



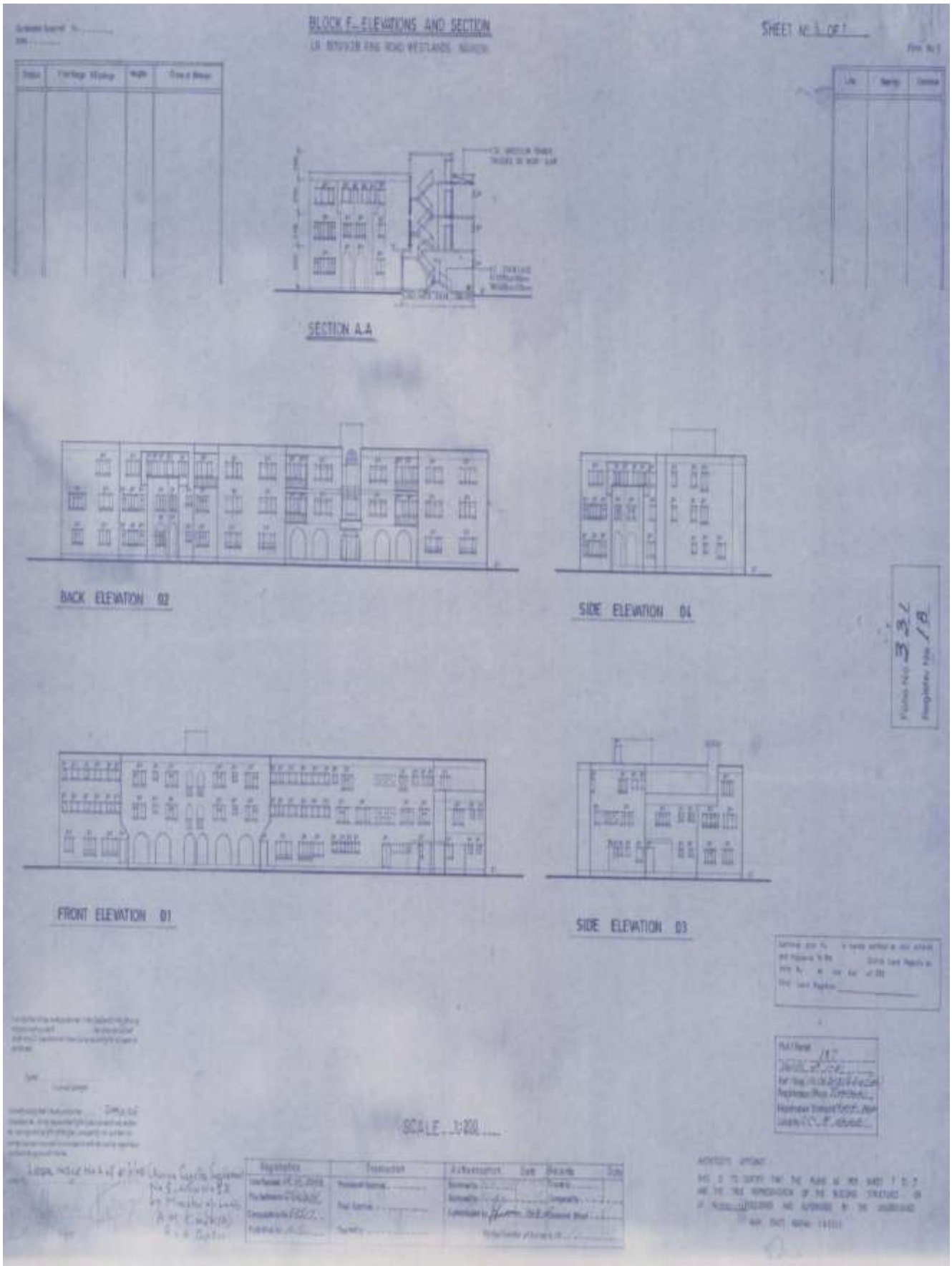
Appendix C: Floor Plan



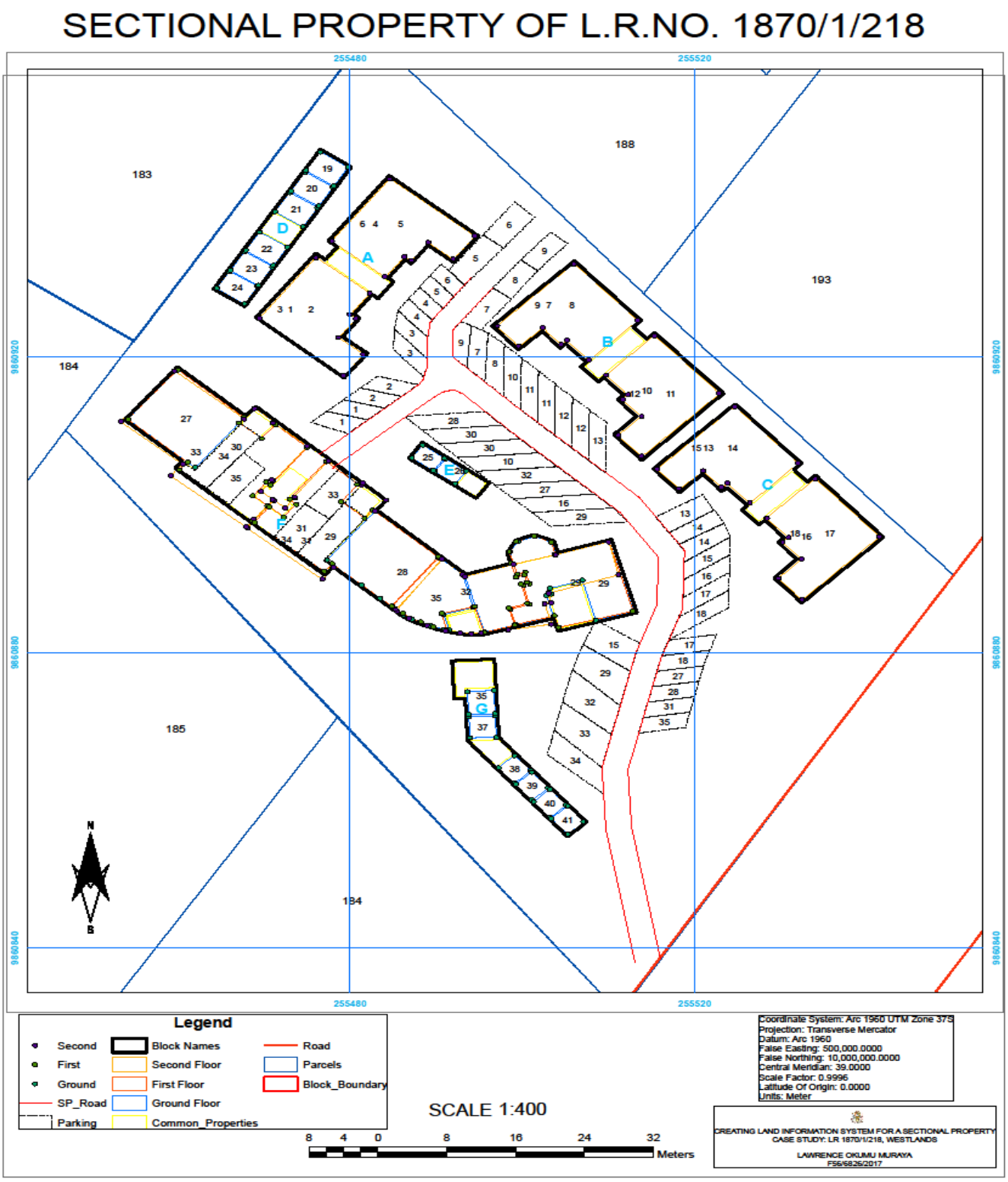
Appendix D: Architectural Plans for Block A, B and C



Appendix E: Architectural Plans for Block F



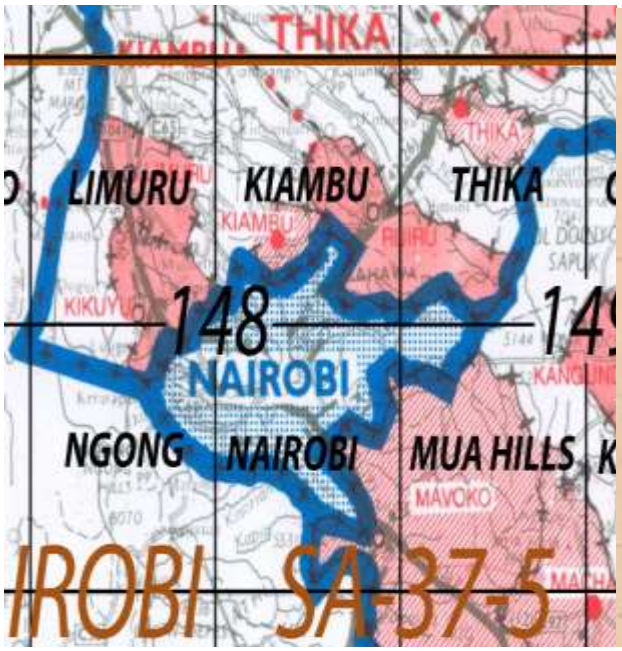
Appendix F: Sectional property Plans

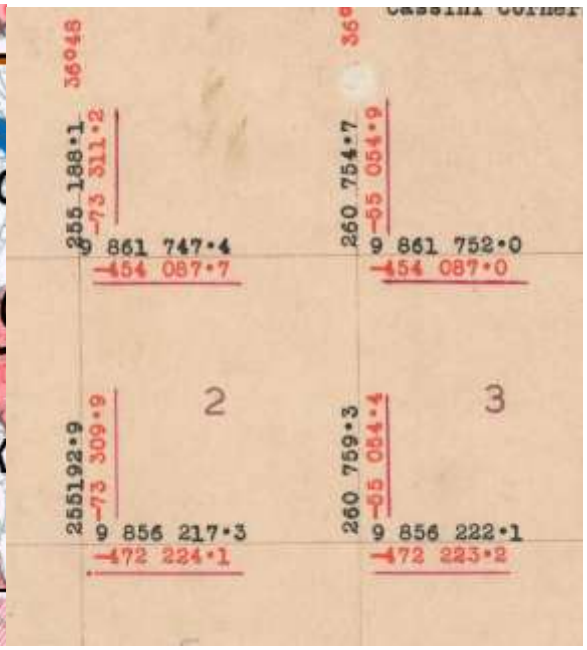


Appendix G: Conversion of Cassini Coordinates to UTM Arc 1960

$$X = A_o + A_1 x + A_2\ y + A_3 x^2 + A_4\ xy + A_5\ y^2$$
$$Y = B_o\ + B_1\, x + B_2\, y + B_3\, x^2 + B_4 xy + B_5\, y^2$$

Where X = Eastings in UTM Y = Northings in UTM x = Eastings in Cassini y = Northings in Cassini





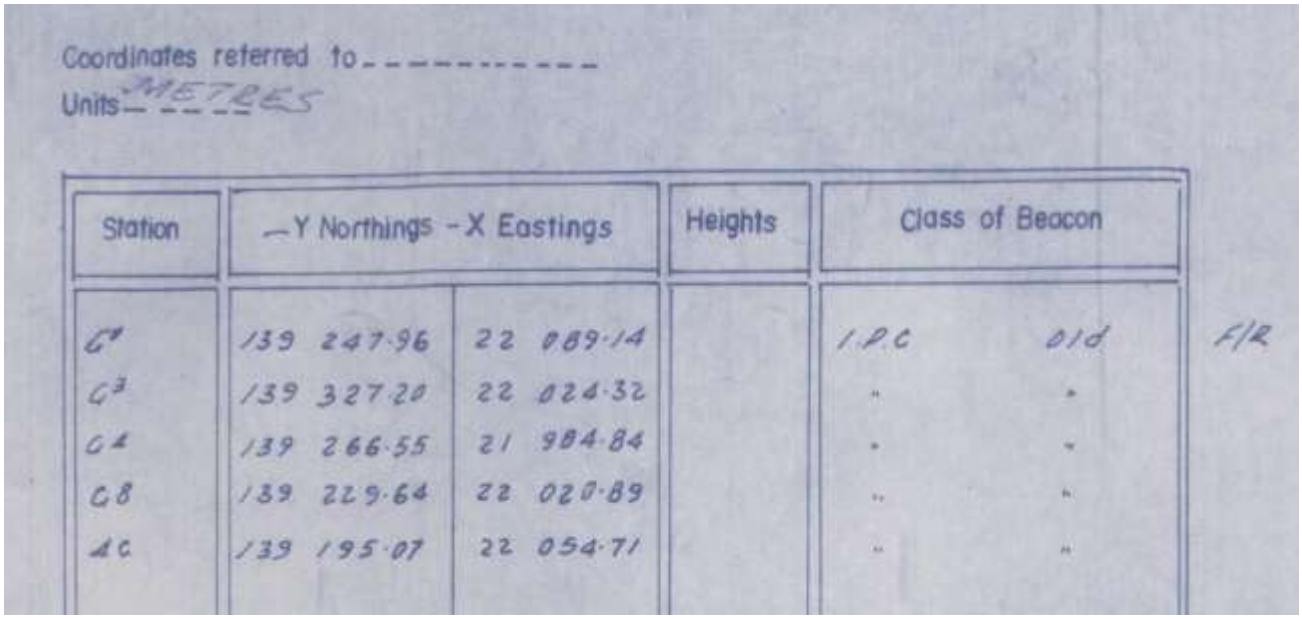
COORDINATE TRANSFORMATION (CASSINI TO UTM)			
DATUMS	**148/IV/2**		
CASSINI (X)	**CASSINI (Y)**	**UTM (E)**	**UTM (N)**
-73311.200	-454087.700	255188.100	9861747.400
-55054.900	-454087.000	260754.700	9861752.000
-73309.900	-472224.100	255192.900	9856217.300
-55054.400	-472223.200	260759.300	9856222.100

UTM Transformation Parameter

TRANSFORMATION PARAMETERS			
a=	**0.304914254**	**b=**	**0.00024405363**
TX=	**277430.9048**	**Ty=**	**10000223.0778**
	E	equals	**aX-bY+Tx**

	N	equals	**bX+aY+Ty**

Cassini Coordinates, Units in Metres, FR No. 331/13



Coordinates referred to _____

Units METRES

Station	Y Northings	X Eastings	Heights	Class of Beacon		
C4	139 247·96	22 089·14		I.P.C	old	F/R
C3	139 327·20	22 024·32		"	"	
C4	139 266·55	21 984·84		"	"	
C8	139 229·64	22 020·89		"	"	
4C	139 195·07	22 054·71		"	"	

Transformed Coordinates to UTM

	COORDINATE TRANSFORMATION (CASSINI TO UTM)				
DATUMS	**148/4/2**				
CASSINI (X)	**CASSINI (Y)**	**UTM (E)**	**UTM (N)**		
-73311.200	**-454087.700**	**255188.100**	**9861747.400**		
-55054.900	**-454087.000**	**260754.700**	**9861752.000**		
-73309.900	**-472224.100**	**255192.900**	**9856217.300**		
-55054.400	**-472223.200**	**260759.300**	**9856222.100**		
TRANSFORMATION PARAMETERS					
a=	**0.304914254**	**b=**	**0.00024405363**		
Tx=	**277430.9048**	**Ty=**	**10000223.0778**		
	E	equals	**aX-bY+Tx**		
	N	equals	**bX+aY+Ty**		
	CASSINI (X)	**CASSINI (Y)**	**UTM (E)**		**UTM (N)**
4C	-72357.97244	-456676.7388	**255479.381**		**9860958.171**
G1	-72470.93176	-456850.2625	**255444.981**		**9860905.234**
G3	-72258.26772	-457110.2362	**255509.888**		**9860826.016**
G4	-72128.74016	-456911.2533	**255549.335**		**9860886.721**
G8	**-72247.014**	**-456790.190**	**255513.242**		**9860923.606**

Appendix H: Building Model for Block A, B and C

Appendix I: Corporation board Members

Name	Designation	Date appointed	Contact
Joseph Kamau Kiberenge	Chairman	3/1/2015	0721673610
Andrew Oloo Ndege	Secretary	3/1/2015	0724566722
Mary Owako	Deputy Chairman	3/1/2015	0720245123
Evanson Ngugi Gedeon	Treasurer	3/1/2015	0722910509
Joshua Amugune	Member	3/1/2015	0720548736
Beatrice Wambui	Member	3/1/2015	0725804558