MOBILE GIS FOR ENHANCED PROPERTY TAX COLLECTION: A CASE OF LUSAKA PROVINCE LOCAL AUTHORITIES

BY

VICTOR NEENE

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DECLARATION

I, the undersigned declare that the work in this dissertation is original except where indicated by special reference in the text and no part of the research has been submitted for any degree, diploma or academic qualification. I further declare that the research has not been presented to any other College/University for examination either in Zambia or outside Zambia.

Name:...

Signature:..Date:...................................

Supervisor:...

Signature:..Date:...................................

CERTIFICATE OF APPROVAL

This document by VICTOR NEENE is approved as partial fulfillment of the requirements for the award of the degree of Master of Science in Computer Science of the University of Zambia.

Examiner's Name:...

Signature:..Date:..................................

Examiner's Name...

Signature:..Date:..................................

Examiner's Name:...

Signature:..Date:..................................

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DEDICATION

I would like to dedicate this work to the memory of my late son Daniel Sunzu Neene who passed away on the 9th of July, 2015. May His Soul Rest in Eternal Peace.

LIST OF KEYWORDS

Cloud Computing

GeoJSON

Global Positioning System

Leaflet Mapping Library

Local Authorities

Location Based Services

Mobile Geographical Information Systems

OpenstreetMaps

Participatory Geographic Information Systems

Property Tax

ABSTRACT

Property tax is a means of raising the much-needed revenue for local authorities in Zambia. However, the local authorities are faced with problems of identifying and capturing properties that qualify for property tax. This has resulted in them having a significant number of properties that are not assessed and in the process depriving them of the finances that they require to provide basic services to the communities in their jurisdictions. The aim of this study was to develop a prototype field based GIS Application that local authorities can use to identify and capture properties and create a database that will provide knowledge of rateable properties in their localities for the efficient collection of property tax. A study was carried out in four local authorities in Lusaka province to assess the current methods used to identify and capture properties and to investigate the challenges that are experienced. The literature revealed that low levels of property tax collection are also experienced in other developing countries and attempts that have been made to develop software applications to help in property identification and tax collection have used expensive software development tools, and the systems developed lacked real time field based features. The methodology used in the study involved a ground truth exercise that was conducted in four local authorities and one planning authority in Lusaka province. Purposive homogenous sampling was used and 40 questionnaires were administered to staff in senior and middle management involved in the property tax administration process. In addition, structured interviews were used for the purposes of understanding the current procedures and processes. The developed field based GIS Application has features that allow the capture of property spatial, attribute and image data. It was was designed to run on the Andriod operating system version 4.3 and above. The application was trialed in the field in Parkview Estates of Kafue local authority in realtime using a laptop computer and a mobile phone. The mobile device's Internet speed and the saving of the property attribute, spatial and image data on the laptop using the phone's WIFI (802.11 b/g/n) did not manifest any adverse latency during the mapping sessions. The latency was less than 100 milliseconds (0.10 seconds) on average. Ten properties were successfully mapped during the trial and the design of the system successfully met the user requirements that were formulated.

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CHAPTER 1

RESEARCH INTRODUCTION

1.1 Introduction

Revenue generated within the jurisdiction of the local Authority is spent on the provision of basic services, infrastructure development and maintenance. Despite the benefits that would accrue to local authorities through the collection of property taxes, it still only makes a small contribution of 0.5 percent to the GDP in Sub-Saharan Africa compared to a contribution of 2 percent in the developed world. This has in turn affected the social and economic development of the local communities local authorities preside over because of inadequate revenues [3] [4]. According to the Zambian Auditors General's Office report on local authorities, the failure to collect property taxes has negatively impacted their cash flow such that they have been unable to provide the needed basic services [5]. A lot of properties in the newly built up residential and commercial areas are not captured on the existing property registers and valuation rolls because of the many loop holes that exist in the process of property identification and capture. [6]. As of February 2017, Lusaka city council had an estimated total of 362,000 residential and commercial properties within its jurisdiction. Property tax was collected from an estimated 62,000 mapped and assessed properties. The remaining 300,000 unassessed properties were too significant for the local authority to forgo the tax revenue that would have gone a long way in providing the much needed basic services to the community [6]. In the year 2007, the estimated number of properties in the city was about 100,000. From this number, property tax was collected from an estimated 70,000 mapped and assessed properties. Once again, 30,000 unassessed properties were very significant from the revenue perspective [7]. From the statistics presented, it can be clearly seen that the number of new unmapped and unassessed properties has been increasing over the years at a very fast rate. The problem of having a significant number of unmapped and unassessed properties has resulted in low revenue inflows to the local authorities. The low revenue inflows have led local authorities to make repeated appeals to the private sector companies and residents of their respective jurisdictions to help them with financial aid that would enable them provide basic services such as solid waste disposal [8]. The problem of the significant number of unmapped and unassessed properties can mainly be attributed to challenges in discovery

and subsequent mapping of the newly constructed properties. The discovery and mapping challenge has been attributed to the shortcomings in the property tax administration processes that employ manual methods in the capture of spatial(geographical map data) and attribute data of the properties [9]. The manual techniques have resulted in the property registers becoming obsolete over the years as a result of keeping outdated property attribute and map data [10] [11] [12].

1.2   Problem Statement

Local authorities in Zambia face low revenue inflow challenges of property tax that is charged on properties within their jurisdiction because they have a significant number of unmapped and unassessed properties brought about by the inefficient paper based property mapping techniques that are used to capture property attribute and map data [5].

1.3   Aim of the Research

The aim of the research was to study the challenges local authorities in Lusaka province exprience in property capture and Identification and to subsequently develop a prototype field based GIS application that they can use to efficiently map properties within their jurisdictions so that geographic knowledge can be collected for efficient property tax assessment and collection.

1.4   Objectives of the Research

1. To Assess the current methods used to identify and capture properties for property tax.

2. To investigate the challenges that are experienced in identifying and capturing properties for property tax.

3. To capture specifications, design, develop and deploy a prototype field based GIS application that will provide geographical knowledge the councils can use to collect property tax.

1.5   Research Questions

1. What are the current methods used to identify and capture properties for property tax?

2. What challenges are experienced in identifying and capturing properties for property tax?

3. Will the capture of specifications, design, development and deployment of a prototype field based GIS application help provide geographical knowledge local authorities can use to collect property tax?

1.6   Rational of the Study

The study will help local authority management in planning and decision making that relates to the property tax administration processes. By having the geographical knowledge of properties in their respective jurisdictions, local authority management will be able to forecast cash inflows that will in turn help them formulate plans regarding the timely and efficient provision of the much needed basic services for the well being of the community.

1.7   Contribution of the Study

The study has made a contribution to the existing literature on the GIS technologies and tools that can be used to develop efficient software mapping applications. In particular, it has made a contribution on how mobile computing and cloud computing technologies can be harnessed to develop robust and scalable mobile applications in conjunction with software tools such as the Leaflet mapping library meant for use in both mobile and desktop applications. In addition, it has also contributed knowledge of how free mapping data provided by OpenStreetMaps can be incorporated in mobile mapping software applications. As regards the problem space, the contribution lies in the development of real time mobile GIS applications that can be harnessed to capture property mapping data within a short period of time.

1.8   Outline of the Dissertation

The dissertation is divided into five chapters. Chapter one introduces the research by giving the background, the aim, objectives and the significance of the research. In Chapter two, an extensive literature review giving a background to property tax, GIS, mobile computing, cloud computing and related works is discussed. In chapter three, the methodology used in the research for the ground truth exercise survey and the system design and implementation is presented. In chapter four, the results of the ground truth exercise survey are presented and discussed. Chapter five concludes the dissertation by briefly discussing the research, making recommendations and the future works to be carried out.

1.9   Chapter Summary

In this chapter, we introduced and gave a background to the research. We specifically stated the problem to solve and the main aim of the research. We then proceeded to list the measureable objectives to be attained and then proceeded to formulate the research questions. The rational of the study was then discussed in detail and thereafter, we proceeded to discuss the contribution the study has made to computer science and the problem space. We then concluded by giving an outline of how the dissertation will be presented.

CHAPTER 2

LITERATURE REVIEW

2.1   Chapter Overview

In this chapter, we review the relevant literature for our study. We begin by first giving a background of property tax and its importance as a source of revenue for local authorities. We then discuss its characteristics and then proceed to discuss the aspect of property identification as a very important determinant in enhancing property tax collection. We then proceed to discuss factors that impede the successful identification of properties for inclusion in the property tax net. A General discussion of property tax in developing and transitional countries is presented to highlight legislation that gives local authorities powers to collect property tax and the specific localised challenges that are experienced in its administration. A background to Geographical Information Systems (GIS) is then presented. This is followed by the study of software tools that are used to develop GIS software solutions. Location based services and geo-tagging technologies are then presented as GIS technologies that provide helpful added services that can be incorporated in GIS software solutions. Participatory GIS is then discussed as an aspect of GIS that can involve the local community in mapping and decision making. Mobile GIS cloud computing is then reviewed as a new efficient technology that can be used to build field based GIS applications. We then conclude by reviewing similar GIS software solutions that have been developed to help in the administration of property tax, property identification and property database management.

2.2   Property Tax

2.2.1   Introduction

Property tax is a tax that is charged by local authorities on land and buildings on a yearly basis [3]. It has been in existence since ancient times on the Asian and European continents and it has constituted the biggest source of revenue for local authorities beginning in the middle ages [4]. To this day, it is still the most common tax regime for local authorities in many parts of the world [13] [14]. Despite property tax being the biggest source of revenue and the most common tax in many local

authorities around the world, it is the least exploited source of revenue for local authorities in many developing countries. It only makes up a small contribution of 0.5 percent to the GDP in Sub-Saharan Africa, while in the developed world the contribution is 2 percent [3]. This has in turn affected the social and economic development of the local communities the local authorities preside over because of inadequate revenues [3] [4] [15] .

2.2.2 Sources of Revenue For Local Authorities

Sources of revenue for local governments differ from one country to the other and the sources are usually determined by legislation. Revenue sources can be external and internal. External sources include funds from the Central Government and credit facilities from financial institutions. Internal sources include property rates, market taxes and levies, liquor license fees, marriage, birth and death registration fees, sewage and refuse disposal fees and sign board and advertisement permits fees [16]. In some jurisdictions, revenue sources are categorised into tax and non tax sources. Tax sources include property tax, advertisement tax, passenger and goods tax, timber tax, education tax, and land revenue. Non tax sources include water charges, dog fees, parking fees, rent fees from municipal properties, market fees, fire services fees and building application fees [17]. Because of the importance of property tax, many local Governments around the world collect it as shown in table 2.1 [17]

	Taxes								Social contributions	Grants	Other revenue	Total revenues
	Individual income	Corporate income	Payroll	Property	Goods and services	Excise	Other	Total taxes				
Central and Eastern Europe:												
Belarus	17.9	10.5	0	9.2	21.4	1.1	7.2	67.3	0	30.2	2.5	100
Bulgaria	0	0	0	20.1	0	0	0.1	20.3	0	69.9	9.9	100
Croatia	39.5	15.5	0	3.5	0.4	0	2.3	61.2	0	12.3	26.5	100
Georgia	50	2.1	0	11.1	0	0	3.7	66.9	0	28	5	100
Kazakhstan	17.2	0	24.6	5.9	0	3.3	5.3	56.3	0	43	0.6	100
Kyrgyz Republic	9.2	7.5	0	7.8	11.1	2.4	1.7	39.8	0	45.8	14.4	100
Latvia	48.4	0	0	6.5	0	0	0.8	55.6	0	31.3	13.1	100
Lithuania	30.2	0	0	4.1	0	0	0.9	35.3	0	57.9	6.8	100
Moldova	23.4	13.8	0	4.9	0.8	0.1	4.9	47.9	0	45.2	6.9	100
Romania	38.6	0.2	0	7.8	31.4	0	3.7	81.7	0	8.4	10	100
Russian Federation	19.2	4.2	0	3.6	0	0	3.7	30.7	0	58.2	11.1	100
Slovenia	24	0	0	7.2	0	0	2.8	34.1	0	47.5	18.5	100
Ukraine	32.9	1.4	0.2	2.3	0	0.1	5	41.8	0	47.9	10.3	100
Asia, Africa and Latin America:												
China, PR	2	5	0	2.4	18.4	0	2.2	30	13.3	28.9	27.9	100
Kenya	0	0	0	15.6	0	0	5.9	21.4	0	32.8	45.8	100
Mauritius	0	0	0	11.9	0	0	13.9	25.8	0	67.1	7.2	100
South Africa	0	0	0	16.8	0	0	2.8	19.7	0	24.9	55.4	100
Uganda	1.2	0	0	2.8	0	0	0.9	4.9	0	91.3	3.8	100
Bolivia	0	8.2	0	18.6	18	24.5	3.1	72.3	0	17.6	10	100

Figure 2.1: Sources of Revenues for Local Authorities, Source[21].

2.2.3   Characteristics of Property Tax

Property tax is called an Ad-Valorem tax (unit tax) because of the strong relationship that exists between the value of the property and its actual physical geographic location. It is very suitable for local authorities to administer because the land and building are immovable [18]. Property tax revenues can easily be predicted hence making its revenue stream more durable over long periods of time to locally finance basic services in the jurisdiction of the local authorities [19]. Property is composed of residential and commercial land. It includes all the permanent structures that are built on the land. Privately owned property is taxed in most local authority jurisdictions around the world. However, properties owned by religious institutions such as churches, mosques, schools and hospitals are usually excluded from taxation. [15].

The most important features of the property include the location, the dimensions, the physical characteristics, the value of the land, the use of the land and the ownership details. These characteristics play a very important role in the valuation of the property since the tax is calculated on the value of the property. [4] [20]. Because of the geographic location characteristic of the property, the tax is very difficult to evade by property owners especially if there is a proper property tax administration system in place that includes property identification, property database creation, property assessment, tax billing and tax collection [19].

2.2.4   Calculation of Property Tax

The basic formula used to calculate property tax is shown in Figure 2.2 [14]. The tax rate is determined by the local authority in the jurisdiction. The tax base is the value that is assigned to the property during the property assessment and valuation stage. Two methods are employed in the assessment and calculation of property tax namely Area Based Assessment and Value Based Assessment [1] [2]. Value based assessment is further broken down into Market and Rental Value [3].

Figure 2.3 shows the different methods of calculating property tax as described above. [1] [2].

$$\text{Tax Revenue} = \text{Tax Rate x Tax Base}$$

Figure 2.2: Property Tax Formular, Source[12].

$$\text{Tax Revenue} = \text{Area of Land/Building} \times \text{Tax Rate}$$

$$\text{Tax Revenue} = \text{Market Value} \times \text{Tax Rate}$$

$$\text{Tax Revenue} = \text{Estimated Rental Assessment} \times \text{Tax Rate}$$

Figure 2.3: Property Tax Calculation Methods, Source[1][2].

2.2.5 Pros and Cons of Property Tax

Property tax gives local authorities financial autonomy from the central Government [21] and as already pointed out, it is very difficult to evade because of the conspicuous nature of the properties in the locality. This makes the revenue to be realised to be always known by the local authorities through the use of property tax registers [22]. Therefore, knowing the expected revenue to be realised can lead local Authorities to achieve collection rates of about 95 percent [13] [21]. The conspicuous nature of the tax creates a very strong connection between property values and the basic services that are funded at the local government level for example water and sewerage reticulation and garbage collection that in turn create the expectation that local authorities with many properties should be able to provide the basic services in the local community [3]. The property registers used for property tax purposes can also be used by other institutions for information and decision making. For example, water reticulation companies can use it in determining water charges to the residential and commercial areas that they service.

The process of property identification can be a very time consuming exercise especially if manual processes are used [13]. In addition, manual property registers are costly and technically difficult to maintain because they require many personnel to manage [22]. These factors lead to reduced collected revenues [15].

2.2.6 Property Identification Process

The process of property identification is very important before a property can be evaluated and property tax subsequently charged and collected. The identification process involves the gathering of data that pertains to the property characteristics. The most cardinal property characteristics include

ownership details, physical property location and the physical boundaries that demarcate the areas where the property is located. The information collected is used in creating a property database for the local authority. The physical property location data is in turn used to generate a map that shows where the property is located. [20] [4].

The identification activities can be divided into two parts: continuous and periodic. Continuous activities involve receipt of building and land development plans subsequent analysis and verification, maintenance of cartographic (map) data, assignment of unique cadastral codes to new properties and integration of property attribute data and map data. Periodic activities on the other hand involve identification of map gaps, identification of discrepancies between maps and property attribute data, generation of statistics, inclusion of informal properties and implementation of special land surveys to identify more property [23].

2.2.7 Challenges of Identifying Taxable Properties

The manual property databases that exist in most local authorities do not substantially help in the process of identification of the properties for taxation purposes and follow ups. The reason lies with the fact that the property databases do not have the required geographical information on the properties that are physically on the ground [20] [4]. There is also a very big discrepancy between property records that are kept by local authorities and the properties that are physically on the ground more especially in relation to the classification of properties for example the type of construction, the type of use and the year the property was built [12]. The absence of street names and property numbers especially in developing countries is also a very big challenge. This has resulted in the failure by the local authorities to locate the properties for purposes of bill delivery either physically or through the postal office system. In addition, follow-ups to residents that have defaulted in the payment of the property tax bills has also proven to be a common problem [24].

The other challenge pertains to the update of the maps that show the geographical locations of the properties that are captured in the property databases. This problem is more pronounced because of the high number of properties that are being developed more especially in developing cities most of which are found in developing countries. Existing manual mapping techniques in use by most local authorities have been unable to cope with this high growth rate [25].

2.2.8 Property tax in Africa, Asia and South America

In South Africa, the constitution of the republic grants the South African local authorities powers to raise revenues. Among the powers granted, are powers to collect rates on the properties within the

local authority's jurisdiction. In total there are 278 local authorities known locally as municipalities in the country. Property tax revenues make up between 18 and 19 percent per year of all the total revenue collected by the all the local authorities. The percentage suggests that property tax is a potential source of revenue. The challenge of maximising property tax revenue in South Africa has in part been the variations in assessment values of similar properties brought about as a result of valuation inconsistencies [19].

In Nigeria, local authorities are empowered by the 1976 Local Government Reforms to collect property tax in their respective jurisdictions [26]. Local authorities are grappled with very low property tax collections in comparison to the other local authorities in developed Countries. In Owerri, Municipal Council for Example, property tax accounted for only about 15 of the total municipality revenue according to a report released in 2010 [27]. Discovery of properties that qualify for property tax is another big problem that has contributed to the low collection rates. In addition, existing property registers are seldom updated to reflect current property values. This problem in turn distorts the actual revenue that is finally collected [28]. Land registration and corresponding detailed documentation have also been an impediment to the assessment of properties and eventual collection of the property taxes [27].

In Zambia, local authorities are charged with the responsibility of collecting property rates (taxes) by the Rating Act Chapter 192 of the laws of Zambia. Property tax is charged on residential and commercial buildings within the Local authority jurisdiction. Certain properties such as religious buildings, Government buildings are exempt from the tax [27]. Property tax constitutes one of the biggest sources of revenue that is generated by Local authorities in Zambia. Despite being a top revenue earner, property tax collection rates are still very Low. The low collection rate is attributed to the non capture of newly developed properties on the existing valuation rolls. Some of the properties not captured include houses that the local authorities sold to sitting tenants. Furthermore, the discovery of properties mainly on unsurveyed land has also proved to be a challenge. Lack of Property tax administration capacity has also been a major problem [9]. A critical shortage of skilled manpower has also been cited as one of the problems of the very low rate of property tax collection. This has resulted in a significant number of unassessed and unidentified properties over long periods of time [29].

In Malaysia, the Local Government Act has given powers to state Governments to collect property taxes. The taxes are collected through the local authorities that are created and managed by the state Governments. In total there are about 147 local authorities throughout the country. Property tax accounts for about 50-60 percent of all the total tax revenues that the local authorities collect on an annual basis. Despite the seemingly higher property tax collection rates when compared to

local authorities in other countries, the collection rates are still very poor. This poor collection rate is attributed to the present billing systems being based on old outdated property registers. The property registers have seldom been updated over the years because of the high urbanisation rates especially in cities [19].

In India, local authorities are charged with the powers to collect property taxes. The property tax collection average hoovers around 37 with some local authorities exceeding this average. The lower collection rates in many jurisdictions are attributed to many properties in the jurisdictions not being recorded in the property register. In addition, the properties that are recorded are in many cases wrongly classified. The wrongly classified properties distort the final calculated property tax [30]. In Brazil, the authority to collect property tax is shared between the central and municipal Government. The central Government is in charge of collecting revenue from rural municipalities. Property tax constitutes about 0.44 percent of the share of the county's Gross Domestic Product(GDP). This share of GDP has been increasing over the years. The low collection rate is attributed to the high costs that are incurred in the production of cadastres that record the location of the properties and the associated attribute information in the local authority jurisdiction. This has in turn caused the low rate of property discovery and capture on the property registers. Other problems include property tax administration and rates collection issues [10].

In Peru, the municipal and district Governments are charged with the responsibility of the collection of property taxes. The property tax share of the country's GDP is about 0.16 percent. The reasons for the low collection of property taxes is attributed to incomplete property tax registers and the relevant cadastre that show the location of the properties. Furthermore, old obsolete property values are used in the assessment of properties because property information in the registers is seldom updated [10].

2.2.9 Summary of Property Tax Challenges in Africa, Asia and South America

Table 2.1 Summarises the challenges of property identification and capture in Africa, Asia and South America. It can be seen that the challenges are very similar in nature as they all hinge on the aspect of identification and capture.

Table 2.1: Summary of Property Tax Challenges

Country	Challenges of Property Tax Administration
South Africa	-Property valuation inconsistencies
Nigeria	-Discovery of properties that qualify for property Tax -Seldom updated registers to reflect current values -Lack detailed property information leading to wrong assessments
Zambia	-Capture of new properties on valuation Roll -Discovery of property on un-surveyed Land -Critical shortage of skilled man power
Malaysia	-Billing system based on outdated register -Property registers seldom updated
India	-Omitted properties on the register -Wrongly classified properties
Brazil	-High cost of producing property maps -Low rate of property discovery
Peru	-Incomplete property registers -Use of old values in property assessment

2.3 Geographical Information Systems

Geographical Information Systems(GIS) are defined as "an organised collection of computer hardware, software, geographical data and personnel designed to efficiently capture, store, update, manipulate, analyse and display all forms of geographically referenced information" [31],p1]. Figure 2.4 depicts the processing capabilities of GIS as given in the definition above.
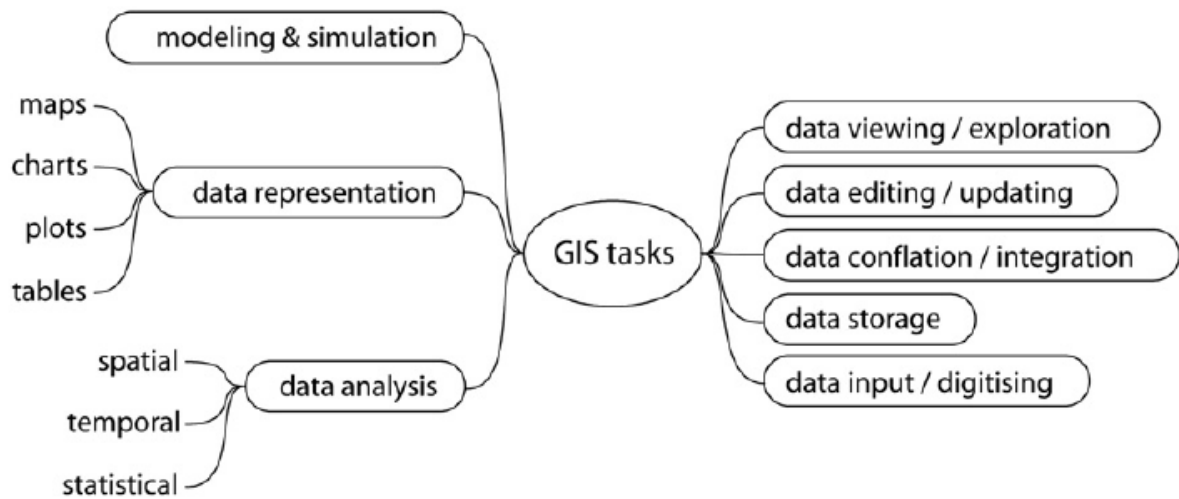
Figure 2.4: Tasks Performed by GIS Software, Source[42].

GIS dates from as far back as the 1960s when attempts to use computers to capture and process geographic information were first made [32]. It is a very important tool that is used in a variety of applications. The scope of GIS application is interdisciplinary and it eclipses a number of very distinct fields such as Cartography, Environmental Science, Agriculture, City Planning, Geology, the Military, Computer Science, Surveying, Logistics and transportation, Biology, Mining, Geo-informatics, Forestry and Hydrology [33] [31] [34] . figure 2.5 depicts the Components of GIS. The Components include computer hardware, software, databases, procedures and people.
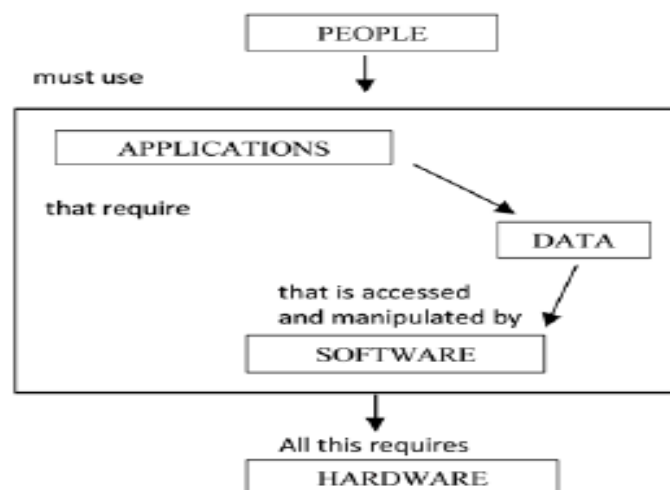
Figure 2.5: Components of GIS, Source[40].

The computer network component allows the sharing of data that is processed and stored. The hardware equipment processes the data into information. Software consists of computer instructions that are executed by the hardware. The database is a specialised software that stores data and

information for future fast retrieval and processing. Procedures ensure that the information kept in the database is accurate. People input and update data in the database [35].

Geographic data is made up of maps. Maps are the representation of parts of the earth's surface that show the position of features of interest. Natural features can include for example rivers and mountains. Artificial features can include for example roads and buildings [36]. The maps are generated through the use of computer graphics technology using database structures and techniques [37]. Spatial data (geographic data) is created through primary or secondary data sources. Primary data sources include Global Positioning System (GPS). GPS is a technology that uses a network of satellites to locate stationary locations on the earth's surface through the use of latitude and longitude co-ordinates [38]. In the past years, the data collection process employed paper based techniques that involved multiple points of data entry. These techniques lacked real-time information and the ability to accurately transmit field data to the central receiving and storage station. Nowadays, GIS uses GPS technology to locate and record the position and attribute information about geographic features that are of particular interest. GPS provides a very reliable recording of positional information [39].

Remote sensing is another primary data source that uses satellite images of parts of the earth's surface. Secondary sources include external data sources for example census data of a location of interest, market research data of an area, internet sources and the phone directory [38]. Spatial data obtained from satellite imagery and ariel photography is digitized and then geocoded [40]. Geotagging is the process of assigning address information of features of interest on the map with the corresponding latitude and longitude [38].

GIS applications have the ability to interface with other application software such as spreadsheets, databases and web browsers. Computer programming languages have components that enable the development of applications that can handle spatial data [40]. These GIS capabilities enable GIS applications to be merged with the existing ecosystem of the organisations information systems [35].

2.3.1 GIS Software Tools

GIS software tools can be categorised in five types namely Productivity Software, Spatial Database Management Systems(SDBMS), Web Mapping Software, Mobile Software, Libraries and Remote Sensing. [41] [42]. The Software tools can further be grouped into Advanced and Core tools as shown in Figure 2.6.
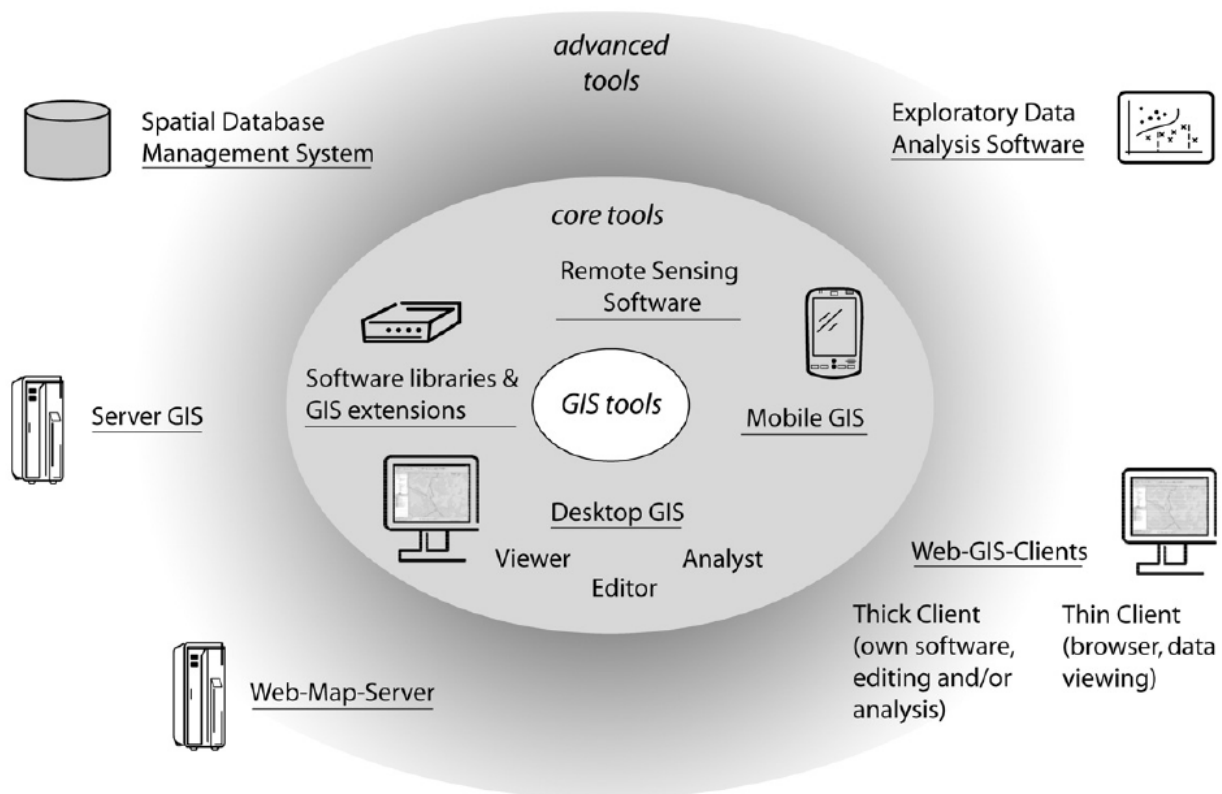
Figure 2.6: Geographic information Software Tools, Source[42].

GIS productivity software is the most widely used and it includes software that is installed on desktop computers either as stand alone or as server/client software [41]. Productivity software enable users to display, query, update and analyse geographical location data and the software usually uses a graphical user interface to carry out these operations [42] [43].

Geographic data relates to natural and man made features such as lakes and buildings. SDBMS store geographical data(spatial data) in relational tables as opposed to data files on the operating system file system. Since geographical data is made up of large data sets and fast storage and query facilities are needed, SDBMS are, therefore, a natural choice for quick data storage and retrieval operations [41]. Geospatial relates to the relative position of things on the earth's surface. Advancement in geospatial technologies have given rise to technological standards. The Open Geospatial Consortium (OGC) standard is one standard that many vendors of major SDBMS comply with. The standard describes how to access and store geographical data types including the relevant functions and operations that are performed on the data types [44].

Web mapping software consists of server and client software. It employs the standard Internet protocols in the viewing and display of spatial data. Most of the web mapping software is compliant with the OGC Standard [41]. Web mapping software can be further categorised into two categories

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namely Map Server and Web Map Application Development Frameworks. A map server is a specialised web server that provides Web Mapping Services(WMS), Web Feature Services(WFS) and Web Coverage Services(WCS) [42]. It provides a mechanism to deploy GIS based applications on the Internet and the functionality provided includes facilities to interact with SDBMS, interfaces to other geographic software libraries and support for vector and raster image graphics [44]. WMS uses Geo-referenced jpeg and tiff image types to display rasterised map layers. WFS enables the querying, addition and update and removal of geo-spatial features and also provides access to vector features. WCS on the other hand provides direct access to geographic features on the map [42].

Web application development frameworks such as Ruby on Rails enable applications developed for the web to have the same features and functionality as the productivity GIS desktop software. They use scripting languages such as Asynchronous JavaScript and XML(AJAX) and Cascading Style Sheets(CSS) to achieve the desktop experience in the web browser [42].

Mobile software runs on mobile devices that include tablet computers, Personal Digital Assistants (PDAs) or mobile phones. The software is used in the field for data acquisition, storage and update. The features of mobile software are usually a subset of the features that are found on desktop productivity software. Mobile software is useful in situations where data entry needs are fixed and simple user interfaces are required [41] [42].

Libraries are software that provide functionality that can be used by other software [41] [42]. They provide an Application Programming Interface(API) to read, access, manipulate and write geo-spatial data to and from data files or SDBMS [45]. One noticeable feature of libraries is that the Graphical User Interface (GUI) and the Command Line Interface (CLI) are absent. Libraries can Further be categorised into four groups namely: Data Input/Output and Conversion, Geometry, Projection, Geographic Data Processing and Analysis. Data input and conversion libraries read and write geo-spatial data formats. Geometry libraries provide spatial data types and operations used for the analysis of geographic data. They are normally used by desktop GIS applications. Projection libraries allow users to convert spatial data among different coordinate systems. Geographic data processing libraries allow the analysis and processing of vector and raster data types [41] [42].

Remote sensing software allow the opening, display, editing and processing of image data. The images consist of 8-bit, 16-bit and 32-bit and the image formats could either be TIFF, GIF, JPEG, PNG, DICOM, BMP, PGM. Remote sensing software provide tools that comprehensively process and

analyse these image data formats. The images consist of images from satellites and aerial photography [43].

2.3.2 Location Based Services

Location Based Services (LBS) are GIS based services that provide information that is relevant based on the users current geographical position [46]. They help users retrieve information about their current geographical location and process the data to get useful information within the proximity of their location. They use knowledge of the geographical position of the mobile devices to provide services based on the location information [47]. Services that are provided are personalised according to the location of the user and include real time traffic information, querying of nearest restaurants, cinemas, shopping malls, hotels and advertising for example sending promotional information to customers within the proximity of the gas station where they usually refuel from [47] [48].

LBSs can be classified into public safety/emergencies and consumer services. In safety/emergencies the location of the client is determined by the mobile carrier hence making this group of LBS ideal for safety and emergency applications. Consumer services help users to use multiple services based on their geographical location [47]. The users geographical position is retrieved through the use of GPS enabled mobile devices and through location services provided by the cellular network operator or WIFI positioning technologies. GIS provides the maps and geographic data that includes location of buildings, street names, mountains, rivers and other features [46].

The basic components of LBS are shown in Figure 2.7. The components include mobile devices, positioning, communication network and service provider (content providers) [46].
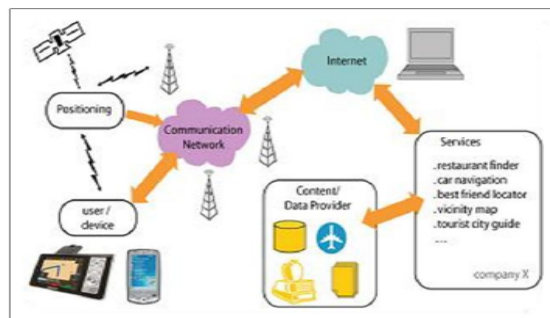
Figure 2.7: Basic Components of LBS, Source[46].

Positioning technology is in three basic parts namely basic, satellite and cellular networks. Basic technology uses cell phone signals provided by the cellular network provider to determine the location information. Satellite technology uses satellites to determine the location while cellular networks employ mobile based data technologies to identify the location of the device. [46]. GPS is based on satellite technologies and is made up of a constellation of 24 satellites that orbit the earth. It calculates the position by finding the differences in times the radio signals from different satellites take to reach the GPS receiver [47]. Radio signals used by the satellites suffer from signal multipath problems that can cause low position accuracy in high density and highly developed urban environments. Cellular networks mobile technologies are, on the other hand, free from signal multipath problems [49] [50]. Despite GPS being susceptible to multipath radio signal problems in urban environments, it is still the most common positioning technology in use [46].

Assisted GPS (A-GPS) technology was created to provide better accuracy and to enhance performance of standard GPS in devices connected to wireless networks(3G,4G and GPRS) in urban environments. Figure 2.8 shows the architecture of A-GPS. A-GPS uses the mobile network in conjunction with GPS and
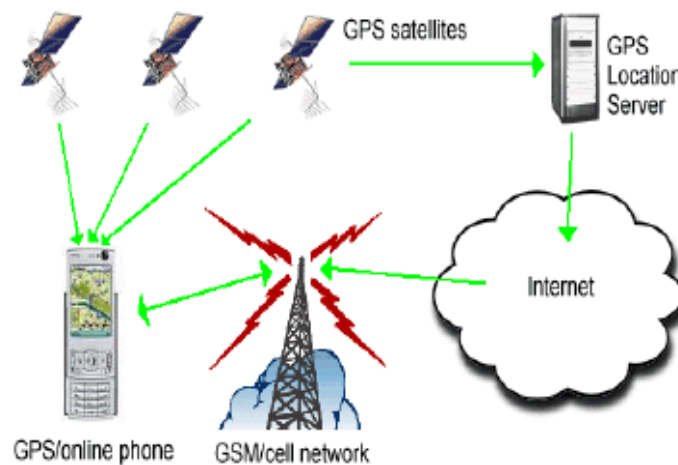
Figure 2.8: Architecture of A-GPS, Source[47].

satellite constellation to provide better positioning accuracy. It acquires and stores information on location through the cellular providers network. It helps position mobile devices when GPS satellite radio signals are obstructed by the built environment [47]. Other benefits of A-GPS include quick acquisition of positional information, consumption of less battery power and indoor use to provide accurate positioning [46].

2.3.3   Geotagging

Geotagging is the ability of associating multimedia data such as photographs, videos, SMS messages and QR codes to a particular physical location by using GPS receivers. The GPS receivers are embedded into smart phones and tablets devices used by millions of people worldwide on a daily basis. It associates content to the geographic location by linking multimedia information to the physical world. It makes it possible to create facilities that are used to organise and present multimedia content based on the associated physical location [51] [52].
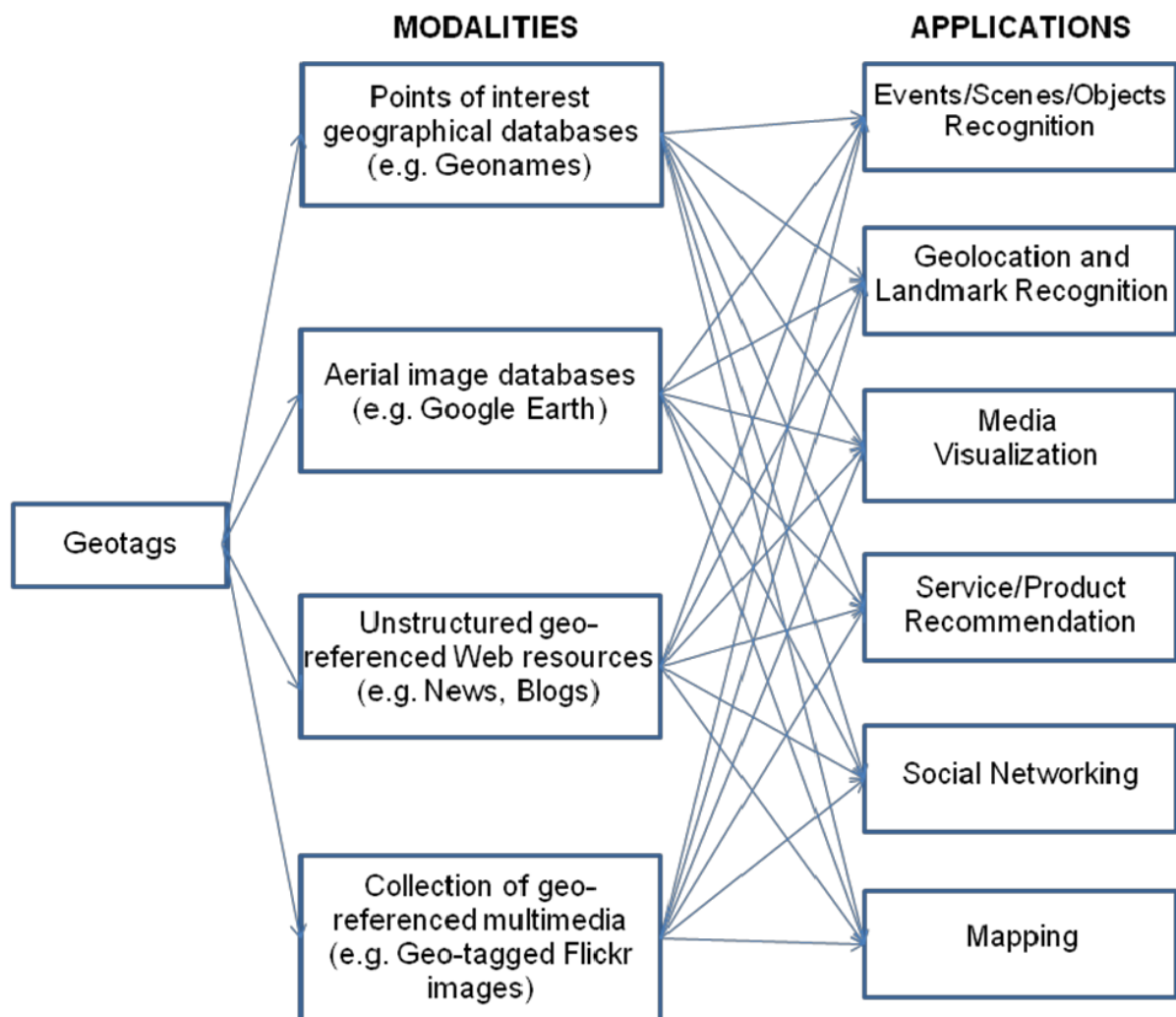
Figure 2.9: Geotagging Modalities and Applications, Source[53].

Figure 2.9 shows the modalities in which multimedia data is geotagged and its relationship to the various applications it gives rise to. Geotagging also helps users to discover information that

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is location specific for example finding images that were photographed in a given area. Images are retrieved by entering the geographic latitude and longitude coordinates in a search facility or simply by clicking on the map. Geotagging has further given rise to widespread geographic awareness in a great deal of multimedia database repositories and this has in turn created a thriving research community [53].

The example of entering GPS coordinates to search for images taken in a particular location is what is referred to as reverse geotagging(Geocoding). Reverse Geotagging uses point of Interest (POI) GIS databases to provide useful geographical knowledge of important landmarks. The GIS POI database contain the latitude and longitude information of country, population and other demograhics [53].

The geotagging of multimedia data and information is achieved through the attaching of metadata of location information. The Exchangeable Image File Format (EXIF), designed and introduced by the Japanese electronic industry, is the most common file format used to attach metadata location information. The meta location data is retrieved from the geo tags through the use of software libraries that parse multimedia data files [54].

2.3.4   Participatory Geographic Information Systems

Participatory Geographic Information Systems (PGIS) involves the use and application of geo-spatial information and GIS technologies that allow members of the local community to participate in spatial decision processes that affect their daily lives [55] [56]. The term PGIS was introduced in the mid 1990s to emphasize the use of GIS as a tool for promoting community involvement in the decision making processes and to promote community participation in the collection of geographic data and production of maps within the community [57]. Decision making in PGIS involves the exchange of information, discussion and negotiation among the stakeholders to clarify, refine and resolve spatial problems of development projects and programs in the local community in turn making PGIS a potential informative tool for use by policy makers and town planners [58] [59].

PGIS involves the production of maps, through the use of GPS technology in the collection of spatial data, and subsequent utilisation of maps. The production of maps is carried out by the community without much help from GIS experts. The maps are used by the community in understanding problems, formulating solutions, participating in decision making and the monitoring

of solution implementation with minimal GIS expert help [60] [61]. These activities empower local communities in building capacity and confidence in the use of GIS technologies and in turn helps the local communities acquire knowledge of how local authorities handle spatial knowledge. They also help the local communities exchange spatial knowledge with local authorities on a stakeholder equal basis especially in informal settlements that are not acknowledged by local authorities [61] [62]. The involvement of the local community in the decision making processes and the production of maps also help the local authorities in the promotion of good governance and the upholding of good governance principles of inclusiveness, transparency, efficiency, appropriateness and ownership [63]. Community involvement also enables the production of large volumes of spatial data at very low cost and within a short period, making it ideal for resource constrained organisations to capture spatial data and produce maps [64].

2.3.5   GIS Cloud Computing

Mobile Cloud GIS Computing is the convergence of Mobile Computing, GIS and Cloud computing. Its emergency has been facilitated by the growing number of cloud services used by millions of people around the world [31]. Computing tasks are delivered and provided as services as opposed to products [65].

Mobile computing has experienced phenomenal growth because of the utilisation of portable devices such as phones, tablets and laptops on a very large scale and the inherent desire of people to be continuously in touch through the connectivity of the devices. The device connectivity has resulted in the biggest connectivity platform in the history of mankind where it is estimated that there are about 6.8 billion mobile subscribers of which 1.08 billion are smart phones and 2.7 billion people use the internet. Mobile computing is achieved through the access of computing services at any location and time. It uses 4G and LTE connectivity technology that was designed to be very fast and reliable. Its emergency has given rise to many applications such as m-commerce, m-learning, m-healthcare, m-travelling and m-GIS application. Despite it wide adoption, mobile computing still faces challenges of limited resources, network throughput, security standards and power consumption [31].

Cloud computing was designed to address and overcome challenges that Mobile computing experiences. It provides software and information as utilities over the internet. The utilities can be compared to utilities like the electricity grid and the water reticulation system. It does not require the user to know the physical location and the system configuration of the computational, software and

storage services [65]. Cloud computing has five essential characteristics namely on demand self-service, broad network access, resource pooling, rapid elasticity and measured services. It is also delivered using three distinct models namely software as a service(SaaS), Infrastructure as a Service (IaaS) and Platform as a Service (PaaS). SaaS Provides end users with access to specific applications for example facebook and gmail. Paas – Provides API and programming Environments for application developers for example MapBox Application Engine(GAE) and Amazon web Services. Iaas Provides computational and storage facilities through the use of virtualisation technology for example Amazon's EC2 and S3 [31] [65]

2.4 Related Works

2.4.1 GIS based Property Information System (GPTIS)

In Ghana, Saviour Mantey and Naa Dedei Tageo [66] developed a GIS based Property Information System (GPTIS). GPTIS was developed to help in the administration of property tax through the use of a digital map that shows the properties in the municipality. It was developed for Tarkwa Nsuaem Municipal Assembly (TNMA). GPTIS was programmed using the .NET development framework and Visual Basic was used as the programming Language. The map object library developed by the Environmental Systems Research Institute Inc(ESRI) was used to provide Mapping functions. MapBox earth API's were also used. The backend for data storage used shape data files, image files and Microsoft access database. GPTIS interface allowed users to perform spatial and non-spatial queries, update of newly registered properties, update and processing of property attribute data. Spatial data was obtained by digitising the map of the study area and GIS software was used to geo-reference the map. Non spatial attribute data was entered through the user interface. GPTIS was designed as a standalone application with limited remote access features. GPTIS used data files to store property spatial data. Naturally, data retrieval using files is slower as compared to relational database management systems. However, property attribute data was stored in a relational database. GPTIS also lacked the ability to capture property spatial, image and attribute data in real time.

2.4.2 Olorunda local Government authority GIS

In Nigeria, Caleb Oluwadare and Olatoye Ojo [28] used GIS in Olorunda local Government authority to determine the geographical location of each property with the associated property

attribute data to help in the effective collection of tenement rates (property taxes). Spatial data was collected using a GPS receiver devices on 85 parcels of land in Orolanda local Government authority. Satellite imagery of the area was downloaded from MapBox Earth software application. The Satellite image was then digitised into vector maps using Corel Draw 11 and ILWIS 3.0 environment for georeferencing software applications. The final digitised map layers were then exported to ArcView 3.2a software. Property attribute data and GPS co-ordinates were input in a Microsoft access database and the liked with ArcView GIS. The GPS dataset helped in determining the shape and size of the property Land Parcels. Olorunda local Government authority GIS digitised a satellite image that was already in digital format using the skills of a highly skilled GIS expert. In addition, the GIS application was purely developed using desktop GIS software and as a result it lacked multiuser data input features. The system lacked the feature of capturing image data of the properties in Olorunda local Government authority.The GIS application also lacked the ability to capture property spatial and attribute data in real time.

2.4.3 Integrated Geographical Buffering System (IGBS)

In Sri Lanka, an Integrated Geographical Buffering System (IGBS) was developed for use to value land parcels for the purposes of property taxation in the Gampola region in Kandy District in the Central Province of Sri Lanka. A high resolution satellite image of the area was digitised using ArcView GIS Version 3.1. A hand held GPS Receiver Device (Geo Explora XT) was used to assign co-ordinates on the image of the location of interest. IGBS features included acquisition, storage and retrieval of valuation and taxation information about the land, compilation of complete tax records, graphical display of spatial data, analysis and processing of meaningful land valuation. IGBS digitised a high resolution satellite image of the of Gampola Region. Again desktop Productivity software was used in the capture of spatial and attribute data. The system lacked the feature of capturing image data of the properties in Gampola region. IGBS also lacked the ability to capture property spatial and attribute data in real time. [67].

2.4.4 Cancun Federated Geospatial Information System

In Mexico, Bently Channel Partner innovacion Sistemas y Proyectos(iSP) developed the Cancun federated geospatial information system so that property tax Collection revenues could be increased. Ariel photography was used to capture the image of Cancun Municipality. Mobile hand held GPS devices where used to capture geo-coordinates, property attribute data and images of the property. The property spatial and attribute data was subsequently integrated into a single map desktop GIS.

The GIS system allowed the update of property information, discovery of properties with new development, entering, recording and production of property tax records. The GIS database was centralised and was accessible by other departments within Cancun Municipality. The Federated Geospatial Information System digitised the ariel photograph of ues could be increased. Ariel photography was used to capture the Image of Cancun Municipality that was later digitised using desktop GIS productivity software. This task involved services of highly trained GIS experts. Property spatial, attribute and image data was captured in offline mode in the field. The system lacked real time capture of property data despite it using a computer network and having multiuser capabilities and features.[68].

2.4.5 Service Oriented GIS

In China, a service oriented GIS based web application was developed to provide information on Land and the corresponding prices in Feng County in the Jiangsu Province of the People's Republic of China. Latest city maps of Feng County were digitised using ArcGIS and later uploaded to a Server. SQL Server 2008 was used as the main relational database management systems and ArcSDE and ADO.NET were used as communication tools between the business logic tier and data tier. This was done to facilitate management of spatial and attribute data in SQL Server 2008. ArcGIS server was used to display, query and analyse Land prices. The features of the GIS based web application included, mapframe for viewing of spatial land price information, Zoom in/out, Map Printing, document download, upload of new data sets of spatial and attribute data. The Service Oriented GIS application digitised the maps of Feng County using ArcGIS desktop productivity software. The map consisted of an ariel photograph of the county. The spatial and attribute data of the properties in the county was input in offline mode. The application lacked real time capture of the property data capture and storage.[69].

2.4.6 Summary of Related Works

Table 2.2 summarises the related works that have been discussed in preceding section. It can be seen that the tools used in the development of the software solutions were proprietary and consequently required huge financial resources to acquire them considering the low cash flows local authorities in developing countries experience. Secondly, the maps of the areas used in the study were digitised into vector maps using desktop productivity software and the digitisation of maps involved the use of highly skilled man power. Lastly, the systems developed lacked field based operation and real time property data capture features.

Table 2.2: Summary of Related Works

COUNTRY	DEVELOPERS	YEAR	FINDING	METHODOLOGY/DESCRIPTION	GAPS
Ghana	Saviour Mantey Naa Dedei Tageo	2012	Property Tax Administration for Tarkwa Nusame Municipality	-Used .Net Framework Visual Basic -Esri Map Object Library -Mapbox Earth Apis -Microsoft Access Database -Digitised Map Of Study Area -Designed as stand alone with limited remoted access features	-Standalone -Limited remote access features -Used data files to store property spatial data -No real time data capture
Nigeria	Caleb Oluwadare Olatoye Ojo	2014	Olorunda Local Government Authority	-Digitised mapbox earth satellite -Imagery Using Corel Draw 11 And Ilwis 3.0 -Exported digitised maps to ArcView 3.2a software and linked attribute data to Ms Access Database	-Used desktop productivity software -Does not capture image data -No real time data capture
Sri Lanka	Ravindra S. Thilakarathne	2008	Property Taxation Gampola Region Kandy District	-Digitized high resolution satellite -Image of area using arcview 3.1 -Used gps receiver to assign coordinates on the map -Features include acquisition, storage and retrieval of valuation information	-Digitised satellite image -Used desktop productivity software -Does not capture image data -No real time data capture
Mexico	Bentely Partners Innovacion Sistemas	2015	Property Taxation Cuncun Municipality	-Digitised ariel photography maps -GPS used to capture coordinates -Mobile device used to capture property images system -Features include capture, update of property tax records	-Digitised ariel image -No real time data capture
China	Yongjin Yang Et Al	2015	Provision of land price information In Jiang Su County	-Digitised latest map of area using arcgis and uploaded to sql 2008 server -Used arcsde and ado.net as communication tools. -ArcGIS server used to display, query land prices	-Digitised ariel image - Used destop productivity software -No real time data capture

2.5 Chapter Summary

In this chapter, we reviewed the relevant literature for our study. We began by first giving a background of property tax and its importance as a source of revenue for local authorities. We then proceeded to discuss its characteristics and the aspect of property identification as a very important determinant in enhancing property tax collection. Factors that impede the successful identification of properties for inclusion in the property tax net were then discussed. A General discussion of property tax in Africa, Asia and South America was then presented to highlight legislation that gives local authorities powers to collect property tax and the specific localised challenges that are experienced in its administration. A background to Geographical Information Systems (GIS) was then presented. This was followed by the study of software tools that are used to develop GIS software solutions. location based services and geotagging technologies were then presented as GIS technologies that provide helpful added services that can be incorporated in GIS software solutions. Participatory GIS was then discussed as an aspect of GIS that could involve the local community in mapping and decision making. Mobile GIS cloud computing was then reviewed as a new efficient technology that can be used to build field based GIS Applications. We then concluded by reviewing similar GIS software solutions that have been developed to help in the administration of property tax, property identification and property database management.

The review of related works showed that the systems were limited in the capture of complete property data in real time. In some cases, they lacked the feature to capture the image data of the mapped properties. In addition, they lacked the multi-usability feature and as a result they were not efficient in capturing large property data sets within a short period of time. Furthermore, they required the services of highly trained GIS experts in the digitisation and geo-referencing of the property maps.

The review also showed that different GIS software tools can be used in conjunction with each other to develop mobile GIS applications. This is possible through the use of web technologies such as Web Map server, spatial databases and Web GIS Clients. Data between the application client and servers is handled by the http application layer protocols. Software libraries are used to perform specialised complex tasks such as map retrieval from spatial database and subsequent rendering on the client application.

CHAPTER 3

METHODOLOGY

3.1 Chapter Overview

In this chapter we describe in detail the methods and materials that were used in this study. We first discuss the ground truth exercise survey that was conducted and then proceed to discuss the design and implementation of the field based GIS prototype application.

3.2 Ground Truth Exercise

The purpose of the ground truth exercise was to understand the challenges that the local authorities experience in identifying and capturing properties for property tax and to assess the current methods that are used. A descriptive research design was used in the study. A descriptive design is a research design that is used when the researcher wants to find out the state of affairs as they exist. It helps in the formulation of important solutions to problems that exist and also helps in gathering knowledge about a problem. It encompasses the aspects of data collection measurement, analysis, comparison and interpretation [70].

3.3 Study Location

The study was carried out in four local authorities and one planning authority in Lusaka province of the Republic of Zambia namely Lusaka City Council, Chilanga District Council, Kafue District Council, Chongwe District Council and the Lusaka Province Planning Authority. The local authorities have in the recent years experienced a very high rate of property construction because of their proximity to Lusaka District which hosts the capital city of Zambia. The increase in property construction is attributed to the increase in the population of Lusaka city where land has become very scarce to find prompting residents looking for land to turn to the neighbouring local authorities.

3.4 Sampling

Purposive Sampling was used on the study population and in particular homogenous sampling was used. Purposive sampling is carried on a group of people that the researcher firmly believes can give trustworthy information that is relevant to the study. Homogenous sampling focuses on a small group of people that share similar characteristics that describe some particular sub group [70]. In the study the homogenous group included staff in senior and middle management of the local authorities that are involved in the administration of the property tax process from property identification to billing. The homogenous sample was representative of staff involved in the tax administration process.

3.5 Data Collection

Data for the study was collected over a period of five weeks from the first week of February 2017 to the second week of March 2017. The research instruments used were questionnaires and interviews. Forty eight questionnaires were administered after identifying the homogenous group with the help of the human resources department during this period and sufficient time was given to the respondents to answer the questions. The questionnaires were collected as and when the respondents finished answering them and a total of forty(40) were collected at the end of the period. Interviews where carried out during this same period for purposes of understanding the current business processes and collecting qualitative data to inform the design of the prototype system.

3.6 Data Analysis And Presentation

Data analysis for the study was done using descriptive methods with the aid of a statistical software package called GNU PSPP. The presentation of data was done using graphical techniques consisting of pie charts, tables and bar graphs.

3.7 Ethical Consideration

The study touched on sensitive challenges that are experienced in the property tax administration process. Therefore, respondents were asked not to include their names on the questionnaires to avoid any possible reprisals from the authorities. The questionnaires also included an assuring statement that the responses were going to be treated in the strictest of confidence to encourage them to answer the questions without fear and truthfully.

3.8 Ground Truth Exercise Limitations

Respondent apathy was experienced in returning the questionnaires and a total of about 10 questions were left blank by respondents who managed to return the questionnaires. Figures of property tax and other revenue streams could not be provided as the local authorities deemed the information to be very confidential for publication by a third party. The figures would have helped in giving a picture of the current actual collection rates of property tax in relation to other revenue streams.

3.9 Systems Requirements

Systems requirements were obtained through interviews and questionnaires administered to management and middle management staff involved in the property tax administration process. The interviews mainly informed the study in the current business processes that the local authorities used to capture, valuate and bill properties for property tax. The open-ended questions in the questionnaires supplied qualitative data that specified the features the stakeholders wanted the prototype system to have in order for it to address the challenges that the ground truth exercise validated and revealed. Both the interviews and the questionnaires allowed the developer to come up with a detailed model design of the prototype. The system development methodology used for the requirements gathering, specification, modeling and implementation was the Agile Unified Process (AUP).

AUP is based on the principle that the Unified Process Activities of inception, elaboration, construction and transition can be done in a linear manner that facilitates the visualisation of the process flow of the system's development project. Within each activity, iterations that are meant to attain agility and deliver the software increments to the end users are achieved very quickly. The iterations address the following activities: modeling, implementation, testing, deployment, configuration and environmental management. AUP is used in conjunction with the Unified Modeling Language(UML) [71]

3.10 Proposed Automated Property Identification And Capture

In the current business processes, properties are only captured when the construction of the building on the land is fully completed and when the local authority issues an occupancy certificate to the property developer. In addition, a property is only valued during the statutory valuation cycle that

takes place every five years. Only when this valuation is completed, is a property added to the billing system. In between property valuations cycles, some existing land parcels are subdivided and new buildings are erected. New properties are captured for billing in the next valuation cycle. Furthermore, illegal properties, including subdivisions without planning permission, also spring up. The illegal building constructions and subdivisions have compounded the problem of unidentified properties that are non-existent on the current property registers. These illegal properties can only be discovered through routine physical inspections. Local authorities can come up with a property discovery policy that will help in the discovery of these properties. During this property discovery exercise, local authorities can use the field based GIS application to capture ownership, land and property attribute data remotely in the field. Property owners, can also be encouraged to submit property attribute and location spatial data via the mobile application that they can install on their mobile devices. However, they can only submit the attribute data after successful registration using the mobile application. When the required information is captured, the local authority surveying staff can then proceed to capture the spatial data of the land parcels. For owner supplied attribute data, the mapping can only be done after thorough verification of the data by the local authority planning staff. During valuation cycles, valuation surveyors, can use this attribute and spatial information to carry out valuations so that these properties can be captured on the billing systems. Figure 3.1 Depicts this proposed business process model as described.
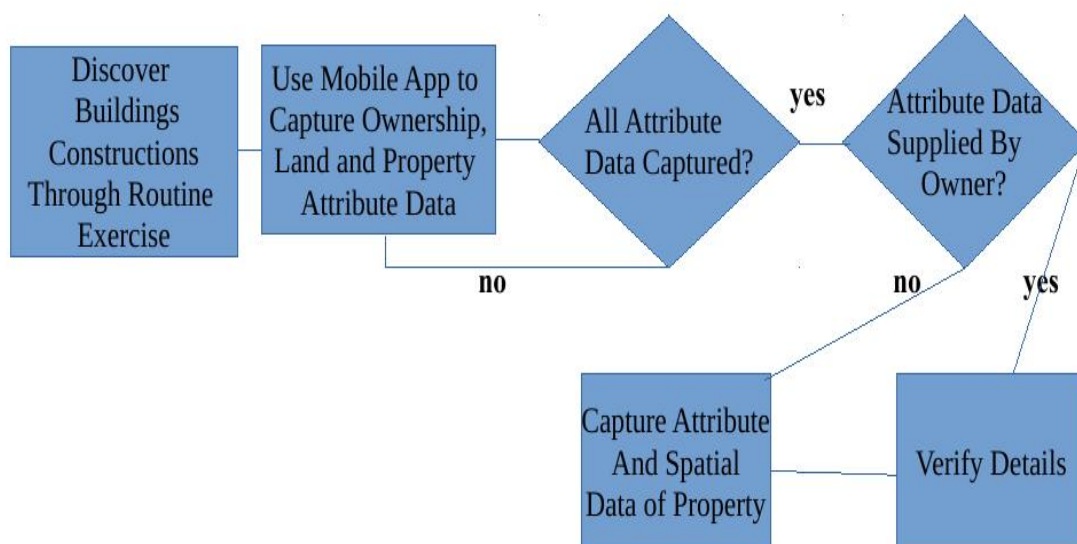
Figure 3.1: Proposed Business Process Model As Described.

In the case of the scenario were the attribute data was captured when existing property owners followed the due legal process of the current business process, the same proposed business model depicted in Figure 3.1 can be adapted to re-capture the attribute data using the application in the field and after that the spatial data can be captured as well. New property owners can also be encouraged to submit the attribute data remotely using the mobile application. After verification by planning staff, valuation staff can proceed to capture the spatial data in the field.

3.11   System Architecture

In this section, we discuss the architecture of the field based Mobile application. Roger S Pressman [71] describes system architecture as the manner in which the various parts of the software system are integrated to form a cohesive whole. The components can include a simple program module, object oriented classes, databases, middle ware, networks, clients and server hardware. System architecture is important because it enables communication among stakeholders involved in the computer based system development. It also simplifies the model of how the system will be structured and how the components will work together

3.11.1   Field Based GIS Architecture

In Figure 3.2, the architecture of the prototype field based mobile application is illustrated. The components include GPS satellites, the internet, cloud based mapping web services, spatial database server, webserver, desktop clients, mobile clients, WIFI, HSDPA, 4G and LTE network technologies. The mobile application client will run natively on mobile devices running Android operating. Spatial and attribute data will be captured in the field using the mobile app. Spatial data will be captured with the aid of GPS satellites and geo-referenced satellite based maps from the cloud-based mapping services. The spatial and attribute data will be transmitted using either WIFI, 4G or LTE network technologies via the internet to the local authority's data centre for storage on the spatial database server. The webserver will run the business layer logic that will be invoked the mobile and desktop clients.
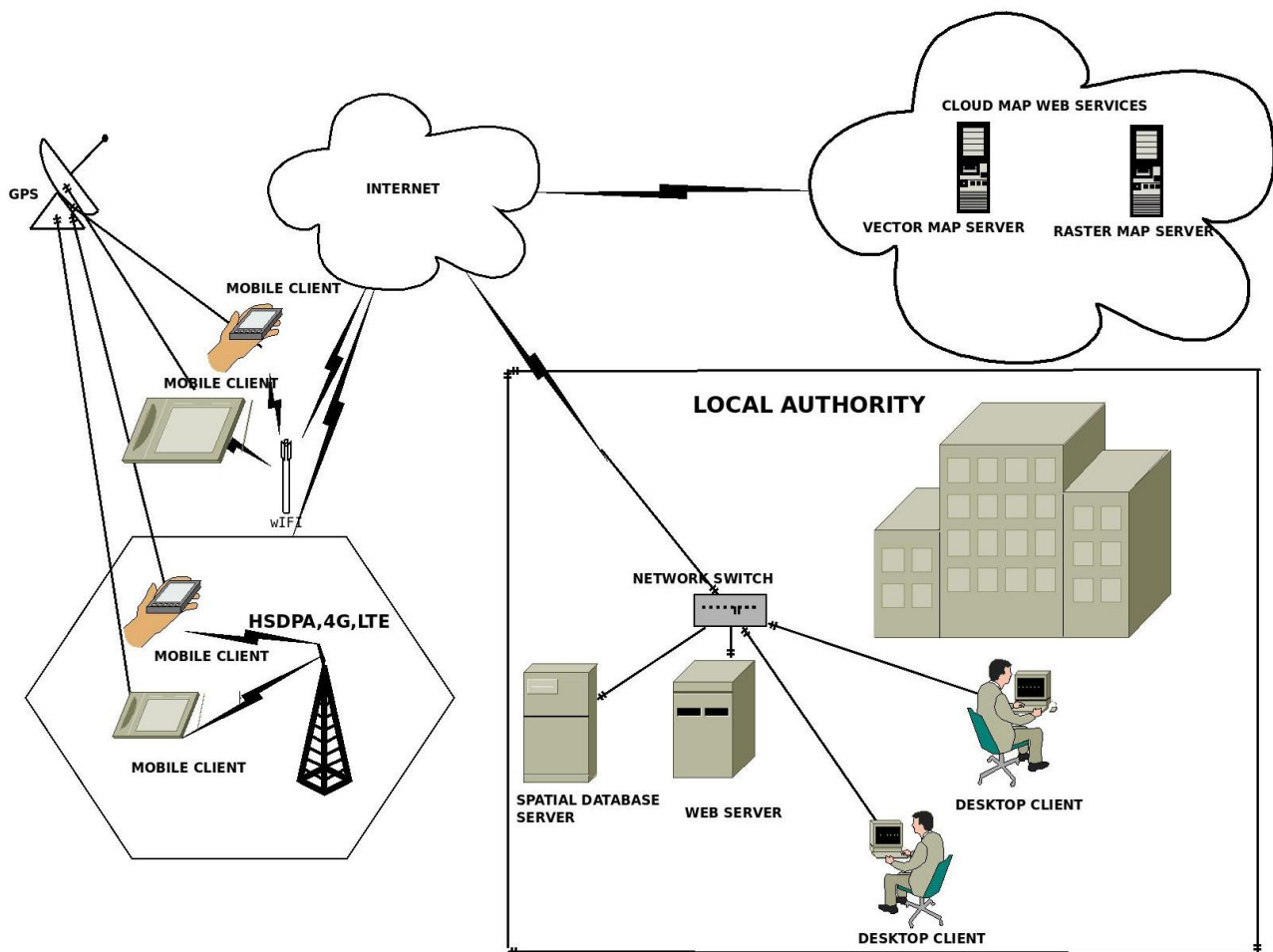
Figure 3.2: System Architecture.

3.12 Field Based Mobile GIS Deployment Diagram

A deployment diagram shows the placement of the various software components across different locations. A component can either be a computer(s) depicting a computing resource. It can also be a physical entity residing a specific location [72]. It is useful for illustrating how the software is distributed among hardware and software platforms and the execution environments [71]. The deployment diagram in Figure 3.3 depicts the three Layer software architecture components of the field based GIS application, their location and configurations. The mobile device clients will run the view layer code that will provide the user interface for data capture and information retrieval. The Application server component will run the business layer logic that will receive data from clients, process it and the pass the information for storage by the database server component or the client. The mobile app components will depend on the map web services from the cloud for the retrieval and rendering of vector and raster satellite maps
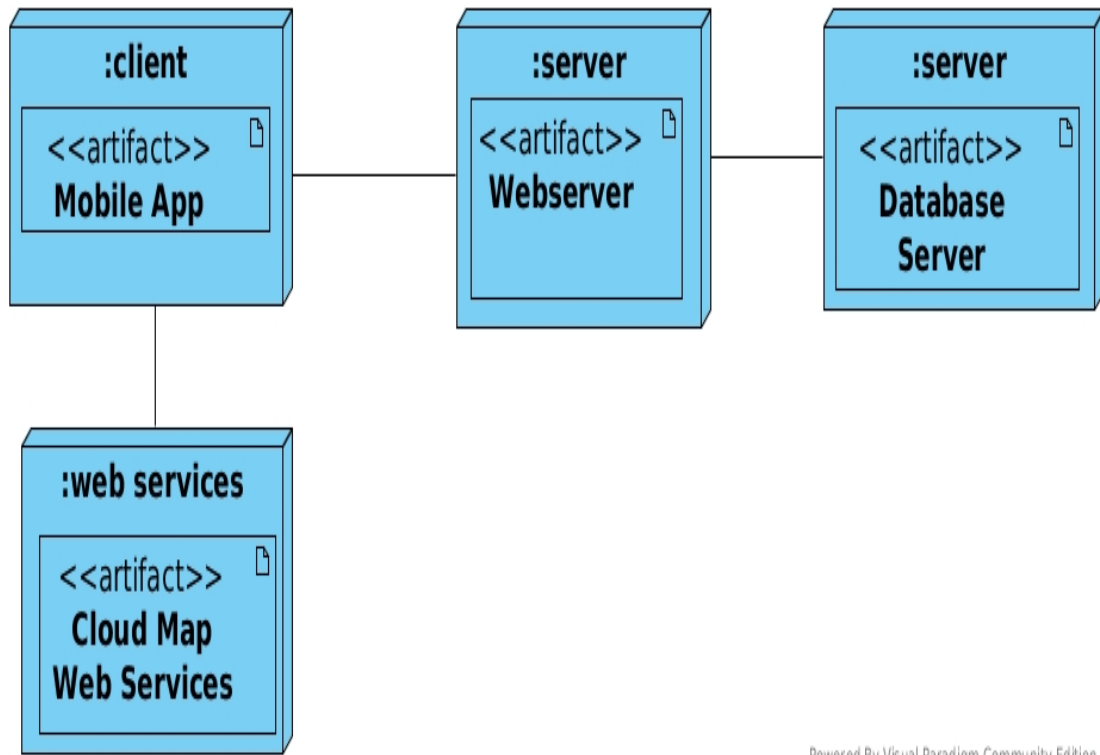
Figure 3.3: Field Based Mobile GIS Deployment Diagram.

3.13 Requirements Specification

In this section, we specify the Functional and Non-Functional Requirements of the field based GIS application.

Systems requirements are all the functions and limitations that the new system must fulfill. They can be categorised into two groups namely Functional and Non-functional requirements. Functional Requirements are specifications that describe the activities that the new system should carry out. On the other hand, Non-functional Requirements are features of the new system other than the functions that it should perform [72].

3.13.1 Functional Requirements

This section tabulates the functional requirements. Property owner requirements are given in table 3.1 User management requirements are given in table 3.2 while those for property management are given in table 3.3.

Table 3.1: Functional Requirements – Property Owners.

Code	Requirement Description
FR1PO	Property owners should be able to submit property information using their mobile devices
FR2PO	Property owners should be able to register an account using their mobile devices before submitting property ownership information
FR3PO	The System should be able to notify property owners upon successful account registration
FR4PO	The System should be able to notify property owners upon successful submission of property information
FR5PO	The System should allow property owners to activate an account through an email link
FR6PO	The System should allow property owners to log in using the log in credentials supplied during account creation
FR7PO	The System should allow the property owner to retrieve the account password of the property location

Table 3.2: Functional Requirements – User Management.

Code	Requirement Description
FR1UM	The System should allow the systems administrator to create users that will use the system
FR2UM	The System should allow the systems administrator to update user account profiles
FR3UM	The System should allow the systems administrator to delete a user account
FR4UM	The System should allow the systems administrator to log in with privileged rights
FR5UM	The System should allow the systems administrator to assign user rights

Table 3.3: Functional Requirements- Property Management.

Code	Requirement Description
FR1PM	The System should allow local authority users created by the systems administrator to log in
FR2PM	The System should grant access to system resources that are authorised
FR3PM	The System should allow authorised users to view property details
FR4PM	The System should allow authorised users to update property records
FR5PM	The System should allow authorised users to delete property records
FR6PM	The System should allow authorised users to create a property record
FR7PM	The System should allow authorised users to map a property
FR8PM	The System should allow authorised users to add property valuation information
FR9PM	The System should allow authorised users to view the property valuation report
FR10PM	The System should allow authorised users to view the properties mapped between two dates
FR11PM	The System should allow authorised users to view the area mapping status report

3.13.2 Non-Functional Requirements

This section tabulates the non-functional requirements. Technical requirements are given in table 3.4. Performance requirements are given in table 3.5. Security requirements are given in table 3.6

Table 3.4: Non Functional Requirements – Technical Requirements

Code	Requirement Description
NFR1TR	The mobile client of the system will run on the Andriod operating system Version 4.3 and above
NFR2TR	The desktop client will run on the latest version of Mozilla Firefox web browser
NFR3TR	Both the mobile and desktop clients will use JavaScript Leaflet Mapping Libraries and JavaScript MapBox Maps APIs
NFR4TR	Apache web server will host PHP Scripts that will run the business logic, provide the interface, and connect to Postgres Spatial Relational Database Management System (SRDMS) with PostGIS Extensions
NFR5TR	Postgres with PostGIS extensions will be used as the SRDMS
NFR6TR	OpenStreetMaps will be used as the source of vector map tiles
NFR7TR	MapBox Maps will be used as the source of raster satellite map tiles
NFR8TR	All property images captured will be geotagged
NFR9TR	The Postgres SRDMS and Apache webserver will run on Ubutntu Linux Version 14.04
NFR10TR	Ubuntu Linux 14.04 will run on an Intel core i5, 4GB RAM and 1 terabyte HDD

Table 3.5: Non Functional Requirements – Performance Requirements

Code	Requirement Description
NFR1PR	The Apache webserver will support multiple simultaneous Mobile and Desktop Client Connections
NFR2PR	The Mobile and desktop client JavaScript Code will use AJAX technology to make the application more responsive
NFR3PR	The mobile client will run on a high speed WIFI, HSDPA, 4G and LTE networks to achieve fast network data transfers
NFR4PR	The mobile devices location will use the Assited GPS location feature to attain high positioning accuracy in built up environments

Table 3.6: Non Functional Requirements – Security Requirements

NFR1SR	Data transmitted between the Apache webserver and the Mobile and Desktop Clients will be encrypted using an SSL certificate
NFR2SR	All user passwords stored in the SRDMS will be encrypted using SHA3 encryption algorithm
NFR3SR	All privileged access to the SRDMS will be done by the SRDMS administrator
NFR4SR	All Access to SRDMS will be done by using a valid user name and password

3.14   System Modeling and Design

In this section, we model the system using the UML modeling tools namely use cases, use case descriptions, system sequence diagrams, Three layer sequence diagrams, class diagrams and entity relationship diagrams.

A model is a depiction of an aspect of the system that is undergoing development. Different types of models are used to depict these different aspects of the system depending on the level of complexity and abstraction. Models are helpful in clarifying and refining the design of the system. They also assist in communicating the design to the people that will use the system and also the development team. Most importantly they are used to documenting the design of the system for future maintenance and enhancements of the system when it is operational [72].

3.14.1 Use Cases

A use case diagram is a graphical model that helps the user in understanding the features and functionality of the software application. It describes how the user interacts with the system by specifying steps of how to accomplish a task. A sticky figure represents an actor and the actor is named according to the role they are playing. The Case is represented by an oval shape and it represents an activity that an actor performs. Actors and cases are connected by a line. The rectangle represents the system automation boundary [71].

Figure 3.4 depicts the use case model of the property owner account registration and activation
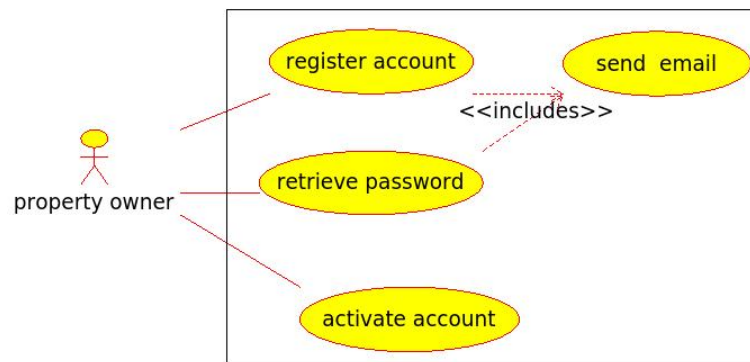
Figure 3.4: Property Owner Account Management Use Cases.

Figure 3.5 depicts user management use cases. The actor involved is the systems administrator. The use case activities can only be carried out after successful authentication.
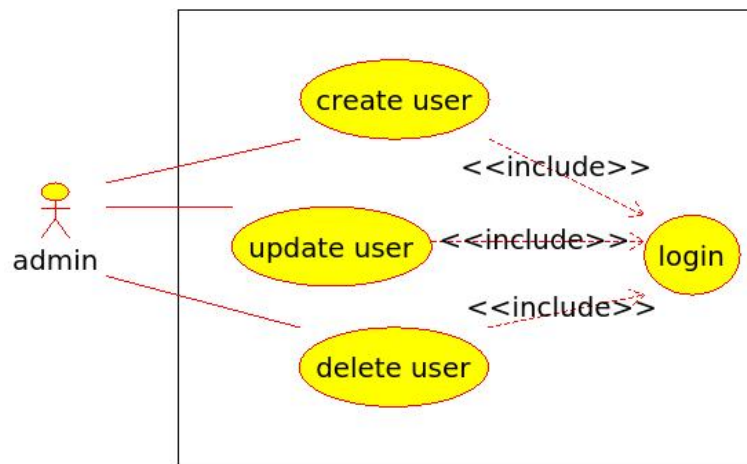
Figure 3.5: User Account Management Use Cases.

Figure 3.6 depicts property management use cases. The actors involved are local authority staff in the planning departments and the property owner. The use case activities can only be carried out after successful authentication. The update property attribute data, delete property attribute data and map

property activities require that property details exist
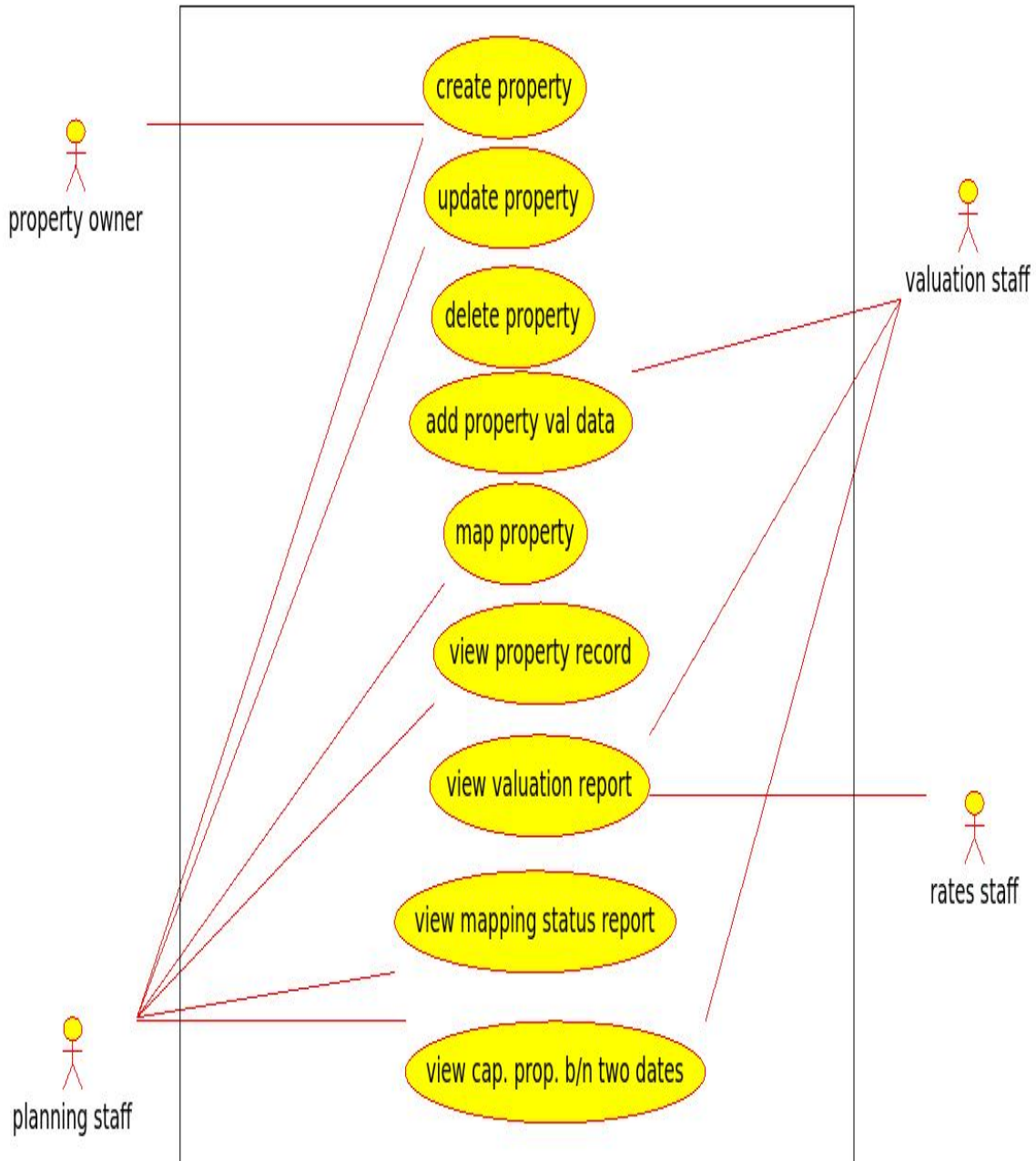
Figure 3.6: Property Management Use Cases.

3.14.2   Use Case Descriptions

Use cases provide a high level overview of the activity an actor carries out. Use case descriptions are used to describe in detail information about the use case. It lists all the use cases in the automation boundary and for each use case it describes in detail the processing activities. They help in defining the specific requirements of the automated system [72].

3.14.3 Actors Roles

Table 3.7 show the actors and the role that they play

Table 3.7: Actors Role Description

Actor	Descriptions
Property Owner	The property owner owns the buildings and the land
Rates Staff	Rates staff are responsible for the management of the property rates billing function. They prepare and dispatch bills. They also perform debt management.
Valuation Staff	Valuation staff are charged with the responsibility of carrying out property valuations. They Value properties and prepare the valuation roll
Planning Staff	Planning staff are responsible for approving building plans submitted by property developers. They also do land surveys and plots delineation
Administrator	The administrator is responsible for the management of all the users of the system. He creates users and assign them rights.

3.14.4 Case Descriptions

Table 3.8 Describes in detail the Register account use case scenario

Table 3.8: Register Account Scenario

Flow of Activities for Scenario Register Account Use Case
Main Flow
1. Property owner Starts app on their mobile phone
2. Register account option is selected
3. Account information is entered
4. Submit button is clicked
5. Account Creation message is displayed when the owner is registered successfully
Exception Condition(s)
3. If any mandatory fields are left blank, a message is displayed and property owner is prompted to enter them.

Table 3.9 Describes in detail the email use case scenario

Table 3.9: Send Email Scenario

Flow of Activities for Scenario Send Email Use Case
Main Flow
1. Send email
2. Display Email Sent confirmation message
Exception Condition(s)
1. If email cannot be sent, a message informing the user is displayed

Table 3.10 Describes in detail the activate account use case scenario

Table 3.10: Activate Account Scenario

Flow of Activities for Scenario Activate Account Use Case
Main Flow
1. Property owner clicks the link to activate the account in their email message
2. When account is activated, a message is displayed
Exception Condition(s)
2. If account fails to be activated, a message is displayed

Table 3.11 Describes in detail the retrieve password use case scenario

Table 3.11: Retrieve Password Scenario

Flow of Activities for Scenario Retrieve Password Use Case
Main Flow
1.Property owner starts app on their mobile phone
2. Property owner clicks on the forgot password button
3. Property owner is prompted to enter email
4. Property owner clicks on the retrieve password button
4. Email with password is sent
Exception Condition(s)
4. If the email cannot be sent, a message is displayed

Table 3.12 Describes in detail the Create user use case scenario

Flow of Activities for Scenario Create User Use Case
Main Flow
1. Administrator access mobile application and logs in
2. Administrator invokes create user Screen
3. Administrator enters authentication details for user
4. Administrator clicks on create user button
5. When the user is created successfully, a message is displayed
Exception Condition(s)
4. if any mandatory field is not entered, a message is displayed
5. If there was a problem creating the user, a message is displayed

Table 3.13 Describes in detail the Update user use case scenario

Table 3.13: Update User Scenario

Flow of Activities for Scenario Update User Use Case
Main Flow
1. Administrator accesses the mobile application and logs in
2. Administrator invokes update user screen
3. Administrator changes the required user information
4. Administrator clicks on the update button
5. When the User information is updated successfully a message is displayed
Exception Condition(s)
5. If there was a problem updating the user, a message is displayed

Table 3.14 Describes in detail the delete user use case scenario

Table 3.14: Delete User Scenario

Flow of Activities for Scenario Delete User Use Case
Main Flow 1. Administrator accesses mobile application and logs in 2. Administrator invokes the delete user screen 3. Administrator searches for the user 4. if user exists the delete button is enabled 5. Administrator clicks on the delete button 6. Deletion confirmation message is displayed 7. if the the yes button is clicked, the user is deleted
Exception Condition(s) 4. if user does not exist, a message is displayed and the delete button remains disabled 7. if the no button is deleted, the delete process is canceled

Table 3.15 Describes in detail the login user use case Scenario

Table 3.15: Login User Scenario

Flow of Activities for Scenario Login User Use Case
Main Flow 1. User accesses the mobile application 2. User enters the authentication credentials 3. If the authentication credentials are correct, the User is granted access to the application
Exception Condition(s) 3 if the authentication credentials are incorrect, a message is displayed

Table 3.16 Describes in detail the View property record use case scenario

Table 3.16: View Property Record Scenario

Flow of Activities for scenario View Property Record Use Case
Main Flow
1. Authorised staff log into the mobile application
2. Staff invokes the view property record screen
3. Staff enters the owner identification number
4. if the property exists, the details are displayed on the screen/page
Exception Condition(s)
4. if the property does not exist, a message is displayed

Table 3.17 Describes in detail the View property valuation use case scenario

Table 3.17: View Property Valuation Report Scenario

Flow of Activities for Scenario View Property Valuation Report Use Case
Main Flow
1. Authorised Staff login into the mobile pplication
2. Staff invokes View Property Valuation Status
3. Property Valuation Status map is displayed

Table 3.18 Describes in detail the properties captured between two dates report use case scenario

Table 3.18: View Properties Between Two Dates Report Scenario

Flow of Activities for Scenario View Captured Prop. Btwn two Dates Report Use Case
Main Flow
1. Authorised staff logs in to the mobile application
2. Staff then invokes the properties captured between two dates screen/page
3. Staff then enters the start and end date range of interest
4. Staff then clicks the view properties button
5. All the properties captured with the specified range are then displayed in the report
Exception Condition(s)
4. if the property was not captured with the specified period, it will not be displayed on the report

Table 3.19 Describes in detail the Area mapping status Report use case scenario

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Table 3.19: View Area Mapping Status Report Scenario

Flow of Activities for Scenario Area Mapping Status Report Use Case
Main Flow
1. Authorised Staff login into the mobile
2. Staff invokes area mapping status screen
3. Mapping status of area is displayed.

Table 3.20 Describes in detail the create property record use case scenario

Table 3.20: Create Property Record Scenario

Flow of Activities for Scenario Create Property Record Use Case
Main Flow 1. Authorised staff logs into the mobile application 2. Staff then invokes the create screens – Owner, land, property respectively 3. Staff then enters ownership, land and property details appropriately 4. Staff then clicks on the create buttons in the ownership, land and property details screens appropriately 5. If the records are updated successfully, appropriate messages message are displayed
Exception Condition(s)
5. If the Records fail to be Created successfully, appropriate messages are displayed

Table 3.21 Describes in detail the update property record use case scenario

Table 3.21: Update Property Record Scenario

Flow of Activities for Scenario Update Property Record Use Case
Main Flow 1. Authorised Staff logs into the mobile application 2. Staff then invokes the update screens - owner, land, property 3. Staff then searches for the property by entering the property owner identification numbers in the appropriate screens 4. If the property owner is found, the ownership, land and property details will be accessible for amendment in the appropriate screens 5. Staff then makes the required change to the record and updates the records when done 6. If the records are updated successfully, appropriate Messages message are displayed
Exception Condition(s) 4. If the owner identification number is not found, a message is displayed 6. If the Records fail to be updated successfully, appropriate messages are displayed

Table 3.22 Describes in detail the Delete Property record use case scenario

Table 3.22: Delete Property Record Scenario

Flow of Activities for Scenario Delete Property Record Use Case
Main Flow 1. Authorised Staff logs into the mobile application 2. Staff then invokes the delete property 3. Staff then searches for the property by entering the owner identification number 4. If the property owner is found, the details are displayed on the screen appropriately 5. Staff the click on the delete button appropriately to delete the Property details 6. The delete confirmation screen is then displayed in each screen
Exception Condition(s) 4. If the property number is not found, a message is displayed

Table 3.23 Describes in detail the Map property use case scenario

Table 3.23: Map Property Scenario

Flow of Activities for Scenario Map Property Use Case
Main Flow 1. Authorised Staff logs into Mobile application in the field 2. Staff then searches for property details supplied by the Property Owner using the property owner identification Number 3. If the property is found, staff clicks on the map using GPS button or map using satellite map to capture the GPS coordinates of the property and the pictures of the property are captured and saved while on the property 4. If the details are saved successfully, a message is displayed on the phone screen
Exception Condition(s) 2. If the owner identification Number is not found, a message is displayed 3. If the property owner identification number is not found, GPS coordinates and Pictures are not captured 4. If the captured details fail to be saved, a message is displayed

Table 3.24 Describes in detail the Map add property valuation data use case scenario

Table 3.24: Add property Valuation Data

Flow of Activities for Scenario Add property Valuation Data Use Case
Main Flow 1. Valuation Staff logs into the mobile application 2. Staff then invokes the add property valuation Information Screen 3. Staff searches for the property by entering the property number and searches for the property 4. If the property exists details are displayed on the screen 5. The staff then enters the required valuation information and saves it when done 6. If the valuation information is saved successfully, a message is displayed
Exception Condition(s) 4. If the property does not exist, a message is displayed 6. if the valuation information is not saved successfully, a message is displayed

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3.15 Sequence Diagrams

3.15.1 System Sequence Diagrams

System Sequence Diagrams (SSDs) are used to describe how information moves in and out of an automated system. It documents the data input into the system and the information produced from the system and also the interaction between the actors and the system. It focuses much on the interaction between the Actor and the System. The :System objects depicts the whole automated system. Vertical dashed lines represent the lifeline. Lifelines are extensions of objects or actors throughout the duration of the SSD. Messages sent between lifelines are represented by arrows. Dashed arrows represent return messages. SSDs are used in close conjunction with use case descriptions [72].

Figure 3.7 shows the register account system sequence diagram. The property owner invokes the methods that opens the account registration screen by sending a message to the system. The registration screen is displayed and the property owner inputs the details. Upon submission of the details, the create account message is sent to the system. The system responds by sending a confirmation message to the property owner.
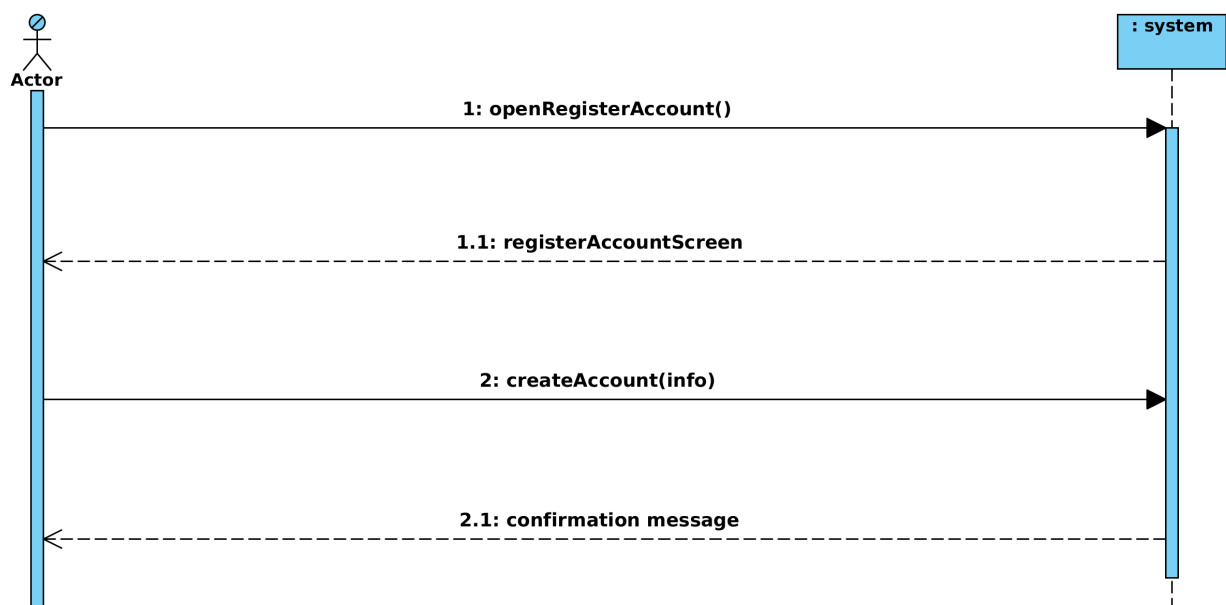

Figure 3.7: Register Account System Sequence Diagram.

Figure 3.8 Shows the Send email system sequence diagram. The System sends the email to the email system and the email system responds with the status message.
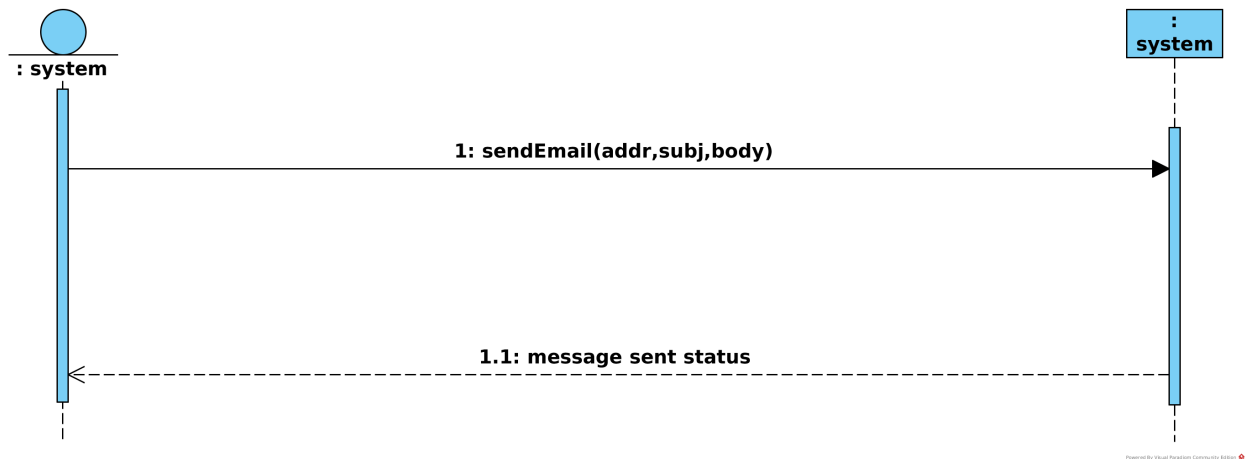
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Figure 3.8: Send Email System Sequence Diagram.

Figure 3.9 shows the Activate account system sequence diagram. The Web system sends an activate account message to the System. The System responds with an account activation confirmation message.

Figure 3.9: Activate Account System Sequence Diagram.

Figure 3.10 shows the create user system sequence diagram. The administrator sends a message to open the create user screen to the system which turn displays the screen. The administrator then enters the user details and then sends a create message to the system which saves the user details. The system then responds with a confirmation message when the details are saved successfully.

Figure 3.10: Create User System Sequence Diagram.

Figure 3.11 shows the system sequence diagram for the update user. The administrator sends a message to the system to open the update user screen and the system displays it. The administrator then enter the user identity and sends a message to the system to retrieve the user details. The administrator then makes amendments to the details and sends the change user details message to the system and it responds with a confirmation message when the changes are saved successfully.
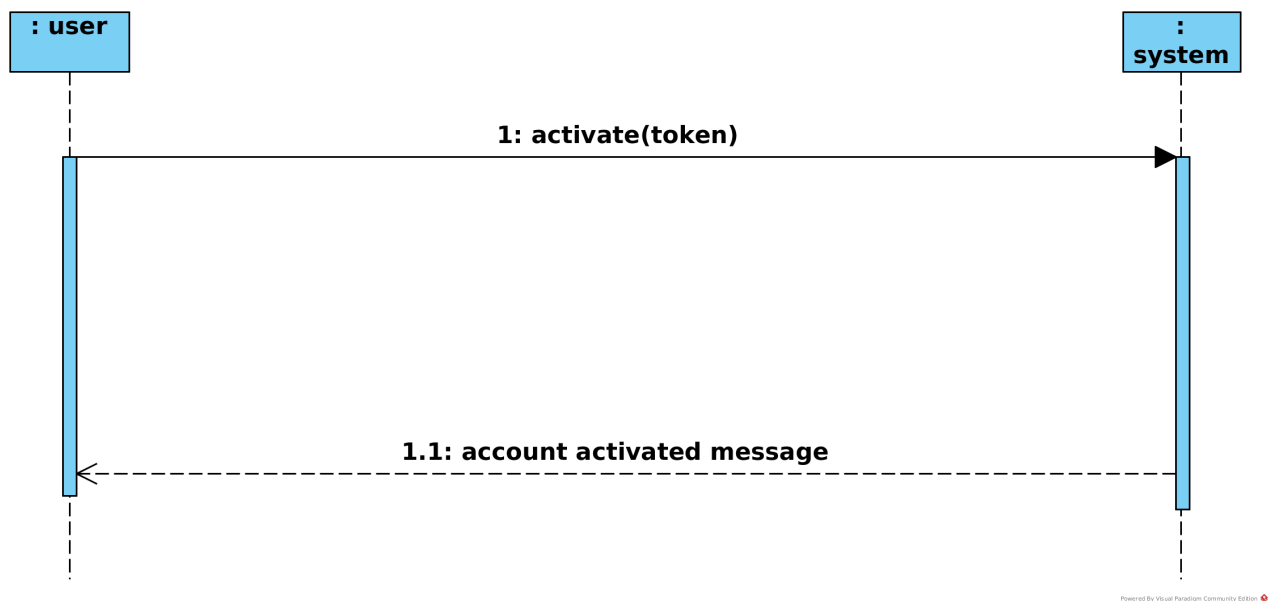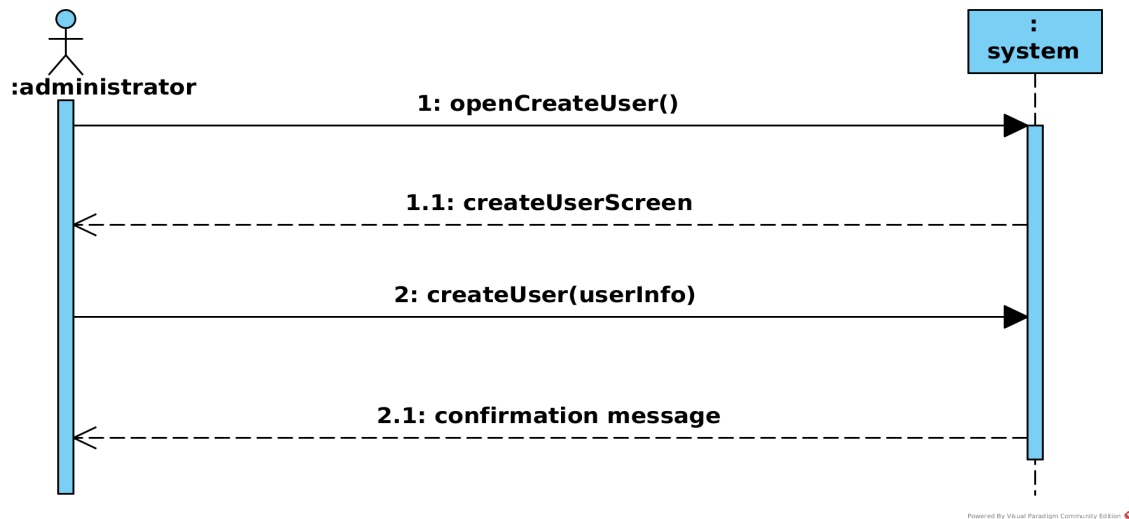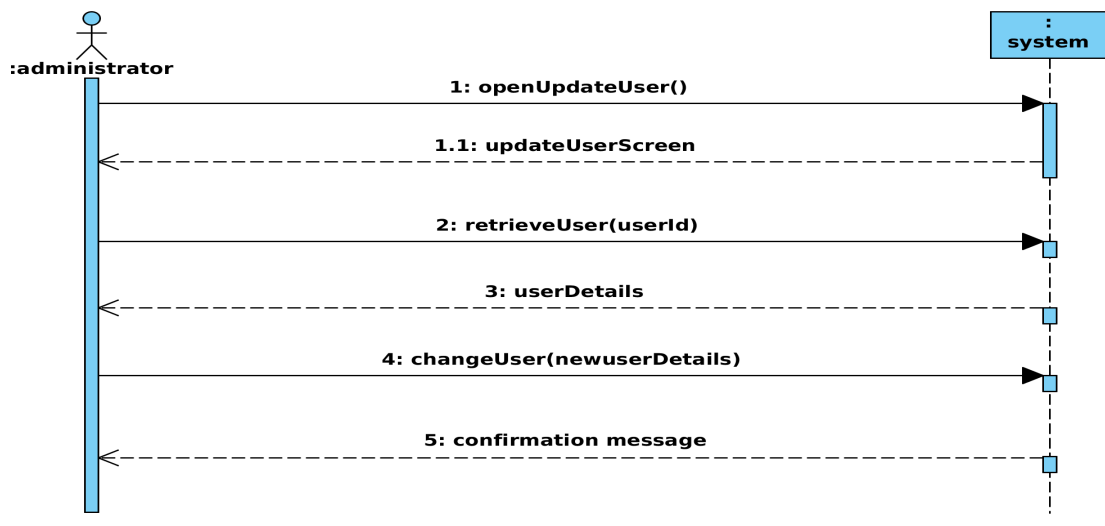

Figure 3.11: Update User System Sequence Diagram.

Figure 3.12 shows the delete user system sequence diagram. The administrator sends the message to open the delete user screen to the system. The system displays the screen and the administrator enters the user identity and sends a message to the system to retrieve the user details. The administrator then sends a message to remove the user and the system responds with a confirmation message when the user is removed successfully.

Figure 3.12: Delete User System Sequence Diagram.

Figure 3.13 shows the Login system sequence diagram. The user sends the message to the system to open the login screen and the screen is displayed. The user then enters the username and password after which the user sends the login message to the system to login. The system responds by opening the main menu screen.

Figure 3.13: Login User System Sequence Diagram.

Figure 3.14 shows the retrieve password system sequence diagram. The user sends the message to the system to open the retrieve password screen and the screen is displayed. The user then enters the email address and sends email password message to the system. The system responds by sending the email to the user's mail box.
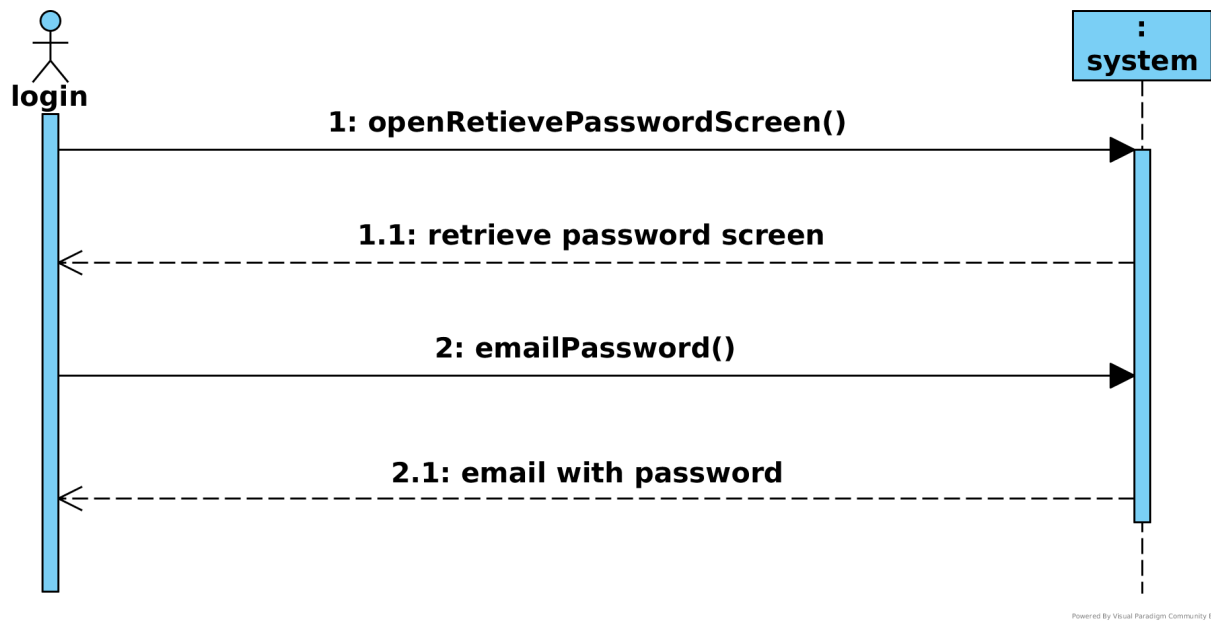
Figure 3.14: Retrieve Password System Sequence Diagram.
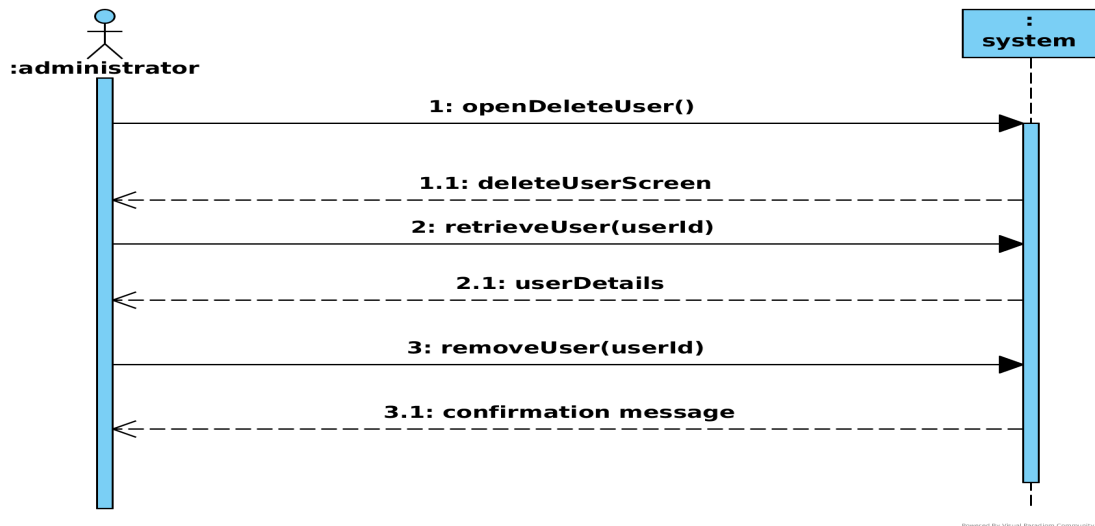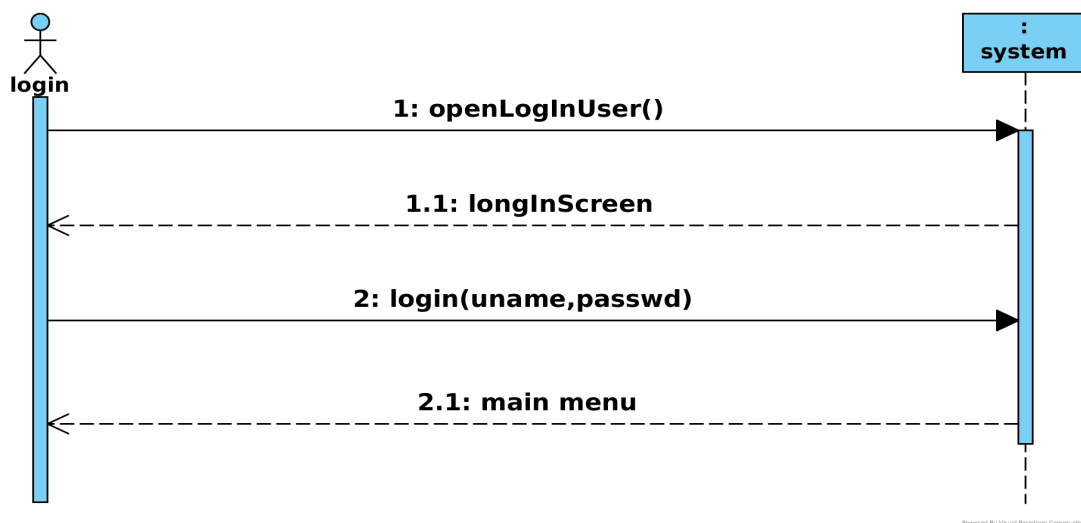
Figure 3.15 shows the view property System sequence diagram. The User sends the message to the system to open the View property screen and the system opens the screen. The User then enters the owner identity number and sends a retrieve property details message to the system. The system responds with the property details.

Figure 3.15: View Property Record System Sequence Diagram.

Figure 3.16 shows the create property record system sequence diagram. The User sends a message to open the create owner screen and the system displays the screen. The user enters the details and sends a create owner message and the system responds with a confirmation message and displays the create land screen. The user enters the land information and sends a create land information message

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and the system responds with a confirmation message and displays the create property screen. The user enters the property details and sends a create property details message and the system responds with a confirmation message.

Figure 3.17 shows the Update property record system sequence diagram. The user sends a message to open the update owner screen and the system displays the screen. The user enters the owner identity number and sends a retrieve owner details message and the system retrieves the details. The user then changes the details and sends an update owner details message and the system responds with a confirmation message and the change land information screen. The user changes the land information and sends an update land information message and the system responds with a confirmation message and displays the update property screen. The user changes the property details and sends an update property details message and the system finally responds with a confirmation message.

Figure 3.16: Create Property Record System Sequence Diagram.
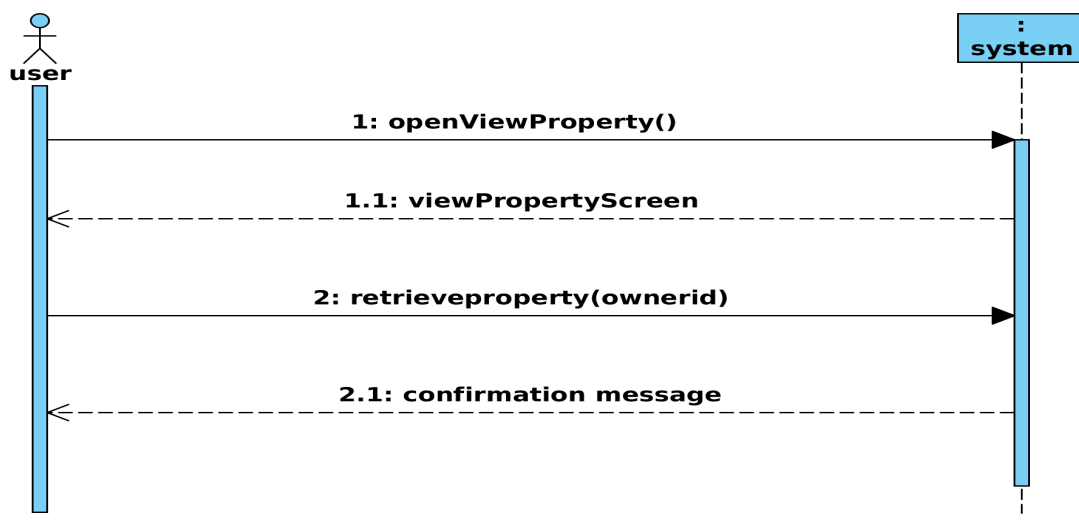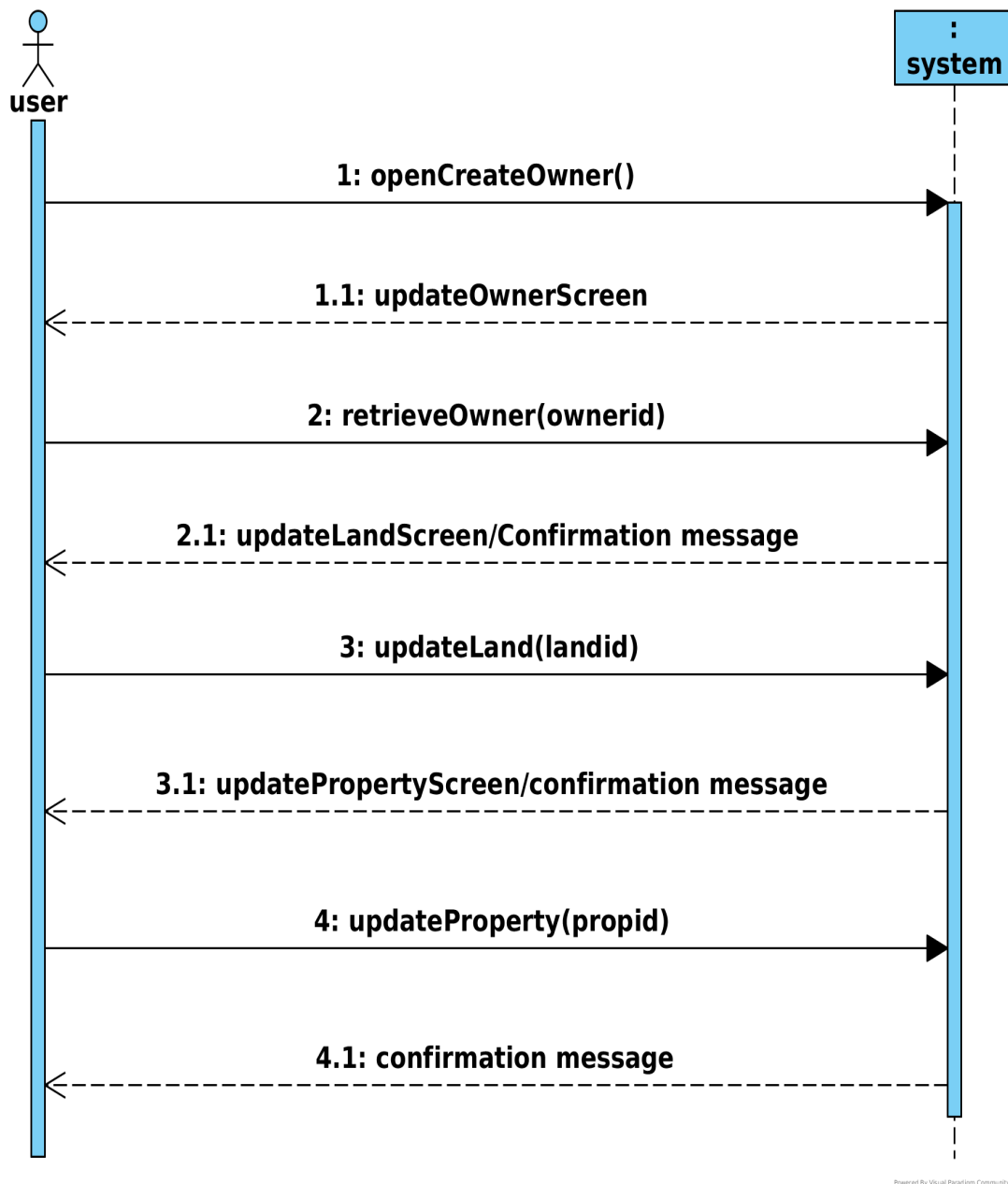
Figure 3.17: Update Property Record System Sequence Diagram.

Figure 3.18 Shows the delete property system sequence diagram. The user sends the open delete property message to the system and the system displays the screen. The user enters the property identity and sends a retrieve property message and the system displays the details. The user then sends the delete property message and the system displays a confirmation message.

Figure 3.19. shows the system sequence diagram for the map property. The user sends a message to open the screen and the system displays the map property details. After verifying the details, the user creates the map of the property by capturing GPS coordinates using GPS or a geo-referenced satellite image and also captures the pictures of the property. An upload picture message is sent each time a picture of the property is captured.
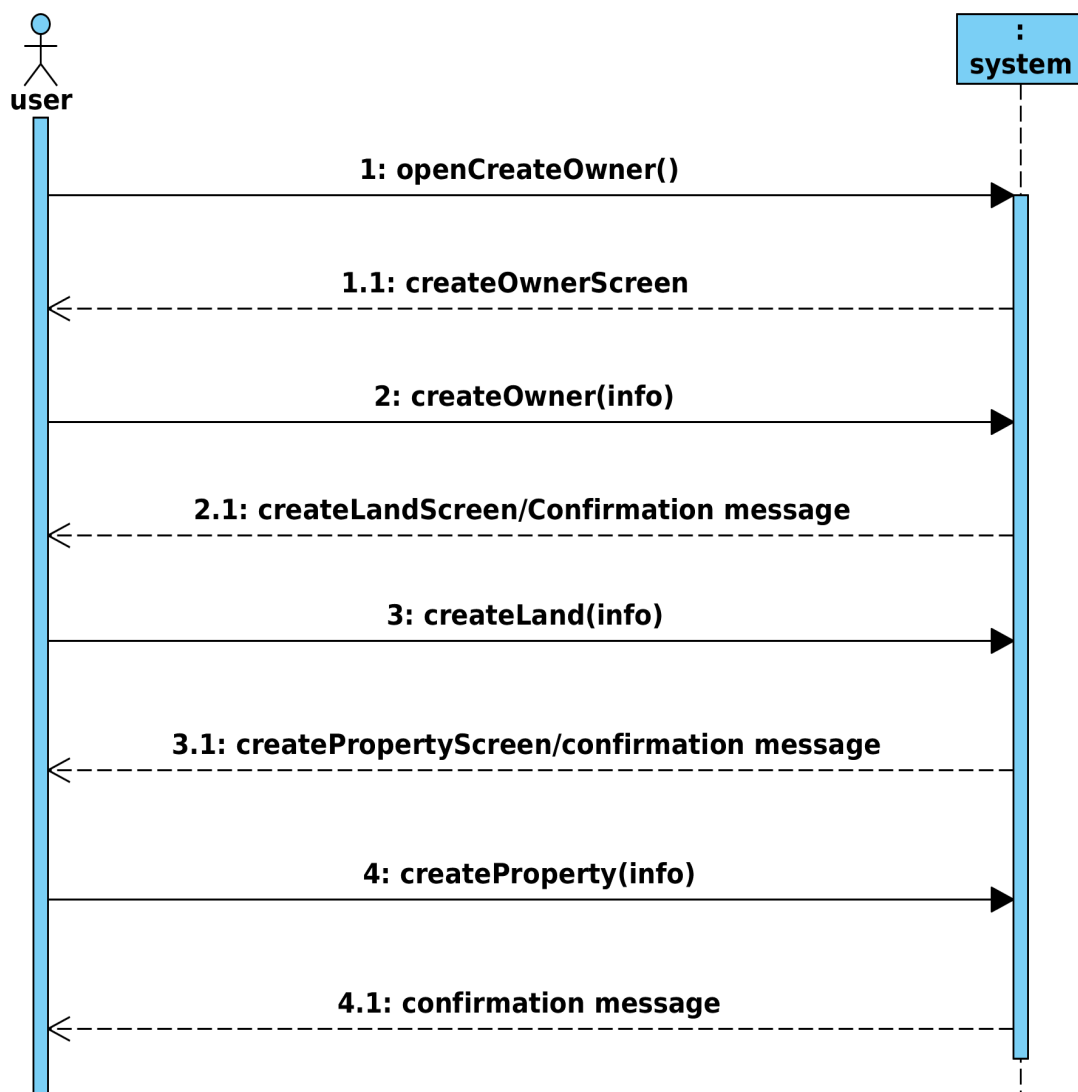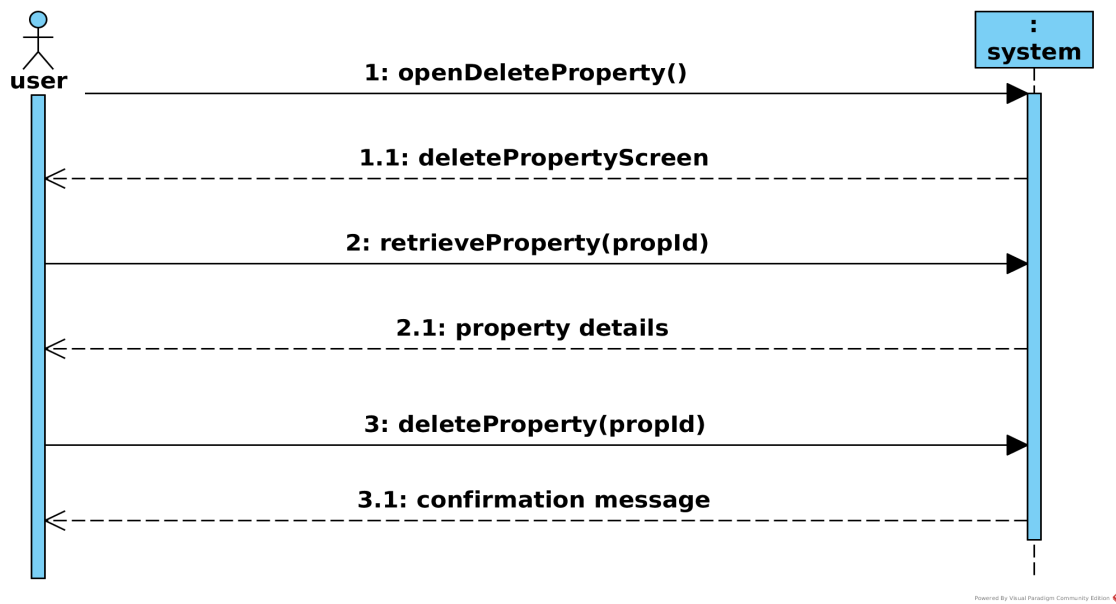
Figure 3.18: Delete Property Record System Sequence Diagram.
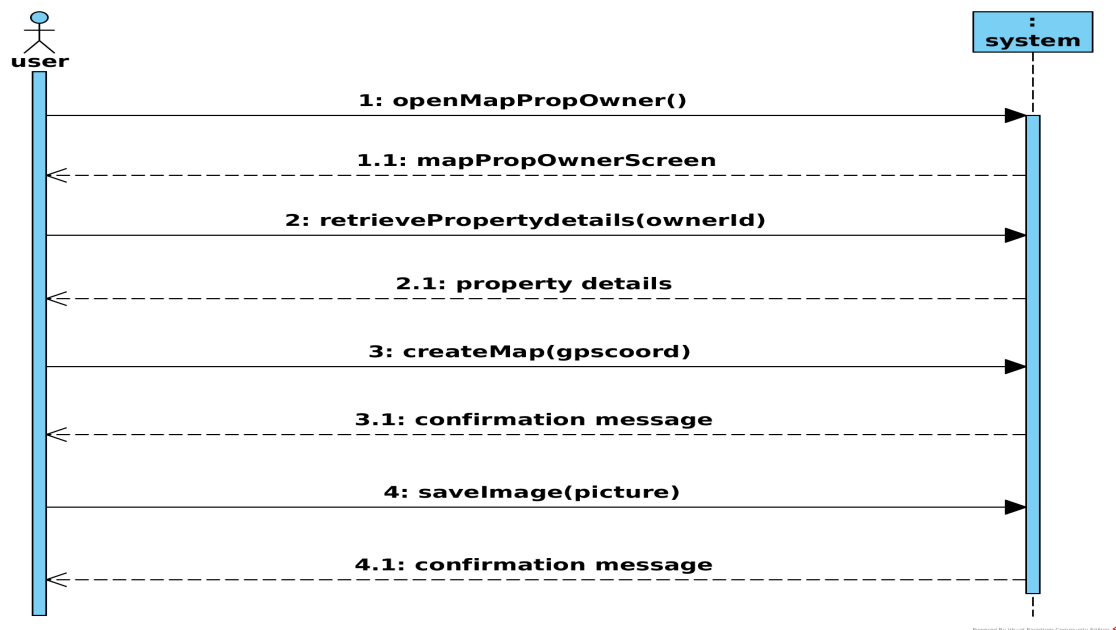
Figure 3.19: Map Property system sequence diagram.

Figure 3.20 Shows the Add property valuation information system sequence diagram. The user sends the message to display the add valuation information screen to the system and the screen is displayed. The user the enters the property identity number and sends a message to retrieve the property details and the system displays the details. The User adds the property valuation details and sends an add valuation information message to the system and the system responds with a confirmation message.
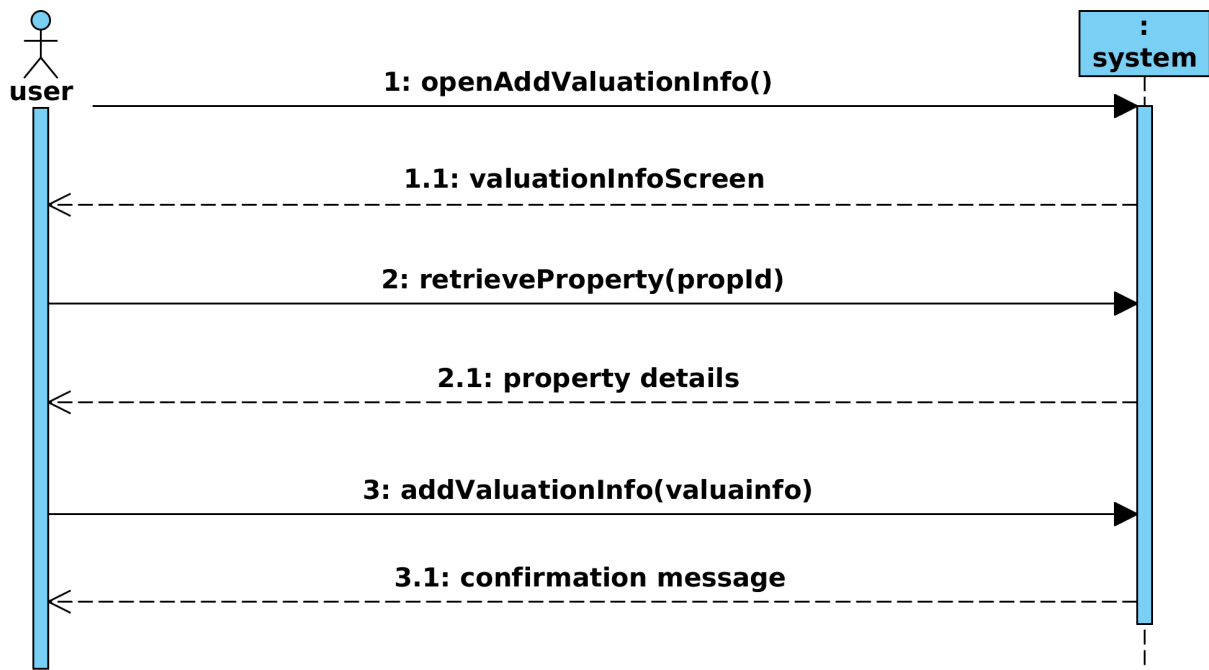
Figure 3.20: Add Property Valuation Data System Sequence Diagram.

Figure 3.21 shows the Area mapping status report system sequence diagram. The user sends a message to open the mapping status report to the system and the system responds with the area status map.

Figure 3.22 Shows the Valuation status map area mapping status. The user sends the open valuation status report message with a start and end cycle range and the system responds with the valuation status report.
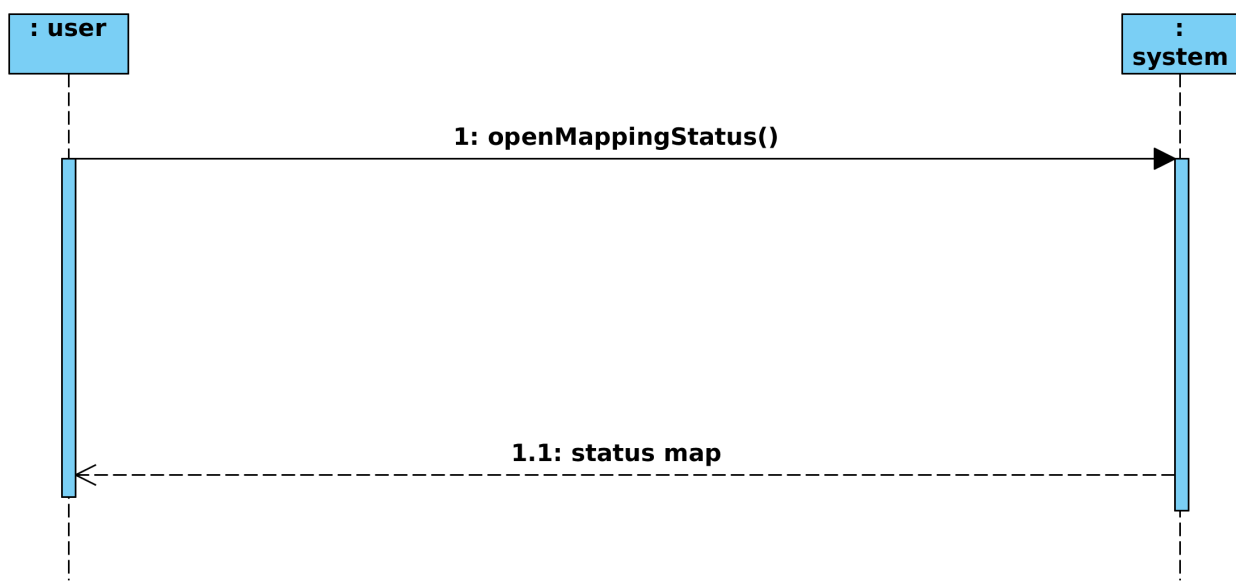
Figure 3.21: Area Mapping Status Report System Sequence Diagram.

Figure 3.22: Valuation Status Report System Sequence Diagram.

Figure 3.23 Shows the view properties mapped between two dates report system sequence diagram. The user sends the open captured between two dates report message with start and end dates and system responds with the captured between two dates report.
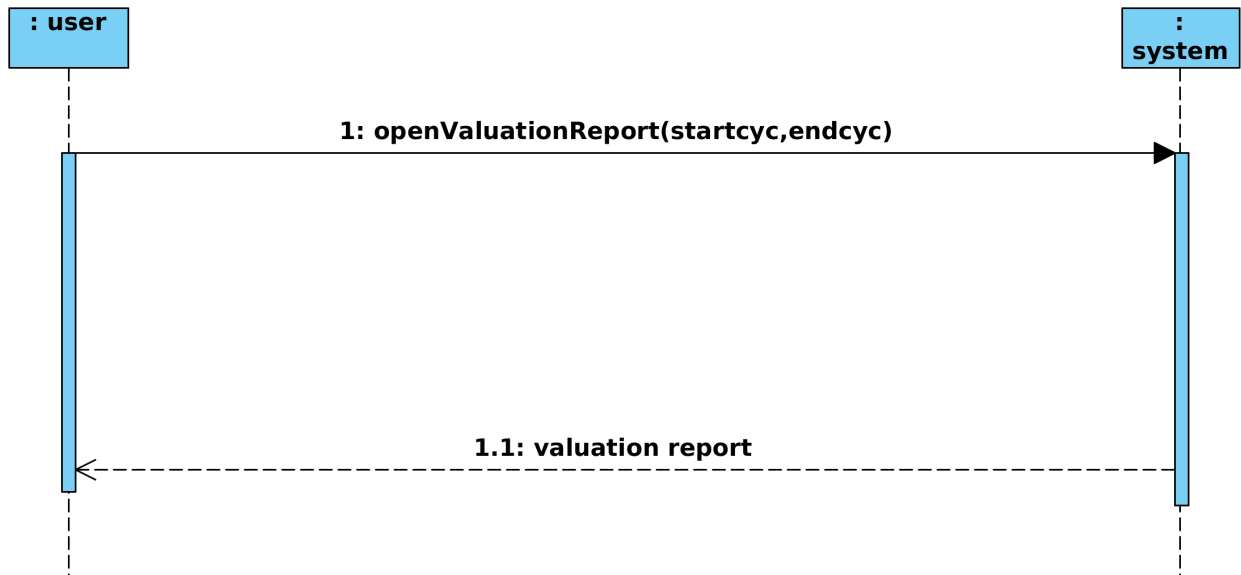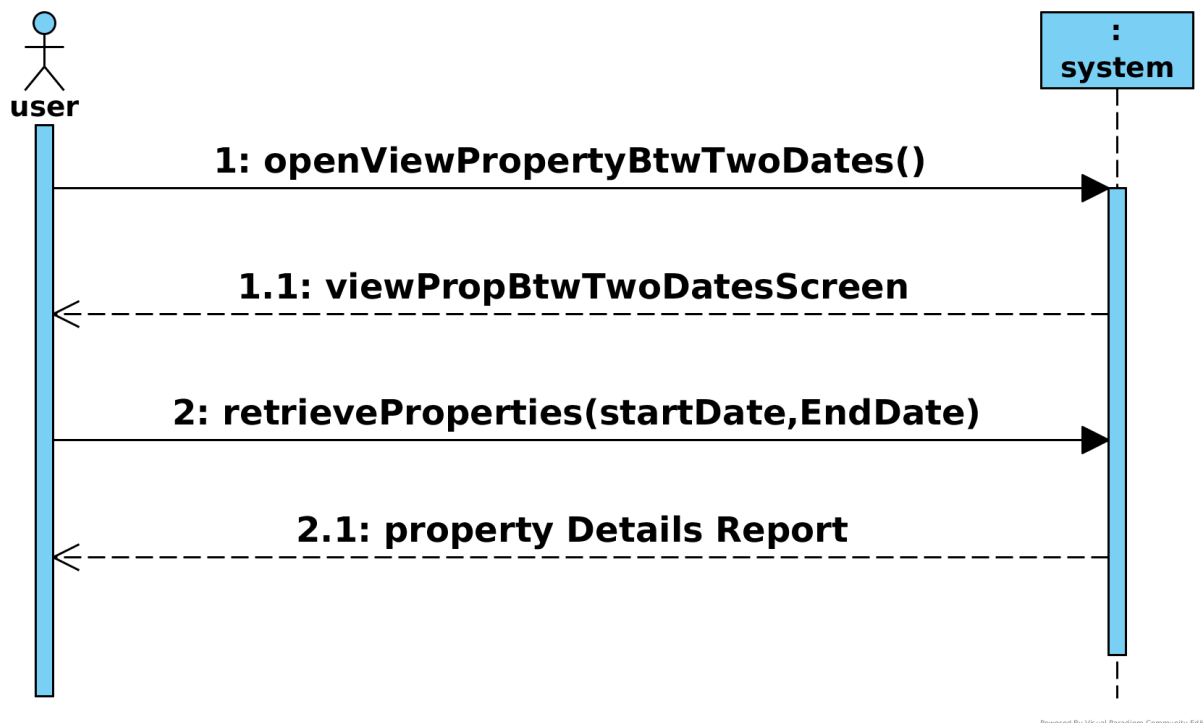

Figure 3.23: View Properties Mapped Between Two dates report Sequence Diagram.

3.15.2 Three Layer Sequence Diagrams

System sequence diagrams treats the system as a single object. It also has only two lifelines one for the actor and one for the system. The three layer sequence diagram is used to depict classes that collaborate and the messages they send and receive. They have more than one lifeline and multiple objects. The Objects in this sequence diagram are grouped into View layer classes, Business layer classes and data layer classes. View layer classes model the system interface. Business layer classes model the business logic while the data layer classes model the database access and storage. Table 3.25 below shows the stereotypes that are used to depict the view, business and data classes [72].

Table 3.25: Classes Stereotypes.

Class Name	Stereotypes
Boundary	
Entity	
Control	

Boundary classes represent the view layer classes. Entity classes are domain classes that wait for events to happen and they are active throughout the system operation. Control classes receive messages from the boundary classes and they pass them on to the entity classes. Entity and Control Classes make up the Business layer classes. Data layer classes get data from the Entity classes and save the data in the database [72].

Figure 3.24 shows the Create user three layer Sequence diagram. The view layer is made up of two boundary objects namely menu and createUser. The business layer is made up of the createUserHandler control object and the user entity object. The messages sent by the administrator initiates other messages that result in the saving of the user object.

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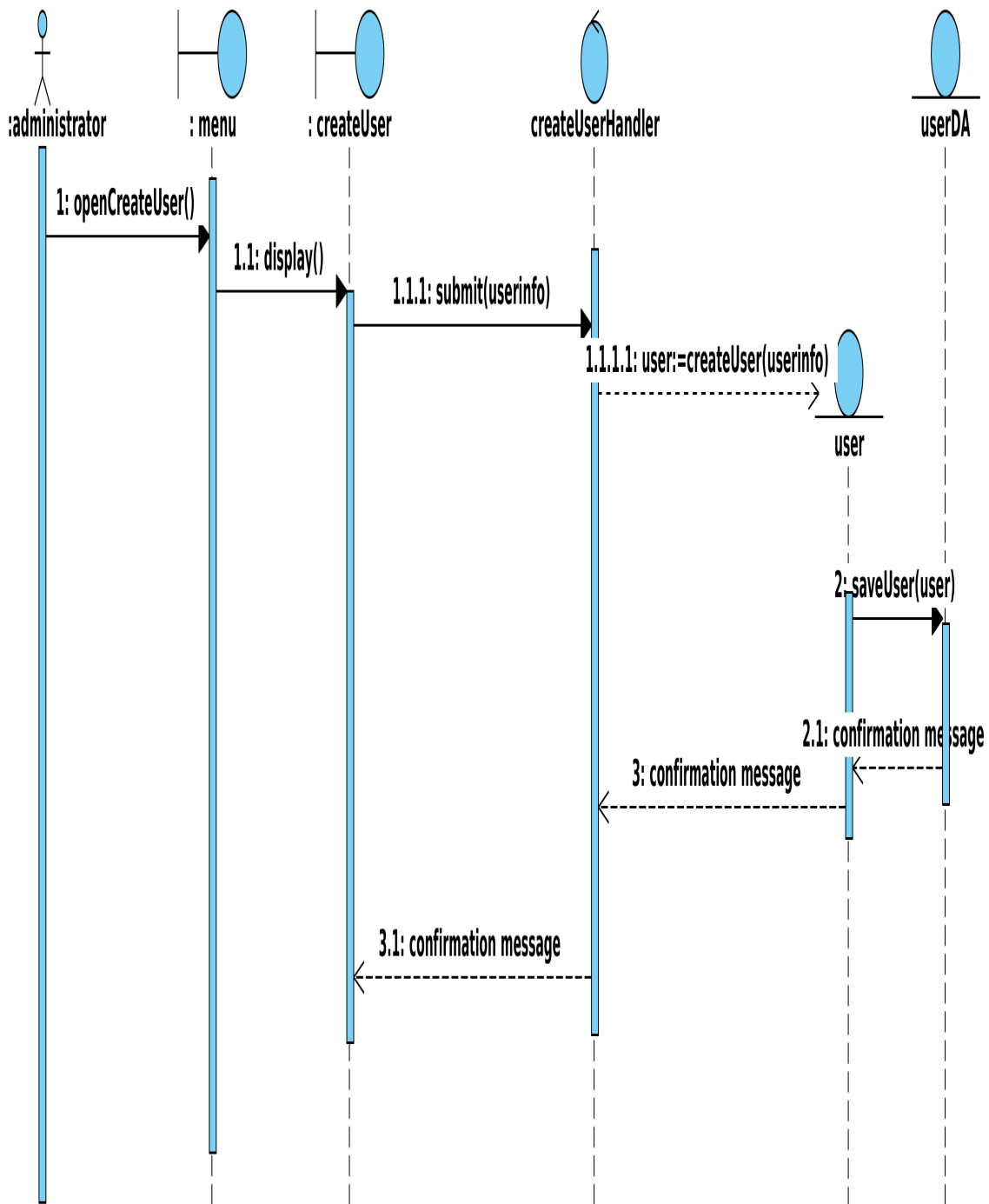
Figure 3.24: Create User Three Layer Sequence Diagram.

Figure 3.25 shows the Update user three layer sequence diagram. The view layer is made up of the menu and updateUser boundary objects. The business layer is made up of the updateUserHandler control object and the user entity objects. The data layer is represented by the userDA and loctionDA entity classes. The messages initiated by the administrator result in a series of messages sent among objects that result in the update of the user details.
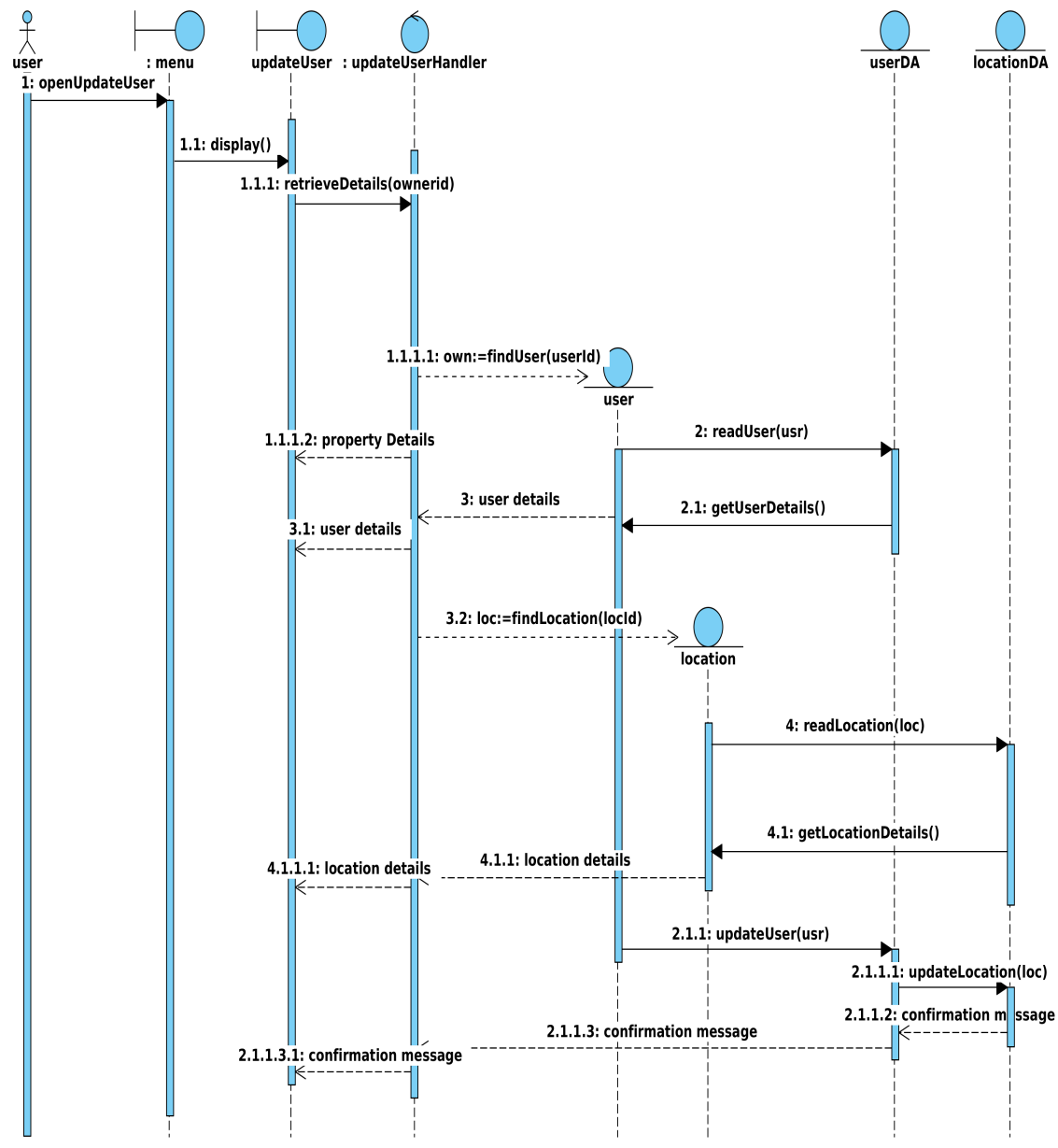
Figure 3.25: Update User Three Layer Sequence Diagram.

Figure 3.26 shows the Delete user three layer sequence diagram. The view layer is made up of the menu and deleteUser boundary object is made up of the deleteUserHandler object and the user entity object control objects and the user entity object. The data layer is made up of the userDA entity class. Messages are sent and the collaborations of the objects are shown.

Figure 3.27 shows the login three layer sequence diagram. The view layer is made up of the userLogin and MainMenu boundary objects. The Business Layer is made up of the userLoginHandler and the User entity classes. The data layer is made up of the userDA entity class object. Message passing and object collaboration are illustrated.
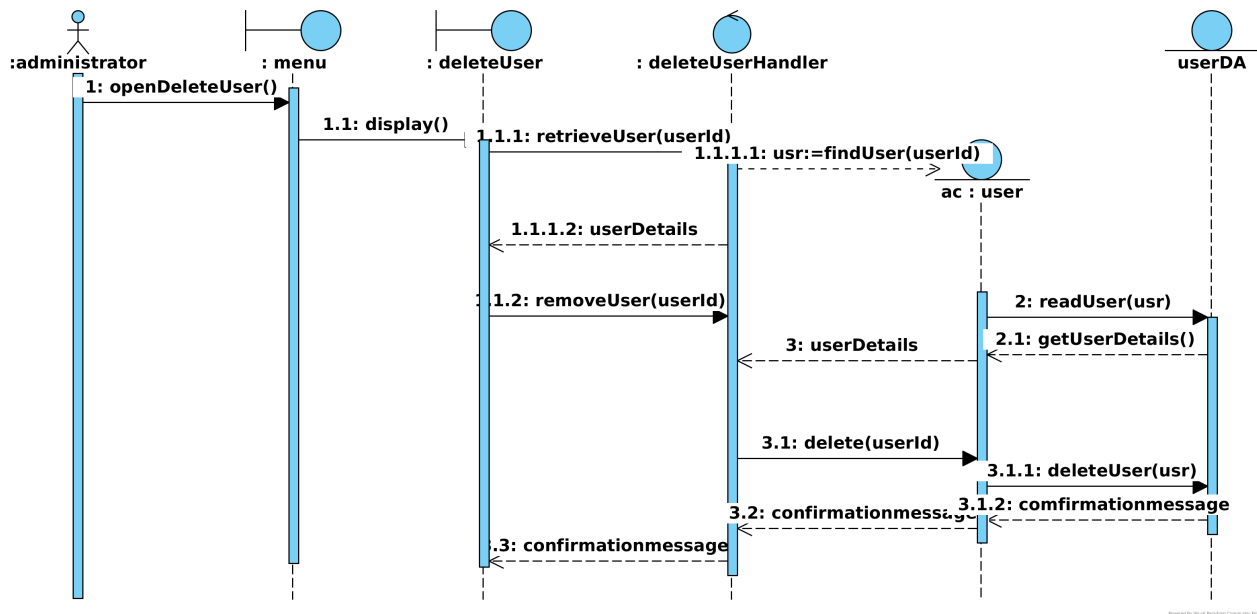
Figure 3.26: Delete User Three Layer Sequence Diagram.
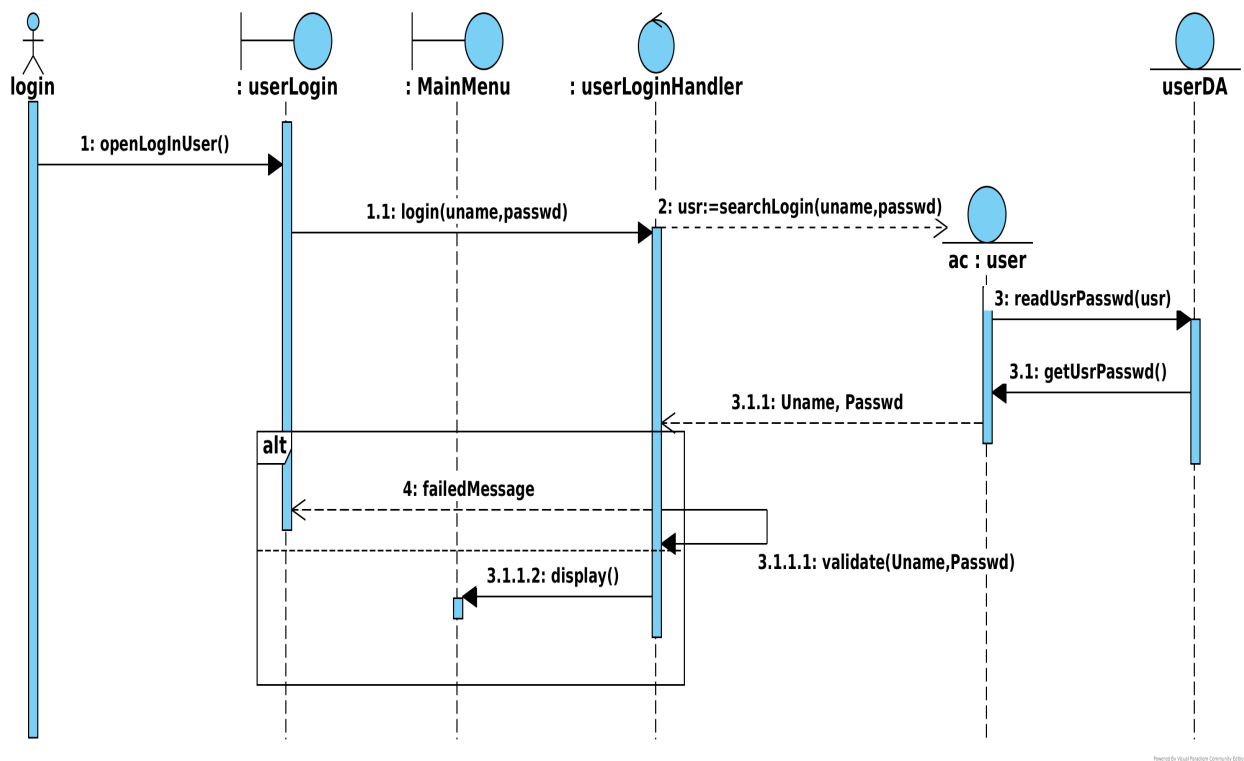
Figure 3.27: Login User Three Layer Sequence Diagram.

Figure 3.28 shows the view property record three layer sequence diagram. It is made up of boundary objects menu and viewProperty. The business logic is made up of the viewPropertyHandler control object and the entity objects property, owner, land, map and location. The data access layer is made up of the propertyDA, ownerDA, locationDA, landDA and mapDA. The objects collaboration and message exchanges are also depicted.
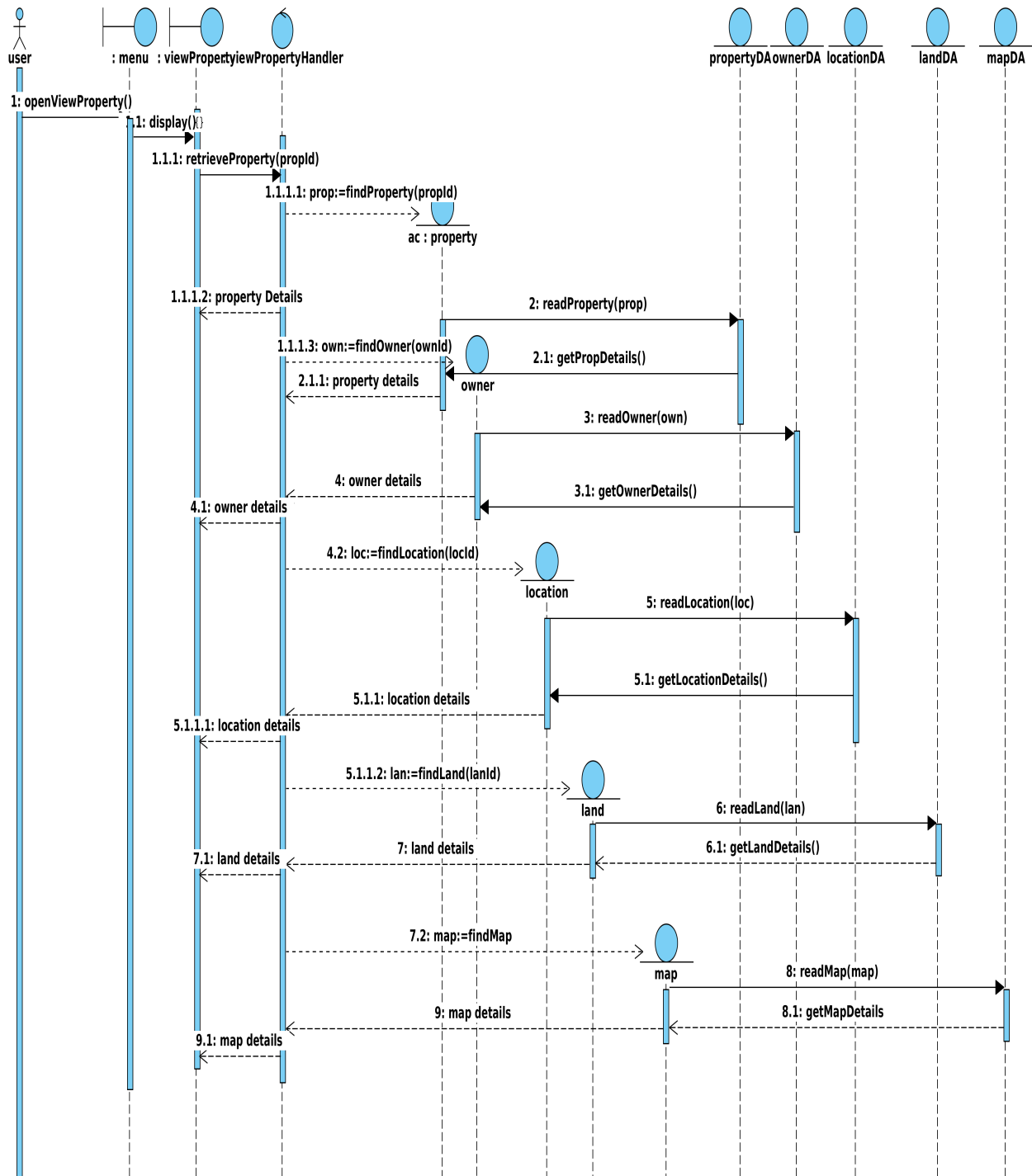
Figure 3.28: View Property Record three layer sequence diagram.

Figure 3.29 shows the Add property valuation Information three layer sequence diagram. Menu and addValuation info boundary objects make up the View Layer. The business layer is made up of the Entity objects property, owner, location, land, valuation and the viewPropertyHandler control object. PropertyDA, ownerDA, locationDA, landDA, and valuationDA objects constitute the data layer. Messages passing and object collaboration that result in the addition of valuation information are also shown.
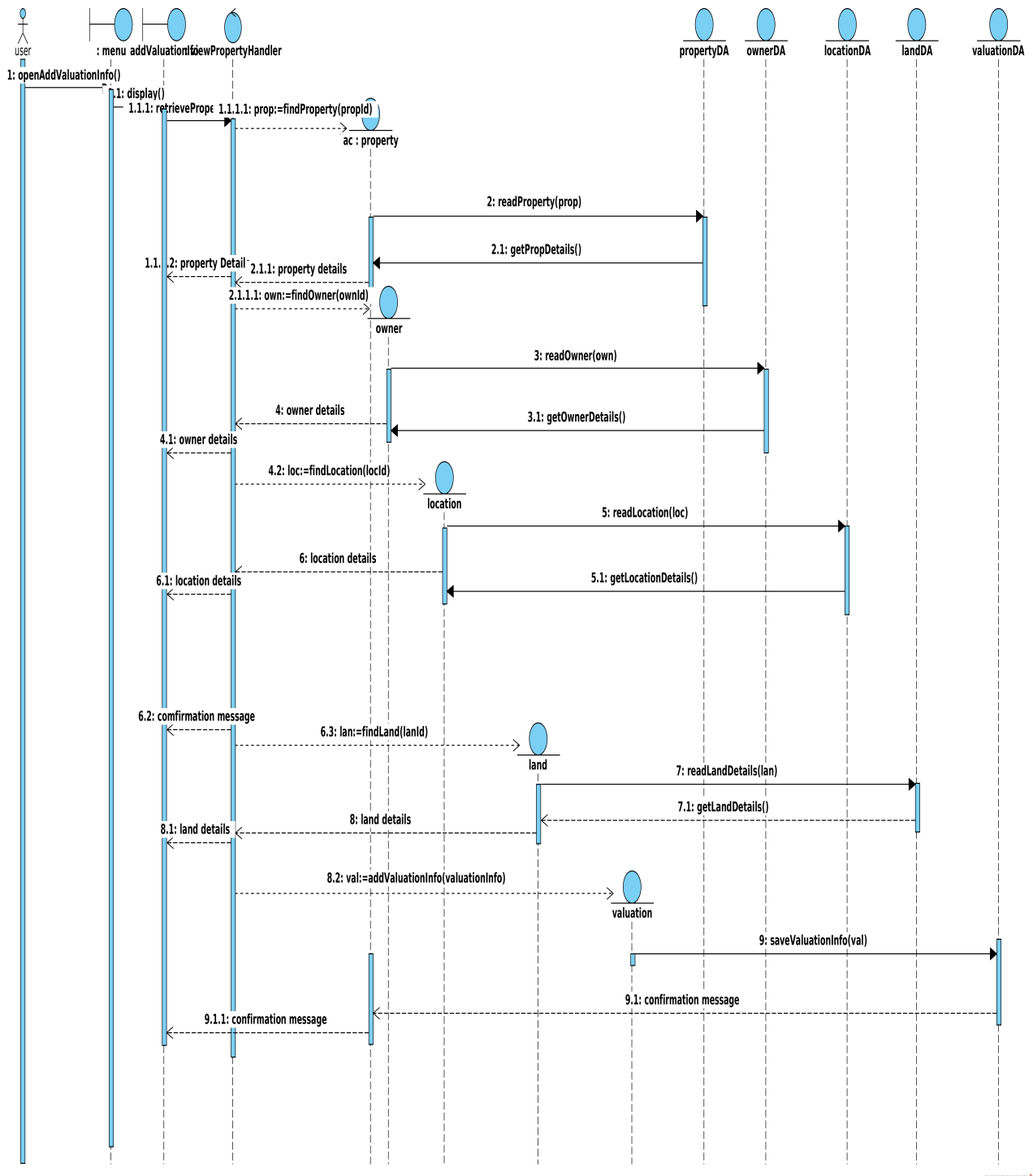
Figure 3.29: Add Property Valuation Data Three Layer Sequence Diagram.

Figure 3.30, 3.31, 3.32 show the Capture property details three layer sequence diagrams. Property detail capture is carried out in three stages namely owner, land and property information as shown by figures respectively. The messages, objects and objects collaboration are all depicted.
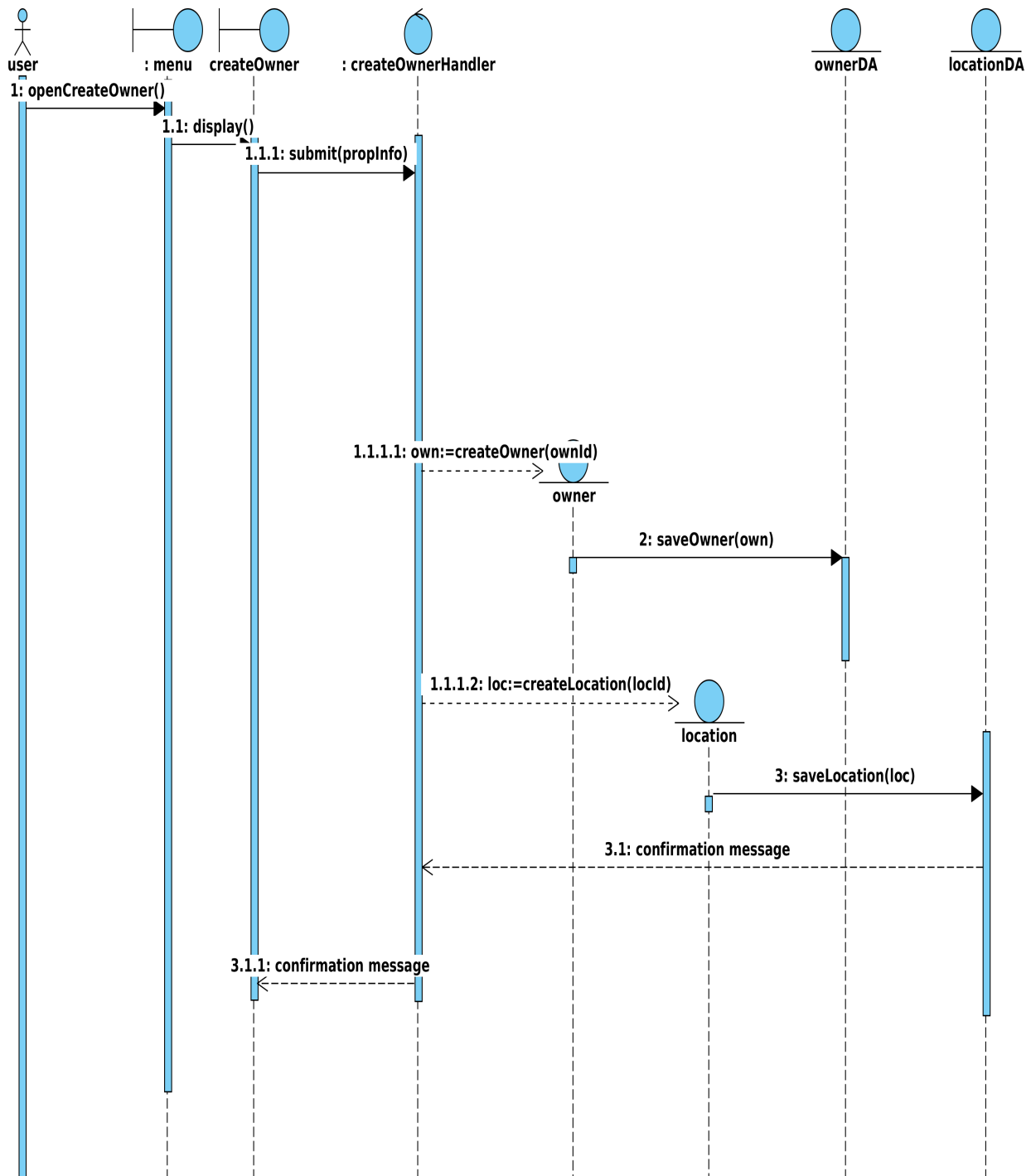
Figure 3.30: Create Owner Record Three Layer Sequence Diagram.
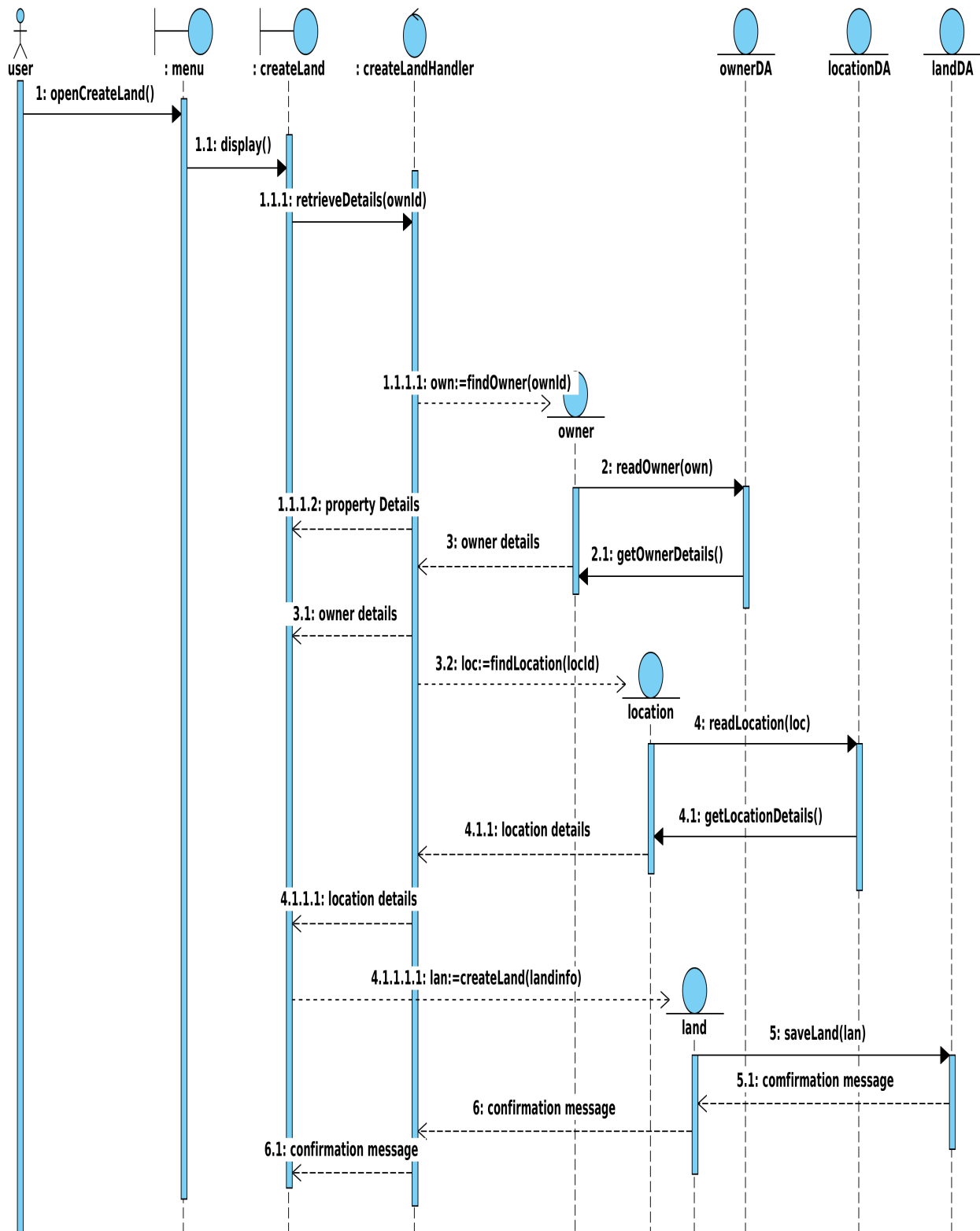
Figure 3.31: Create Land Record Three Layer Sequence Diagram.
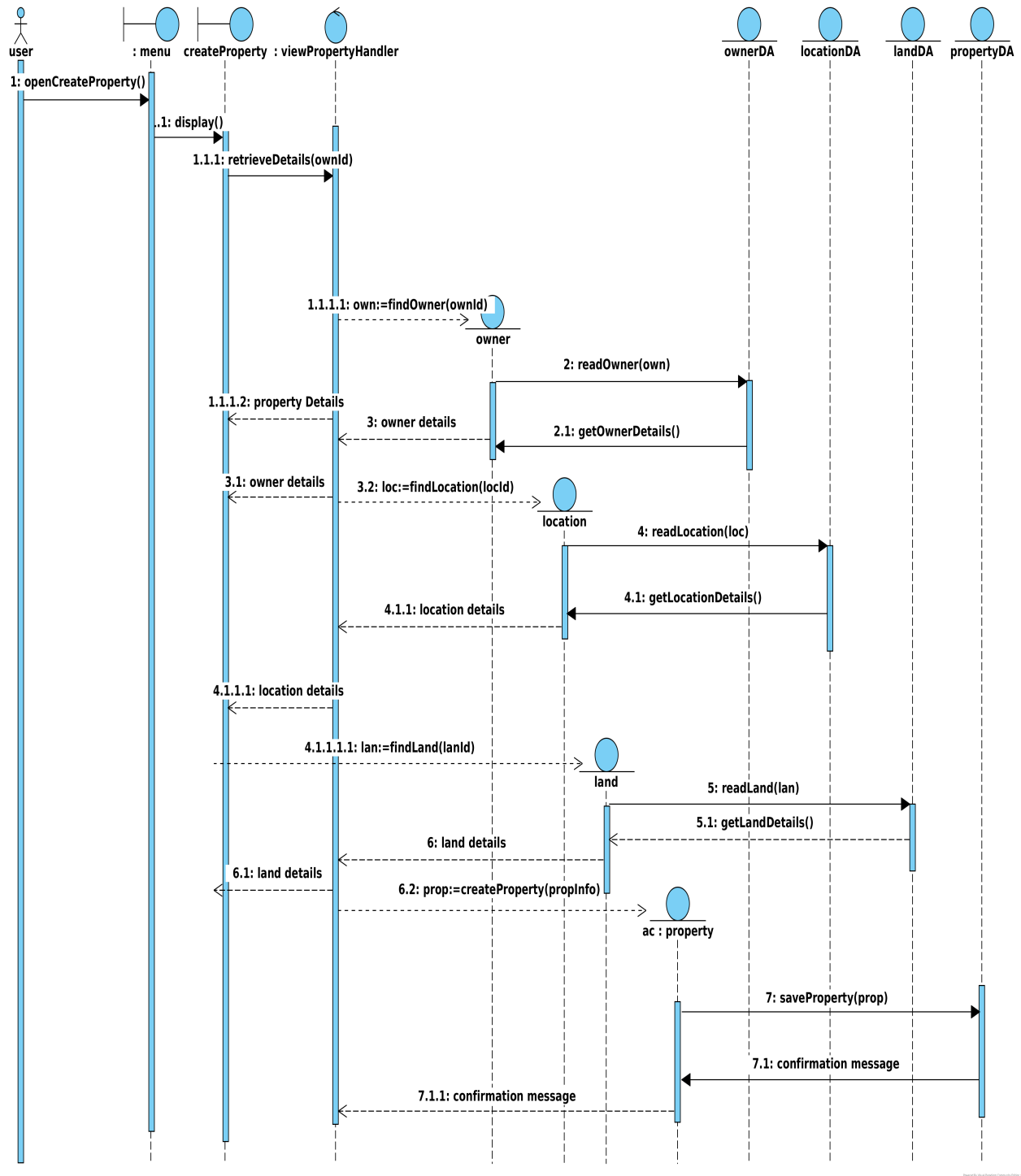
Figure 3.32: Create Property Record Three Layer Sequence Diagram.

Figure 3.33, 3.34, 3.35 shows the Update Property Records three layer sequence diagrams. Property update is also carried out in three stages namely owner, land and property information as shown by figures respectively. The messages, objects and objects collaboration are all depicted.
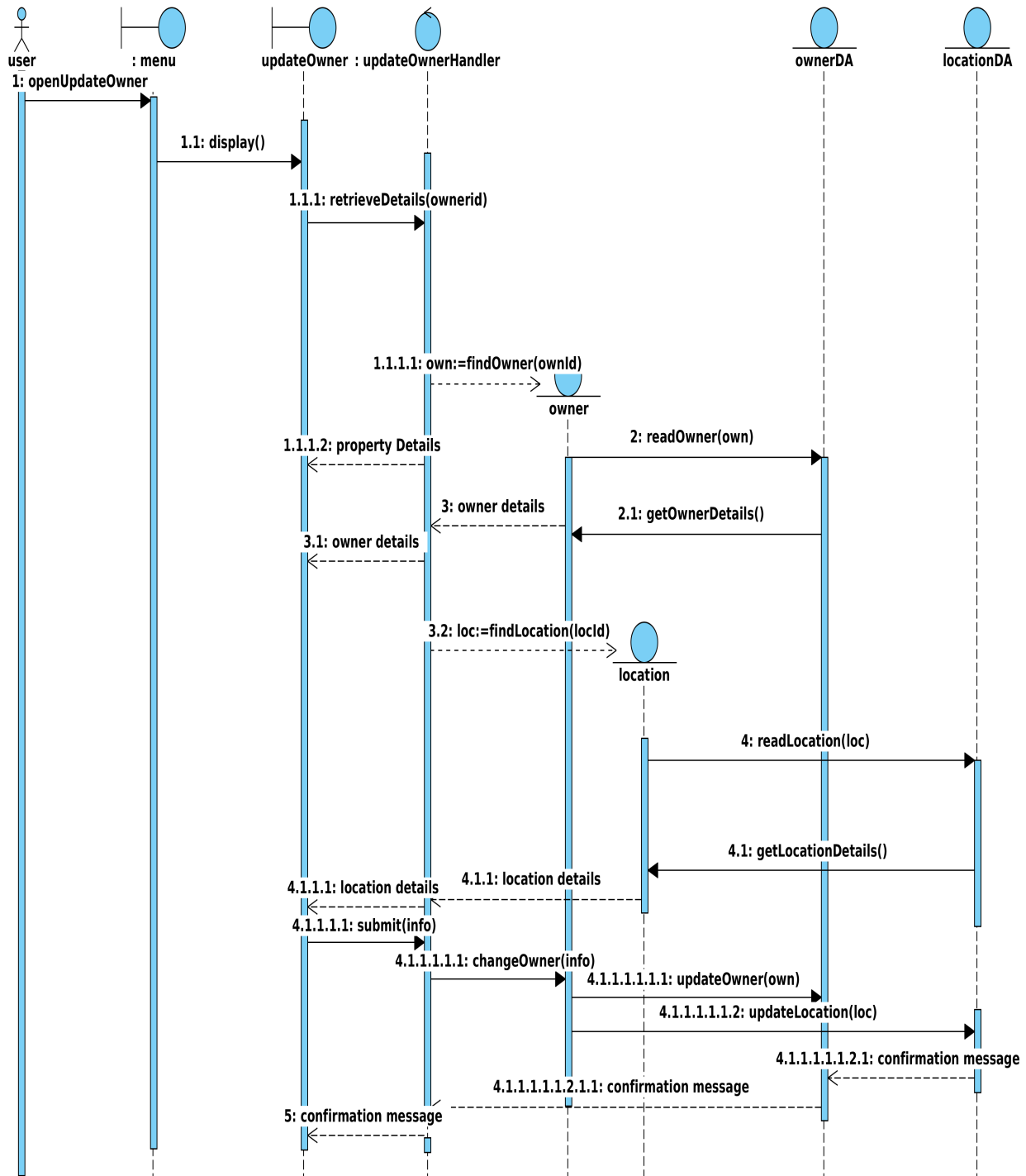
Figure 3.33: Update Owner Record Three Layer Sequence Diagram.

Figure 3.34 shows the Update land record three layer sequence diagram. It consists of menu and updateLand boundary objects that make up the view layer. The business layer is made up of the updatePropertyHandler control object and the entity object owner,location and land. The data layer is made up of the ownerDA, locationDA, and landDA. Object collaboration and message passing that result in the update of the land are also shown.
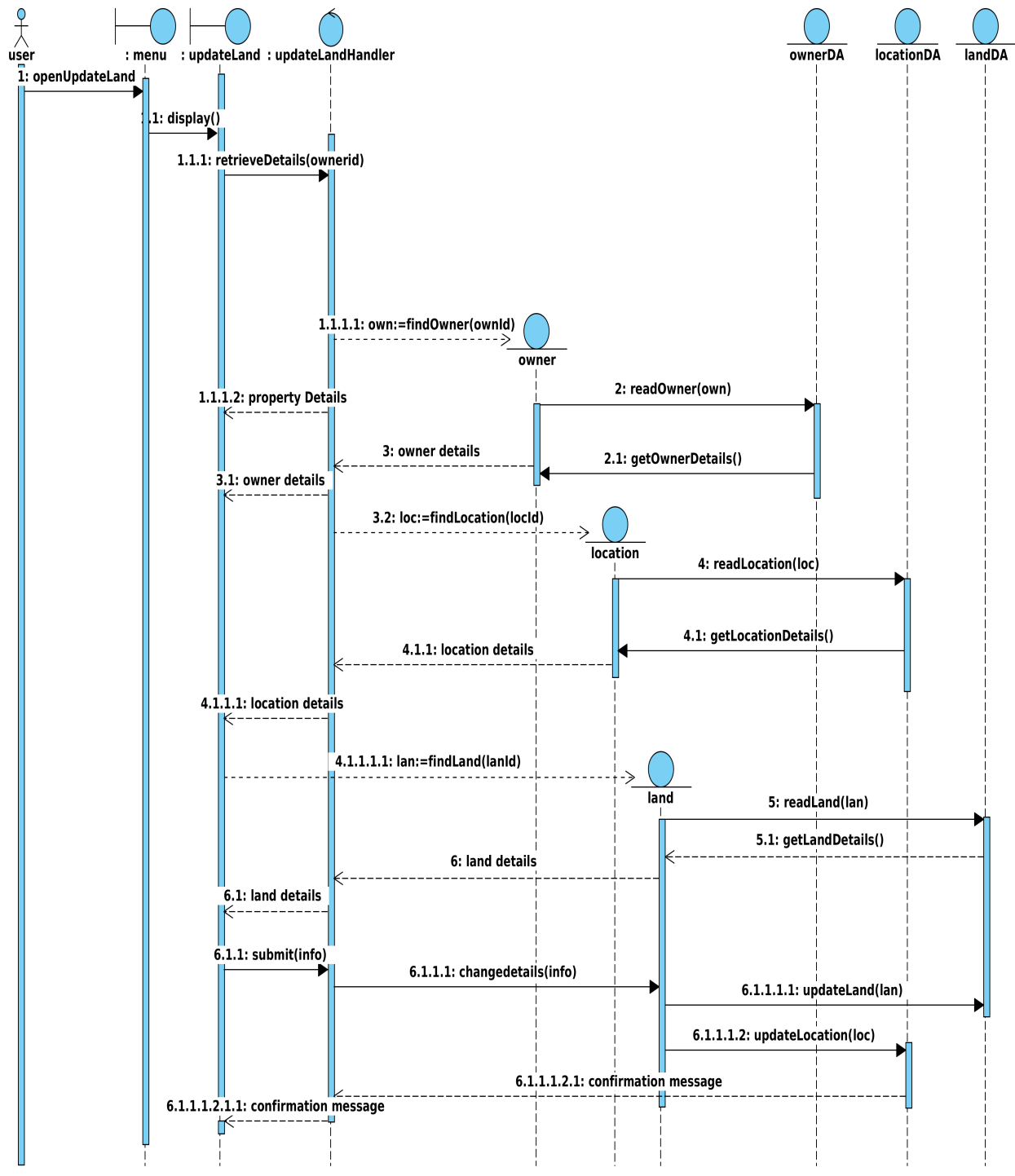
Figure 3.34: Update Land Record Three Layer Sequence Diagram.

Figure 3.35 shows the Update property three layer sequence diagram. The view layer is made up of the menu and updatePropertyInfo boundary objects. The business layer is made up of the property, owner, location, map and land entity classes and the viewPropertyHandler control object. The Data Layer is made up of propertyDA, ownerDA, locationDA and landDA objects. The object collaboration and message passing that result in the update of the property are also shown.
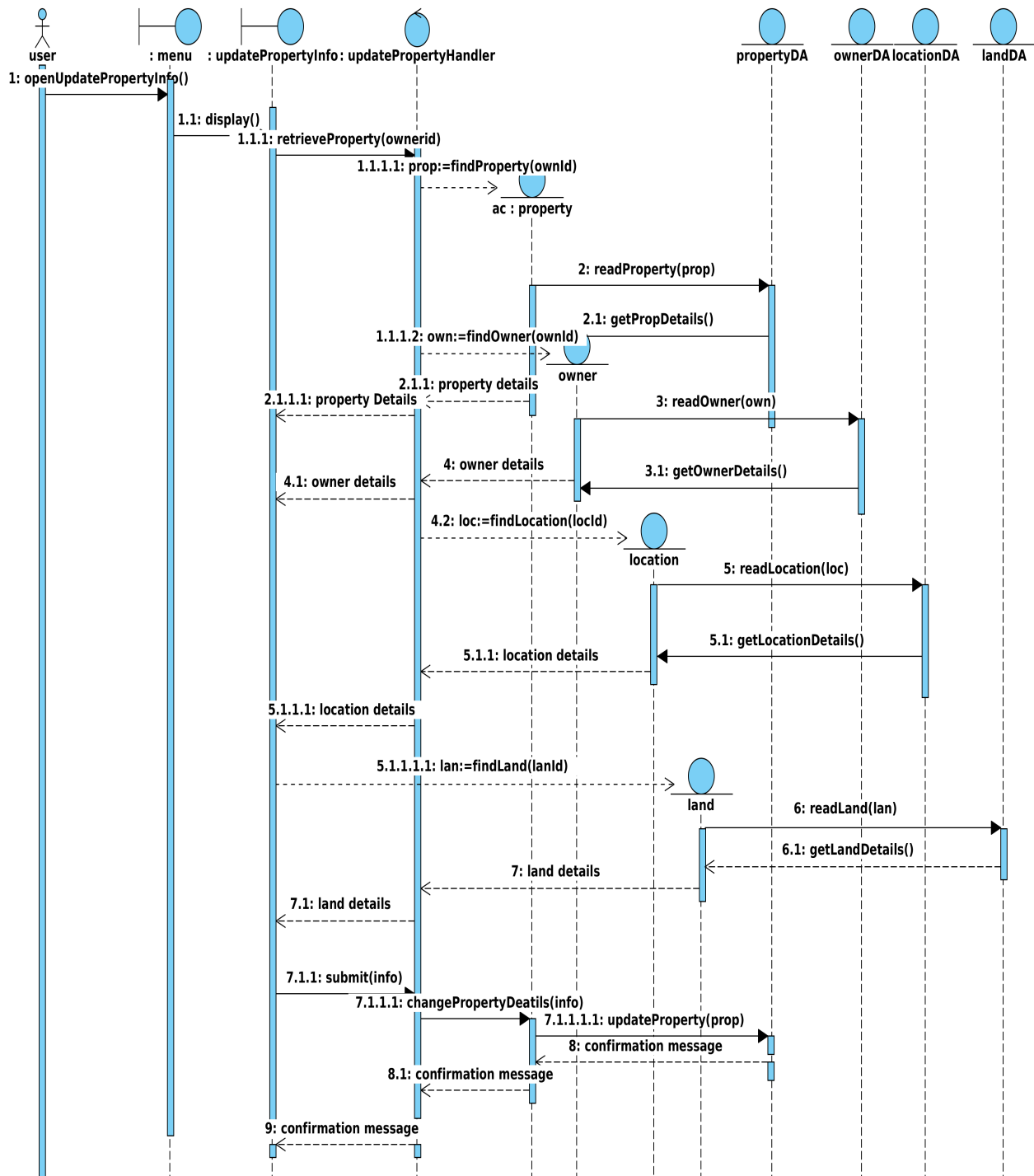
Figure 3.35: Update Property Record Three Layer Sequence Diagram.

Figure 3.36 shows the Delete property three layer sequence diagram. The view layer is made up of the menu and deleteProperty boundary objects. The business layer is made up of the property, owner and location entity classes and the deletePropertyHandler control object. The Data Layer is made up of propertyDA, ownerDA and locationDA, objects. The object collaboration and message passing that result in the mapping of the property are also shown.

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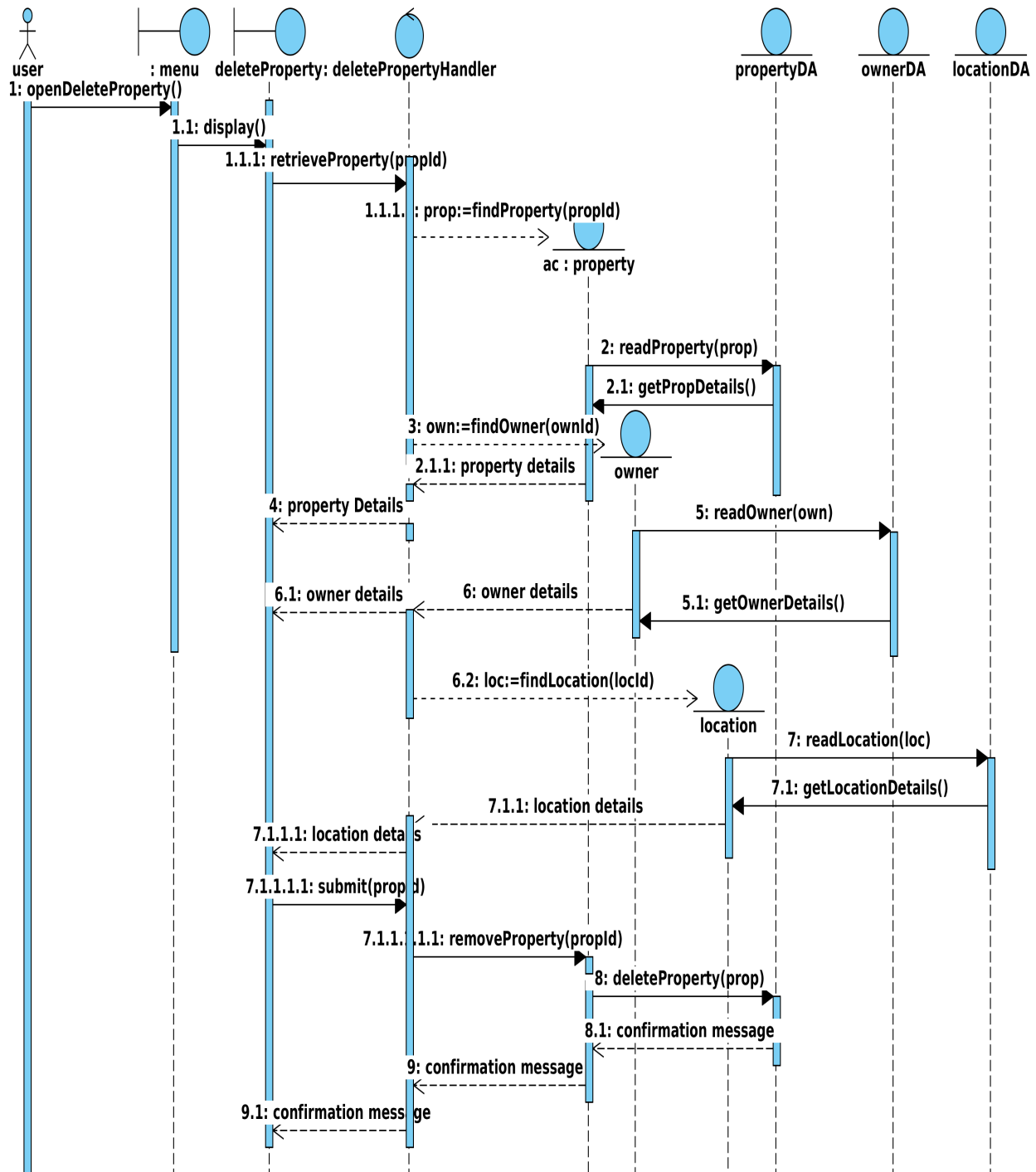
Figure 3.36: Delete Property Three Layer Sequence Diagram.

Figure 3.37 shows the Map property three layer sequence diagram. The view layer is made up of the menu and mapProp boundary objects. The business layer is made up of the property, owner, location and map entity classes and the mapPropertyHandler control object. The Data Layer is made up of propertyDA, ownerDA, locationDA and mapDA objects. The object collaboration and message passing that result in the mapping of the property are also shown. the getGPSCoord() message invokes the retrieveGPSCoord() message which in turn passes the GPS coordinates to the

CreateMap() message.
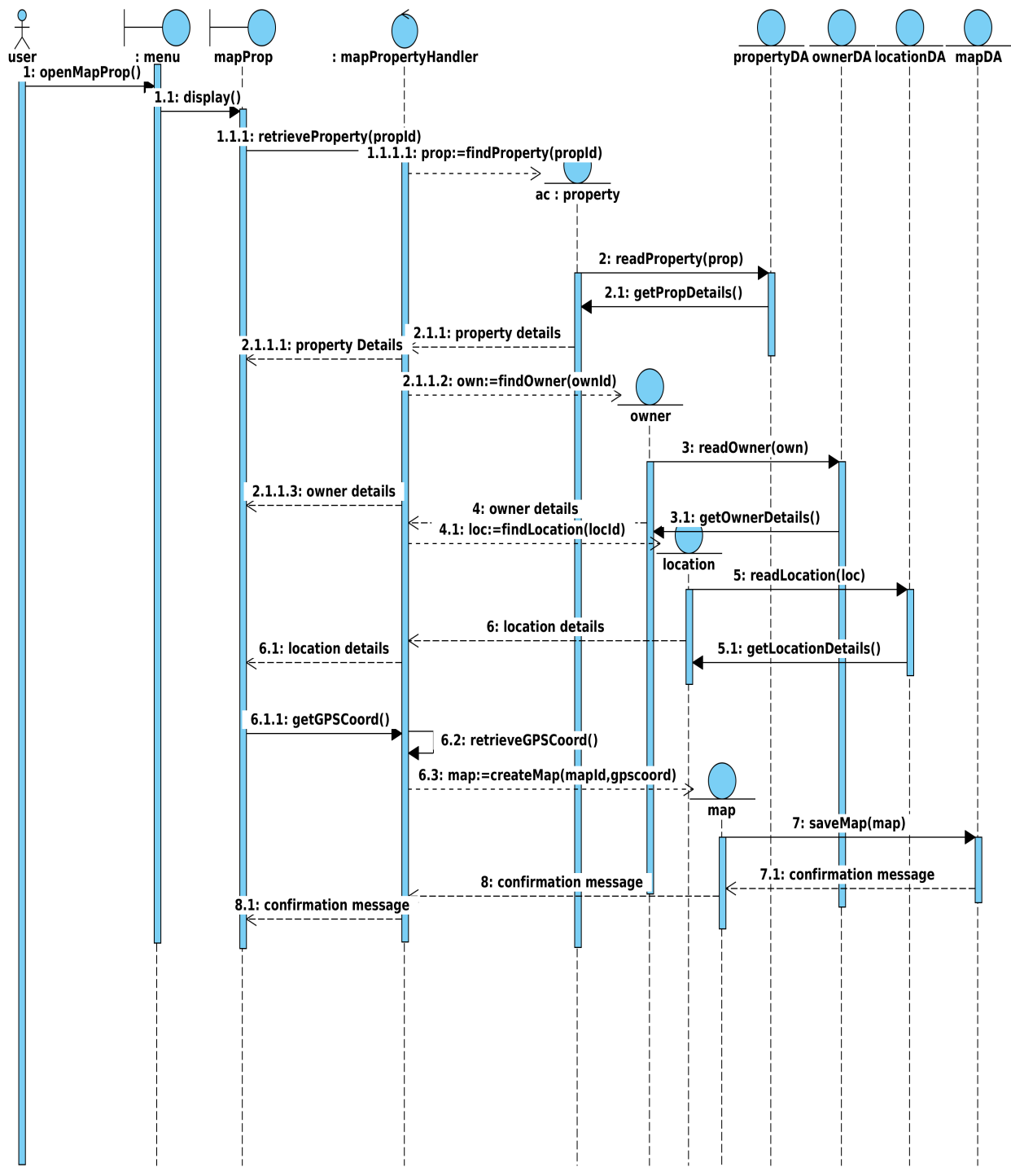
Figure 3.37: Map Property Three Layer Sequence Diagram.

Figures 3.38, 3.39and 3.39 shows the Properties Captured between two dates Report, Area mapping status report and valuation report three layer sequence diagrams respectively. The view layers are made up of boundary classes and control objects that constitute the business layers are shown. Messages initiated by the users and the subsequent collaborations and message exchanges among the objects are also shown.
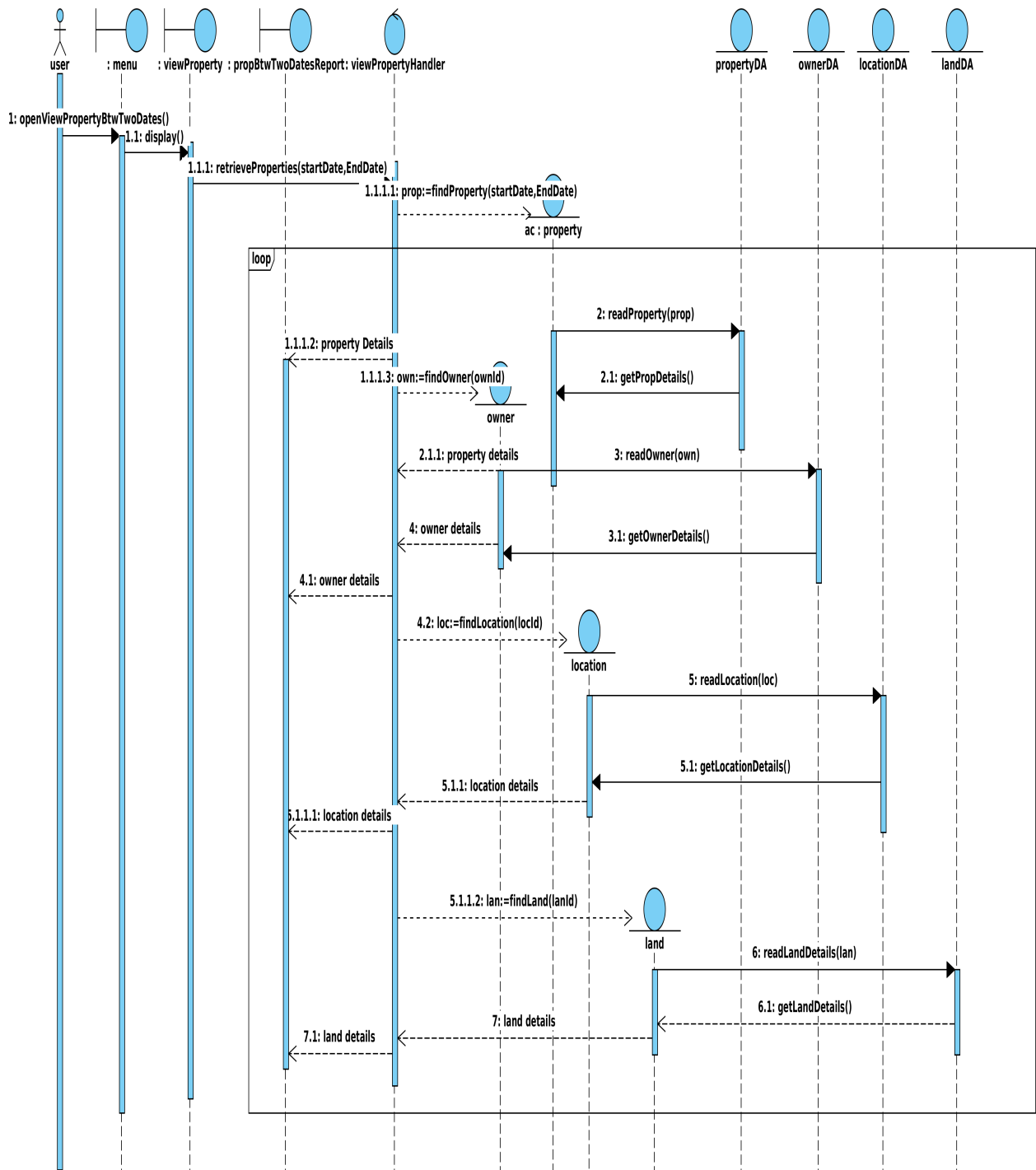
Figure 3.38: View Properties Captured Between Two Dates Report three layer sequence diagram.
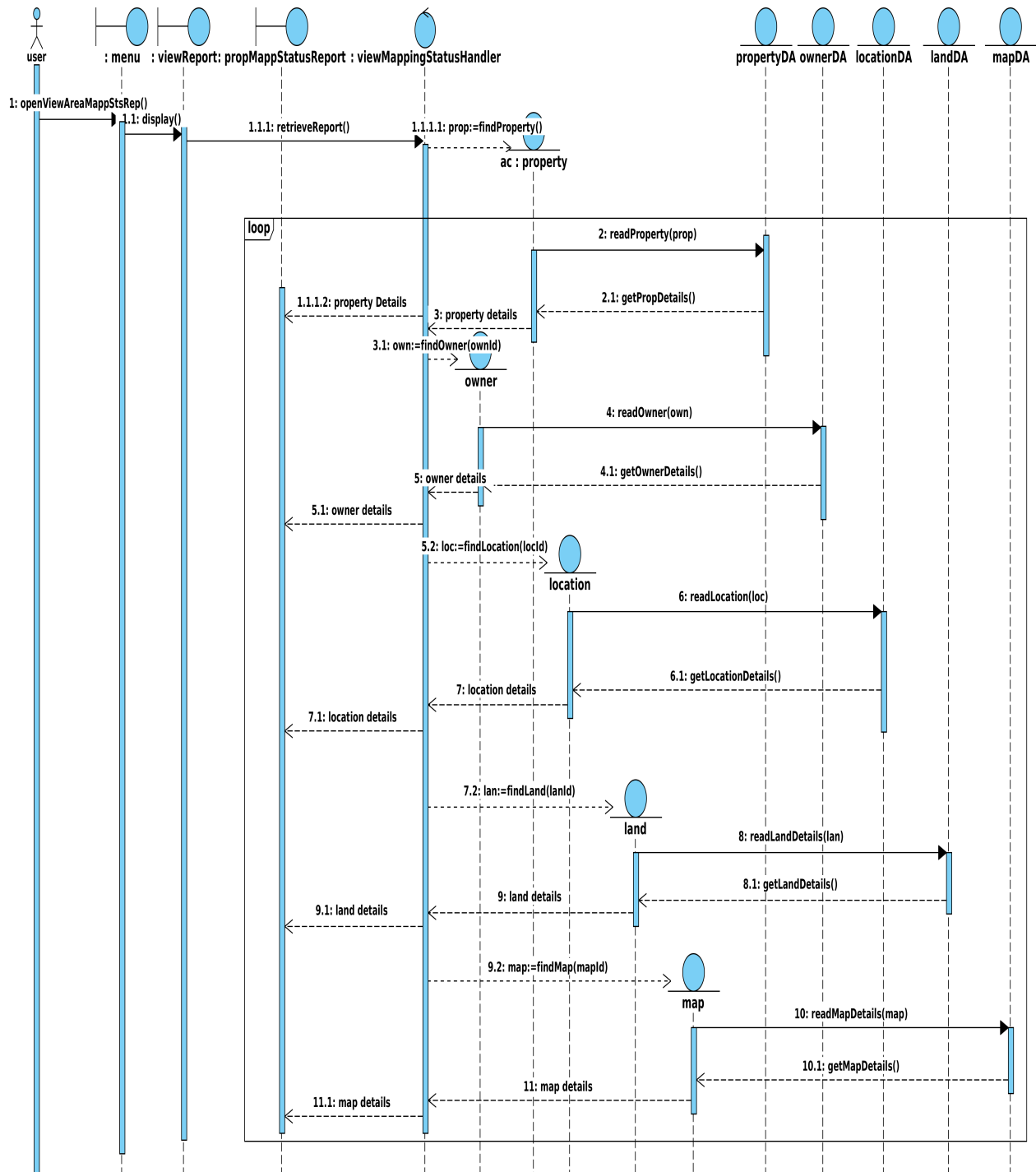
Figure 3.39: View Area Mapping Status Report Three Layer Sequence Diagram.
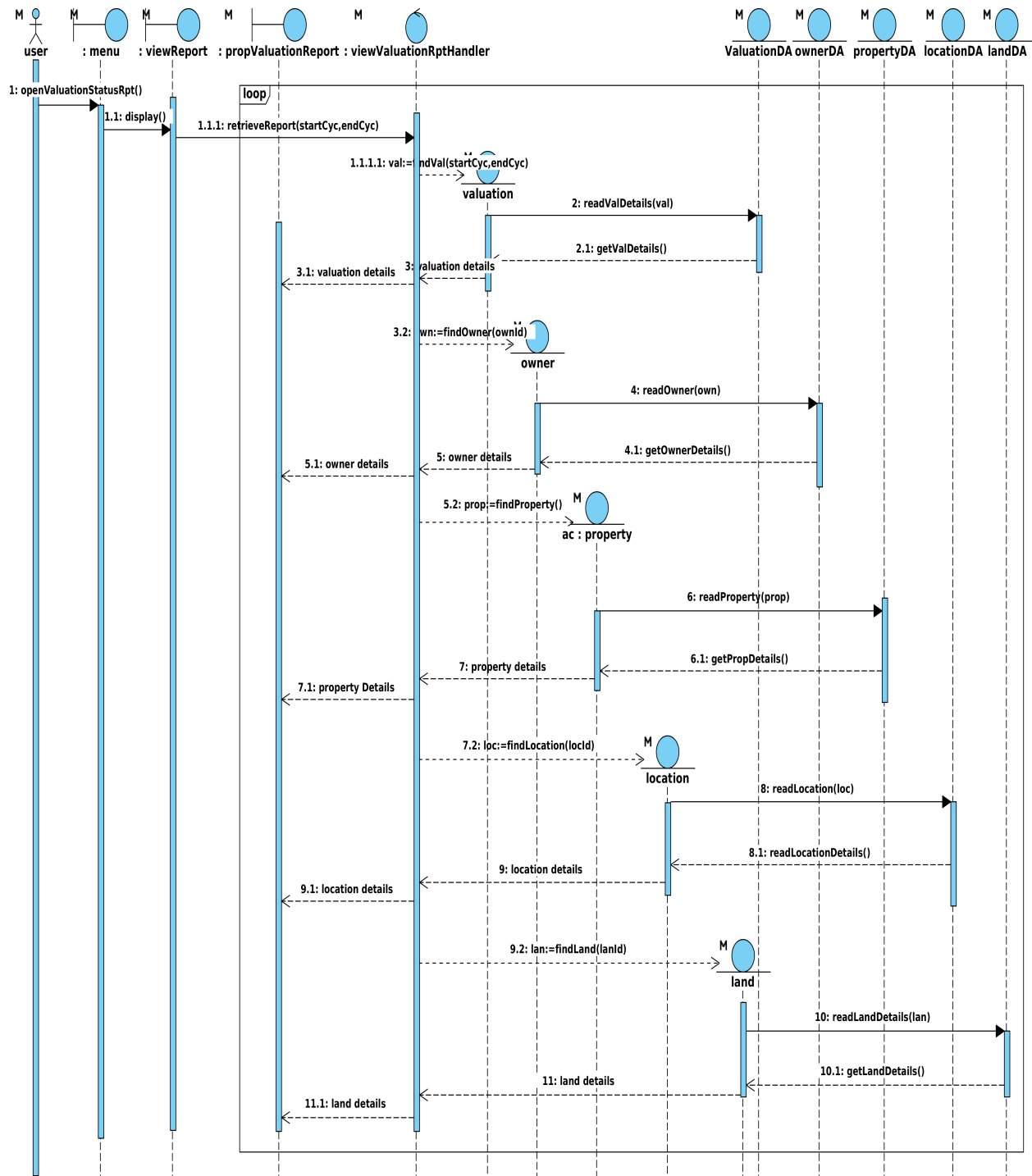
Figure 3.40: View Valuation Report Three Layer Sequence Diagram.

3.16 Class Diagrams

A Class is a collection of similar objects that exist in the system. Object oriented programming uses class diagrams to depict the classes in the system. They help programmers to think about the problem domain in terms of tangible natural intuitive objects that can easily be modelled. Classes also enable

code reuse by programmers thereby resulting in rapid application development [72].

Figure 3.41 shows the classes that were developed to model the Prototype field based GIS application. The classes model the map, location, land, user, owner, property, valuation, owner and individual entities that constitute the mapping problem. The relationships among the classes and data attributes of the classes are also shown in figure 3.42
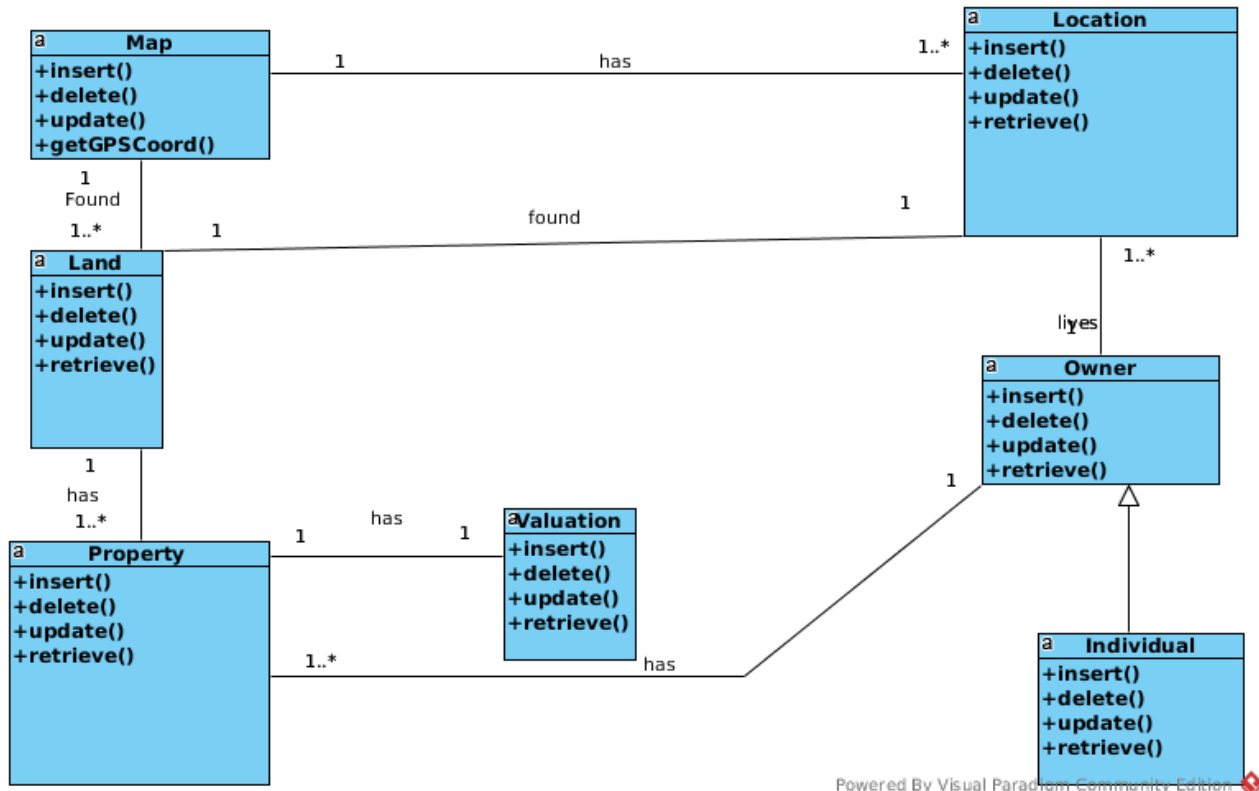
Figure 3.41: Class Diagram for the Prototype Mobile GIS Application.

3.17   Entity Attribute Relationship Diagram (ERD)

The user view of the conceptual database is represented by the ERD. The main components that constitute a database are depicted in the ERD. These include the entities, attributes and the relationships that exist among the entities. Entities are used to represent real world objects that a user is interested in.   Attributes describe the characteristics that an entity possesses.   Relationships represent associations among entities and they operate in both directions [73] [74].

Figure 3.42 shows the ERD diagram of the prototype mobile GIS application. The real world objects modeled that constitute the mapping problem include the map, location, land, user, owner, property, valuation, owner and individual.
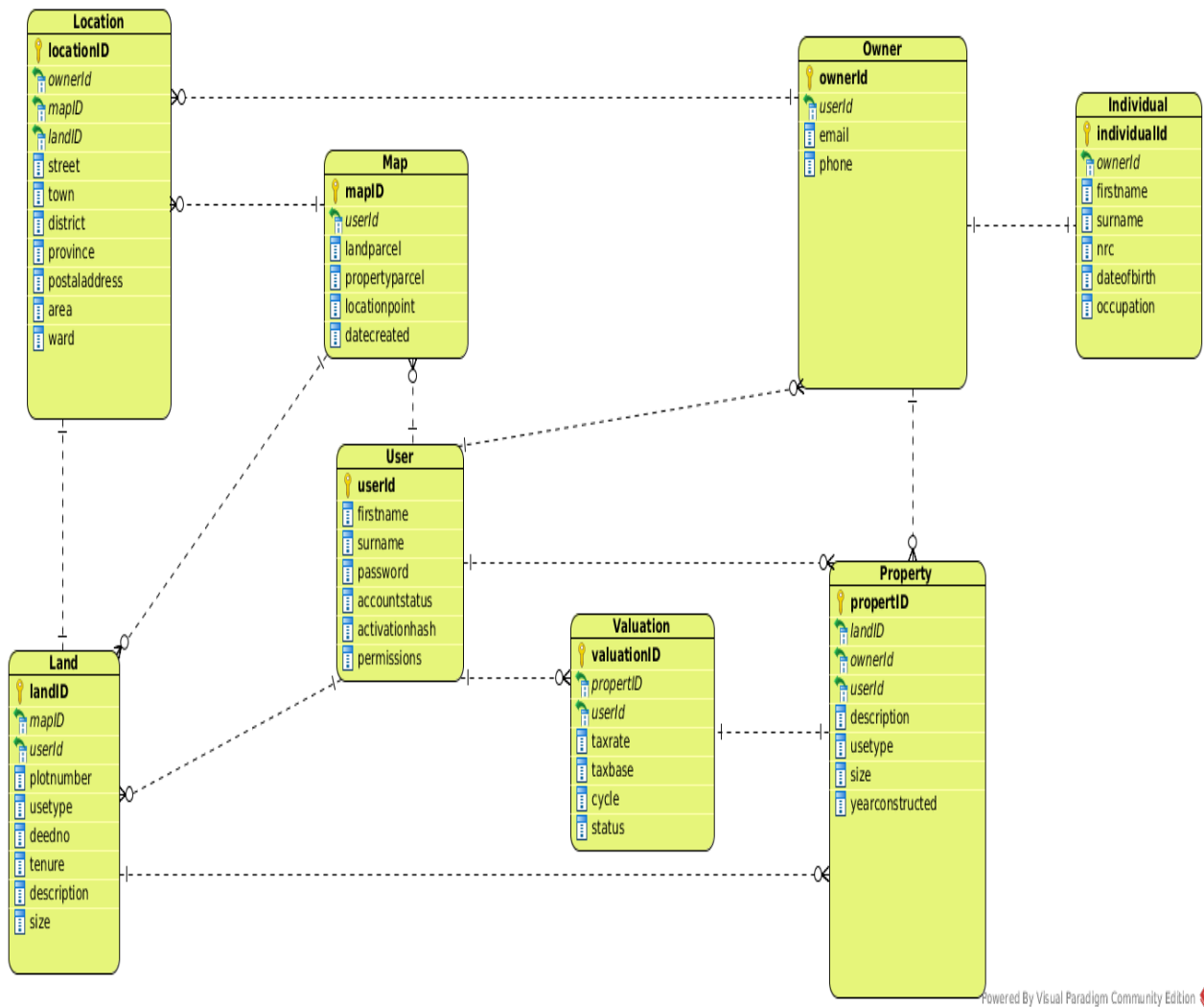
Figure 3.42: ERD for the Prototype Mobile GIS Application.

3.17.1 Summary Of Cardinality

The term cardinality is used to express the maximum number of an entity occurrence that is associated with the entity occurrence of another entity that is participating in the relationship. Participation determines whether all occurrences of an entity participate in a relationship [73].

Table 3.26 summarises the relationships and cardinality among all the entities as depicted in figure 3.42.

Table 3.26: Cardinality Summary

ENTITY	RELATIONSHIP	CARDINALITY	ENTITY
Owner	is	1..1	Individual
Owner	has	1..*	Property
Property	is	1..1	Valuation
Land	has	1..1	Property
Land	exists	1..1	Location
Owner	Lives	1..*	Location
Map	has	1..*	Locations
Map	Has Piece	1..*	Land
User	Create	1..*	Owner
User	Create	1..*	Property
User	Create	1..*	Land
User	Create	1..*	Valuation
User	Create	1..*	Map

3.17.2 Database Relational Schema Schema

A relational schema is a representation of database tables in text format. Each database table is described by its name followed by the attributes [73].

Table 3.27 shows the relational schema of the database entities shown in figure 3.42. It shows the entities and the corresponding data attributes. The primary keys and foreign keys are boldened. The first key represents the primary key. The rest of the attributes are shown with normal text formatting.

Table 3.27: Database Schema

ENTITY	ATTRIBUTES
Owner	**ownerId,userId,**email
Individual	**individualId,owerId,**firstname,surname,nrc,dateofbirth, occupation
Corporate	**corporateId,ownerId,**companyname,dateofincorporation,taxpayerId, businesstype
Property	**propertyId,landId,**ownerId,userId,description,usetype,titledeedno,tenure , description,size,yearconstructed
Land	**landId,mapId,userId,** plotnumber,usetype,titledeedno,tenure,description,size
Location	**locationId,ownerId,mapId,landId,**street,town,district,province, postaladdress,area,ward
Map	**mapId,userId,**landparcel,propertyparcel,locationpoint, datecreated
Valuation	**valuationId,propertyId,userId,**cycle,taxrate,taxbase
User	**userId,**firstname,surname,password,datecreated,activationhash, accountstatus,permissions

3.18 System Implementation

3.18.1 Software Tools Used

The Leaflet mapping library is an opensource JavaScript mapping library that is used for mobile friendly interactive maps. It has a very small JavaScript code footprint of only 38Kb and has most of the mapping features that developers require for use in their mapping application projects. It works on almost all the existing desktop and mobile platforms and it is scalable through the use of plugins [75] [76]. OpenStreetMaps are free vector maps that are being constructed by mapping volunteers around the globe. The OpenstreetMap (OSM) project was started because geographical data is not provided for free in many parts of the world and because of advances in affordable GPS technology. The affordable GPS units embedded in mobile devices have facilitated the voluntary creation of free vector maps by mapping volunteers around the world [77]. OSM is sometimes referred to as the Wikipedia of maps because the project facilities distributed work around a common product(maps). Its database contains geographic data for many parts of the world. Its website has a set of software tools that enables registered users to contribute to, download, or otherwise interact with the spatial database [78]. The most common method used to record spatial data is through a GPS receiver and the spatial data is later edited using the freely available editors. Additional information about the collected spatial is added by supplying attribute data and storing the final data set in the OSM database. Yahoo (up to 2011) and Microsoft Bing rendered support to the OSM project through the provision of various aerial images to the mapping community, which allows the OSM members to digitize data such as streets from the images [79]

PostgresSQL relational database with PostGIS extensions was used to store attribute and spatial data. PostGIS extensions provide support for geographic objects and facilitate the running of location based queries. PostGIS additionally provides features that are not usually found in other databases such as Oracle that support spatial features such as oracle [79] [80].

GeoJSON objects are geographical data formats coded in JavaScript Object Notation (JSON) that are used for encoding different geographic data structures. The geographic structures include point, polygon, multipoint, multistring and multipolygon geometries [81] [82].

Java, PHP and JavaScript programming Languages were used. The mobile device user interface was programmed using Java. The Integrated Development Environment (IDE) used was Android Studio.The Business Layer Logic was programmed in PHP using the Netbeans IDE. The PHP scripts and the leaflet JavaScript mapping library and plugins were hosted on the apache2 webserver. The Leaflet Mapping library was used for the rendering of the OpenstreetMaps vector maps and MapBox

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raster maps.

3.18.2 Hardware tools Used

Table 3.28 below lists the hardware specifications of the laptop computer and the mobile phone that was used in the trial mapping.

Table 3.28: Hardware Tools Used

Hardware	Specifications
Asus Laptop	-1TB HDD -5th gen Intel Core i5 processor 2.2 GHz with Burst Frequency upto 2.7 GHz -2GB Nvidia GeForce 920M -366 x 768 pixel resolution -64 bit Operating System
Huawei G630 Mobile Phone	-GSM/HSPA Network -720 x 1280 pixels (294 ppi pixel density) -Quad-core 1.2 GHz Cortex-A7r -4 GB, 1 GB RAM -Camera - Geo-tagging,8 MP Back , 1 MP front, autofocus, LED flash -GPS with A-GPS -Android 4.3 -microSD, up to 32 GB (dedicated slot)

3.18.3 Mapping Activity

Property owner details (Attribute data) was captured using the mobile application interface. Click and leave focus events on the mobile interface invoked PHP business logic scripts that were executed by the apache2 web server using data that was passed from the mobile application interface. The PHP Scripts connected to the PostegreSQL database and changed its state by either inserting, updating, retrieving or removing data depending on the requested operation. Property owner, spatial and image data retrievals were delivered to the mobile interface through PHP scripts and in some instances the JavaScript code.

Spatial data collection involved the use of either GPS coordinates retrieved from the embedded

GPS unit of the mobile device or trace drawing of land parcels using the Leaflet draw plugin. The land parcels were drawn on the MapBox provided satellite map of the trial property mapping area. The land parcels were further retrieved from the database and drawn on the OpenStreetMap vector map of the trial property mapping area using GeoJSON objects.

The coordinates for the land parcel captured through the mobile devices GPS unit or the tracing of the land parcel boundary on the MapBox satellite map were retrieved from the database as GeoJSON polygons by the php scripts and were passed to the leaflet JavaScript library and were drawn as geometric layers on top of the OpenStreetMap vector map of the trial property mapping area.

The OpenStreetMap vector map of the trial property mapping area (Parkview Estates of Kafue local authority) did not have roads and other points of interest before the trial of the property mapping of the field based GIS prototype application. Only foot paths were visible before the mapping. The researcher first mapped the area by using the embedded GPS unit of his mobile phone and OpenStreetMap mapping tools to include roads and points of interest. The researcher waited for about five days for the changes to become visible on the global OpenStreetMap vector map. The mapping of roads facilitated the smooth mapping of property land parcels and made the whole land parcel mapping presentable.

A total of Ten property land parcels were mapped on the ground in Parkview Estates residential area of Kafue local authority using the field based GIS prototype application. The Laptop Computer ran the Ubuntu 14.04, apache2 webserver and PostgresSQL database was used to simulate the application and the database servers respectively. The OpenStreetMap and MapBox tile maps were accessed over the internet using the mobile phone's HSDPA connection provided by MTN Zambia a mobile phone service provider. Connectivity to apache2 and PostgresSQL on the laptop was provided by the mobile phone hotspot and this simulated connectivity to the local Authority data centre through wifi, VPN or the Internet

3.19   Chapter Summary

In this chapter we described in detail the methods and materials that were used in this study. We began by discussing the ground truth exercise survey that was conducted and then proceeded to discuss the Modeling, Design and Implementation of the field based GIS prototype application. Research objective one and two in the introduction chapter, was addressed by the Ground truth excercise that was carried out using structured questionnaires and interviews administered to the four local authorities and one planning authority. This excercise facilitated the assessment of the existing

methods used to identify and capture property for property tax purposes and also the associated challenges. Objective two was addressed by the procecess of formulating the systems requirements using the output from the ground truth excercise. System modelling and implementation also ensured that the mobile prototype application was developed and trialed in the field. The trial provided an opportunity for the developed application to be validated against the user requirements that were formulated.

CHAPTER 4

RESULTS

4.1 Chapter Overview

In this chapter, the results of the ground truth exercise that was conducted to investigate challenges of property identification and capture are presented. The existing current business processes used in the identification and capture of properties is also presented. In addition, the implementation of field based GIS prototype is also presented through screen shots.

4.2 Ground Truth Exercise

4.2.1 Demographic Data

Forty Questionnaires were collected from Four local authorities and the Lusaka province planning authority. Table 4.1 shows the distribution.

Table 4.1: Questionnaires Distribution Table

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
	Lusaka City	12	30	30	30
	Chilanga	11	27.5	27.5	57.5
	Chongwe	7	17.5	17.5	75
	Kafue	7	17.5	17.5	92.5
	Planning Authority	3	7.5	7.5	100
Total		40	100	100	
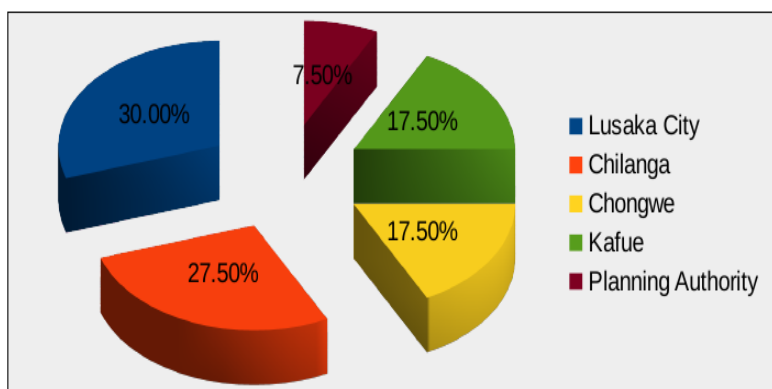
Figure 4.1: Demographic Data Pie Chart.

The respondents in figure 4.1 were as follows. 12 (30 percent) from Lusaka City Council, 11(27.50 percent) from Chilanga District Council. 7(17.50 percent) from Chongwe District Council, 7 (17.50 percent) from Kafue District Council and 3(7.50 percent) from Lusaka Province planning Authority.

4.2.2 Disparity Between Physical Properties on the Ground and the Register

The results of the respondents, when asked whether there was a disparity between physical properties on the ground and the properties in the current register are shown in table 4.2. The results show that 71.05 percent admitted that the disparity existed and 28.95 percent said a disparity did not exist. Two respondents did not answer the question.

Table 4.2: Disparity Between Physical Properties on the Ground and the Property Register Table

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
Yes	1	27	67.5	71.05	71.05
No	2	11	27.5	28.95	100
	9	2	5	Missing	
Total		40	100	100	

Figure 4.2 shows the summary of the responses in pie chart form.
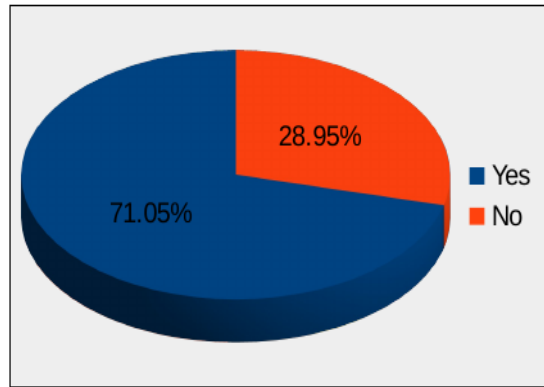
Figure 4.2: Disparity Between Physical Properties on the Ground and the Property Register Table.

4.2.3 Locating Property Using Existing Property Register

The results of the respondents, when asked about how difficult it was to locate the physical properties on the ground using the property register, are shown in Table 4.3. 43.59 percent of the Respondents said it was easy, 43.59 percent said it was difficult, 10.26 percent said it was very difficult and 2.56 percent said it was very easy. One respondent did not provide the answer.

Table 4.3: Locating Property Using Existing Property Register Table

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
Easy	1	17	42.5	43.59	43.59
Difficult	3	17	42.5	43.59	87.18
Very Difficult	4	4	10	10.26	97.44
Very Easy	2	1	2.5	2.56	100
	9	1	2.5	Missing	
Total		40	100	100	

Figure 4.3 is shows the summary of the data in Table 4.3 in form of a bar chart.
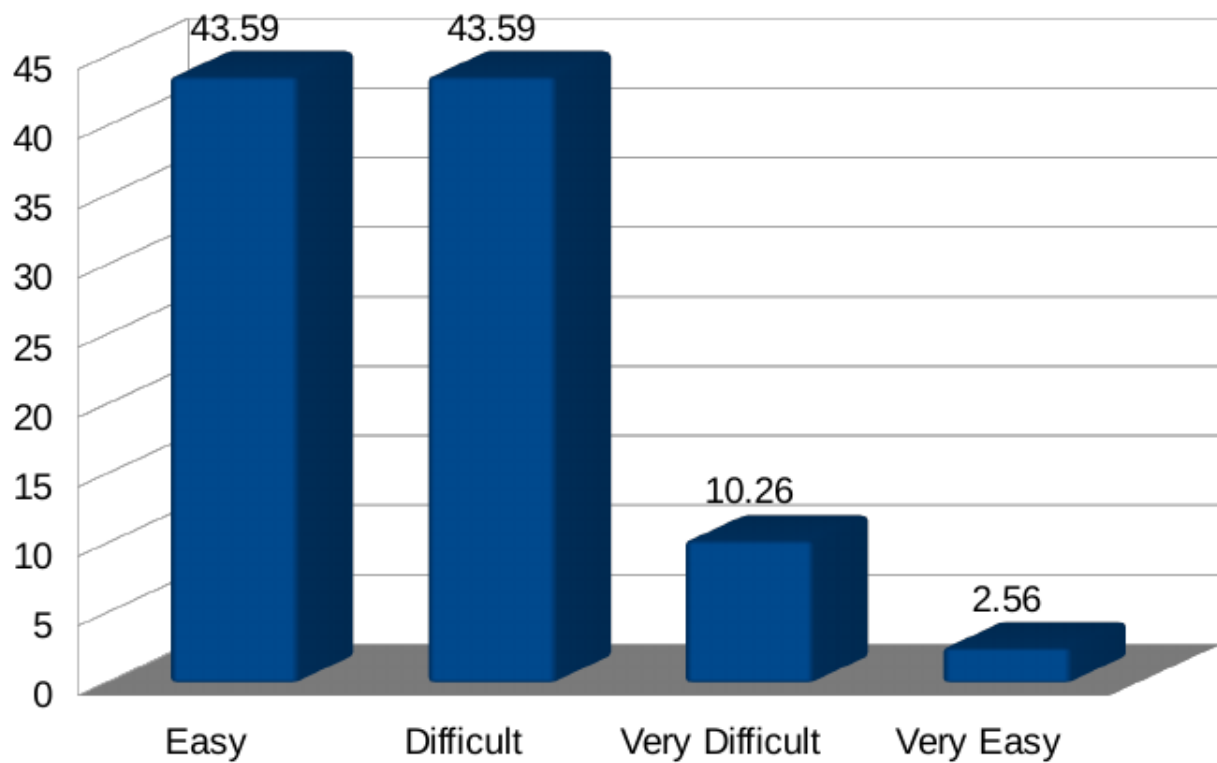
Figure 4.3: Locating Property Using Existing Property Register Bar Chart.

4.2.4 Property GPS Coordinates

Table 4.4 shows the results of the respondents when asked whether the current property registers had GPS Coordinates or not. 82.5 percent responded that the current property registers did not have the coordinates while 17.50 percent responded that they had.

Table 4.4: Property GPS Coordinates Table.

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
No	2	33	82.5	82.5	82.5
Yes	1	7	17.5	17.5	100
Total		40	100	100	

Figure 4.4 summarises the data in table 4.4 in a pie chart.
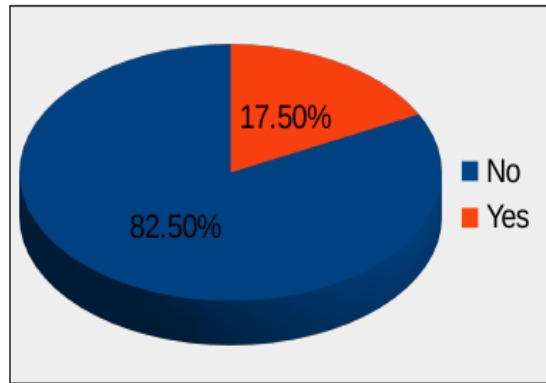
Figure 4.4: Property GPS Coordinates Table.

4.2.5 Street Names and Unique Property Numbers

Table 4.5 shows the results of the respondents when they were asked whether the current property registers had street names and unique property numbers. 65 percent responded the current registers did not have the street names and unique property numbers while 35 percent responded that they did.

Table 4.5: Street Names and Unique Property Numbers Table.

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
No	2	26	65	65	65
Yes	1	14	35	35	100

Figure 4.5 summarises the data in table 4.5 in pie chart form.
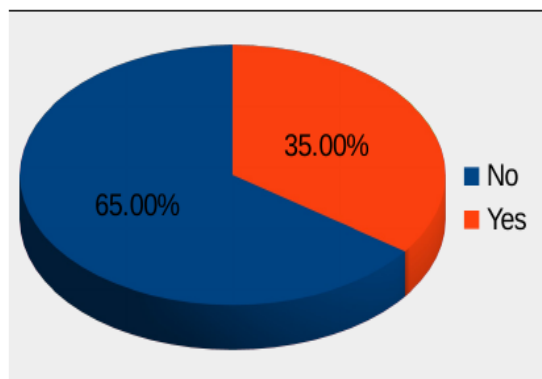
Figure 4.5: Street Names and Unique Property Numbers Pie Chart.

4.2.6   Up to Date Property Maps

Table 4.6 Show the results of the respondents when asked whether the current property maps were not Up to Date. 84.62 percent of the respondents said that they were Up to Date while 15.38 percent that they were not. One respondent did not provide an answer.

Table 4.6:   Up to Date Property Maps Table.

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
No	2	33	82.5	84.62	84.62
Yes	1	6	15	15.38	100
	9	1	2.5	Missing	
Total		40	100	100	

Figure 4.6 summarises the data in table 4.6 in pie chart form.
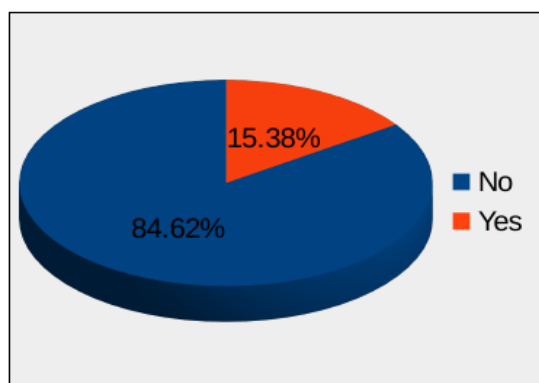
Figure 4.6:   Up to Date Property Maps Table Pie Chart.

4.2.7   Time to Register Property in Existing Property Register

The results of the respondents when asked about how long it took to register a single property are shown in table 4.7. 31.58 percent of the respondents said they did not know, 28.95 percent said it took more than 24 hours, 26.32 percent said it took 1-4 hours and 13.16 percent said it took 1-8 hours. Five respondents did not provide an answer.

Table 4.7: Time to Register Property in Existing Property Register Table.

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
Do Not Know	4	12	30	31.58	31.58
More than 24 Hours	3	11	27.5	28.95	60.53
1-4 Hours	1	10	25	26.32	86.84
1-8 Hours	2	5	12.5	13.16	100
	9	2	5	Missing	
Total		40	100	100	

Figure 4.7 summarises the data in table 4.7 in pie chart form.
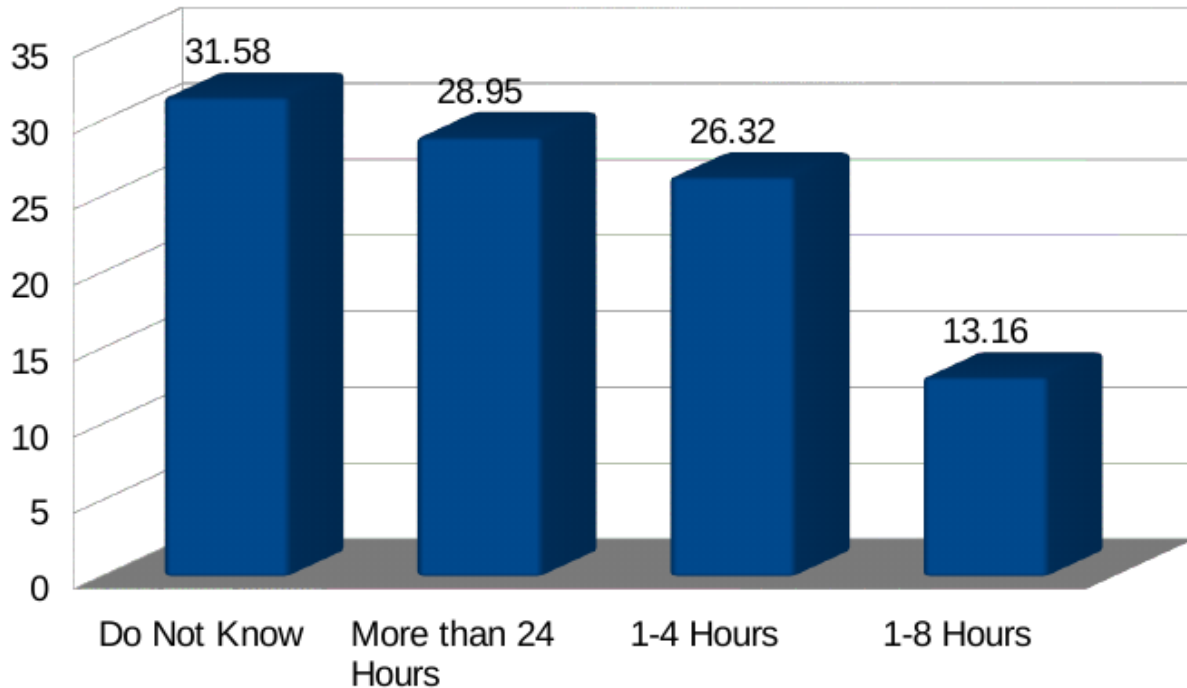
Figure 4.7: Time to Register Property in Existing Property Register Bar Chart.

4.2.8 Impact Property Identification and Rates Collection

Table 4.8 shows the results of the respondents when asked whether the problems of property identification have impacted on the property tax collection. 94.44 percent responded that the impact was there while 8.56 percent responded that the impact was not there. Four respondents did not answer the question.

Table 4.8: Impact of Property Identification on Property Rates Collection Table Table.

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
Yes	1	34	85	94.44	94.44
No	2	2	5	5.56	100
	9	4	10	Missing	
Total		40	100	100	

Figure 4.8 summarises the data in table 4.8 in pie chart form.
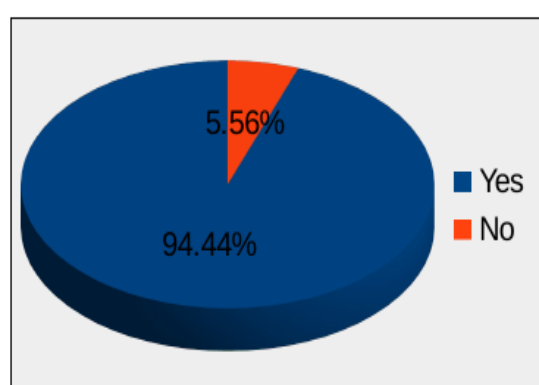
Figure 4.8: Impact of Property Identification on Property Rates Collection Pie Chart.

4.3 Current Property Identification and Capture Business Processes New Properties

The Diagram in Figure 4.9 depicts the process that takes place when capturing new properties for property tax. The local authority first identifies a piece of land in its jurisdiction. It then proceeds to survey the land, demarcate plots and produce a site plan map as shown in figure 4.10 on A3 paper that shows the land parcels. The public is then invited to apply for the plots for purchase and shortlisted applicants are invited for interviews to determine whether they have the financial capacity to develop the land. Successful interviewees are then issued offer letters to buy the piece of land. The offer letter includes the site plan map and the location map of the plot as show in Figure 4.11. Once Payment is made, the developer applies for building permission by submitting building plans together with the site plan and location Maps. When building permission is granted, the developer commences construction and the local authority also commences inspections of the building progress. Once the structure is completed, an occupancy certificate is issued to the developer that allows them to use the

property. The property is the captured for property tax in the next valuation cycle and thereafter on the billing System.
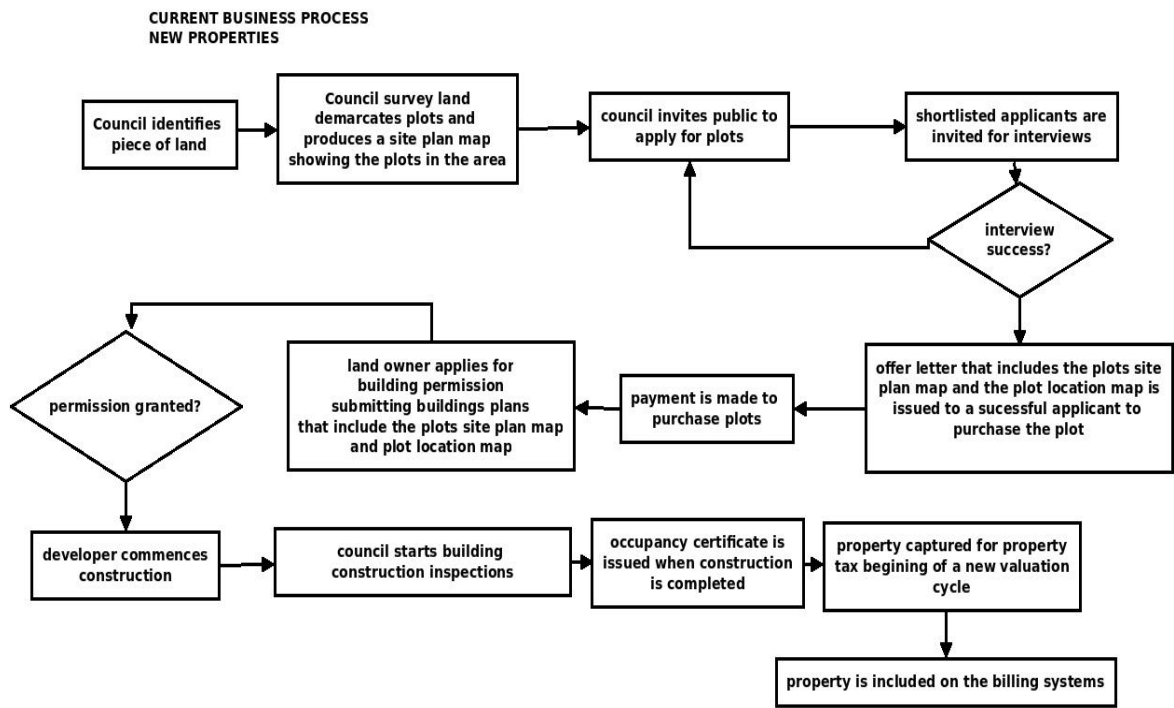
Figure 4.9: Property Capture Process.

Figure 4.10: Sample Site Map Plan.

Figure 4.11: Sample Location and Site Map Plan.

4.4 Valuation

The local authority consolidates the site plan maps of properties in its jurisdiction. It then passes a resolution to prepare the valuation roll for the new and existing properties. Permission is then sought from the parent Government ministry to conduct valuations for that cycle as stipulated in the Rating act. Once permission is granted, a request for valuation surveyors to undertake valuation is made to the Government valuation department. The local authority then proceeds to inform the public about the impending valuation exercise through the press and street bill boards. Valuation surveyors then use the Consolidated site plan maps of the properties to conduct valuation inspections. Floor areas of the properties on the land are captured for purposes of valuing the properties. When the valuation exercise is completed, a draft Valuation roll is produced and the public is invited to inspect it. Property owners who have disputes of the value of their properties register the disputes with the local authority in writing. When the period allocated for the Valuation roll inspections elapses, all the disputes are forwarded to the valuation disputes tribunal for resolution. When all the disputes are resolved, new property values are effected in the existing billing systems and new properties are also included. Figure 4.12 depicts the valuation process.

CURRENT BUSINESS PROCESS PROPERTY VALUATIONS
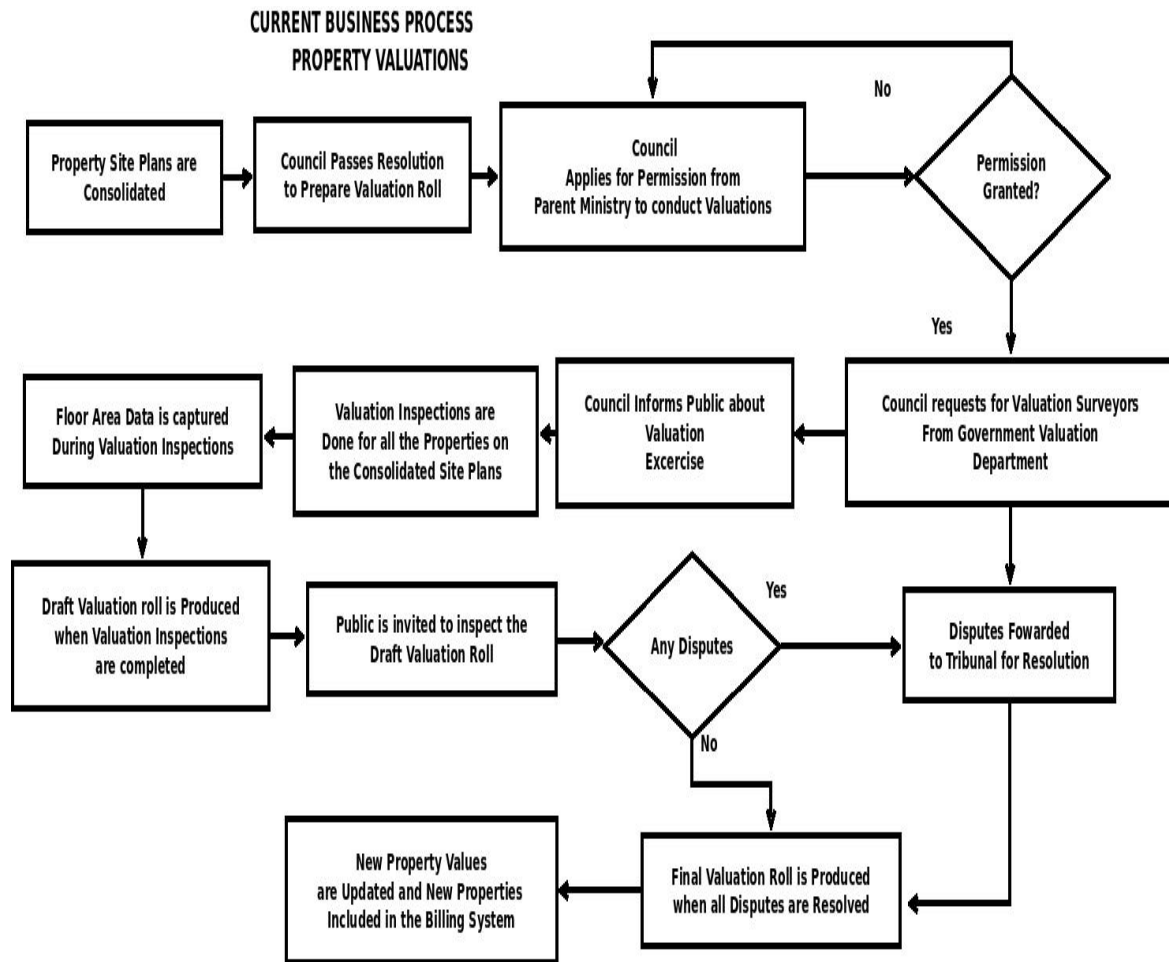
Figure 4.12: Property Valuation Process.

4.5 System Implementation

4.5.1 Logging In

Figure 4.13 Shows the Log in screen for the property owner. It allows the property owner to create an account for submission of property attribute data. It also allows the property owner to retrieve the password in the event that they forget it. Figure 4.14 Shows the log in screen for the local authority Staff. Both set of users are required to enter a valid email address and password. When the log in button is clicked, and the log in credentials supplied are valid, access is granted.
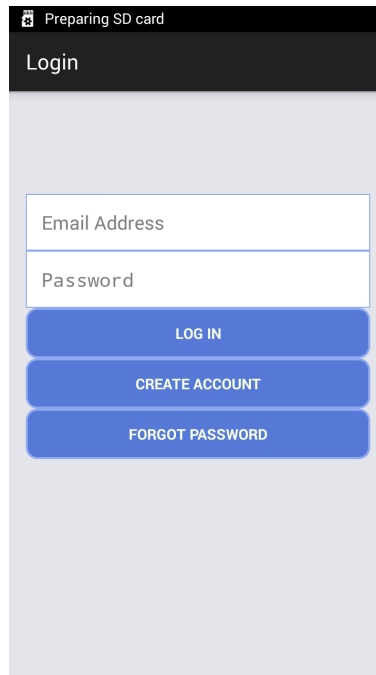
Figure 4.13: Login Screen - Property Owner.
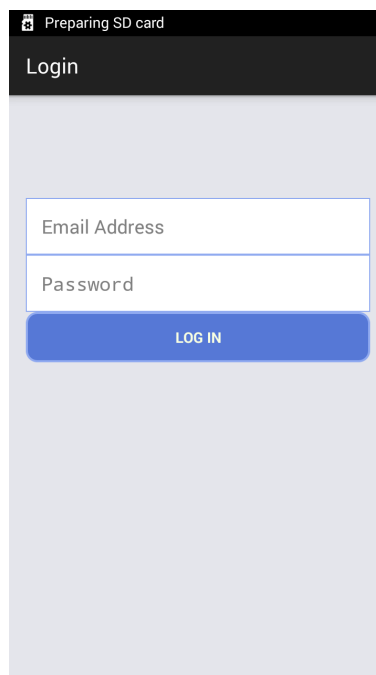
Figure 4.14: Login Screen - Authority Staff.

4.5.2 The Main Menu

Figure 4.15 Show the Main menu screen for a local authority staff who has all the access permissions granted. Figure 4.16 on the other hand, shows the main menu for a property owner who has successfully registered on their mobile devices to submit owner, land and property attribute details for later verification and physical mapping by local authority staff.
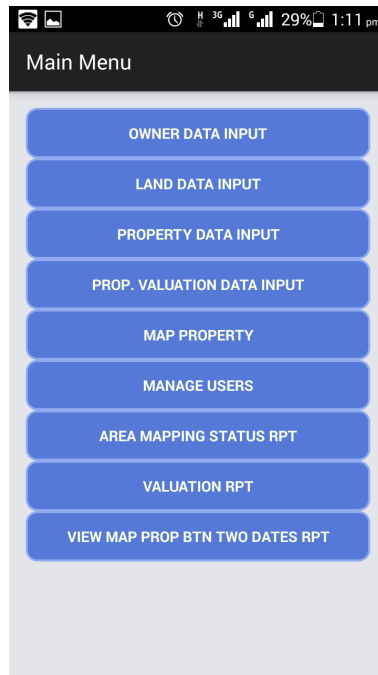
Figure 4.15: Main Menu Council Staff.
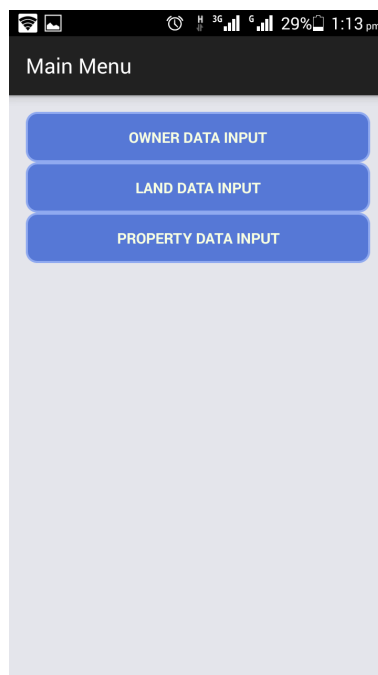
Figure 4.16: Main Menu Property Owner.

Figure 4.17 shows the screen that is used to create users with the email text field coloured green to designate the user creation mode. The access permissions that are selected will be the menu items visible when the staff user logs in. Figure 4.18 Shows the same screen in user update mode. The administrator can update user details and rights in this mode. The email text field is coloured blue to designate the update mode.

Figure 4.17: Create User Screen.
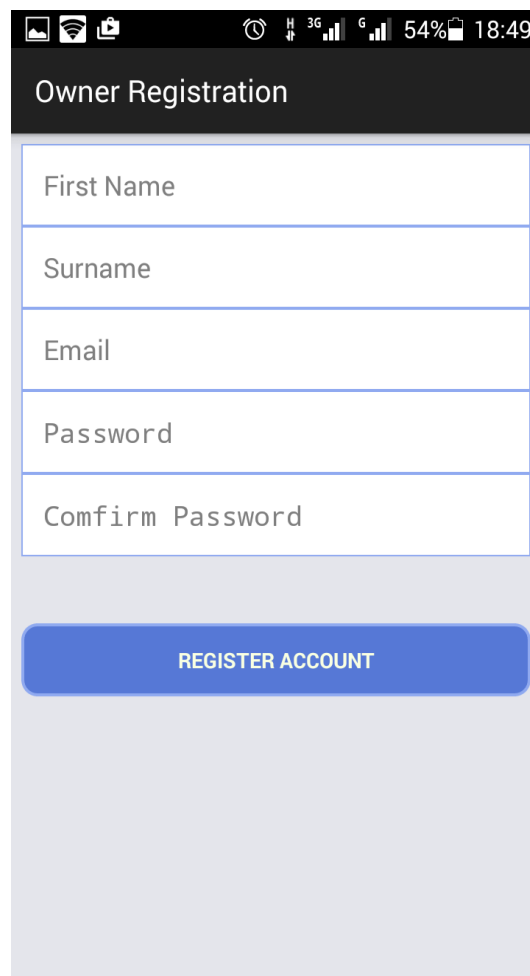
Figure 4.18: Update User Screen.

When the administrator enters a user email that exists in the database and focus moves away from the email name field, the update and delete buttons are displayed as shown in figure 4.18. If the user email does not exist, the create button is displayed as shown in figure 4.17. In the user create mode the administrator inputs the email address, first name, surname and password and selects the appropriate permissions. When the create button is clicked, the user record is created and a confirmation message

is displayed. In the Update mode, when the administrator enters a valid user email, the user's current permissions options are displayed. Once changes are made and the administrator clicks on the update button, the user record is updated and a confirmation message is displayed. If the administrator clicks on the delete button, the user record is removed.

4.5.3 Property Owner Account Registration

Figure 4.19 shows the property owner registration screen. When a property owner fills in the registration details and clicks on the register account button, the account is created and an activation email is sent to the owner.

Figure 4.19: Property Owner Registration Screen.

When the property owner opens their email, the email contains a link(click here) as shown in figure 4.20. Clicking the link activates the account after which the owner can start the application, log in and proceed to submit owner, land and property details.
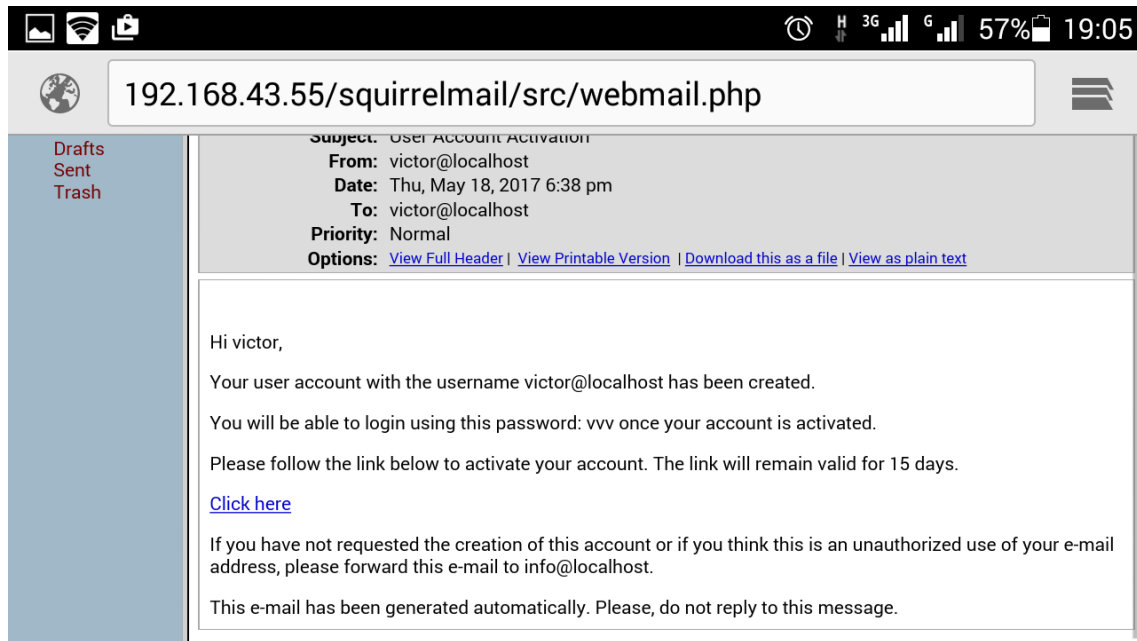
Figure 4.20: Account Activation Email.

4.5.4 Retrieving Passwords

When the property owner forgets their password, they can click on the forgot password button on the log in screen to display the screen in figure 4.21. They are then prompted to enter a valid registered email address and when they click on the retrieve password button, an email containing their password is sent to their email box as shown in figure 4.22.
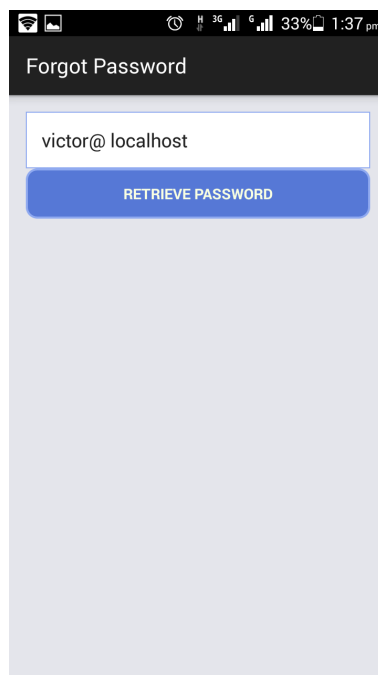
Figure 4.21: Password Retrieval Screen.

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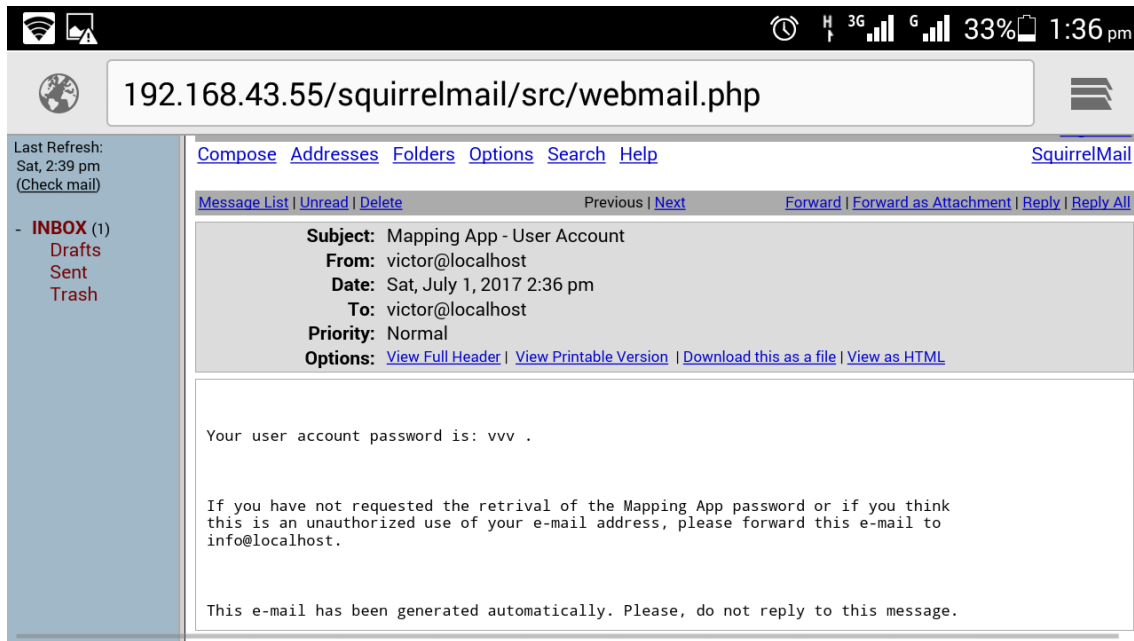
Figure 4.22: Password Retrieval Email.

4.5.5 Capturing Property Attribute Data

Property attribute data capture is carried out in three stages using three different screens. The first screen is shown in figure 4.23. The owner id is coloured in green to designate the owner details create mode. The same screen is shown in the owner details update mode in figure 4.24 with the owner id coloured in blue and the update and delete button visible.

Figure 4.23: Owner Attributes Data Creation Screen.

Figure 4.24: Owner Attributes Data Update Screen.

This screen captures details that pertain to the property owner. As the data is being entered and focus moves to the next field, a validation check is performed to ensure that data is entered correctly and that all mandatory fields are not left blank. When the create button is clicked the property owner record is saved in the PostgresSQL database and a unique owner identity number is generated. When a valid owner id is entered, the details of the property owner are displayed as depicted in figure 4.24. Once changes are made and the user clicks on the update button, the owner record is updated and a confirmation message is displayed. If the administrator clicks on the delete button, the owner record is removed.

Figure 4.25 shows the screen that is used to capture land attribute data. When an Owner identity number is entered and focus moves to the next field, property owner names and national registration card number are retrieved. The rest of the fields from the land use type to ward require the user to fill them manually. As data is entered in the fields, appropriate validation and mandatory checks are done. When the create button is clicked, the land record is created and a unique land identity number is allocated. When a valid owner id is entered, land details pertaining to the owner are displayed as depicted in figure 4.26. Once changes are made, and the user clicks on the update button, the land details record is updated and a confirmation message is displayed. If the administrator clicks on the delete button, the land record is removed. The green and blue owner text fields show the create and update modes respectively as before.

Figure 4.25: Land Attributes Data Creation Screen.

Figure 4.26: Land Attributes Data Update Screen.

Figure 4.27 shows the property details screen used to capture property(building) attribute data. When a valid owner identity number is entered in the owner id field, details from the owner record and from the associated land record are retrieved. Property descriptions, year constructed and building use data fields are entered manually by the user. As the data fields are filled, validation and mandatory field checks are done and the user is notified appropriately. When the create button is clicked, the

property record associated with the owner is saved and a confirmation message is displayed. When a valid owner id is entered, the details of the property owner are displayed as depicted in figure 4.28. Once changes are made and the user clicks on the update button, the property record is updated and a confirmation message is displayed. If the administrator clicks on the delete button, the property record is removed. The green and blue owner text fields show the create and update modes respectively as before.

Figure 4.27: Property Attributes Data Creation Screen.
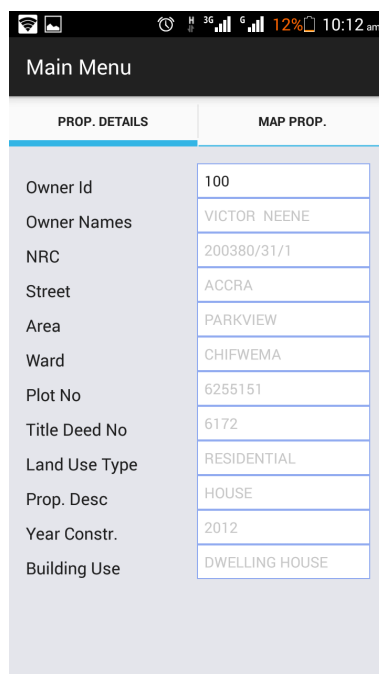
Figure 4.28: Property Attributes Data Update Screen.

4.5.6   Capturing Spatial Data(Mapping a Property)

Figure 4.29 shows the First Tab of the Property Mapping Screen. When a valid owner identity number is entered and the focus moves away from the field, the owner, land and property attribute data are displayed.
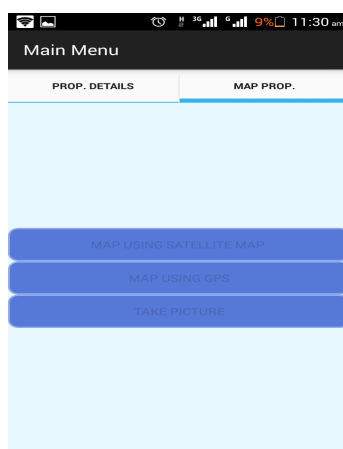
Figure 4.29: First Tab of the Property Mapping Screen.

Figure 4.30 and 4.30 shows the second tabbed screen of the property mapping screen. The former shows the mapping buttons disabled if the property details cannot be retrieved. The later shows the property buttons enabled when the details are found. The screen has two modes of spatial data capture. The first mode captures GPS co-ordinates using a geo-referenced satellite map while the second mode capture GPS co-ordinates using the mobile device's GPS module equipment.

Figure 4.30: Second Tab of Mapping Screen (Mapping Buttons Disabled).
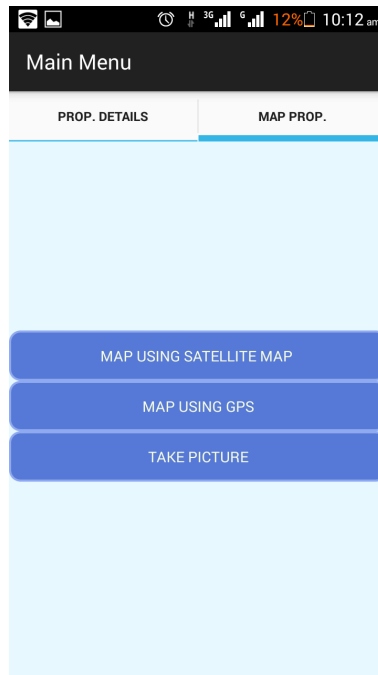
Figure 4.31: Second Tab of Mapping Screen (Mapping Buttons Enabled).

In the first mode, when the map using satellite map button is clicked, it displays a vector MapBox satellite image of the area as shown in Figure 4.32. The mapper then zooms in on the property using the (+) zoom icon. When the property is located, the mapper uses the line tool bar to draw the land parcel as shown in Figure 4.32.
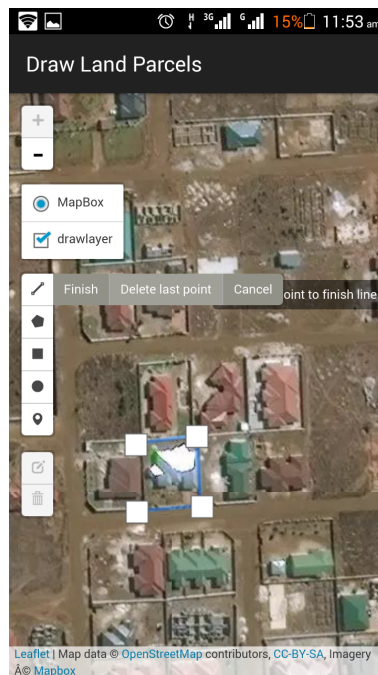
Figure 4.32: Land Parcel Drawing Screen.

When the finish menu item is clicked, the GPS coordinates represented by the white squares are

then saved to the database and an appropriate message is displayed.

When the second mode is selected, the screen shown in figure 4.33 is displayed. The screen first prompts the user to enable the GPS on the mobile device as shown figures 4.34 and 4.35. When the GPS settings are set in figure 4.35, the mobile application initiates the process of locating the GPS satellites.
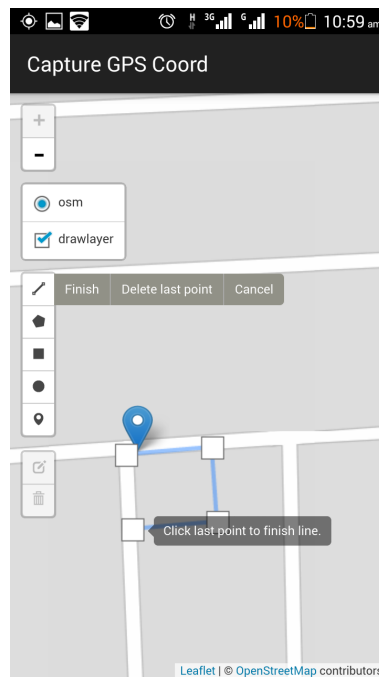
Figure 4.33: Mapping Using the Mobile GPS Device

While the device tries to locate the satellites, the GPS Icon at the top of the mobile device notification area flashes continuously. When the flashing stops and the user stands at an approximate property beacon location, the GPS Blue Marker, shown in figure 4.33, is displayed for ten seconds. As the user moves around, the marker also moves. When the approximate visual position of the GPS marker is on an approximate beacon location as guided by the underlying OpenStreetMap roads, a white square can be placed on top on the marker to capture the GPS coordinate as shown figure 4.33 and this process is repeated for all the beacons. When the finish menu item is clicked, the GPS coordinates represented by the white squares are then saved to the database and an appropriate message is displayed.

When the take Picture button is clicked, the camera application on the mobile device is opened. When the mapper takes the picture of the property the picture is uploaded to the application server. The App allows the mapper to take as many pictures as possible.
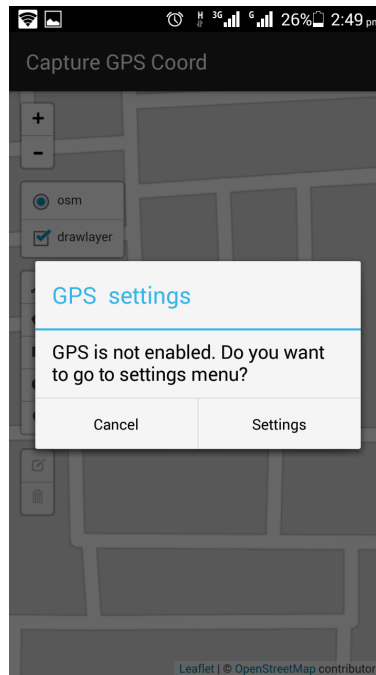
Figure 4.34: Enabling GPS Prompt.
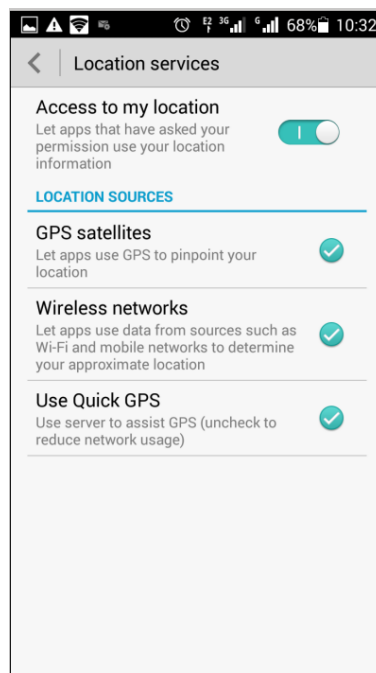
Figure 4.35: Setting GPS Options.

4.5.7 Property Valuation

Figure 4.36 Shows the screen for creating the valuation details of the property. When a valid property id is entered, the details are displayed as shown. The user then proceeds to enter the valuation cycle, tax rate and the base rate. When the user clicks on the create button, the valuation details of the property are created for the chosen valuation cycle and and appropriate message is displayed.

Figure 4.36: Property Valuation Capture Screen.

4.5.8 Reports
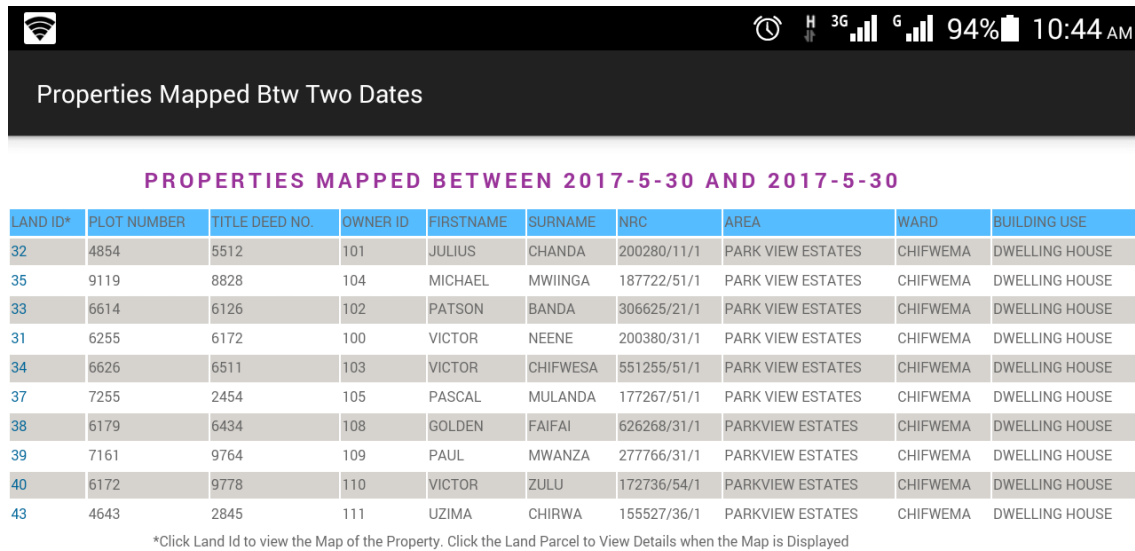
Figure 4.37 shows the screen of the View properties captured between two dates dates report. The user is prompted to enter the date range.

Figure 4.37: Date Range Selection.

Clicking the view button, displays a list of properties captured as shown in Figure 4.38. The user can optionally view the map of each property by clicking on the land id number.

Figure 4.38: View Properties Mapped Between Two Dates Report.

Figure 4.39 Shows the View mapping status report. When the land parcel is tapped on the map, details of the property are displayed as shown. Clicking on the view photos link displays the pictures of the property that were captured as shown in figure 4.40.
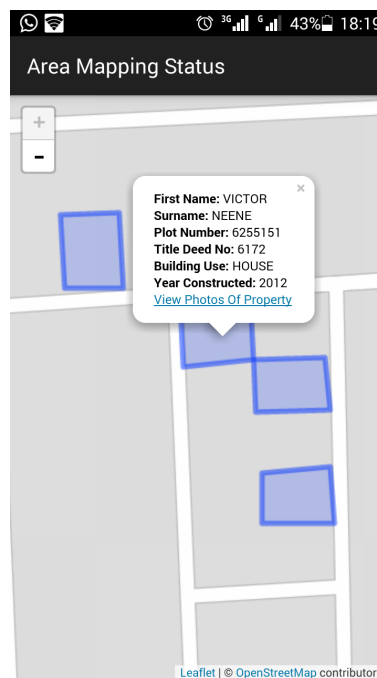
Figure 4.39: View Mapping Status Report.
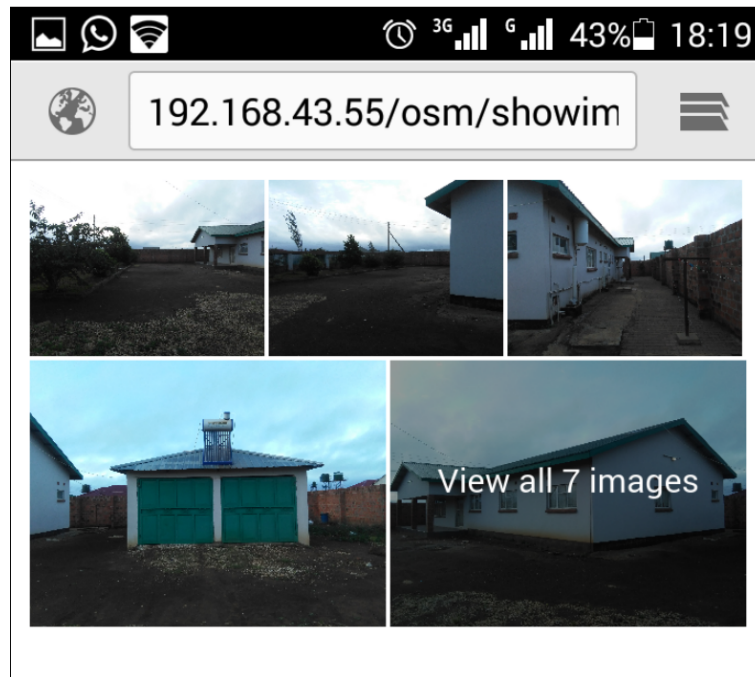
Figure 4.40: Property Pictures.

Figure 4.41 Shows the property valuation report for the cycle 2015-2020. The property tax due for the year is given in the last column. It is calculated by multiplying the tax rate by the tax base. Clicking the Land id will display the corresponding land Parcel.

PROPERTY VALUATIONS FOR CYCLE 2015-2020

LAND ID*	PLOT NUMBER	TITLE DEED NO.	OWNER ID	FIRSTNAME	SURNAME	NRC	AREA	WARD	BUILD. USE	TAX RATE	TAX BASE	PROP. TAX/ YEAR
35	9119	8828	104	MICHAEL	MWIINGA	187722/51/ 1	PARK VIEW ESTATES	CHIFWEMA	DWELLING HOUSE	0.125	1300000	162500
33	6614	6126	102	PATSON	BANDA	306625/21/ 1	PARK VIEW ESTATES	CHIFWEMA	DWELLING HOUSE	0.125	1200000	150000
31	6255151	6172	100	VICTOR	NEENE	200380/31/ 1	PARK VIEW ESTATES	CHIFWEMA	DWELLING HOUSE	0.125	800000	100000

*Click Land Id to view the Map of the Property. Click the Land Parcel to View Details when the Map is Displayed

Figure 4.41: View Properties Valuation Report.

4.6   Validation and Testing

4.6.1   Validation

System validation is the process of determining whether a particular design will satisfy the requirements that were formulated. It provides confidence that the system software was built

adequately and that it will meet the needs of the end users. Activities include checking the outcome of the developed software application with respect to the expectations of the customer. [83] [84] [85].

The tables 4.9, 4.10 and 4.11 below show the validation results of the user functional requirements. They gives an outline of the requirements that were formulated in the methodology chapter against the implementation results presented in the immediate preceding sections.

Table 4.9: System Validation – Property Owners.

Code	Requirement Description	Figure
FR1PO	Property owners should be able to submit Property Information using their mobile devices	4.23,4.25,4.27
FR2PO	Property Owners should be able to register an account using their mobile devices before submitting property ownership information	4.19
FR3PO	The System should be able to notify Property Owners upon successful account registration	4.20
FR4PO	The System should be able to notify Property Owners upon successful submission of property information	4.23, 4.25, 4.27
FR5PO	The System should allow Property Owners to activate an account through an email link	4.20
FR6PO	The System should allow Property Owners to log in using the log in credentials supplied during account creation	4.13
FR7PO	The System should allow the property owner to retrieve the account password of the property location	4.21, 4.22

Table 4.10: System Validation – User Management.

Code	Requirement Description	Figure
FR1UM	The System should allow the Systems Administrator to create users that will use the system	4.17
FR2UM	The System should allow the Systems Administrator to update user account profiles	4.18
FR3UM	The System should allow the Systems Administrator to delete a user account	4.18
FR4UM	The System should allow the Systems Administrator to log in with privileged rights	4.14
FR5UM	The System should allow the Systems Administrator to assign user rights	4.17, 4.18

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Table 4.11: System Validation- Property Management.

Code	Requirement Description	Figure
FR1PM	The System should allow Local Authority users created by the Systems Administrator to log in	4.14
FR2PM	The System should grant access to system resources that are authorised	4.16
FR3PM	The System should allow authorised users to view property details	4.29, 4.38
FR4PM	The System should allow authorised users to update property records	4.26, 4.24,4.28
FR5PM	The System should allow authorised users to delete property records	4.26, 4.24,4.28
FR6PM	The System should allow authorised users to create a property record	4.23, 4.25, 4.27
FR7PM	The System should allow authorised users to Map a property	4.29,4.30,4.31,4.32,4.33
FR8PM	The System should allow authorised users to add property valuation information	4.36
FR9PM	The System should allow authorised users to view the property valuation report	4.41
FR10PM	The System should allow authorised users to view the properties mapped between two dates	4.37, 4.38
FR11PM	The System should allow authorised users to view the area mapping status report	4.39, 4.40

4.6.2 Testing

Software testing involves the verification as well as validation activities. The main objective of software testing is to determine if the thoughts, actions or products are as per the formulated requirements. The software application is executed in the real environment to determine that it operates correctly [85] [86].

Testing of the entire application was conducted after the development of the system was completed and after seeking permission from property owners in Park View Estates to have their properties mapped in the study. The Testing was conducted in real time and it used the attribute data that property owners provided in the field and the spatial data of the their physical properties on the ground. It also included the testing of the connectivity speed between the cloud based mapping services delivered on the Internet and the application and also the between the application and the the web and database servers. The results of the test attribute and spatial data are shown in figure 4.37,4.39 and 4.40 respectively in the preceding section. The data was captured according to the requirements and design of the system. No data input and output errors were experienced during the testing.

The connectivity speeds between the application and the cloud mapping services ranged from

12Mbit/s to 14 Mbit/s. The connection was stable during the mapping of all the ten properties. The WIFI speed between the application and the servers ranged from 10Mbit/s to 15 Mbit/s and the connection was also stable.

4.7 Chapter Summary

In this chapter, the results of the ground truth exercise that was conducted to Investigate challenges of Property Identification and capture were presented. The existing current business process used in the identification and capture of properties was also presented. The implementation of field based GIS Prototype was presented using screen-shots of the mobile application.

CHAPTER 5

DISCUSSION AND CONCLUSIONS

5.1 Chapter Overview

In this chapter we discuss in detail the results and the methodology that was used in the research. In particular we show how the objectives formulated in chapter one were addressed by discussing the methodology used to produce the desired results. In addition, we also draw conclusions from the research results obtained and we then proceed to make recommendations to local authorities. Lastly, the future works that can be carried out to enhance the prototype application are described.

5.2 Discussion

5.2.1 Ground Truth Exercise Survey

5.2.1.1 Disparity Between Physical Properties on the Ground and the Existing Property Register

More than 70 percent of the respondents reported that the existing property registers did not record all the properties that existed on the ground in the local authority jurisdiction. On the contrary about 30 percent reported that the all physical properties on the ground were recorded . These findings are consistent with what the Literature Review chapter in section 2.2.7 which shows that local authorities especially in developing countries are grappled with this problem. During oral interviews, most respondents attributed the disparities to the property owners constructing properties without approval from the local authorities which resulted in these properties to be omitted on the existing property registers. From the results it can be concluded that the field based GIS prototype will significantly help capture spatial and attribute property data and will help to resolve the issues of these disparities because both attribute and spatial property data will be captured on the ground in real time. This will ultimately result in the subsequent inclusion of these properties on the existing valuation and billing systems.

5.2.1.2 Locate Physical Properties on the Ground Using Existing Registers

About 44 percent of the respondents reported that it was easy to locate the physical properties on the ground using the existing Property Registers. About 44 percent reported that it was difficult while about 10 percent reported that it was very difficult. Only about 3 percent reported that it was very easy. From the results, it can be concluded that it is generally difficult to locate most of the physical properties using the existing property registers. Respondents attributed the problem to not all property registers having street names and unique property numbers and also not having GPS coordinates of the properties. These results support what the literature review shows in section 2.2.7 and 2.2.8. and also the results presented in this chapter in section 4.2. The failure to locate some properties results in properties being missed during the valuation exercise and bill delivery. These challenges contribute to the reduction in property tax revenues. From the researcher's observation during the research, the problems of missing street names were as a result of the failure by the local authorities to name roads in the residential and commercial areas with existing properties. The problem of duplicate plot numbers came about because the local authorities do not have proper computerised property registers that can detect duplicate plot number allocations. As regards to the problem of properties lacking GPS coordinates, the problem arises because the existing manual property registers are unable to store and present spatial data. It can be concluded from the findings that the field based GIS prototype will help resolve problems of property location because it will integrate attribute and spatial data into a single database. Even if street names are not captured because they are not available, properties will still be located using spatial data (GPS coordinates). Unique property numbers will also always be generated as long as a property is captured in the Field Based GIS Prototype.

5.2.1.3 UN-updated Property Maps

About 85 percent of the respondents reported that the property maps are not up to date. About 15 percent reported that they were up to date. Maps are not updated because of the problem of subdividing legal existing properties illegally by property owners without the consent and approval of the local authority. In addition, new properties on unsurveyed land are also built illegally as discussed in the literature review chapter in section 2.2.8. This problem is also amplified by the fact that the local authorities use paper based location and site maps as shown in figures 4.10 and 4.11 in this chapter. This method of map preparation is time-consuming and requires skilled man power to draw the maps as pointed out by some local authority staff during the interviews. The field based GIS prototype will be an ideal tool to update the property maps using spatial data from the illegal constructions and it will not require skilled man power to carry out this task because of the simplicity of operation. During the

ground truth exercise Survey, 95 of the respondents owned smart mobile phones and about 66 of these reported that they had used a form of a mapping application on their phones as shown in appendix D. These results suggest that the local authority can use the existing human resource in the mapping projects with minimal training in using the field based GIS prototype.

5.2.1.4 Time Taken to Register a Property

About 31.58 percent of the Respondents said did not know how long it took to register properties, 28.95 percent said it took more than 24 hours, 26.32 percent said it took 1-4 hours and 13.16 percent said it took 1-8 hours. From the results obtained and from the interviews that were conducted, it generally takes a long time to register a property. This problem arises mainly because the local authorities use manual based methods in registering properties as discussed in the literature review chapter in section 2.2.8 and in chapter 4 section 4.3. Despite some of them having some desktop GIS applications, the applications have not been used for this purpose mainly because they lack features needed to develop fully fledged networked applications. The applications are generally used for spatial analysis of areas in the localities of the authorities. Furthermore, the acquisition of off the shelf application has proved to be beyond the financial reach of the authorities more especially when it comes to initial set up and recurring licensing costs. It can be concluded from the findings that the field Based GIS prototype will help improve the time it takes to register a property because of its inherent real time feature it has. Furthermore, the participatory GIS module where property owners can submit property attribute data will also greatly reduce property capture time.

5.2.2 System Implementation

The system implementation consisted of system requirements specification, systems design and system development as discussed in chapter 3. Results of the prototype Application have been presented in section 4.5 of this chapter. In the literature review, the systems reviewed lacked real time operation features. In addition, the literature review in section 2.3.1 of the chapter 2 discussed software GIS tools that included web map servers, software libraries and mobile GIS that can be used to develop real-time systems. Furthermore, the literature review chapter in section 2.3.4 showed that the community can be brought on board to help in the mapping activities through the use of Participatory Geographic Information Systems (PGIS). The Field Based GIS prototype utilised OpenStreetMaps and MapBox map services to provide vector and raster tile maps that were rendered with the help of the Leaflet mapping library that was designed for mobile and desktop platforms. The aspect of participatory GIS was also incorporated in the prototype through the feature that allowed

property owners to submit property information through their mobile devices. This feature does not only capture property attribute data but also captures spatial location data of the property. The GIS Prototype has demonstrated that it is an affordable technology that local authorities can harness to help identify and capture properties for property tax purposes. The affordability is facilitated by the freely available OpenStreetMap vector Maps and the MapBox raster satellite maps. In addition, the cost of mobile devices running the android operating system is within the financial reach of the local authorities. There is also no need of employing only expensive skilled manpower because the GIS Prototype is user-friendly such that even non GIS experts can operate it with very minimal training.

5.2.3   Current Business Processes Mapping and Modeling

The current Property Identification and Capture Business Processes findings are presented in section 4.3 and 4.4 of this chapter. In section 3.10 of chapter 3, the Proposed Automated Property Identification and Capture Business Model was developed. UML diagrams were used in section 3.14 of chapter 3 to translate the proposed automated business model into a Field Based GIS System Prototype whose operation and results are presented in section 4.5 of this chapter. Furthermore, the Proposed System Architecture to support the proposed property identification and capture business process and the field based GIS System Prototype was presented in section 3.11 of chapter 3. As pointed out, the process of property identification and capture is very important before properties can be valued and the tax subsequently charged and collected. The field based GIS system prototype and the proposed property identification and capture model will help very much in the process of property identification and capture as evidenced from the results of the field based GIS system prototype. The system will come in handy more especially where putting properties that are built without planning permission in the tax net is concerned.

5.2.4   Challenges of the Study

Virtual Private Networking (VPN) and production server hardware resources were not available to test the prototype mobile GIS application. Local Authorities did not have these computing resources in place. If these resources were in place, the testing and trialing was going to be very comprehensive as depicted by the system architecture in chapter three. This would have allowed the observation of the prototype performance with regards to the speed with which the spatial, attribute and property data would travel over this mode of connectivity for retrieval and storage operations. Server hardware would also have provided an opportunity to come up with minimum specification requirements of the server hardware computing resources needed to run the application and database servers. Lastly, local

authority staff could not be incorporated in the testing and validation of the mobile GIS prototype because of administrative challenges. This opportunity would have generated valuable feed back on usability enhancements that would have improved the prototype application.

5.3 Conclusions

In this study, an extensive literature review was conducted in order to understand: the challenges of property identification and capture in developing countries, short comings of systems that have been developed to address these challenges and the available GIS software tools and technologies that can be used to develop affordable software solutions. A ground truth exercise Survey was conducted to investigate the current methods and challenges that are experienced in identifying and capturing properties for property tax. Based on the results of the survey, systems specifications, design and development activities of the Field Based GIS Prototype were conducted and the prototype was trialed in the field and property attribute, images and spatial data were captured in real time successfully.

The Study showed that:

A. Local authorities in Lusaka province face challenges of property identification and capture that has resulted in:

1. Disparities between physical properties on the ground within respective jurisdictions and the properties that are recorded in the existing property registers

2. Difficulties in locating properties on the ground using existing property registers because of absence of street names, unique property numbers and GPS coordinate data of property location and land parcels

3. Outdated property maps that are seldom updated to reflect new property constructions on the ground

B. The Field Based GIS Prototype application trial results demonstrated that it can help local authorities identify and capture properties for property tax. Property attribute, image and spatial data can be captured in the same time frame in real time in the field. The cost of implementation of the fully fledged Field Based GIS system will be minimal because of the use of free OpenStreetMap and MapBox vector and raster maps respectively, free leaflet mapping library and free android software development kit for mobile devices. It will also eliminate the cost of hiring only skilled GIS Experts in the property mapping projects because of intuitive user interface of the prototype.

5.4   Recommendations

The following recommendations are made.

1. The fully fledged field based GIS System should be implemented by local authorities to overcome the challenges of property identification and capture that were identified during the ground truth Survey.

2. Local authorities can take advantage of the user-friendly features of the fully fledged field based GIS system and hire additional non GIS expert man power to help in the property identification and capture to clear the huge backlogs.

5.5   Future Works

Software application Interfaces libraries can be developed in the fully fledged field based GIS system in order to facilitate the integration with existing billing and valuation systems. This will help improve efficiency in the property tax administration process.   Furthermore, the aspect of Participatory GIS should also be extended to include the submission of spatial data by property owners in addition to the attribute data to attain a high rate of property identification and capture. Automated methods to verify this user submitted spatial data should also be explored to make guarantee the integrity of this data.

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APPENDICES

APPENDIX A: SOURCE CODE LISTING

```java
// Android Java Source Code for Class for Getting current GPS coordinates from the
    mobile Device's GPS hardware module
package gis.mobile.mgpi;


import android.app.AlertDialog;

import android.app.Service;

import android.content.Context;

import android.content.DialogInterface;

import android.content.Intent;

import android.location.Location;

import android.location.LocationListener;

import android.location.LocationManager;

import android.os.Bundle;

import android.os.IBinder;

import android.provider.Settings;

import android.util.Log;


public class GPSTracker extends Service implements LocationListener {

    public AsyncResponse delegate = null;

    private final Context mContext;

    // flag for GPS status
    boolean isGPSEnabled = false;

    // flag for network status
    boolean isNetworkEnabled = false;

    // flag for GPS status
```

```java
boolean canGetLocation = false;

Location location; // location
double latitude; // latitude
double longitude; // longitude

// The minimum distance to change Updates in meters
private static final long MIN_DISTANCE_CHANGE_FOR_UPDATES = 0; // 10 meters

// Declaring a Location Manager
protected LocationManager locationManager;

public GPSTracker(Context context) {
    this.mContext = context;
    getLocation();
}

public Location getLocation() {
    try {
        locationManager = (LocationManager) mContext
                .getSystemService(LOCATION_SERVICE);

        // getting GPS status
        isGPSEnabled = locationManager
                .isProviderEnabled(LocationManager.GPS_PROVIDER);

        // getting network status
        isNetworkEnabled = locationManager
                .isProviderEnabled(LocationManager.NETWORK_PROVIDER);

        if (!isGPSEnabled && !isNetworkEnabled) {
            // no network provider is enabled
        } else {
            this.canGetLocation = true;

            // if GPS Enabled get lat/long using GPS Services
```

```java
            if (isGPSEnabled) {
                if (location == null) {
                    locationManager.requestLocationUpdates(
                            LocationManager.GPS_PROVIDER,
                            MIN_TIME_BW_UPDATES,
                            MIN_DISTANCE_CHANGE_FOR_UPDATES, this);
                    Log.d("GPS Enabled", "GPS Enabled");
                    if (locationManager != null) {
                        location = locationManager
                                .getLastKnownLocation(LocationManager.GPS_PROVIDER);
                        if (location != null) {
                            latitude = location.getLatitude();
                            longitude = location.getLongitude();
                        }
                    }
                }

            }

        } catch (Exception e) {
            e.printStackTrace();
        }


        return location;
    }


    /**
     * Stop using GPS listener
     * Calling this function will stop using GPS in your app
     * */
    public void stopUsingGPS() {
        if (locationManager != null) {
            if (checkSelfPermission(Manifest.permission.ACCESS_FINE_LOCATION) !=
                PackageManager.PERMISSION_GRANTED &&
                checkSelfPermission(Manifest.permission.ACCESS_COARSE_LOCATION) !=
```

```java
            PackageManager.PERMISSION_GRANTED) {

            return;
        }
        locationManager.removeUpdates(GPSTracker.this);
    }
}




/**
 * Function to get latitude
 * */
public double getLatitude(){
    if(location != null){
        latitude = location.getLatitude();
    }


    // return latitude
    return latitude;
}


/**
 * Function to get longitude
 * */
public double getLongitude(){
    if(location != null){
        longitude = location.getLongitude();
    }


    // return longitude
    return longitude;
}


/**
 * Function to check GPS/wifi enabled
 * @return boolean
```

```java
 * */
public boolean canGetLocation() {
    return this.canGetLocation;
}


/**
 * Function to show settings alert dialog
 * On pressing Settings button will lauch Settings Options
 * */
public void showSettingsAlert(){
    AlertDialog.Builder alertDialog = new AlertDialog.Builder(mContext);


    // Setting Dialog Title
    alertDialog.setTitle("GPS settings");


    // Setting Dialog Message
    alertDialog.setMessage("GPS is not enabled. Do you want to go to settings
        menu?");


    // On pressing Settings button
    alertDialog.setPositiveButton("Settings", new
        DialogInterface.OnClickListener() {
        public void onClick(DialogInterface dialog,int which) {
            Intent intent = new Intent(Settings.ACTION_LOCATION_SOURCE_SETTINGS);
            mContext.startActivity(intent);
        }
    });


    // on pressing cancel button
    alertDialog.setNegativeButton("Cancel", new DialogInterface.OnClickListener()
        {
        public void onClick(DialogInterface dialog, int which) {
            dialog.cancel();
        }
    });
```

```java
    // Showing Alert Message
    alertDialog.show();
}


@Override
public void onLocationChanged(Location location) {


    location =getLocation();
    String lat = Double.toString(location.getLatitude());
    String lon = Double.toString(location.getLongitude());


}


@Override
public void onProviderDisabled(String provider) {
    // called when the GPS provider is turned off (user turning off the GPS on
        the phone)




}


@Override
public void onProviderEnabled(String provider) {
    // called when the GPS provider is turned on (user turning on the GPS on the
        phone)




}


@Override
public void onStatusChanged(String provider, int status, Bundle extras) {
    // called when the status of the GPS provider changes
}


@Override
public IBinder onBind(Intent arg0) {
```

```
            return null;
    }




// JavaScript Source Code for loading OpenstreetMaps and MapBox vector and raster
    maps repectively
//also contains code for capturing Geo-referenced GPS coordinates from the raster
    map by drawing and tapping and
//calling of php scripts to save the data

<script>
                var landidlocationid = '<?php echo $_GET['landidlocationid']; ?>';


                var lnglatArray = new Array();
                var dblnglatstr,firstcoordpair;


                 //get landid and locationid
                 var lanloc = [];
                 lanloc = landidlocationid.split(",");


                 var landid = lanloc[0];
                 var locationid = lanloc[1];


        var osmUrl = 'http://192.168.43.55/osm/{z}/{x}/{y}.png',
           osmAttrib = '&copy; <a
              href="http://openstreetmap.org/copyright">OpenStreetMap</a>
              contributors',
           osm = L.tileLayer(osmUrl, { maxZoom: 18, attribution: osmAttrib }),
           map = new L.Map('map', { center: new L.LatLng(-15.4831, 28.34807), zoom:
              13 }),
           drawnItems = L.featureGroup().addTo(map);


 L.control.layers({"MapBox":
     L.tileLayer('https://api.tiles.mapbox.com/v4/{id}/{z}/{x}/{y}.
png?access_token={accessToken}', { attribution: 'Map data &copy;
```

```
<a href="http://openstreetmap.org">OpenStreetMap</a> contributors,

<a href="http://creativecommons.org/ licenses/by-sa/2.0/">CC-BY-SA</a>,

Imagery   <a href="http://mapbox.com">Mapbox</a>',id:

'mapbox.satellite', accessToken:

'pk.eyJ1IjoidmljdG9ybVlbmUiLCJhIjoiY2l0YnM3ZnB4MDAzajJ5bzN5cTNwanVrbiJ9.BlmXZqTz7a2APKKQctpI4Q
        })
    }, { 'drawlayer': drawnItems }, { position: 'topleft', collapsed: false
        }).addTo(map);



    map.addControl(new L.Control.Draw({
edit: {
    featureGroup: drawnItems,
    poly: {
    allowIntersection: false
    }
},
draw: {
    polygon: {
    allowIntersection: false,
    showArea: true
    }
}
}));


    map.on(L.Draw.Event.CREATED, function (event) {
var layer = event.layer;


drawnItems.addLayer(layer);


    var type = event.layerType;


    if (type === 'polyline') {


            //lnglatArray has all the co-ord pairs, repeat the first
                coord.
```

```javascript
                    for(i=0;i<lnglatArray.length;i++){


                        if(i==0){
            dblnglatstr = lnglatArray[i];
                            firstcoordpair= lnglatArray[i];//get first
                                coord pair
                        }else{
                            dblnglatstr = dblnglatstr + "," +
                                lnglatArray[i];
                        }


                    }


                        //clear array
                        while(lnglatArray.length > 0) {
            lnglatArray.pop();
        }


    }


            //call controller_map.php directly with param to save land
                parcel


            var http_request = new XMLHttpRequest();

http_request.open("GET",
    "http://192.168.43.55/osm/mgpi/controller/controller_map.php?addMap=1&landparcel
="+dblnglatstr + "," + firstcoordpair+"&landid=" + landid + "&locationid=" +
    locationid, true);

http_request.onreadystatechange = function () {
  var done = 4, ok = 200;
  if (http_request.readyState === done && http_request.status === ok) {
```

```
                        alert(http_request.responseText);



    }
};


http_request.send(null);


    map.addLayer(layer);


 });


            //show coordinates
         var popup = L.popup();


function onMapClick(e) {


                //get lat and lon
                var coordstr=[];
                var coordstr2;
                var coordstr3=[];
                var latlng=[];


                coordstr = e.latlng.toString().split("(");
                coordstr2 = coordstr[1];
     coordstr3  = coordstr2.split(")");
                 latlng=coordstr3[0].split(",") ;


                // add lng lat pair to array
                lnglatArray.push(latlng[1] + " " + latlng[0]);
                //alert(lnglatArray[0]);


}


map.on('click', onMapClick);
```

```
        map.on(L.Draw.Event.DRAWSTART, function (event) {


                        //clear array
                while(lnglatArray.length > 0) {
            lnglatArray.pop();
        }


        });




</script>




//php source code to save spatial data to the PostgresSQL database




//controller source code


<?php
/*
 * To change this template, choose Tools | Templates
 * and open the template in the editor.
 */
    include('../lib/map.php');


//create map
$map = new Map();



if(!empty($_POST['addMap'])){


    //map
     $map->setlandid($_POST['landid']);
```

```php
    $map->setlocationid($_POST['locationid']);
    $map->setlandparcel($_POST['landparcel']);
    $map->setdatecreated(date("Y/m/d"));


    if($map->saveMap()){


            if($map->getLastSequence()){


            if($map-> updateLandMapId()){
              echo "The Map was Created Successfully";
            }


            }


    }else{


            echo "The Map NOT was Created Successfully" ;


    }
}


if(!empty($_GET['addMap'])){


    //map
    $map->setlandid($_GET['landid']);
    $map->setlocationid($_GET['locationid']);
    $map->setlandparcel($_GET['landparcel']);
    $map->setdatecreated(date("Y/m/d"));



    if($map->saveMap()){


            if($map->getLastSequence()){


            if($map-> updateLandMapId()){
              echo "The Map was Created Successfully";
```

```php
        }

        }

    }else{

        echo "The Map NOT was Created Successfully" ;

    }

}


?>



// source code for Class to save to the database

<?php
/*
 * To change this template, choose Tools | Templates
 * and open the template in the editor.
 */

/**
 * Description of registration
 *
 * @author root
 */
class Map {
    //put your code here

    public $mapid;
    public $landid;
    public $locationid;
```

```php
   public $landparcel;

   public $propertyparcel;

   public $locationpoint;

   public $landids;

   public $datecreated;




  public $connection;


   public function __construct() {

       $this->connection = pg_connect("host=localhost port=5432 dbname=MgPi

           user=postgres password=xxxxxx") or print("cant connect");

   }




   public function saveMap(){
$result = pg_query($this->connection, "INSERT INTO map (landparcel,datecreated)

      VALUES ($this->landparcel,'$this->datecreated')") ;




return $result;



   }




public function updateLandMapId(){


      $result = pg_query($this->connection, "UPDATE land set mapid

         ="."'".$this->mapid."'"." WHERE landid = "."'".$this->landid."'");


      if(pg_affected_rows($result) > 0){


    return true;

   }else{
```
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```php
        return false;

    }


}


    public function getGeoJSon(){


        $result = pg_query($this->connection, "SELECT ST_AsGeoJSON(landparcel) from
            map m join land la on (m.mapid=la.mapid) where landid =
            "."'".$this->landid."'");

    while ($row = pg_fetch_row($result)) {


            $this->setlandparcel2($row[0]);


        }




    return $result;




    }


    public function getLastSequence(){

    $result = pg_query($this->connection, "SELECT last_value FROM map_seq");

    while ($row = pg_fetch_row($result)) {


            $this->setmapid($row[0]);


        }
```

```php
    return $result;

   }


public function retrieveLandIds(){

        $count = 0;

        $result=pg_query("SELECT landid from land la join map m
            on(la.mapid=m.mapid)") ;



        if($result){

            while($row = pg_fetch_assoc($result)) {



                    if($count==0){
                       $this->landids = $row['landid'];
                       $count = $count + 1;

                    }else{
                        $this->landids = $this->landids.",".$row['landid'];
                    }


                }



                return true;

        }else{
```

```php
            return false;
        }


}



  public function setmapid($mapid){

            $this->mapid = $mapid ;
   }


   public function setlandid($landid){

            $this->landid = $landid;
   }


  public function setlocationid($locationid){

            $this->locationid =$locationid;
   }


  public function setlandparcel($landparcel){


            $this->landparcel = "ST_GeomFromText('POLYGON((".$landparcel."))',4326)";
   }




  public function setlandparcel2($landparcel){


            $this->landparcel = $landparcel;


   }


  public function setpropertyparcel($propertyparcel){

            $this->propertyparcel = $propertyparcel;
   }


   public function setlocationpoint($locationpoint){

            $this->locationpoint = $locationpoint;
```

```php
}


public function setdatecreated($datecreated){
        $this->datecreated = $datecreated;
}




public function getmapid(){
        return $this->mapid;
}


public function getlandid(){
        return $this->landid;
}


public function getlocationid(){
        return $this->locationid;
}


public function getlandparcel(){
        return $this->landparcel;
}


public function getlandparcel2(){
        return $this->landparcel;
}




public function getpropertyparcel(){
        return $this->propertyparcel;
}


public function getlocationpoint(){
        return $this->locationpoint;
```

```php
    }

    public function getdatecreated(){
            return $this->datecreated;
    }



    public function getLandIds(){
            return $this->landids;
    }




}
?>
```

APPENDIX B: QUESTIONNAIRE ADMINISTERED

THE UNIVERSITY OF ZAMBIA

School of Natural Sciences
Department of Computer Sciences

RESEARCH QUESTIONNAIRE

Dear Respondent,

I am a Graduate Student at the University of Zambia (UNZA) doing a *Master of Science in Computer Science(Msc) programme*. I am doing a Dissertation Entitled *"Mobile GIS for Enhanced Property Tax Collection: A Case of Lusaka Province Local Authorities"* . The objectives of the research are to investigate the challenges experienced by Local Authorities in identifying and capturing rateable properties and to develop a Computer Based Mobile *Geographical Information System (GIS)* solution that can be used to help collect Property Rates.

Thanking you in Advance.

Yours Sincerely,

VICTOR NEENE

INSTRUCTIONS

1. *Answer all Questions*
2. *Circle or tick the appropriate number of the Answer to the Question*
3. *Write the answers to the Questions in the spaces provided where required*
4. ***DO NOT*** *write your name on this questionnaire*
5.

SECTION A - LOCATION

Council Name:_____

Department/Section Name:_____

SECTION B – LEVEL OF KNOWLEDGE

1. What is the level of your Education?

   1. Certificate

   2. Diploma

   3. Degree

   4. Advanced Degree

2. Do you own a Smart Mobile Phone?

   1. Yes   2. No

3. If answer in 2 is yes, have you used any Mapping application on it to locate a place of interest?

   1. Yes   2. No

SECTION C – PROPERTY REGISTER

4. How long does it take to register a new Property in the existing Property Register?

   1. 1-4 hours   2. 1-8 hours   3. More than 24 hours   4. Do Not Know

5. How long does it take to retrieve all the required Property information from the existing Property Register for a single Property?

   1. 1-30 min   2. 1-4 hours   3. 1-8 hours   4. Do Not Know

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6. How easy is it to locate properties physically on the ground using the existing Property Register for purposes of bill delivery and property valuations?

   1. Easy   2. Very Easy   3. Difficult   4. Very difficult

7. Does Each Property in the Property Register have Physical Geographic Global Positioning System (GPS) coordinates?

   1. Yes   2. No

8. Is there any disparity between Property Records in the Property Register and the Physical Properties on the ground?

   1. Yes   2. No

9. Do all Properties in the Property Register have Street Names and Unique Property Numbers?

   1. Yes   2. No

10. Are all the property Location Maps in the existing Property Register always up to date?

    1. Yes   2. No

11. Does the Property Register have all the required information about each property?

    1. Yes   2. No

12. What specific challenges do you experience in using the existing property register?

    _____

    _____

    _____

    _____

SECTION D – VALUATION ROLL

13. Does the Property Valuation Roll always have values that reflect current property values in

the current Valuation Cycle?

1. Yes   2. No

14. Does the Property *Valuation Roll* include all the newly developed properties in the current Valuation Cycle?

1. Yes   2. No

15. Is the existing Property Rates Billing System based on an updated Valuation Roll in the current Valuation Cycle?

1. Yes   2. No

SECTION E – PROPERTY IDENTIFICATION

16. What specific Challenges Exist in the Discovery of New Rateable Properties?

_____

_____

_____

_____

_____

17. Do the Challenges of Property Identification have any impact on the Property Rates Revenue Collection?

1. Yes   2. No

18. Do the Challenges of Property Identification have any impact on Property Valuations?

1. Yes   2. No

SECTION F – GIS SOLUTION

19. Can a GIS Computer based Property Register Solution help in *addressing some* Challenges of Property Identification?

1. Yes   2. No

20. If answer in 19 is Yes, What *features* would you like the GIS Based Solution to have?

_____

_____

_____

_____

21. Can the GIS based Solution *help* to bring a good number of Rateable Properties in the *Tax Net*?

    1. Yes   2. No

22. Can the GIS   Solution help *improve* Property Rates Revenue Collection?

    1. Yes   2. No

    Thank You very much for taking your time to Respond to the Questions.

APPENDIX C: INTERVIEW QUESTIONS ADMINISTERED

PRELIMINARY INTERVIEWS

Objective of Interview
1. To gather preliminary information that will be used to generate a questionnaire that will be used to gather systems requirements for the mobile GIS tool
2. To understand the operations and processes that are involved in the Administration of Property Tax and the Property Register
3. To validate known challenges from the literature review inherent in managing a Property Register
4. To gather information about the specific inherent institutional challenges in the management of the Property Register/ Property tax Management

Interview/Discussion

A) Open Ended Questions
1. What Department Stake Holders are involved in the management of Property Tax/Property Register and what are their roles?
2. What are the processes involved in the creation of the Property Register?
3. What information is need to perform these processes?
4. What Challenges exist in discovering new properties?

B) Closed Questions?

---

1. Does Each Property in the Property Register have physical Geographic GPS (GNSS) coordinates?
2. Is there any disparity between Property Records in the Property Register and the Physical Properties on the ground?
3. Do all Properties in the Property Register have Street Names and Unique Property Numbers?
4. Are the property maps in the existing Property Register always up to date?
5. Do Property Registers always have values that reflect current property values?
6. Does the Property Register have all the required information about each property?
7. Does the Property Valuation roll include all the newly developed properties?
8. Is the existing Property Tax Billing System based on an updated property Register?
9. Are the Property Maps very expensive to produce?
10. Does each Property in the Register has corresponding Map information?

C) Other Questions
Are their any specific challenges experienced in the property tax administration process/property register management other than the ones already discussed?

D) Any Follow up questions from **A**

APPENDIX D: GROUND TRUTH EXERCISE GRAPHS

Own Mobile Phone

Used Mapping Application
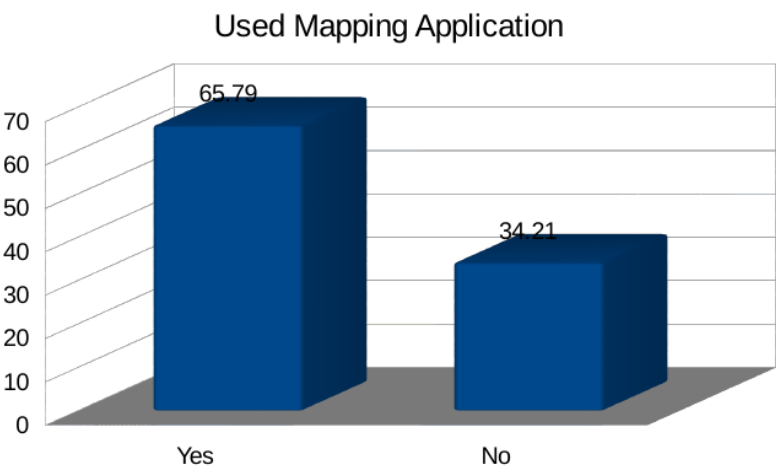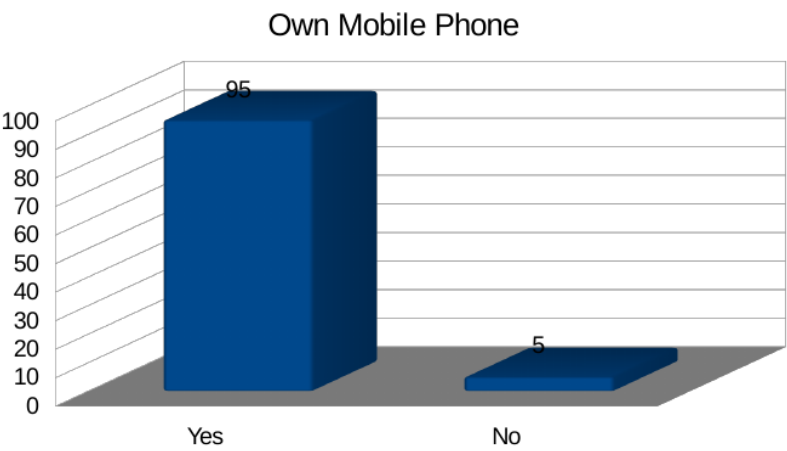
PUBLICATIONS

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Victor Neene and Monde Kabemba, "Development of a Mobile GIS Property Mapping Application using Mobile Cloud Computing" International Journal of Advanced Computer Science and Applications(ijacsa), 8(10), 2017. http://dx.doi.org/10.14569/IJACSA.2017.081008